Physicochemical Properties of Bamboo Shoots of Selected Species grown in Kenya and Utilization as Human Food

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DECLARATION

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

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This research work is dedicated to my lovely family members namely Nyambura, Karanja, Mumbi and Mwathi for their continued support and understanding.

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LIST OF ABBREVIATIONS AND ACRONYMS

AD	Airflow
b.p.	Boiling point
BVP	*Bambusa vulgaris* powder
AOAC	Association of Official Analytical Chemists
CE	Catechin Equivalent
DPPH	1,1-Diphenyl-2-picrylhydrazyl
DWB	Dry Weight Basis
FAN	Forest Action Network
FAO	Food and Agriculture Organization
FD	Vacuum Freeze Drying
FWB	Fresh Weight Basis
GAE	Gallic Acid Equivalent
HPLC	High Pressure Liquid Chromatography
Hrs	Hours
IBC	International Bamboo Conference
IDRC	International Development Center
INBAR	International Network for Bamboo and Rattans
ISAAA	International Service for the Acquisition of Agri-Biotech Applications
IUCN	Union for Conservation of Nature
JICA	Japan International Cooperation Agency
JKUAT	Jomo Kenyatta University of Agriculture and Technology
KALRO	Kenya Agriculture and Livestock Research Organization
KEFRI	Kenya Forest Research Institute
KES	Kenya Shillings
LC_{50}	The lowest concentration that will cause 50% inhibition against oxidation
Min	Minutes

Ml	millilitres
mM	millimoles
MPND	Ministry of Planning and National Development
N	Normality
NACOSTI	National Commission for Science, Technology and Innovations
Nm	nanometers
NMBA	National Mission on Bamboo Applications
NAP	The National Academic Press
PEM	Protein Energy Malnutrition
PROTA	Plant Resources of Tropical Africa
QE	Quercetin Equivalent
RSC	Royal Society of Chemistry
Rpm	Revolutions per minute
SNE	Scitable by Nature Education
SSD	Superheated steam
TBPT	Tree Biotechnology Program Trust
UNDP	United Nations Development Programme
UNIDO	United Nations Industrial Development Organization
USDA	United States Department of Agriculture
VNS	Vietnam News Society
°C	Degrees Centigrade

DEFINITION OF TERMS AND TERMINOLOGIES

Antipyretic:	Substances which reduce fever or relieve pain.
Diuretic:	A substance that promotes increased production of urine by the kidney.
Chelate:	A case where bonding of ions and molecules to metal ions takes place
Neurodegenerative diseases:	Describes a range of conditions which primarily affect the neurons in the human brain. Neurons normally do not reproduce or replace themselves, and so when they become damaged or die, they result in diseases such as parkinson's, alzheimer's and huntington's.
Nutraceutical products	Plants or food products with medicinal value
Osteoporosis:	Bone weakening making it susceptible to breakage due to a fall or even a minor impact
Renal failure:	Refers to a medical condition of impaired kidney function in which the kidneys fail to adequately filter metabolic wastes from the blood
Vasodilatory:	Describes the widening of the blood vessels due to relaxation of the smooth muscle cells within the vessel walls of the large veins, large arteries and small arterioles. Dilation of the blood vessels increases the flow of blood in the body.

ABSTRACT

A survey on consumption of bamboo shoots was carried out in Mt. Elgon and Nairobi regions to establish the status of utilizing the shoots as food. Three species namely *Dendrocalamus giganteus, Bambusa vulgaris* and *Yushania alpina* were analyzed for some physicochemical properties. To determine the best part of the shoot to consume, the shoot of *Y. alpina* was divided into upper (15 cm from the apex) and lower portions and the content of physicochemical constituents determined separately in the two portions. The effect of traditional processing techniques on quality was carried out by boiling shoots of *B. vulgaris* in 1, 2 and 5% ash of bean stalks and NaCl solutions for 10, 30 and 60 min. Products made with bamboo shoots were evaluated for consumer acceptance using 7 and 9-point hedonic scales. Results of the survey showed that all interviewees had consumed the shoots of *Y. alpina,* 37.5% of restaurants in Nairobi sold bamboo shoots, and 62.5% of the hotels sold less than 0.5 kg per week by 62.5%. Composition (%g/100gfwb) of the three species showed carbohydrates of 1.9-3.6%, protein of 2.3-2.6% and ash content of 0.98-1.17%, with potassium content of 288.8-362.6mg/100g. *D. giganteus* and *B. vulgaris* contained up to 288.8mg/100g total flavonoids compared to 53.14mg/100g in *Y. alpina*. *Y. alpina* was found to contain on dry weight basis carbohydrates and fibre contents of 23.6 and 23.9% respectively in the upper compared to 17.3 and 30.7% respectively in the lower portion. K content of 3,590mg/100gdwb in the upper and 2,760mg/100gdwb in the lower portion was also observed. Boiling shoots of *B. vulgaris* in 2-5% NaCl solution for 60 min was found to reduce fibre content (dwb) from 29.4 to 7.7-8.8% compared to ash which reduced it to 21.2-24.4 %. Similarly, K content reduced from 4,000 to 2,000mg/100g in NaCl solution but rose to 3600-10,000mg/100g in shoots boiled in 2-5% ash. Both NaCl and ash were effective in reducing anti-nutrients with ash causing up to 70% reduction after only 10 min. On products, fried shoots were rated “like” whereas cookies made with 200 g purees of shoots scored “like very much” compared with those with 100g which were rated “like moderately”. Porridge and biscuits with shoots powder higher than 5% were not acceptable to consumers due to bitterness. These findings shows that business in

bamboo shoots as human food is low but has potential to grow and produce processed foods of high consumer acceptance by Kenyans.

CHAPTER ONE

INTRODUCTION

1.1. Background Information

Bamboo is botanically a grass belonging to perennial evergreen plants in the family of Poaceae, and have a large diversity in growth habitat and geographical distribution in the world (Upreti & Sundriyal, 2001). They are thought to be native to Asia although they naturally exist in the tropical and sub-tropical regions, and can also be found growing in mild temperate zones in Europe and North America (Feleke, 2013; IBC, 2008). Today, bamboo is commercially and extensively cultivated in Eastern and South Eastern Asia which is believed to hold about 65% of the world bamboo resources contributing to 63% of the world market, whereas Africa constitutes a mere 5% of the world market share (IBC, 2008). It is estimated that there are over 1,250 species of bamboo worldwide and most of them are found in South East Asia (Nongdam & Tikendra, 2014). China and Japan are said to be among the major bamboo producing countries possessing 300 and 237 species respectively (Sharma, 1980).

There are about 75 genera of bamboo reported worldwide with China having 44 genera on 33,000 km^2 (Singhal, Bal, Satya, Sudhakar & Naik, 2013). In India, bamboo covers about 96,000 Km^2 representing 13% of the total forest area (Scurlock, Dayton & Hames, 2000). Africa is estimated to contain about 2.7 million hectares of bamboo (Lobovikov, Paudel, Piazza, Ren & Wu, 2007). In Kenya, *Yushania alpina*, (also known as *Arundinaria alpina* K. Schum or the alpine bamboo), is an indigenous species found on Kenyan and East African highlands at altitudes of between 2,400 and 3,400 m above sea level. The species is currently estimated to cover about 150,000 ha and grows on the Aberdare ranges, Mt Elgon, Mt Kenya, Mau escarpment and Cherangany Hills, amongst other areas (Kibwage, Odondo & Momanyi, 2008; Muchiri & Muga, 2013). This species is also found in Ethiopia at altitudes of 2,200-4,000 m above sea level and consumption of the shoots has been

reported, although the bamboo is mainly used as construction material (Feleke, 2013). Some exotic varieties belonging to the genera of *Bambusa*, *Dendrocalamus*, *Gogantochloa*, *Oxytenanthera* and others, have also been planted in Kenya through the activities of Kenya Forest Research Institute (KEFRI) (Ongugo, Sigu, Kariuki, Luvanda & Kigomo, 2000). In western, Kenya farmers are replacing tobacco with bamboo through a project called tobacco to bamboo launched in 2006 by Maseno University‘s school of Environment and Earth studies (Irwin, 2010).

The giant bamboo species are the largest members of the grass family and they are among the fastest growing plants in the world (Farrelly, 1984; Lee, Xuesong and Perry, 1994) attaining about 60cm in 24 hours due to a unique rhizome-dependent system. The largest bamboos in Asia can grow as tall as 40 m. The shoot of *Phyllostachys edulis* is said to elongate at 121 cm in 24 hours (Farrelly, 1984). Bamboo is therefore a renewable resource whose growth rate is however, dependent on the species, soil and climatic conditions.

Energy, climate change and food security are some of the major challenges facing the world today. Bamboo, with its diverse uses is posed to help in overcoming some of these problems (Satya, Singhal, Bal, & Sudhakar, 2012). Development of bamboo has continued in mainstream economy with plantations developing from the natural plants to being cultivated as agricultural plant and resulting into many more uses. Troy Wiseman of Ecoplanet Bamboo Company in Chicago grows bamboo privately for wood and fiber production. Bamboos are also considered as an answer to re-afforestation and environmental conservation due to the fact that they can trap large amounts of carbon dioxide in the air. During the Paris conference in France on climate change, bamboo growing featured prominently as a possible solution to mitigate against global warming effect, a subject of serious debate in the world today (INBAR, 2015). Carbon sequestration by bamboo has been reported by Sohel, Alamgir, Akhter and Rahman (2015), who found that a five-year old *Bambusa vulgaris* was able to store up to 77.67 tons of CO_2 per hectare compared to other trees such Acacia (11 years) and Eucalyptus (18 years) which stored 10.21 and 10.12 tons per hectare per year, respectively. Its ability to produce great amount of biomass

makes the giant bamboo an ideal resource for controlling carbon emissions and reforestation of demolished forests (Nath, Lal, & Das, 2015).

Bamboo has many diverse uses. It is used in the handicraft sector where small volumes of raw bamboo are manually processed into high-end value added products such as baskets, mats, carpets, bamboo fans, utensils, decorative wares among other items. Some industrial processing is also done where large volumes of bamboo stems are mechanically processed into either premium products such as, flooring and laminated furniture or medium value products such as chopsticks, mat boards, or low value and bulk products (charcoal, paper and pulp) or unprocessed culms for traditional construction. It is also used in textile for making clothes amongst other uses (Kigomo, 2007).

Bamboo is also used for producing edible shoots. These are high value agricultural products that are produced simultaneously with culms. They are described as the juvenile shoots that emerge from the pseudo-rhizome bamboo plants in the ground. The shoots consist of meristematic cell tissue with massive cell division and differentiation (Farrely, 1984). The usage of bamboo plants to produce edible shoots is an old Asian culture. These shoots are said to be very nutritious and nutritive value of over 20 species has been reported (Chongtham, Bisht, & Haorongbam, 2011; Choudhury, Sahu, & Sharma, 2012; INBAR, 2006; Satya et al., 2012). The shoots have been found to be good sources of protein, dietary fiber, minerals, and vitamins, among others (Nongdam & Tikendra, 2014). They are also said to be among the top five most healthcare foods in the world (Chongtham et al., 2011).

Food shortage and malnutrition have persistently been disturbing problems in Kenya, more than 50 years after independence (Kunyanga, Imungi, & Vellingiri, 2013). The poverty level in the country is also worrying. In 2003, the population living below the poverty line was 56% and following the trends, it was projected to rise to 65.9% by 2015 (MPND, 2005). This has put Kenya off the mark in achieving some of the development goals particularly eradication of extreme poverty and hunger (Walingo & Sewe, 2009). Protein Energy Malnutrition (PEM), a nutrients-deficiency condition is also of great concern. The prevalence of stunting and underweight among the

preschool children in East African stood at 48 and 36% respectively in 2003 and was expected to rise further by 2013 (Teller & Alva, 2008).

Since supply of kales and cabbages that Kenyans rely on for their vegetable needs is inadequate, the nutrient-rich shoots of bamboo may provide an alternative vegetable source. Bamboo shoots are also said to be richer in nutrients than most common vegetables (Cantwell, Nie, Zong & Yamaguchi, 1996; Gopalan, Rmasastri & Balasubramanian, 1971; USDA, 2006). They are also termed as a functional food helping in weight loss due to low caloric value, improvement in bowel movement due to high fibre content and thereby reducing the incidence of colon cancer (Park & Jhon, 2009).

1.2 Problem statement

The challenge that most Kenyans face is lack of diversification in their foods. Majority continue to depend on common vegetables such as kale and cabbage as accompaniments for starches with little or no diversity. This has continued to exert strain on demand for these vegetables, thus rendering them inadequate as a source of important nutrients necessary for growth and maintenance of a healthy body. The situation is worsened by inadequate rainfall that makes these common vegetables scarce. There is therefore a dire need for alternative crops to help in fighting this insecurity and malnutrition quagmire.

Bamboo shoots have been widely utilized as a vegetable in many Asian countries (Chongtham et al., 2011; Satya et al., 2012). This means that the shoots could also help augment the vegetable supply in Kenya. It is of necessity therefore, to determine the nutritional value of the various species of bamboo shoots growing in Kenya and encourage their usage. Currently, the compositional information is either lacking or insufficient and this masks the potential of this resource as a food (Ongugo et al., 2000; Satya et al., 2012). Kigomo (1995) pointed out that lack of adequate information about the bamboo resource was a major hindrance to its utilization in Kenya. Choudhury et al. (2012) cited inadequate research on bamboo as a cause of

shortage of bamboo-based products in the international market. Sood, Walia, Gupta, and Sood (2013) reported that there is underutilization of bamboo as a food, whereas Singhal et al. (2013) found that literature on nutritional and medicinal aspects of bamboo is limited.

1.3 Justification

Bamboo is said to be among the fastest growing plants in the world (Farrelly, 1984) and it can grow successfully on wasteland with minimal agronomical inputs (Satya et al., 2012). Bamboo grows naturally in the tropical and sub-tropical regions and therefore Kenya provides suitable land and climate for its cultivation. The Kenyan highlands are said to have about 150,000 Ha of land covered with the indigenous species of *Y. alpina.* These species which grow in protected public land are however underutilized since the government banned their felling in 1986. On its part, the Kenya Forest Research Institute (KEFRI) initiated a programme of research on the potential of bamboo and subsequently developed strategies for its cultivation in Kenya (Kigomo, 1988; Kigomo, 1995; Kigomo & Sigu, 1995; Kigomo, 2005; Kigomo, 2007). Currently there are several farmers who have planted the Asia bamboo species on their farms and many more investors have shown interest in planting bamboo in Kenya. Bamboo therefore, cannot be ignored as a plant with high potential for utilization for the welfare of Kenyans and development of the country as a whole.

1.4 Objectives

1.4.1 General objective

To determine consumption status of bamboo shoots, characterize the physicochemical properties of shoots of three species grown in Kenya and improve their food value through optimized processing methods and value addition.

1.4.2 Specific objectives

i. To map the consumption of bamboo shoots in Kenya.
ii. To determine the nutrients, phytochemicals, antioxidant activity and anti-nutrients of bamboo shoots of three species grown in Kenya.
iii. To determine the differences in physicochemical properties and antioxidant activity between and upper and lower portions of *Y. alpina.*
iv. To determine the effect of traditional processing methods on the physicochemical properties of processed bamboo shoots.
v. To enhance utilization of bamboo shoots through product development and consumer studies.

1.5 Conceptual framework

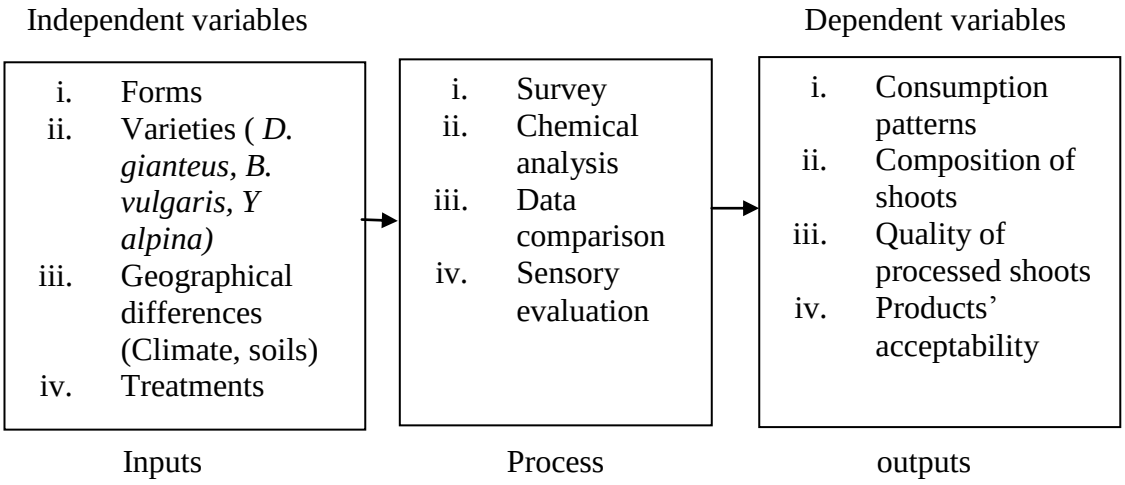


Figure 1.1: Diagram showing flow of research activities

1.6 Hypotheses

The following hypotheses were tested:

i. There is no consumption of bamboo shoots in Kenya.

ii. There is no difference in chemical composition between bamboo shoots growing in Kenya and those grown elsewhere in the world.

iii. There is no difference in distribution of physicochemical properties and antioxidant activity within the shoot of *Y. alpina.*

iv. Traditional processing methods of bamboo shoots practiced in Kenya cannot produce high value products.

v. Bamboo shoots-based food products cannot be accepted as food for human beings.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin of bamboo

Bamboo is a common term describing members of large woody grasses of the family Poaceae in the subfamily Bambusoideae, and is one of the most widely used bioresources (Kigomo, 1988; Sood, Walia, Gupta, & Sood, 2013). Bamboos are distributed mostly in the tropics but also occur naturally in the sub-tropical and temperate regions of all continents except Europe, at latitudes of 46° N to 47° S (IFAR/INAR, 1991, Tewari, 1992). There are 1,250 species of bamboo which have been identified and 1,000 are found in Asia growing more on natural stands than on artificial plantations. China and India are the main bamboo-producing countries possessing 300 and 130 species respectively (Qiu, 1992). Different species are native in different countries. For example *Dendrocalamus strictus* is native in India whereas *Dendrocalamus asper* and *Thyrsostachys siamensis* are thought to be from Thailand and *Phyllostachys pubescens* from China (Scurlock et al., 2000). Ethiopia has two types of bamboo mainly the *Arundinaria alpina* which grows between 2,000-4,000 m and lowland bamboo of *Oxytenanthera abyssinica* which grows at 1,200-1,800 m. (Feleke, 2013). The East African highlands are also home to indigenous species of *Arundinaria alpina* (MENR, 1994).

2.2 Growth characteristics of bamboo

Bamboo culms differ in morphology and height depending on the species. They range from lower ground cover growing to 20-50cm high to the giant ones of 20 m or more. Bamboo culms are unique because they develop in a single period of growth by a strong cell elongation and cell division. They have no secondary thickening as they grow, unlike normal trees, and they attain their ultimate diameter when a new culm or shoot appears (Seethalakshmi & Kumar, 1998). Bamboo culms, branches and rhizomes are all built of similar module units called nodes and internodes (Stapleton, 1997). It is at the nodal zone that buds, leaf organs and eventually roots ultimately appear. The internodes are generally hollow and at the nodes, diaphragms are found which separates the hollow internodes. The culm wall is thick or thin

depending on the species. The length of the internodes also varies even in same plant. The *Phyllostachys aurea,* for example, have shortened basal internodes which appear swollen whereas the upper ones are longer than the lower (Stapleton, 1997). Bamboo consists of rhizomes or subterranean stems that supports the growth of the plant. These rhizomes store and transport water and nutrients and also stabilizes the soil. It is from these rhizomes that buds develop into new culms or shoots. Rhizomes are classified into two types namely pachymorph and Leptomorph rhizomes.

Figure 2.1 below shows a pachymorph rhizome. It is thicker than the culm and its buds develop into new rhizomes. The apical bud of the rhizome develops into a culm or a shoot. The rhizome neck connects the rhizome and the culm with the rest of the plant. It is generally short, but can be long resulting into widely spaced culms. The pachymorph or the clumping bamboos, examples of which include *Bambusa* and *Gigantachloa* species, do not run and they are therefore safe to plant even near buildings.

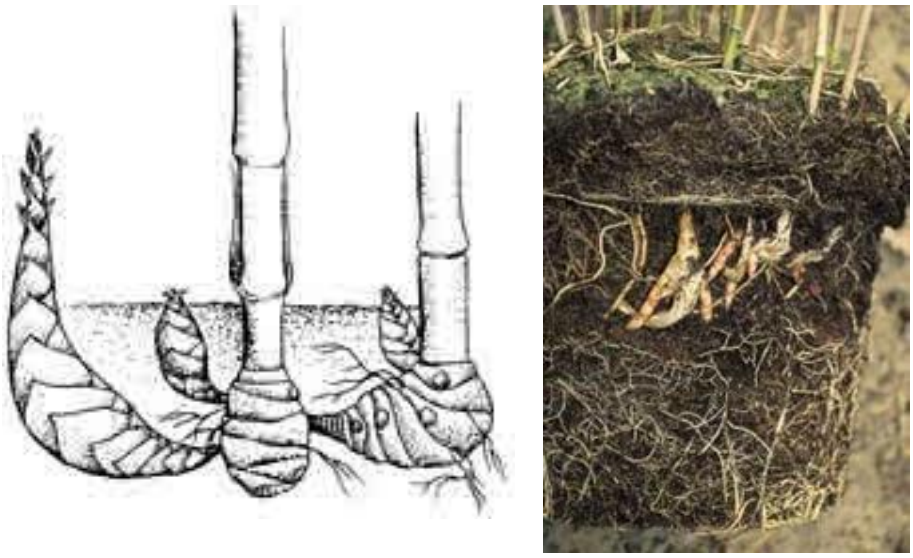


Figure 2.1: Pachymorph rhizome of bamboo (Bamboo Botanicals 2016, American Bamboo Society, *www.bamboobotanicals.ca*)

A leptomorph rhizome on the other hand is thinner than the culms, grows dia-geometrically as modified stem and some of the auxillary buds develop into new culms (Stapleton, 1998). Figure 2.2 shows the leptomorph rhizome. It grow

horizontally to a distance of up to six meters underground between the culms and thus they are not safe near buildings for they can crack the walls.

Figure 2.2: Leptomorph rhizome of a bamboo plant (Australian Owner builder Network Pty Ltd, 2011-2016, *www.bamboobotanicals.ca*)

The shoots therefore will develop from either of the rhizome system. Huge shoots are produced by giant species like *Dendrocalamus giganteus,* Dendrocalamus *asper* and *Phyllostachys edulis* whereas others are slender at about 2" in diameter such as *Phyllostachys nigra* and *Yushania alpina*.

2.3 Growth diversity

The diversity in bamboo plantations can be seen in that it can grow in tropical, subtropical and temperate regions of the world at altitudes ranging at just above sea level to about 4,000 m (Yeasmin, Ali, Gantait, & Chakraborty, 2015). It can be grown on farmland, along river banks and hillside, and can be used to restore degraded land and prevent soil erosion. The temperate areas grow running bamboos that produce three types of shoots namely, spring or summer shoots, winter shoots and rhizome shoots. Tropical areas grow clumping bamboos which produces only

summer shoots. The most ideal temperature range for most bamboo growing is 15-20°C with an annual rainfall of 1000-1500 mm (Scurlock et al., 2000).

The harvesting of good quality shoots was found to be influenced by age of the shoots. Pandey and Ojha (2013) found that the optimum harvesting age varied between 6-16 days for *Dendrocalamus asper*, *Dendrocalamus strictus* and *Bambusa tulda*. The shoots may be harvested at many stages – before they break the surface of the soil, shortly afterwards, or once they have reached about a meter high. The stage at which they are harvested determines their fiber content and tenderness, with younger shoots being more palatable and nutritious than older ones (Nirmala, David & Sharma, 2007). The fiber content also determines the way shoots are handled or processed.

2.4 Bamboo shoots

The evergreen bamboo plant consists of aerial stems known as culms, which arise from a network of rhizome system. An emerging young culm is known as bamboo shoot or juvenile shoot and contains short vertical nodes and internodes tightly clasped with overlapping sheaths that have to be removed to extract the edible part (Chongtham et al., 2011). Culms which are more than six months old are used for making handicraft and novelty items as well as furniture and construction (Adams, 2003).

It is not all bamboo species found in the world that are edible (Choudhury et al., 2012). In India there are about 128 species, out of which about 30 produce edible shoots which are mainly of *Bambusa* and *Dendrocalamuus* species. The area under bamboo in India is reported to be on the increase due to the government's intervention in promoting the expansion of the plantations (Premlata, Saini, Nirmala & Bisht, 2015).

The demand for shoots has been on the rise. The production of fresh ones however is limited because they are only harvested for one or two months per year and best shoots are obtained about two weeks after emerging from the ground (Choudhury, Sahu, Sharma, 2010; Pandey & Ojha, 2013). Due to this seasonality and perishable

nature of the shoots, they must therefore be preserved through some methods of processing such as canning, drying, fermentation or through other value addition process (Nongdam et al., 2014). China and India are among the largest producers of bamboo shoots. About 2 million tons of bamboo shoots are consumed in the world, out of which 1.3 million comes from China alone (Chongtham et al., 2011; Sood et al., 2013). In Africa, Ethiopia is said to have the largest bamboo cover totaling to about one million hectares (Feleke, 2013). Some consumption of shoots of *Arundinaria alpina* has been reported although the species is mainly used as construction material (Feleke, 2013). These resources however have remained commercially untapped and provide huge potential for economic revolution in Ethiopia (Mckenna, 2013).

2.5 Bamboo growth and cultivation in Kenya

There are both indigenous and exotic species in Kenya. The indigenous variety *Yushania alpina* is native and found in protected areas where felling is prohibited by the government. Due to the government ban on felling of the *Yushania* species, the Kenya Forest Research Institute (KEFRI) took the initiative and introduced into the country many exotic species mainly from Asian countries, in order to promote the on-farm cultivation and reap the benefits accruing from this renewable resource (Kigomo, 2007). Over twenty exotic bamboo species have been introduced into the country during the last two decades, with the support of International Development Research Centre (IDRC) (Ongugo et al., 2000). Introduction of the species was done through cuttings, offsets and seeds although tissues culture has been tried by KEFRI with mixed success rates for *Y. alpina, D, giganteus* and *B. tulda* (Omenda & Kariuki, 2006). Fifteen species have been successfully established in various ecological zones in the country. The successful species are *Bambusa bambos, Dendrocalamus strictus, Dendrocalamus giganteus, Dendrocalamus hamiltonii, Dendrocalamus asper, Dendrocalamus membranacea, Bambusa tulda, Bambusa vulgaris var. striata,* and *Thyrsostachys siamensis.* These species are yet to be widely planted by farmers. Demonstration plots have been established at various ecological zones as part of bamboo promotion strategy.

Today bamboo growing in Kenya is replacing the tobacco through a project called tobacco to bamboo launched in 2006 by Maseno University's School of Environment and Earth Studies (Irwin, 2010). The project began as a research study on encouraging the cultivation and utilization of bamboo as an alternate livelihood to tobacco farming in South Nyanza and Western Kenya. Later, the school set up nurseries in Migori, Kuria, Homa Bay and Suba districts, with the ultimate goal of using the bamboo to make bamboo products and construct bamboo houses for the poor people.

It is also worth noting that the growing of *Eucalyptus* trees at river banks has been banned by Kenyan Government due to the heavy water intake of the trees which causes the rivers to dry up. Consequently these trees are being replaced by the giant bamboo (Newspaper Reporter, 2010). This development may be one of the factors that has led to creation of private institutions which are promoting cultivation of bamboo through training and provision of seedlings. Examples of these are Waterways Bamboo Kenya Ltd in Nairobi, Aberdares Green Earth, Bamboo Trading Company and Tree Biotechnology Programme Trust.

2.6 *Yushania alpina*

The *Y. alpina*, formerly known as *Arundinaria alpina* or the alpine bamboo is a vast indigenous species growing wildly in Kenyan and East African highland areas with altitudes ranging 2,400-3,400m (Kigomo, 2007). The major districts with highest bamboo cover in Kenya are Nakuru (8,565 ha), Mt Elgon (10,250 ha), Nyeri (25,133), Kiambu (5,723 ha), Nyandarua (9,060), Malindi/Kilifi (unknown), and Narok (4,207 ha) (Kibwage, 2008; Kigomo et al., 1995; MENR, 1994). There is no inventory of any cultivation on the farms. This bamboo is mainly used as props in flower farms, handicraft, domestic fencing, as well for minor cottage industries like tooth picks, basketry and incense sticks.

According to Ongugo et al. (2000), *Y. alpina* was found to have an average stem length of 10.2 m and a diameter of 7.5 cm. Bamboo from farmland had an average length of 9.6 m and diameter of 6.2 cm and stocking levels were found to be higher in natural forests than on the farmlands. The average number of culms per hectare in

forest areas was 10,480. According to Kigomo (1988) there are about 10,000 to 17,000 stems per hectare in undisturbed stands of *Y. alpina*.

Between 1940 and 1980, there was massive over-harvesting of the bamboo to meet the demand and since there was no replanting, this species became endangered. This prompted the then president of Kenya Mr. Moi to ban felling of the indigenous bamboo in 1986. The *Yushania* has been under protected forest ever since, and this caused closure of many cottage industries which relied on bamboo as their main raw materials (UNIDO, 1986).

2.7 Successful exotic species of bamboo in Kenya

2.7.1 *Oxytenanthera abyssinica* (A. Richard) Munro

This species is woody perennial, also known as *Bindura* bamboo and was introduced in Kenya from Zimbabwe in 1954. It has been put in plantation at Muguga which is 2,100 m above sea level with a mean annual rainfall of 970 mm and an average monthly temperature of 16ºC. It is a drought-resistant bamboo which has its habitat in the savanna woodland, semi-arid woodland grassland and thicket of tropical Africa especially Senegal, Angola, Ethiopia, Mozambique and Northern South Africa. In Ethiopia *Oxytenanthera* is also referred to as lowland bamboo growing at altitudes of 300-700m and is estimated to cover 750,000-900,000 ha (Kigomo, 2007). It forms clumps with canes that are sometimes zigzag. It flowers after about seven years and produces seeds before dying.

The young culms planted at Muguga were able to attain a maximum height of 6.5 m after 2 – 3 months and diameter of 3-8 cm. They are capable of producing 14 - 28 tons of dry culms per hectare/year depending on the year's rainfall. Planting materials are better raised from seeds because propagation from cuttings is difficult. In countries where the species is well established such as Mali and other sub-Saharan African countries, the species has a wide range of usage. These includes house construction, fencing, furniture, fish traps and basketry. Young stems (referred to as shoots), leaves and seeds are eaten particularly during famine (Burkil, 2004; Mcclure, 1966). The seeds and sap are used for making alcoholic drink (Yuan, 1983).

In Tanzania the juice is obtained from cultivated species of *Oxytenanthera braunii* and is used as a soft drink or fermented into alcohol. Stems are also used as fuel and for paper making. The leaves and roots are also used traditionally to treat various ailments such as dysentry, diabetes and rheumatism (Burkil, 2004).

2.7.2 *Dendrocalamus giganteus* Munroe

This is a perennial evergreen, the fastest growing and the tallest giant bamboo in the world, being grown commercially for culms for construction of houses, walls, furniture and edible large shoots (Nirmala et al., 2008). It is native in China, India, Myanmar and Thailand and was also introduced in Madagascar and Sri Lanka in 1856. It occurs in moist forest and along riverbanks and flowers after more than 29 years (Contu, 2013). The culms have smooth internodes and propagation is done using node culm cuttings of the upper internodes (Kigomo, 2007).

2.7.3 *Bambusa vulgaris* Schrad ex Wendl

The species *Bambusa vulgaris* is native in Indochina but was introduced into Kenya from India many years ago and is widely distributed on farmlands and urban centers as ornamentals (UNIDO, 2006). It grows as loose clumps and has a lemon-yellow stems with green stripes with dark green leaves and the species is raised through cuttings and offsets. The culms of *B. vulgaris* are mainly used for construction, furniture, making musical instruments and paper (Louppe, Oteng-Amoako & Brink, 2008; Ohrnberger, 1999; Rao, Ramanatha & Dansfield, 1998). The shoots are yellowish after cooking and are eaten throughout Asia (Clay, Hubbard & Golt, 1987). The leaves are traditionally used for medicinal application and are believed to cure measles in Congo and sexually transmitted diseases in Nigeria (Louppe et al., 2008).

2.8 Utilization of bamboo in Kenya

Bamboos in Kenya are mainly *Yushania s*pecies and have found diverse uses because they are important renewable resources. They are used on a small scale as plant supports in the horticulture industry, especially the flower industry around Lake Naivasha. They are also used as raw materials in the handicraft industry, and in the

construction industry for fencing and interior decorations. Fencing uses about 74% of all the bamboo harvested in the study areas, the flower industry 20%, the construction industry 4% and the rest of the sectors use about 2% (Ongugo et al., 2000). Some consumption of the shoots of *Alpina* was reported in Cherenganyi, and Mt. Elgon regions with an average annual consumption of 1,200 in each of the market centers and towns, at a mere KES 12.00 per three shoots. Other products which were selling in major towns such as Nairobi, Mombasa, Nakuru, Nyeri, Kisumu and Eldoret included culms, toothpicks, skewers, baskets and incense sticks.

It is said that development of bamboo market in Kenya is hampered by the fact that bamboo is inadequate. In order to compete in a supply driven market of bamboo materials, UNIDO report (2006) says that adjustment is needed in the production model that the plantation is currently based upon, considering that the exotic species introduced in the country have not been widely planted by farmers. This setback has prevented the take off by bamboo sector.

2.9 Nutrients in bamboo shoots

Bamboo has played an important economic and cultural role across Asia and its usage is growing rapidly in Latin America and Africa as well (IBC, 2008). The Bamboo shoots form an essential ingredient in dishes of many countries like India, Indonesia, Nepal, Vietnam, Philippines, China, and Japan. Several researchers have reported the nutritional value of bamboo shoots (Chongtham et al., 2011; Choudhury et al., 2012; Satya et al., 2012; Shanmughavel & Francis, 2002).

2.9.1 Carbohydrates

Carbohydrates are molecular compounds made from carbon, hydrogen and oxygen, and are broadly classified as either non-structural or structural. Non-structural carbohydrates (NSC) are found inside the cells of plants and are more easily digestible than the structural ones which are found in the cell walls. The NSC includes sugars, starches, organic acids and fructans and these are the main source of energy in animals (NAP, 2001). Carbohydrates in bamboo mainly occur in the form of cellulose which can release fermentable xylose to produce cellulosic ethanol. Three main sugars have been identified in bamboo shoots namely, fructose, glucose

and sucrose (Kozukuen, Kozukue & Kurosaki, 1983). The main function of carbohydrates is to provide energy to the body. Carbohydrates content was found to vary between species (Chongtham et al., 2011; Kumbhare & Bhargava, 2007;). It was observed that cooking methods also affect the content of carbohydrates in the processed product (Pandey & Ojha, 2014).

2.9.2 Proteins

Proteins are important in the body for they are responsible for growth, structural support, movements, enzymatic activities and other interaction with external environment (SNE, 2016). Protein intake has been reported to have an effect on chronic renal failure because the kidney is responsible for eliminating the products of protein metabolism (NAP, 1999). Deficiency of protein in the diet will lead to protein-energy malnutrition characterized by diseases such as kwashiorkor and marasmus in children. In adults protein deficiency was found to cause an increase in both the extracellular and intracellular fluid of the body (Stanier, 1958). Fresh Bamboo shoots have been found to contain varying amounts of protein content (Chongtham et al., 2011; Sundriyal & Sundriyal, 2001). Low protein content was detected in canned shoots at 1.98% of *D. giganteus* (Nirmala, Sharma & David, 2008). Fermentation was however observed to boost protein content from 3.1 to 8.1% after eight days (Devi & Singh, 1986), whereas storage of the shoots of *D. asper* and *D. strictus* was found to significantly reduce protein content from 1.21 and 1.91% to 0.86% after 10 days (Zhang, Ji, Hu, Cheng, & Ye, 2011). Cooking methods were also found to adversely affect the protein content of bamboo shoots (Pandey & Ojha, 2014).

Bamboo shoots are also rich sources of amino acids containing 17 of them with 8 essential ones for the human body. Qiu (1992) and Xu, Wan-You and Song (2005) found that 12-49% of total amino acids in nine bamboo species were essential to the body. Amino acids profile was found to vary significantly depending on the species (Sharma, Nirmala & David, 2004). Tyrosine was found to be the main amino acid in *Phyllostachys pubescens* (Kozukuen, Kozukue & Kurosaki, 1983). It has been reported that storage of shoots for 10 days significantly reduce the free amino acid

content (Nirmala et al., 2007). Boiling too was found to significantly reduce the amount of free amino acids and the free total amino acids (Zhang et al., 2011).

2.9.3 Fibre

Bamboo shoots qualify as functional food because they contain dietary fibre important in prevention of hypertension, and colon cancer (Sharma et al., 2004). Dietary fibre helps in digestion by providing a substrate for intestinal bacteria that comprise 50% of fecal solids and thus has been found to increase bowel movement, prevent constipation and subsequent stomach pains (Park & Jhon, 2009). They help in reducing cholesterol in the body and lowers demand for insulin in the blood (Brown, 1999). Regular consumption of shoots is also said to help improve lipid profile and bowel movements in young women (Bhatt, Singh & Singh, 2005). Significant amount of fibre content has been reported in the shoots and fermentation of *D. giganteus* was found to increase the dietary fibre significantly (Chongtham et al., 2011).

2.9.4 Minerals

Bamboo shoots have been reported to contain ash of up to 1.38% and are endowed with important mineral elements such as K, Na, P and Fe (Chongtham et al., 2011). These minerals are required by the body for proper functioning of important metabolic processes. Bamboo shoots are particularly rich sources of K whose content vary from one species to another and also depending of the ecological zone (Bhargava, Kumbahare, Srivastava & Sahai, 1996; Bhart, Singh & Singh, 2005; Nongdam & Tikendra, 2014,). Reduction of K in shoots of *D. hamiltonii* 10 days after emerging from the ground was observed where the amount dropped by almost 50% from 416mg/100g fresh weight to 210mg/100g fresh weight, whereas in others species only slight reduction was noted (Nirmala et al., 2007). High amount of K has been reported by Feleke (2013) in Ethiopian species of *O. Abyssinica* obtained from Assosa (6.63%), Dhidhesa (7.02%) and Pawe (7.15%), and thus making this bamboo shoots be higher in K than the most popular vegetables like *Amaranthus spinosus*, *Hibiscus species* and *Solanum macroparcon*. Consumption of Bamboo shoot is therefore able to provide the daily recommended dose of 2-5g/day for this vital

mineral important for maintaining a healthy heart beat and control of hypertension (Belitz & Grosch, 1999). Bamboo shoots are rich in Fe, Mg and P as well as other important micronutrients such as Zn and Se. Zinc deficiency is of major concern particularly in the Western diets and is associated with poor healing and slow growth rate in children (Silverman, Romano, & Elmer, 1999). It is an essential mineral in more that seventy body enzymes and is utilized in synthesis of DNA and RNA needed for cell division, cell repair and cell growth. It plays important role in bone growth and development and also helps in maintaining normal reproductive health. Processing shoots by boiling has however been found to reduce the total mineral content of the shoots (Pandey & Ojha, 2014).

2.9.5 Fat

Bamboo shoots contain low amount of fat and are therefore considered ideal food for healthy weight loss and for people with diabetes and cardiovascular diseases (Chongtham et al., 2011; Kumbhare & Bhargava, 2007). A maximum of 1% fat content was reported by Bhatt et al. (2005) in *B. nutans*. Juvenile shoots were found to contain about half the amount of fat found in older shoots of 10 days after emerging from the ground (Nirmala et al., 2007). Boiling and steaming of shoots of *Phyllostachys praecox* reduced fat content whereas in stirred fried shoots it was found increased (Zhang et al., 2011).

Bamboo shoots are not only eaten by human beings, but they are also food for many animals. The giant red panda found in Asia feeds solely on the shoots of bamboo for survival (Fuwen, Zuojian, Zuwang, Ang & Jinchu, 1999). The nutrients content in bamboo shoots was reported to be higher in the shoots than in leaves and stems, and was also found to vary between different parts of the shoots (INBAR, 2006). They contain vitamins B, C, E as well as folate and β-carotene (Chongtham et al., 2011; USDA, 2006;).

2.10 Phytochemicals in bamboo shoots

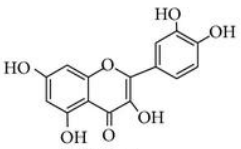
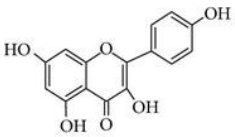
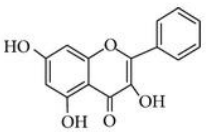
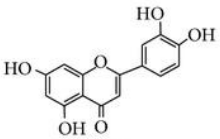
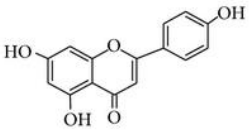
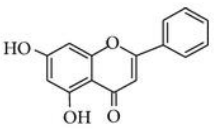
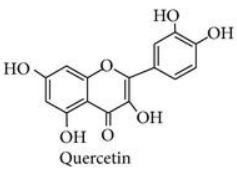
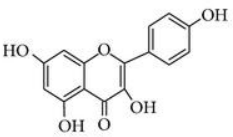
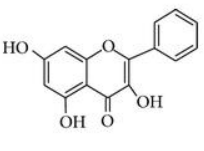
Phytochemicals is a broad name describing a wide range of naturally occurring non-nutritive biologically active compounds found in plants (Figure 2.3). Some of these

phytochemicals acts as a natural defense system against attacks from insects and grazing animals whereas others produce color, aroma and flavor thus drawing attention from potential predators. Among these are antioxidants, flavonoids, phytonutrients, flavones, isoflavones, catechins, anthocyanins, carotenoids, and polyphenols, among others. The phytochemical constituents in a plant often influences the physiological action in a human body (Pamplona-Roger, 1998). For example, indole in cabbages is known to stimulate enzymes that make estrogen less effective and thus reducing the risk for breast cancer (Ju et al., 2000), whereas isoflavones in soy are said to imitate human estrogens helping to reduce menopausal symptoms (Nams, 2011; Vincent & Fitzpatrick, 2000). Their consumption is known to reduce the risk of age-related chronic diseases such as coronary heart disease, diabetes, hypertension and certain types of cancer (Olajire & Azeez, 2011). They are therefore important for health and wellbeing throughout life particularly in adulthood and in the elderly.

Saponins are chemical substances found in beans and are said to interfere with the replication of cell DNA thus preventing spread of cancer cells. They were first reported to kill worms in as early as 1962 by Watt and Brayer, a property that has been associated with the ability of bamboo leaves extract to treat stomach ailments. Saponins are also said to cause frothing by lowering the surface tension of water and negatively contributes to various causes of bloat in ruminants. They are also thought to promote the bursting of the red blood cells. Some phytochemicals such as proanthocyanidins are known to physically bind to cell walls and thus preventing adhesion of pathogens to the human cell wall. Phytochemicals are classified into terpenoids such as carotenoids and phenolic compounds such as flavonoids and alkaloids and have received much attention as vital candidates for treating inflammatory bowel diseases (Sahil, Ketan, Anuradha & Bhakti, 2015).

Various researchers have found different types of phytochemicals in different species of bamboo growing in separate ecological zones. Supriyatin and Dalia (2014) detected secondary metabolites consisting of alkaloids, saponins and triterpenoids in leaf extracts of *manggong* bamboo in East Java, Indonesia. In a research done using

bamboo growing in Ghana, saponins, general glycosides and coumarins were found in all the three species of *B. vulgaris, B. ventricosa* and *O. abussinica* whereas tannins, polyphenols, and flavanoids were found only in the last two species (Coffie, Antwi-Boasiako & Darkwa, 2014). Jovale, Remil, and Ramon (2014) detected saponins, diterpenes, triterpenes, phenols, tannins, and flavonoids in both the ethanolic and aqueous leaf extracts, and phytosterols were only in the ethanolic extract of the Phillipine bamboo (*Schizostachyum lumampao*). The seeds of *Bambusa arundinaceae* were found to contain tannins, phlobatannins, flavonoids, cardiac glycosides and phenols but saponins, alkaloids, terpenoids and anthraquinines were absent (Manohari, Saravanamoorthy, Vijayakumar & Vijayan, 2016). On his part, Tanaka et al. (2014) found that phytochemicals in bamboo are not only contained in leaves and shoots but also in other different parts such as culms, knots, branches, rhizomes and roots of *Phyllostachys pubescens*, the major species in Japan.

Group of flavonoids	**Examples**		
Flavanols	 Quercetin	 Kaempferol	 Galangin
Flavones	 Luteolin	 Apigenin	 Chrysin
Favanols	 Quercetin	 Kaempferol	 Galangin

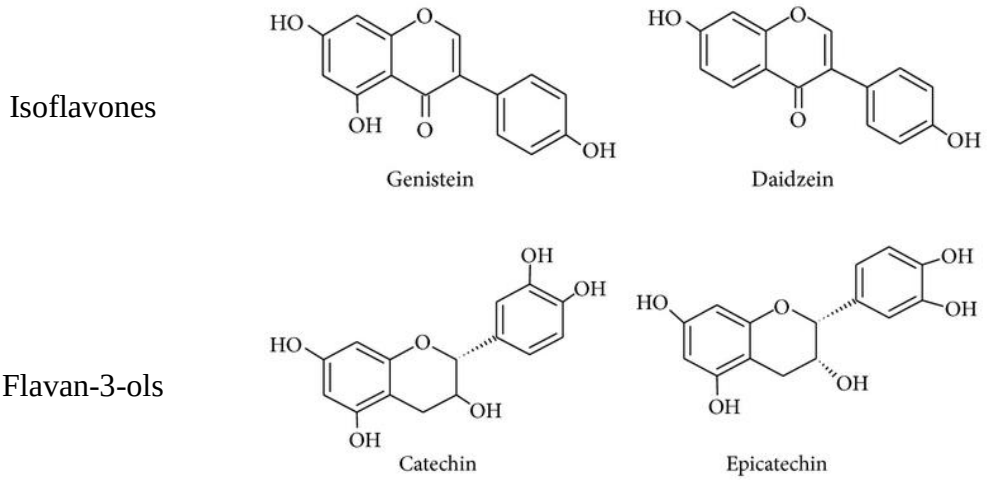


Figure 2.3: Chemical structures of some flavonoids (Kumar and Pandey, 2013)

2.10.1 Flavonoids and polyphenols

Flavonoids are polyphenolic compounds which are secondary metabolites found in most plants. These compounds are believed to offer protection against development of cancer, heart diseases, diabetes, osteoporosis and neurodegenerative diseases (Pandey & Rizvi, 2009). They are also known to have anti-bacterial, anti-inflammatory, anti-allergic and vasodilatory activities (Miller, 1996). Onions, leeks and garlic contain allyl sulfides whereas fruits and carrots are good sources of carotenoids. Flavonoids are present in many fruits and vegetables while tea and grapes are excellent sources of polyphenols.

Flavonoids and phenolic compounds have been found in bamboo. Sarita et al. (2008) determined the phenolic compounds in five species of bamboo found in *Tangjiahe* and *Wolong* Giant Panda reserves in *Siachuan*, China and observed that four species contained flavonoids and one did not have detectable amounts. They also found that species, site and age of the culms or shoots had an influence on the composition and concentration of the soluble phenolic compounds. Leaves of *Bambusa arundinaceae* have been found to contain 3.7-12.71GAE/g of dry extract and 2.31-6.71CE mg/g of total phenolics and total flavonoids respectively (Shaukat et al., 2012). Ethanolic and aqueous extracts of *Schizostachyum lumampao* were found to contain total phenolic content of 76.7 and 13.5 mg GAE per 100 g, respectively, and total flavonoid

content of 70.2 and 17.9 mg quercetin equivalents per 100 g air-dried sample, respectively.

2.10.2 Antioxidants

Most of the phytochemicals may possess antioxidant properties and are therefore important compounds for protecting the body cells from oxidative damage and thus reducing the risk of developing certain types of cancer. Bamboo has been found to possess such compounds with vital antioxidant properties. The leaf extract of *Bambusa arindinaceae* showed positive DPPH radical scavenging IC_{50} and percentage inhibition of linoleic acid peroxidation at 278-1536 μg/ml and 24.41-78.05%, respectively, and was found to be a potent antioxidant against degradation of corn oil (Shaukat et al., 2012). The species, *Phyllostachys edulis* grown in China exhibited significant inhibition against superoxide radical, hydroxyl radical, DPPH radical, and ferrous metal-chelating capacities (Jovale et al., 2014). It was also found that the shoots of Korean bamboo namely *P. pubescens and P. nigra,* showed antioxidant activity, and also inhibited angiotensin-converting enzyme thus displaying potential indicator of its antihypertensive properties (Jovale et al., 2014). Research by Tripathi, Jhumka, Z. and Anjum (2015) has revealed that the leaves of *B. nutans* and *B. vulgaris* are rich sources of phenolic compounds and natural antioxidants.

2.11 Medicinal value of bamboo

The bamboo resource has been used for health interventions (Duke & Ayensu, 1985). Zhang et al. (2007) has widely studied the use of bamboo leaves in China as potential food preservatives and the extracts were found to be safe and highly effective compared to the artificial antioxidants. The antioxidants notably flavones, lactones and phenolic acids in the leaves were found to significantly reduce acrylamide formation in potato-based food during thermal processing, thus helping to keep the original crispness and flavor of potato matrixes and reduce toxicity to human (Zhang, Chen, Zhang & Wu, 2007). The bamboo shoots of *Phyllostachys pubescens* have been found to have antimicrobial activity against *Staphylococcus aureus* (Akinobu, Hyo, Shojiro, Kuniyoshi & Ryuichiro, 2011). Two *bis*-lignans have been detected in

the stems of *Phyllostachys edulis* and one of the phyllostadimers was found to significantly inhibit liposomal lipid peroxidation (Suga et al., 2003). In traditional Chinese medicine, bamboo juice and the roots of *Phyllostachys nigra* have been used in treatment of rubies and upper respiratory infections or cough caused by phlegm that is difficult to expectorate (Bown, 1995). It is also sometimes used with ginger juice or other herbs such as loquat and trichosanthes (Li & Wang, 1999).

Bamboo shoots are ideal for healthy weight loss as they are low in calories (Chongtham et al., 2011; Kumbhare & Bhargava, 2007). They have been used traditionally in Chinese medicines to treat infections and to help reduce low density lipoproteins and thus prevent the incidence of heart disease. The shoots have been found to remove stomach worms and also help in lowering high blood pressure as they contain high potassium content. They also help in curing toxemia, that is, internal poisoning. The high fiber content in the shoots prevents chronic constipation and promotes healthier bowel movements and therefore it is an important neutraceutical product (Chongtham et al., 2011; Sarita et al., 2008; Takeshi, Nobutaka, Yasuhiro, Norihisa & Toshio, 2009). The black bamboo leaves have been found to possess both antipyretic and diuretic properties (Duke & Ayensu, 1985) and therefore are good for reducing fever and enhancing urine production in the body.

2.12 Aroma compounds of bamboo shoots

Bamboo has been found to contain important aroma compounds. About seventy of these compounds were detected from fermented Bamboo shoots of *Phyllostachys pubescens* and twenty nine of these revealed strong aroma activity, with the most odor active ones being *p*-cresol (barn-like), 2-heptanol (mushroom), acetic acid (vinegar), and 1-octen-3-ol that smells like mushroom (Shih-Guei, Youngmo & Russel, 2002). Takahashi, Mizui and Miyazawa (2010) found eighty nine compounds from the same species with the most aroma-active compound being eugenol and 2-nonenal.

2.13 Anti-nutrients in bamboo shoots

Anti-nutrients are chemical compounds found in plants and which are known to either interfere with the absorption of other vital nutrients or cause toxicity in the body. They can also render the food unpalatable. These compounds include oxalates, phytates, tannins, cyanogenic glycosides and silica, amongst others (McClure, 1966).

2.13.1 Cyanogenic glycosides

Some of fresh shoots of bamboo contain hydrogen cyanide which occurs in the form of a glycoside referred to as taxiphyllin that act as an enzyme inhibitor in the human body when released (Holstege, Saathoff, Furbee & Neeer, 2010). Taxiphyllin is a highly toxic compound with a lethal dosage for humans of about 50-60 mg. The toxin is a p-hydoxylated mandelo-nitrile triglochinin that decomposes quickly in boiling water (Ferreira, Yotsuyanagi, & Carvalho, 1995; Nahrstedt, 1993). The mechanism of generation and release of hydrogen cyanide in bamboo shoots during processing is described in Figure 2.3. When the plant cells are disrupted by a predator, taxiphyllin is exposed to the hydrolytic enzyme called β-glucosidase which breaks it down into a sugar and a cyanohydrin compound that rapidly decomposes to hydrogen cyanide and an aldehyde or ketone (Moller & Seigler, 1999).

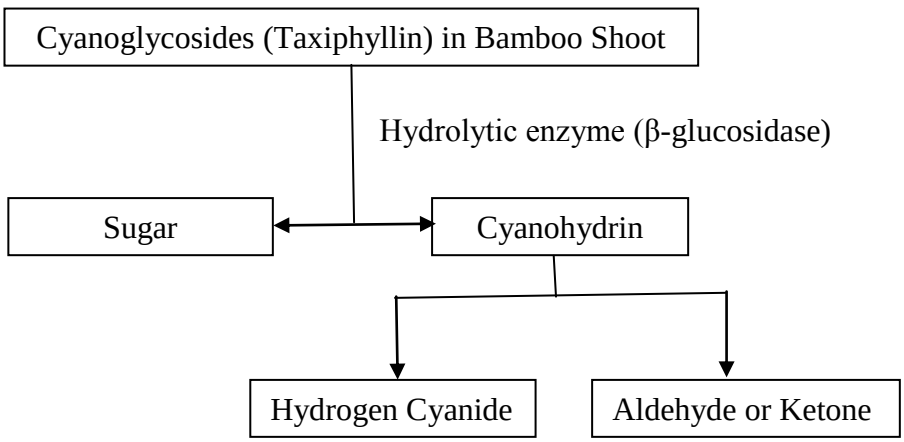


Figure 2.4: Hydrogen cyanide generation in bamboo shoot (Moller & Seigler, 1999)

Bamboo is not the only food plant that contains the toxin. Sorghum leaf, plum stone, apricot stone and apple seed contain levels exceeding 700 ppm and very close to those found in the bamboo shoots (Bradbury & Haque, 2002).

Gibson (1984) also compared bamboo shoots with other plants like cassava, certain lima beans and prunus species and found that the shoots have comparable amounts. Bamboo shoots can be processed free from this toxin because unlike linamarin and lotaustralin toxins in cassava, taxiphyllin in bamboo is highly unstable and is easily decomposed in boiling water. The cyanide level within the bamboo shoot has been found to vary between the basal part and the apex, and also among different species. Haque and Bradbury (2002) found up to 1,600 ppm total cyanide in the tip of the leave reducing to 110 ppm in the base. Cyanogenic glycosides have also been found to differ between different species. Pandey and Ojha (2014) found levels of 110-180 ppm in *B. bambos, B. tulda, D. strictus* and *D. asper*. It is not however, all bamboo shoots that are toxic. Chang and Hwang (1990) tested seven different bamboo species and found that three were totally without cyanogens, whereas four contained significant quantities and that the amount varied with season of harvest. In order to reduce the level of toxin, Sodium Chloride (NaCl) has been found to have good application. Pandey and Ojha (2014) observed that boiling shoots of bamboo in different concentration of NaCl at varying time intervals removed cyanide without much loss of nutrients. In this regard, boiling shoots in 5% NaCl for 15 min was found to be the best method for *B. bamboos*, whereas boiling for10 min in 1% NaCl worked for *B. tulda*, 15 min boiling in 1% NaCl for *D. strictus* and 10 min boiling in 5% NaCl was applicable for *D. asper*. Some communities in Sambarpur, Orissa boil bamboo shoots in water and discard the extract to get rid of the bitter taste (Bal, Naik & Satya, 2009). Ras (2007) obtained 91% reduction in cyanide after boiling shoots for 15 minutes and this reduced further after 30 minutes boiling to about 4.8% remnant. At the end of 60 minutes of boiling, no content of cyanide was detected in the shoots. Boiling for up to 2 hours can detoxify even the most toxic shoots and the lethal dose is 0.5-3.5 mg/kg body weight (Nongdam & Tikendra, 2014).

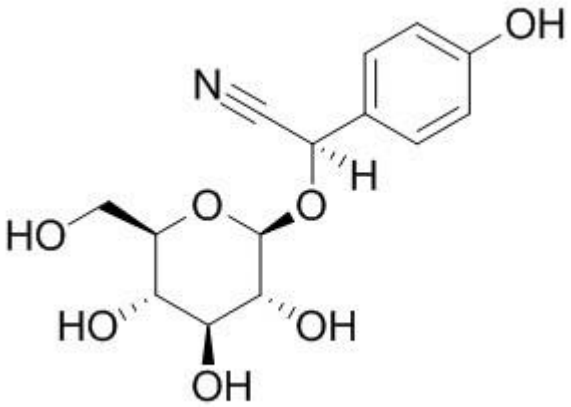


Figure 2.5: Chemical structure of taxiphyllin toxin

2.13.2 Tannins

Tannins in plants are naturally occurring compounds exhibiting polyphenol-like properties and are found in vegetables, fruits and seeds. They occur in form of both hydrolysable and non-hydrolysable (condensed tannins). They are widely distributed in the plant kingdom with the most abundant in dry leaves being the condensed tannins. These tannins are considered anti-nutritive because they are known to precipitate proteins from aqueous medium by inhibiting digestive enzymes and exhibiting anti-trypsin and anti-amylase properties, and thus rendering the proteins unavailable to the body (Soetan & Oyewole, 2009). Tannins have been reported in the bamboo shoots (Zhao, Liu & Ma, 2001). Wang, Pu, Ding and Wan (2009) reported the occurrence of tannins in bamboo known as *Fargesia yunnanensis*. High tannin content in bamboo shoots is said to cause an offensive taste and therefore lowers the deliciousness of the shoots (Xia-Bo, 2006). Lignin and other plant polyphenolic compounds resist decomposition and complex with nitrogen in ways that also reduce nutrients' availability (Gupta, 1999). Tannin are also known to chelate zinc and iron irreversibly and thus interfering with their absorption in the body.

2.13.3 Phytic acid

Phytic acid occur in all plants as inositol hexa-phosphates and is a carrier of phosphorus and other minerals which are needed to support germination and growth.

It is known to complex strongly with certain dietary nutrients such as calcium, magnesium, copper, zinc, iron and proteins, thus decreasing their bioavailability in the body and causing health problems (Jemal, Bray, Melissa, Ferlay, & Ward, 2011; Kigel, 1999). Phytic acid is important to plants because it is known to act as an antioxidant during seed dormancy as well as carrying cations in the cell walls of legumes (Uebersax, 2006). The pH is said to be critical in solubility of fairly stable chelates that phytic acid is capable of forming with almost all multivalent cations (Cheryan & Rackis, 1980). At low pH and low cation solution, a phytate-protein complexes form whereas at pH of 6-7, a tertiary phytic acid-mineral-protein complex form that decomposes at high Na ions concentration. Despite the negative impact of phytic acid, the compound has been reported to be anti-carcinogenous, anti-inflamatory and to possess ability to lower cholesterol and glucose levels in the body (Watzl & Leitzmann, 1999). Dongmeza, Steinbronn, Francis, Focken and Becker (2009) reported the presence of phytic acid in dried leaves of bamboo. In fermentation of bamboo shoots in the North east India, a strain known as *Lactobacillus plantarum* was found to possess high capability to degrade phytic acid in bamboo shoots (Nongdam, 2015) and thus improving the safety of the shoots.

2.13.4 Oxalic acid

Oxalic acid is a common and widespread constituent of plants and considered an anti-nutrient. It occurs as a free acid, as soluble salt of potassium and sodium, and as insoluble salts of calcium, magnesium and iron (Noonan & Savage, 1999). Their presence in the food eaten therefore may reduce the mineral availability to the body. As plant grows oxalates have been found to increase (Yoshikawa, Nakagawa, Kobayashi, Tokieda & Nagai, 1988) and they may occur in either soluble or insoluble form. The soluble form is more harmful because it is more readily bio-available to the body than the insoluble type which is excreted in the faeces (Chai & Liebman, 2004). When oxalic acid binds with calcium, they form insoluble calcium oxalates that are precipitated and deposited in the kidney to form kidney stones (Prien, 1991), which may results to renal failure. Other side effects of consuming oxalic acid includes corrosion of the mouth and gastrointestinal tract and this may cause gastric hemorrhage and haematuria (Concon, 1988). Oxalic acid has been

reported to exhibit a lethal minimum dosage of 4-5% (Fasset, 1973). Some researchers have reported the presence of oxalates in bamboo shoots (Mukda, Suree & Maitree, 1980; Ruan et al., 2013). It was also found that soaking and cooking foodstuff in water reduces the amount of oxalic acid content of the food through leaching losses (Noonan & Savage, 1999; Savage, Vanhanen, Mason & Ross, 2000). Oxalic acid is normally produced by mammalian metabolism. It has also been reported that the mean daily intake of oxalic acid among the English diets is about 70-150 mg and that tea appears to be the source of the highest amount in this diets followed by rhubarb, spinach and beet. People who are vegetarians therefore have high risk factor and are advised to consume high calcium foods (Noonan & Savage, 1999).

2.14 Existing processing technologies of bamboo shoots for human food

Consumption of bamboo shoots in most countries have been reported to be traditional, non-standardized, seasonal and region-specific with little value addition (Choudhury et al., 2012). There is need and opportunity therefore for organized food processing factories to take up the challenge. The main reason for bamboo processing is removal of taxiphyllin toxin which is evolved when the shoot tissues are disrupted. Currently a number of products have been developed in different regions and several processing methods ranging from soaking, boiling, drying, fermentation, and use of salts have been applied.

2.14.1 Soaking

When bamboo shoots are sliced and soaked overnight, some biochemical reactions take place. Taxiphyllin is hydrolyzed enzymatically by β-glucosidase to yield glucose and 4-hydroxy-(R)-mandelonitrile which is further broken down to hydrogen cyanide and benzaldehyde by the enzyme called hydroxynitrile lyase (Gleadow & Moller, 2014). It has been observed that changing the soaking water severally as well as long time soaking in 2% sodium chloride helped to further reduce the toxin before

cooking (Bhardwaj, Sigh, Wangchu & Sureja, 2007; Bhargava, Kumbahare, Srivastava & Sahai, 1996). Shoots can be soaked for 3-4 hours or even overnight before cooking depending on the species, because the toxin levels vary from one species to another (Hunter & Fenge, 2000; Vetter, 2000). The longer the soaking time, the higher the cyanide reduction rate, and soaking for 24 hours was reported to give a reduction of 81-85% for *D, giganteus* and *D. hamiltonii* species (Rawat, Nirmala & Bisht, 2015).

2.14.2 Boiling

Boiling of bamboo shoots is an important processing aspect in order to remove the bitterness in the shoots. Boiling results in rupturing of the cell walls and release of the cell contents including the anti-nutrients (Ogbadoyi, Makun, Bamigbade, Oyewale, & Oladiran, 2006). Boiling time and volume of water used have been found to have effect in removal of the toxin (Montagnac, Davis &Tanumihardo, 2009). Boiling for 10 min reduced cyanide content by 67.8% and 76.9% for *D. giganteus* and *D. hamiltonii,* respectively (Rawat et al., 2015). Further boiling for 20 min reduced cyanide by 87%. Tripathi (1998) has shown that steaming of shoots can reduce the cyanide content to permissible limits. Other researchers have reported that boiling shoots up to 3 hours can reduce hydrogen cyanide by 97% (Ferreira et al., 1995). Slicing the shoots and boiling them for 60 minutes and discarding the brew has however been found adequate to remove the toxins (Sharma & Borthakur, 2008).

2.14.3 Drying

The shelf life of a food product is affected by its moisture content. Reduction of water activity therefore through drying is an important processing aspect if the product is to be stored for long and reduce volatile toxins. Various researchers have dried bamboo shoots using different methods with varying effect on nutrients. It was observed that drying at 60°C using cabinet dryer for 7-8 hours decreased the starch content by 67.5% and vitamin C content by 88.9% (Muchtadi & Adawiyah, 1996). Wongsakpairod (2000) compared superheated steam (SSD) at 120-160°C and high temperature hot air drying at same temperature and found that SSD produced products of darker color than low temperature drying at 70°C. SSD method also

eliminated the bitterness (cyanogens) in the shoots as per the sensory tests conducted. On the other hand Li, Qiu and Yang (2002) explored the traditional convective hot airflow drying (AD) and vacuum freeze drying (FD) methods. The AD products had extremely hard texture, severe browning, low rehydration and low nutritive value. FD had good preservation of color, aroma, taste and shape but extremely expensive and with low yield compared to AD which had high yield and less expensive. Hot air drying was also done by Madamba (2003) and found that there was a linear relationship between the volume change and moisture content and that shrinkage of the shoots occurred. When grated samples were dried in an oven at 60°C for 8 hours, cyanogens reduced by up to 95% (Lambri & Fumi, 2014), whereas drying at 50°C reduced by 81% after 24 hours (Iwuoha, Banigo & Okwelum, 1997).

2.14.4 Fermentation

Fermentation is an ancient method of food preservation and is known to improve the nutrients quality and to enhance sensory attributes of a food (Chaves-Lopes et al., 2014). Bamboo shoots forms an important part of the traditional foods to the people of North Eastern India where they make different fermented products of Bamboo shoots which are used as pickles, condiments and flavoring agents, cooked with fish or meat to make relish, and many others food products used in traditional food preparation (Nongdam, 2015). Fermentation is also known to improve the nutritive value of the food through biosynthesis of vitamins, essential amino acids and degradation of anti-nutrients (Nwosu, 2010).

2.15.1 Bamboo-based food products

A number of food products have been made from the bamboo shoots and plant. Bamboo shoots are a popular food in Asia and are incorporated in many intercontinental dishes in Indian and Chinese restaurants (Fung, 1997; Knechtges, 1986). There are products commercially available in China, Japan, Thailand and Malaysia and these includes canned bamboo shoots, fermented shoots, bamboo pickles, bamboo shoots powder, bamboo shoots juice and bamboo beer and vinegar. Bamboo salt has been made and incorporated in the meat batter and found to improve its physicochemical properties (Kim et al., 2010). Bamboo salt is also reported to possess various therapeutic effects on diseases such as inflammations,

viral diseases, diabetes, circulation organ disorders, cancer, among others (Hwang, Jung, Song & Park, 2008). Biscuits with up to 10% bamboo powder of *Bambusa balcooa* have been developed (Choudhury et al., 2015). Pork nuggets incorporated with fermented bamboo shoots of *Bambusa polymorpha* were found to possess improved microbial and sensory qualities and longer shelf life compared to the control (Thomas, Jedin, Barman & Das, 2014). Other products include *Gulai rebung* made of bamboo shoots with thick coconut milk in Indonesia, *Labong (*shoots, coconut milk and chilies*)* in Philippines, *alui tuma* (a local dish) in Nepals and steam ground pork with finely diced bamboo shoots sprinkled with soy sauce as a very popular dish in China. Boiled bamboo shoots are salted and consumed in Australia and New Zealand (Satya et al., 2012). Vietnamese broth called *sup bun mang gd* is a noodle soup made with chicken and fresh bamboo shoots and taken as breakfast. In the remote hilly areas of Western Ghats, bamboo shoots are boiled and used to prepare pickles, snacks, papads and other fried food stuffs (NMBA, 2009).

2.15.2. Application of ash in food processing

The husks and stalks of beans are a by-product of bean harvest. Ash is obtained by burning this agricultural waste biomass at temperature of about 500°C for 2 hours (Adama & Jimoh, 2012). The ash is the carrier of minerals and it is important to determine the mineral composition of a food sample since it influences the taste, appearance, texture and stability of the food in question. Habibullah, Abbas and Shah (2007) found K of 1,443mg/100g, Ca of 215mg/100g, Mg of 204 mg/100g and P of 374mg/100g in the ash of *Mung* bean. The ash may also contain some insoluble matter which has to be filtered off. Traditionally this is a normal practice in areas where ash is used in food preparation.

The current research work is written chapter by chapter in line with the declared specific objectives.

CHAPTER THREE

CONSUMPTION OF BAMBOO SHOOTS IN KENYA

3.1 Introduction

Bamboo shoots have for a long time been used as food in the Asian countries such as China, India, Japan, Taiwan and Thailand. They have been found rich in important nutrients (Chongtham et al., 2011) and therefore able to supplement some of the nutrient-deficient foods. Consumption of these shoots however has largely remained traditional and region-specific (Nongdam et al., 2014). In Kenya, for example, consumption has been reported in some parts of Western Kenya around Mt. Elgon region where the *Sabaot* and the *Dorobo* utilize the shoots of *Y. alpina* as vegetable (Kigomo, 2007; Ongugo et al., 2000). This report is however scanty and does not reveal much on this natural and renewable resource. Availability of the shoots commercially in urban areas particularly in hotel outlets has not been reported either. Lack of this vital information and stagnation of bamboo growing implies that Kenyans cannot enjoy the benefits associated with a well-developed bamboo industry. The purpose of this study was therefore to determine the extent to which the bamboo shoots are consumed in Kenya as food.

3.2 Methodology

3.2.1 Study site

The survey on consumption of bamboo shoots was conducted in 2011 in two areas of Kenya namely, Mt Elgon region and Nairobi. Mt. Elgon area was selected because some consumption of the shoots of the indigenous species, *Y. alpina* by the local inhabitants had been reported. Nairobi area on the other hand, was chosen because it is the capital city of Kenya and has many food selling outlets of categories ranging from small restaurants to five-star international hotels. Since bamboo shoots are consumed in Asian countries, the survey focused on hotels and restaurants frequently visited by tourists from outside Kenya from the Asian countries. Therefore, the

likelihood that an area or a restaurant would have consumption of bamboo shoots was chosen as the inclusion criteria whereas the exclusion criteria was the possibility that that no consumption of the shoots would be found.

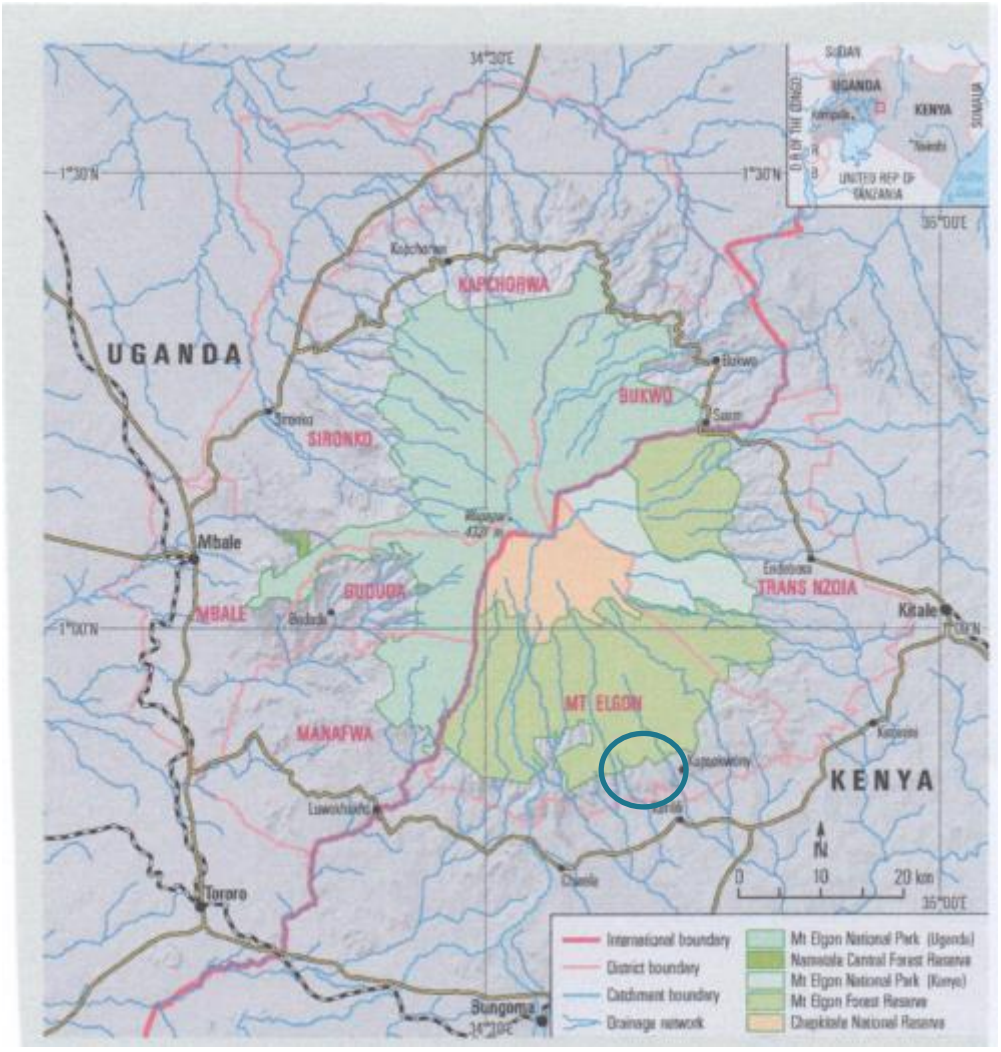


Figure 3.1: Map of Mt. Elgon region (Muhweezi, Sikoyo & Chemong'es, 2007)

3.2.2 Study design and data acquisition

The study was both explorative and descriptive utilizing both interviews, focus group discussion and personal observation. Structured interview forms were used to gather information regarding consumption of the shoots (Appendices 1.1 and 1.2). The enumerator at Mt. Elgon was guided by a resident familiar with the area. The target population was the residents of Kaberwa near Kapsokwony town (Circled area in Figure 3.1) where 15 adult persons were randomly interviewed on the street, at

Kaberwa centre and in homes to avoid bias. The information sought was about awareness of the shoots as food, the sources, preparation methods, eating as well as cultivation. A focus group discussion which included five farmers was also conducted to obtain information about growing, processing and sale of the shoots (Appendix 1.1). In Nairobi a purposive sampling technique was used where eight hotels which had either Japanese or Chinese restaurant outlets were carefully selected for the study. An interview was conducted with key informants who were either the proprietor, hotel manager or the chef. They were interviewed as to whether they serve bamboo shoots, the quantities served per week, the sources of shoots, whether they can buy locally grown shoots and how to serve them to customers (Appendix 1.2).

3.2.3 Data analysis

Results were presented using tables and charts and information gathered through personal observations was also reported.

3.3 Results and discussion

3.3.1 Bamboo shoots and their consumption at Mt. Elgon region

It was noted that bamboo clumps of *Y. alpina* grow inside the Kaberwa forest situated about 4.5 km from the Kaberwa zonal forest's office. The bamboo therefore comprises part of the forest and hence movement in and out of the forest is restricted by the Kenya Forest Service (KFS). Anyone going to harvest the shoots has to be suctioned by the Forest Manager and be provided with security because of wild animals (Plate 3.1). It was also noted that the study area was inhabited by the *Sabaot* community.

Plate 3.1: Mr. Karanja (center) with the forest guards mapping the Kaberwa bamboo forest at Mt. Elgon Region. (Photo taken in September 2011).

Table 3.1 shows the results on awareness of the bamboo shoots and their consumption. All the respondents interviewed said they knew bamboo shoots very well and that they refer to them by the local name *Miyasi*. Asked whether they eat them, they all (100%) responded in affirmative saying it is a delicious vegetable. The

species name is *Yushania alpina.* They also informed that the *Miyasi* are also eaten by animals such elephants, cows, buffaloes and baboons.

Table 3.1: Awareness of bamboo shoots and consumption

Parameter	Percentage score
Awareness of Bamboo shoots	100
Consumption by Respondents	100
Species consumed	*Y. alpina (Miyasi)*

n=15

The discussions with the focus group revealed that most of the shoots are harvested from the forest and sold to consumers when either fresh or as a dried product. It was observed that some dried shoots are also obtained from Uganda and sold in the shops. Fresh shoots are not always available but appear in plenty between April and June every year when the heavy rain starts. It was not possible however, to obtain quantitative data about the amount of shoots obtained from the forest or sold in the shops because such records were not available. It was also noted that towards the end of the dry season and just before the rains, the bamboo clumps are set on fire to reduce the foliage and enhance the sprouting of shoots when the rain starts.

Traditional processing of the *miyasi* was explained as indicated in Figure 3.2. The shoots are boiled when either fresh or dry. Drying is used as a form of preservation of this perishable and seasonal resource. This is done over smoldering fire where some smoking takes place as shown by Plate 3.2. This type of drying imparts some unique flavor to the shoots as well as helping in preservation. The dried shoots can be stored for up to 2 years at room temperature. When the dry shoots are being cooked, they are soaked to soften and then boiled using the extract of ash of bean stalks to remove the bitterness that remained after drying.

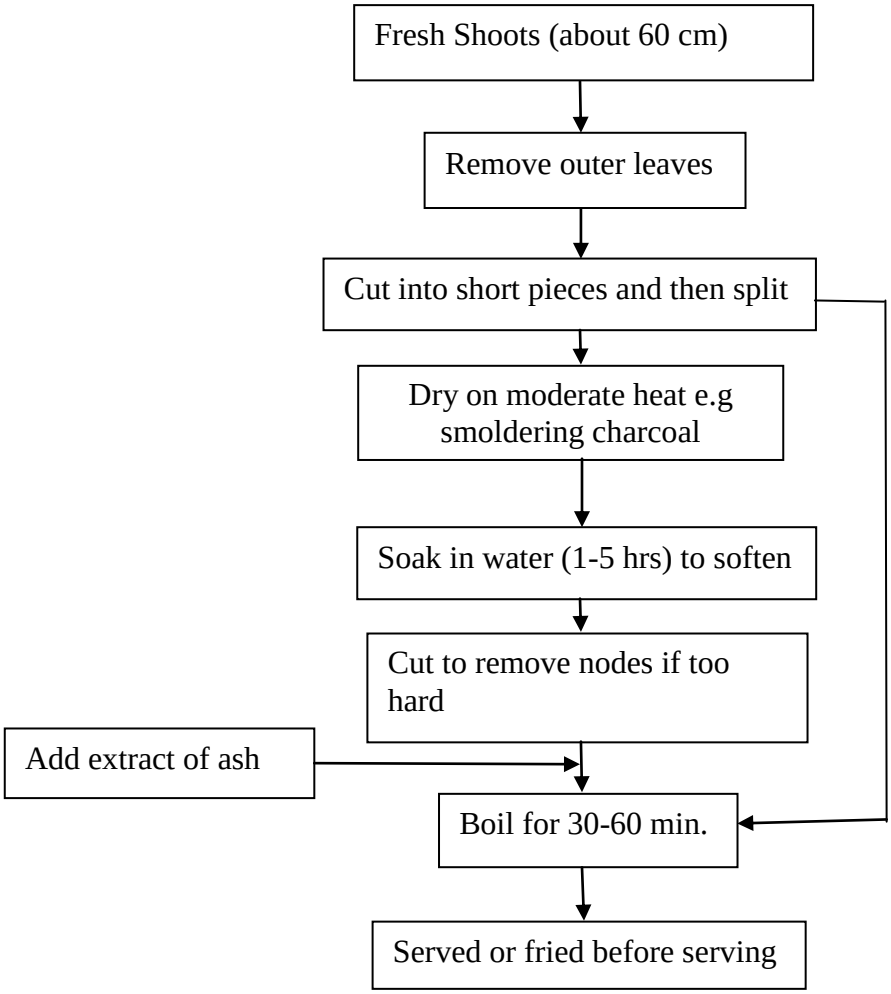


Figure 3.1: Traditional processing of *Y. alpina* among the Sabaot people in Mt. Elgon region of Kenya

The source of the ash was said to be either dry bean stalks waste (by-product of bean harvesting), threshed maize cobs or sweet potato vines which are burnt into ash. The extraction from this ash is done traditionally by putting some into a perforated tin with some dry grass at the bottom to act as sieve for removing insoluble ash from sipping through. The ash is covered with water and allowed to dissolve and drip into another container. It is this liquid which is put into the boiling water to help in cooking. Boiling is done for up to 60 minutes. Some people change the water and boil again whereas others do not change the water, using it as soup. The purpose of

boiling using the ash extract was said to help in reducing bitterness and also to hasten softening. Japanese people boil bamboo shoots with rice bran or pepper for up to 60 minutes to remove bitterness (Woshoku.guide, 2016). The mechanism and effectiveness of this process of reducing or removing the bitterness is not fully understood. It may be that the increased concentration of solutes in the boiling solution accelerates the leaching of the compounds from the shoots by enhanced osmotic pressure in the system. The use of ash of beans' stalks in processing bamboo shoots is explored in Chapter 6.

Asked how they consume the *miyasi,* the respondents said they can eat it either plain after boiling, or sometimes add milk and eat, or simply fry like other vegetables or cook with pumpkin leaves and consume as relish with main dish like *ugali*.

Plate 3.2: Drying shoots of *Y. alpina* on moderate heat at Mt. Elgon region (Photo taken in May 2014)

It was understood from the discussion that artificial cultivation of either the indigenous species or the exotic ones around Mt. Elgon region was uncommon. However there was evidence that growing of exotic species was slowly picking up. Two (2) out of the 15 persons interviewed were found growing the *Dendrocalamus giganteus.*

According to the information obtained as to whether the farmers had any formal training on bamboo growing, one farmer confirmed having been trained at Ruiru in 2005 through an organization known as Forest Action Network (FAN). The local people however said that the exotic species are not eaten in the area and that they were not even aware that such were edible. Some challenges were cited that discourage the local people from growing bamboo. These include water shortage, lack of seedlings, inexperience in the sector and poor market.

3.3.2 Consumption of bamboo shoots in Nairobi area

The results of the survey done in restaurants in Nairobi are summarized by Figure 3.2 below. The restaurants were grouped into three namely, those which were still serving shoots in their menu, those that used to serve the shoots but stopped and those which have never served bamboo shoots to their customers. It was found that out of all the hotels sampled (n=8), only 37.5% were serving bamboo shoots to their customers whereas 25.0% used to sell but stopped, citing shortage of supply and poor demand for the shoots (see Appendix 1.3). It was noted that another 37.5% of the hotels did not know that bamboo shoots are eaten and therefore had never included them in their menu.

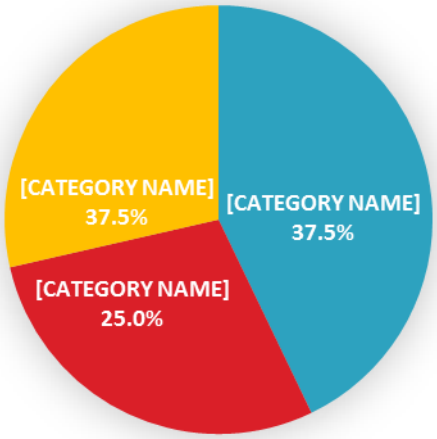


Figure 3.2: Categories of hotels and restaurants based on sale of bamboo shoots

All those restaurants which sold bamboo shoots relied on imports but cited strict import regulation as a challenge. Asked about the preferred sources of the shoots nearly 63% of the proprietors said they would be glad to buy the locally grown shoots, whereas 13% said they would not buy. The rest were non-committal with some citing poor demand for the product.

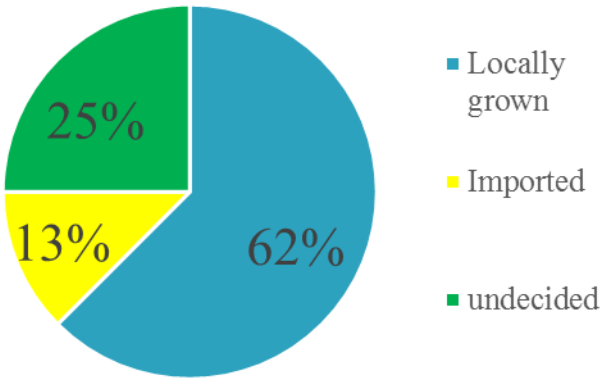


Figure 3.3: Preferred source of bamboo shoots

The weekly sales of bamboo shoots in the restaurants are shown in Table 3.2. It was observed that 62.5% of the restaurants were barely making any sale, with only 25% selling between 0.5 and 1 kg of the shoots per week. The highest sale was found to be 12 kg from only one restaurant representing 12.5% of all the restaurants interviewed.

Table 3.2: Weekly sales of bamboo shoots by the restaurants

Weekly sales (Kg)	No. of Restaurants	Proportion (%)
<0.5	5	62.5
0.5-1	2	25.0
>1<10	0	0
>10<15	1	12.5

Asked how they served the shoots, the hoteliers said that the shoots were not served alone but were mixed with meat and other vegetables. This means that just like in Mt. Elgon region, the shoots were used for making relish for the main dishes.

3.4 Conclusion

The survey on consumption of bamboo shoots in the study areas shows that bamboo shoots as a food material is uncommon to most people due to lack of awareness, shortage of supplies and general lack of knowledge on bamboo shoots as a food matrix. Access to indigenous species is limited whereas the few exotic species being grown by a few farmers in the Mt Elgon region are not being utilized for food. The Sabaot community has a traditional method of processing the shoots to remove bitterness and preserve them for longer periods. The hoteliers in Nairobi on the other hand would like to include the bamboo shoots in their cuisine but the survey results show that supply is unreliable.

CHAPTER FOUR

NUTRIENTS, PHYTOCHEMICALS, ANTIOXIDANT ACTIVITY AND ANTI-NUTRIENTS CONTENT OF BAMBO SHOOTS OF THREE SPECIES GROWN IN KENYA

4.1 Introduction

The importance of bamboo shoots as food item in other countries has been clearly demonstrated in the preceding chapters. These are plants with potential to alleviate food shortage if properly harnessed and cultivated on the farm as is found in most Asian countries. Unfortunately in Kenya, bamboo as a food source is almost unknown by the nationals. Consequently therefore, most ordinary Kenyans have continued to experience shortage of fresh vegetables and thus suffering from malnutrition and other nutrient-deficient complications. Neglect of bamboo shoots has led to poor and slow adaptation of bamboo growing in Kenya. Since bamboo shoots have been utilized widely in the oriental regions, one wonders what the problem is with ones growing locally. The purpose of this section of research work was therefore, to determine the composition of nutrients, phytochemicals and anti-nutrients in three selected species growing in Kenya, comprising two exotic and one indigenous species. The information obtained was then compared with those of edible species reported from other parts of the world and a recommendation made accordingly. It is hoped that the findings of this research work will help to unlock the potential of bamboo shoots as an important food item to be embraced by Kenyan people.

4.2 Methodology

4.2.1 Sampling sites

Two sampling areas were selected for this study. One area was Kaberwa zone in Mt. Elgon region of Western Kenya which was selected for sampling the indigenous species of *Y. alpina*. This species grows naturally in clumps in a government

protected land managed by the Kenya Forest Service. Permission to sample was sought by the researcher and granted by the Forest Officer in-charge at Kaberwa zonal office. An area of about an acre was identified for sampling. The other sampling area for the exotic species was a private coffee farm at Murang'a County situated about 10 km from Thika town along the Thika-Ndakaini road. The researcher also sought permission to obtain samples and was granted by the manager of the farm.

4.2.2 Sample acquisition

In both study areas, random sampling was adopted because the shoots in different clumps of bamboo do not emerge from the ground uniformly and therefore shoots with near equal heights were obtained from different clumps of bamboo. Forty shoots of *Y. alpina,* twenty shoots of *B. vulgaris and* six shoots of *D. giganteus* were harvested during a peak season in May 2014 from the study sites, about two weeks after emerging from the ground. The difference in sample size between the three species was due to availability at source. *D. giganteus* was about 30 cm whereas the *B. Vulgaris* and *Y. alpina* had lengths of about 60 cm. The differences in height were due to the varietal variations that make the shoots morphologically and structurally different. Hence *D. giganteus* is thick at the base (10-15 cm diameter) whereas *Yushania* and *Bambusa* spp. have a base diameter of 5-8 cm. The photos of the shoots without the outer leaves are shown in the Plate 4.1 below. The samples from Mt. Elgon were transported to the laboratory in a cooler box (about 15°C) whereas from Murang'a they were harvested and transported immediately to the JKUAT, a distance of about 20 km. At the laboratory, all the shoots were allowed come to room temperature. The outer leaves were then removed and the hard lower part of the shoot cut off with a knife as is the practice. Six shoots of each species were randomly selected and chopped separately into small pieces and moisture content determined immediately. The remaining shoots were chopped and dried at 70°C for 24 hours in an air-circulating oven (Santosh, Lalit, Poonam & Naik, 2010). They were then ground into powder to pass a sieve of 0.84 mm, homogenized and stored in sealed polyethylene bags at 5°C until analysis. Subsequent analyses were done by performing triplicate determinations from this homogenized powders.

a b c

Plate 4.1: Pictures of shoots: a) *Y. alpina* b) *D. giganteus* and c) *B. vulgaris*

4.3 Analysis of nutrients

4.3.1 Determination of moisture content

Moisture content was determined by drying 5 g of sample in an oven at 105ºC to constant weight according to AOAC Method 930.04 (1995). The moisture level was calculated as shown below.

$$Moisture\ \% = \frac{weight\ before\ drying - weight\ after\ drying}{Sample\ weight\ before\ drying}\ x\ 100$$

4.3.2 Determination of crude fibre

Crude fibre was determined according to AOAC (1995) method 920.86. Approximately 2 g of sample was consecutively boiled in 1.25% H_2SO_4 and NaOH for 30 minutes under reflux. The residual after filtering was washed with alcohol and ether before drying and incinerating at 500ºC for 1 hour. Fibre content was calculated as shown below.

$$Fibre\ \% = \frac{weight\ \ before\ incineration\ (w1) - weight\ after\ incineration\ (W2)}{Sample\ weight}\ x\ 100$$

4.3.3 Determination of fat content

Crude fat was determined by Soxhlet's extraction method 920.85 (AOAC, 1995). The fat was extracted from 5 g sample using petroleum ether (b.P. 40-60°C) and

determined gravimetrically after removing the solvent and drying in an oven. The amount of fat extracted was calculated as a percentage as follows.

$$Fat\ \% = \frac{weight\ of\ fat\ extracted}{weight\ of\ sample}\ x\ 100$$

4.3.4 Determination of protein content

Crude protein was determined by semi-micro Kjeldahl method, AOAC method 978.04 (AOAC, 1995). One gram of sample was digested with concentrated H_2SO_4 and a catalyst until the color turned blue. The digest was then diluted to 100 ml and an aliquot of it steam-distilled using 40% NaOH to release ammonia which was trapped in a solution of boric acid. About 60 ml of the distillate was collected and titrated with 0.02 N HCl until the color changed to orange. The protein content was then calculated by multiplying the percent nitrogen content by 6.25.

4.3.5 Determination of ash content

Ash content was determined by AOAC (1995) method 930.05. About 5 g of the sample was charred and incinerated at 550°C until the ash turned grayish. The weight of the ash was determined gravimetrically and expressed as a percent of the sample weight taken as shown below.

$$\text{Ash } \% = \frac{weight\ of\ ash\ \&\ crucible\ (w2) - weight\ of\ crucible\ (w1)}{weight\ of\ sample}\ x\ 100$$

4.3.6 Determination of total carbohydrate content

Carbohydrates content in percentage was determined by subtracting the sum of moisture, fat, ash, fiber and protein from a 100 (AOAC, 2006).

4.3.7 Determination of mineral composition

Minerals were determined by digesting about 0.1g of ground sample with 2ml of H_2SO_4-H_2O_2 mixture using a block heater. The resulting digest was diluted to 50 ml with de-ionized water. Specific minerals were determined by an inductively coupled plasma spectrometer (ICPS 8100, Shimadzu Ltd, Japan). A range of concentrations of standard mineral solutions were prepared and used to generate standard curves for

computation of concentration of various elements tested (AOAC, 2006 method 985.01)

4.4 Determination of phytochemicals

4.4.1 Determination of total polyphenols

Determination of total polyphenols was carried out using the method of Waterman and Mole (1994). Ten milligrams of sample dried at 70ºC was extracted with 20 ml of 50 % aqueous Methanol at 80ºC for 1 hour, filtered and volume made to 50 ml. One ml of the solution was put into 50 ml volumetric flask and 20 ml of water added followed by 2.5 ml of Folin Denis reagent and 10 ml of 17% Sodium Carbonate. The mixture was homogenized and made to 50ml with distilled water and after 20 minutes, absorbance was read at 760 nm using gallic acid as a standard.

4.4.2 Extraction and determination of flavonoids

The method by Harborne (1973) was applied for sample extraction for analysis of flavonoids and antioxidant activity. Five grams of ground sample were weighed into 250 ml flasks and 100 ml of methanol added. The flasks were closed with parafilm, covered with aluminum foil and shaken for 3 hrs. The samples were kept in the dark to extract for 72 hrs. They were then filtered and concentrated to 20 ml, and kept in closed vials until analysis of flavonoids and antioxidant activity. Working solutions were prepared from these extracts.

The method according to Jagadish, Krishnan, Shenbhagaraman and Kaviyarasan (2009) was used to determine flavonoid content. In a 10 ml volumetric flask, 4 ml of distilled water and 1 ml of shoot's extract were added. After 3 min., 0.3 ml of 5% sodium nitrite solution were added and left to stand for 3 min, after which 0.3 ml of 10% aluminum chloride was added and held for 5 min. Two milliliters of 1 M NaOH were added and the volume was made up to 10 ml with distilled water. The absorbance was read at 415 nm using a spectrophotometer (Shimadzu, UV 180, Japan). Total flavonoids were calculated from a calibration curve prepared using quercetin as a standard.

4.4.3 Determination of free radical scavenging activity

The antioxidant activity of the extracts against 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical was determined using the method of Molyneux (2004). Extracts obtained in 4.4.2 above were prepared in 0.01, 0.1, 1.0, 2.0, 5.0 and 10.0 mg/ml in methanol, and the results were expressed on dry matter basis. L-ascorbic acid was used as a standard at the same concentrations as the extracts in order to compare its antioxidant activity with the sample extracts. One milliliter each of the extract and the standard was put in a test tube and 3.0 ml of methanol added, followed by 0.5 ml of 1 mM DPPH in methanol. A blank solution was prepared using methanol and DPPH. Absorbance was measured at 517 nm after keeping the mixture in the dark for 30 min. The DPPH radical scavenging activity was calculated using Equation 1 below.

$$\text{DPPH radical scavenging activity} = \frac{(Ab - Aa)}{Ab} \times 100$$

Where Ab is the absorbance of the reference (blank) and Aa is the absorbance of the sample.

The inhibition concentration of 50% (LC_{50}) was obtained from a linear plot of concentration against percentage inhibition (antioxidant activity).

4.5 Determination of anti-nutrient content

4.5.1 Phytic acid content

Phytic acid was determined using HPLC method according to Camire and Clydesdale (1982) with slight modification. Five grams of the ground sample were extracted with 3% H_2S0_4 and the phytic acid precipitated with ferric chloride. The precipitate was separated by centrifugation at 2,500 rpm for 10 min and supernatant discarded. Thirty milliliters of distilled water was added and centrifugation repeated and again the supernatant was discarded. The ferric phytate complex was converted to sodium phytate by adding 3 ml of 1.5 N NaOH and sonicating to disperse the precipitate completely. The volume was adjusted to 30 ml with distilled water and boiled for 30 min to precipitate Ferric Hydroxide. The cooled samples were centrifuged and the supernatant was quantitatively transferred into 50 ml volumetric flasks. The precipitate was rinsed with 10 ml of distilled water centrifuged and the

supernatant added into the flask and the volume made to volume. The sample was micro-filtered using 0.45 µm and aliquots of 20 µl injected into a HPLC with an ODS C-18 column using a Refractive Index Detector and 0.025 M KH_2PO_4 as a mobile at a flow rate of 1 ml per min. Sodium phytate (Inositol hexaphosphoric acid) was used to prepare working standard solutions (50-1000 ppm) for quantification.

4.5.2 Oxalic acid content

Oxalic acid content was determined by HPLC according to method by Libert (1981) with modifications by Yu, Peng, Yang, Liu and Fan (2002). Oxalic acid was extracted by mixing 0.5 g of the ground sample with 10 ml of 0.5 M HCl and heating at 80°C for 10 minutes. To the homogenate, distilled water was added to make a volume of 25 ml and then centrifuged at 10,000 for 10 min. The supernatant was filtered with whatman filter paper no. 1 and then micro-filtered with 0.45µm syringe filters. Aliquots of 20 µl were then injected into the HPLC with an ODS reverse phase C-18 column (250 x 4.6mm), mobile phase of 0.01N H_2SO_4 and a photodiode array detector set at 210 nm. The stock standard and working solutions (10-100 ppm) were prepared from Oxalic acid and the standard curve generated was used for quantification.

4.5.3 Determination of tannin content

Condensed tannins were assayed according to vanillin-hydrochloric acid method (Burns, 1971; Price, Van & Butler, 1978). Quarter a gram of ground sample was extracted with 10 ml of 4% HCl in Methanol by shaking for 20 min using a shaker (Labortechnik KS 250b, Germany) and separation done using a refrigerated centrifuge (Kokusan, Type H-2000C, Japan) at 4,500 rpm for 10 min at 25°C. The supernatant was put into a 25 ml volumetric flask and extraction from the residue was repeated with 5 ml of 1 % HCl in methanol. The second supernatant was combined with the first one and diluted to 25 ml. Standards were prepare using Catechin hydrate at 0, 10, 20, 40, 60, 80 and 100 µg/ml. Duplicate aliquots of 1 ml of sample extracts were put into test tubes where one served as sample blank. The samples and standard solutions were reacted with 5 ml vanillin-HCl reagent (prepared by mixing just before use, equal volumes of 8% HCl in methanol and 1%

vanillin in methanol) and allowed to stand for 20 min. To the samples blanks were added 5 ml of 4% HCl in methanol. Absorbance for all prepared solutions was read at 500 nm and tannin content calculated as percent catechin equivalent (CE) using the standard calibration curve.

4.5.4 Determination of cyanogen content

Hydrogen cyanide was determined using the picrate acid paper method described by Pankaj, Rameswar, Sanjay and Kumari (2014). Twenty five milligrams of a bamboo slice or powder was put into 0.5 ml buffer (pH 6.0) inside a small vial with a cap. A stripe of picrate paper was inserted and the vial tightly closed and incubated at room temperature for 18-24 hours. The liberated Hydrogen Cyanide (HCN) was trapped by the picrate paper. At the end of the incubation time, the paper was removed and soaked in10 ml of water and agitated for cyanide to dissolve in the water. Absorbance was then read at 510 nm against a blank (picrate paper incubated without sample). Total cyanide (ppm) was obtained by multiplying the absorbance value by 396.

4.6 Data analysis

The data were analyzed by comparing means for significance using SPSS Version 17.0 and results were expressed as means ± standard deviations. One way analysis of variance (ANOVA) was performed and Duncan's multiple range test at $p \leq 0.05$ was to separate means.

4.7 Results and discussion

4.7.1 Composition of nutrients in bamboo shoots

4.7.1.1 Proximate composition of bamboo shoots

The results of proximate composition in the three species of bamboo shoots analyzed are shown in Table 4.1 below.

Table 4.1: Proximate composition of bamboo varieties (% fwb)

Parameter	*B. vulgaris*	*D. giganteus*	*Y. alpina*
Moisture	91.40 ± 0.40^{b}	91.20 ± 0.30^{b}	92.30 ± 0.20^{a}
Protein	2.30 ± 0.10^{b}	2.30 ± 0.10^{b}	2.60 ± 0.10^{a}
Fat	0.14 ± 0.01^{b}	0.17 ± 0.01^{a}	0.16 ± 0.02^{a}
Ash	1.15 ± 0.02^{a}	1.17 ± 0.07^{a}	0.98 ± 0.03^{a}
Fibre	2.60 ± 0.10^{a}	1.60 ± 0.10^{c}	2.10 ± 0.20^{b}
Carbohydrates	2.43 ± 0.06^{b}	3.60 ± 0.13^{a}	1.90 ± 0.20^{c}

Mean values within each row followed by different letters differ significantly at $p\leq0.05$. Values are mean ±SD, n=6

There was a significant difference in moisture content between *Y. alpina* and the two exotic species of *B. vulgaris* and *D. giganteus* ($p\leq0.05$). Protein content was significantly higher in *Y. alpina* than in the other two species ($p\leq0.05$). The fat content was generally low in all the samples with *B. vulgaris* containing the lowest amount at 0.14%. There was no significant difference in ash content between different species ($p\leq0.05$). Carbohydrates and fiber content differed significantly between all samples analyzed ($p\leq0.05$). In his review paper, Chongtham et al. (2011) reported moisture content of 89.4-90.7%, protein of 1.49-4.04%, carbohydrate of 4.9-

6.5%, fat content of 0.39-0.50%, ash content of 0.89-1.01%, and fiber content of 2.65-4.24%. Santosh, Lalit, Poonam and Naik (2010) also reviewed nutrients in bamboo species of *B. nutans*, *B. vulgaris*, *D. strictus*, *D. asper* and *D. giganteus*, and reported moisture content of 77.0-94.7%, carbohydrates of 2.6-5.1%, ash of 0.8-1.0% and crude fiber of 0.71-0.98%. Bhatt et al. (2005) on their part reported protein content of 1.98-3.29%, carbohydrate content of 3.83-9.94% and fat content of 1.0% in some *Bambusa* and *Dendrocalamus* species in India. When the results of the present study are compared with the findings of the other researchers elsewhere in the world on edible shoots, the potential of the Kenyan bamboo shoots for nutritional interventions is high. The slight variations may be due to differences in maturity at harvest and varying agro-ecological conditions.

4.7.1.2 Mineral composition of bamboo shoots

The composition of minerals for the three species is shown in Table 4.2 below.

Table 4.2: Composition of minerals in bamboo shoots (mg/100g fwb)

Type of Mineral	*B. vulgaris*	*D. giganteus*	*Y. alpina*
Calcium	31.8±0.8^{a}	27.0±1.7^{b}	20.2±0.5^{c}
Magnesium	91.0±0.7^{b}	103.0±6.2^{a}	53.4±1.7^{c}
Potassium	351.2±4.4^{a}	362.6±24.1^{a}	288.8±5.3^{b}
Phosphorus	51.4±3.0^{b}	67.4±4.3^{a}	64.8±0.6^{a}
Zinc	1.3±0.1^{b}	1.5±0.1^{a}	0.9±0.1^{c}
Manganese	1.3±0.0^{a}	0.9±0.1^{b}	0.3±0.0^{c}
Iron	nd*	0.2±0.0	nd
Copper	0.3±0.0	nd	nd

Values within each row followed by different letters differ significantly at $p \leq 0.05$. Values are mean ±SD, n=6
*nd: not detected

The samples analyzed contained considerable amount of major minerals. Potassium (K) level ranged 288.8-362.6 mg/100g and this was comparable with reported results (Chongtham et al., 2011). The content of K in *Y. alpina* was significantly lower than *B. Vulgaris* and *D. giganteus* ($p<0.05$). Nongdam et al., (2014) reported values of 20-1,400 mg/100g in some *Bambusa* and *Dendrocalamus* species in North East India.

Consumption of the shoots can help in boosting the amount of potassium needed by the body. Potassium is a vital electrolyte charged with maintaining proper flow of water inside and outside body cells and is important particularly for athletes who sweat a lot. It is also referred to as a "heart" mineral able to provide protective effect to people prone to high blood pressure (Bellows & More, 2013). Calcium content also varied significantly between 20.2 mg/100g and 31.8 mg/100g among the species. However, the content can vary between 4.0 mg/100g and 180.69 mg/100g as has been reported (Chongtham et al., 2011; Choudury et al., 2012). Magnesium was also found to vary significantly among the three species with *D. giganteus* containing the highest and *Y. alpina* the lowest ($p \leq 0.05$). The content of phosphorus was significantly lower in *B. vulgaris* ($p \leq 0.05$) and similar quantities were observed in *Y. alpina* and *D. giganteus*. These values were however much higher than 6.1-8.7 mg/100g and 19.3-28.1 mg/100g for magnesium and phosphorus, respectively, as reported by other authors (Chongtham et al., 2011; Choudury et al., 2012). The zinc content was similar to amounts found in other leafy vegetables such as *amaranthus* reported to contain 0.6-1.67 mg/100g fresh weight (Muriuki, Sila & Onyango, 2014). Zinc is of particular concern to the government of Kenya which has directed that all the flours be fortified with this mineral to contain about 2.0-3.0mg/100g. The recommended daily intake of zinc of 15mg increased to 20 mg for pregnant women and 25mg for nursing mothers (Silverman et al., 1999).

Other micronutrients such as iron, copper and manganese were also detected though some in trace amounts and compared well with reported values by Chongtham et al., (2011). It is clear that the cultivated exotic species contained significantly higher amount of minerals than the indigenous species. This observation could be attributed to the differences in soil content in the two growing regions. The soil where the exotic species were obtained from appears richer in important soil nutrients due to the application of fertilizers for the coffee plantation. High calcium and magnesium intake is highly beneficial in maintaining strong bones and teeth in the body. Magnesium and dietary fibre intake has also been associated with lower risk of diabetes mellitus (Lu-Cheng et al., 2012). The bamboo species are said to contain more minerals than most common vegetables (Chongtham et al., 2011). The findings

of this study suggest that bamboo shoots in Kenya, particularly the exotic ones under cultivation qualify as an important vegetable capable of providing the much needed micronutrients.

4.7.2 Polyphenols, flavonoids content and antioxidant activity of bamboo shoots

The total polyphenols and flavonoids content in bamboo shoots are shown in Table 4.3 below.

Table 4.3: Total polyphenol and flavonoid content (mg/100 g fwb)

Bamboo species	Total polyphenol (as GAE)	Total flavonoids (QE))
B. vulgaris	16.1±1.4[a]	284.7±5.2[a]
D. giganteus	14.5±1.5[a]	288.4±3.5[a]
Y. alpina	3.0±0.3[b]	53.1±1.6[b]

Mean values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are mean ± SD, n=6

In this study, a significant difference was noted between the exotic and the indigenous species for both polyphenols and flavonoids ($p \leq 0.05$). The total polyphenol content of *B. vulgaris* and *D. giganteus* were 16.1±1.4 and 14.5±1.5 mg/100g respectively and there was no significant difference ($p \leq 0.5$) between them. Likewise flavonoid contents of 284.7±7mg/100g in *B. vulgaris* and 288.4±3.5mg/100g in *D. giganteus* were not significantly different ($p \leq 0.05$). The high differences in concentration of polyphenols and flavonoids between the indigenous species and exotic ones under cultivation may be attributed to the difference in both the varietal and the soil fertility. The exotic species being grown on the coffee plantation showed higher concentrations of phytochemicals compared to the indigenous *Yushania* growing naturally in the forest. Sarita et al. (2008) reported levels of polyphenols of about 1.0 mg/100g in bamboo shoots growing in reserves in Sichuan, China. This report by Sarita et al. (2008) compares very well with the findings of the current study, and this implies that the soil in natural reserve has depleted nutrients and therefore may not give shoots of high quality.

Phenolics and flavonoids have been reported to show a good correlation between the flavonoids content and the antioxidant activity of bamboo (Ayoola et al., 2008; Qinxue et al., 2012).

The antioxidant activities of the three species of bamboo shoots are shown in Figure 4.1 below.

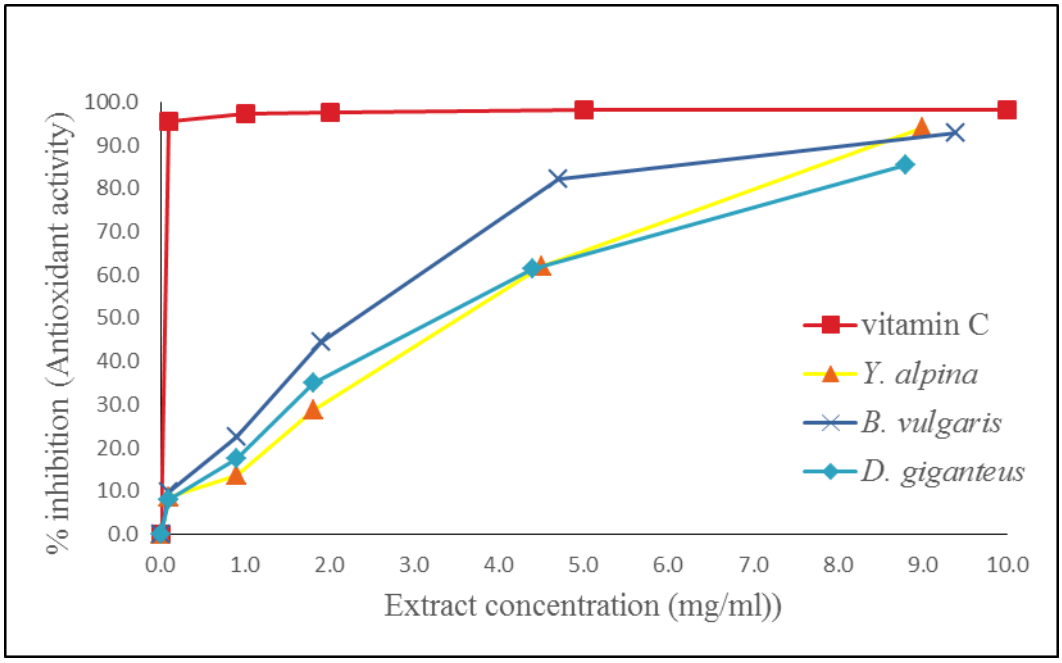


Figure 4.1: Antioxidant activity of extracts of bamboo shoots

Strong inhibition activity against oxidation of DPPH radical was found among the species. It was noted that *B. vulgaris* had the highest LC_{50} value at 2.5 mg/ml compared to *D. giganteus* at 3.5 mg/ml and *Y. alpina* at 4.0 mg/ml. The lower the concentration of the extract at 50% inhibition (LC_{50}), the higher the radical scavenging activity. Thus, *B. vulgaris* was found to have better antioxidant activity than the other two. This high activity may be due to high polyphenolic and flavonoid content as indicated in Table 4.3 above. Strong antioxidant property of bamboo powder has been reported (Takeshi at al., 2009) and it has also been shown that bamboo shoots contain anti-carcinogens, thus helping to reduce production of free radicals in the body and therefore decreasing the chance of cancer development (Chongtham et al., 2011). The results from this study suggest that bamboo shoots growing in Kenya under cultivation possess high potential for promoting good health.

4.7.3 Anti-nutrients content in fresh bamboo shoots

Anti-nutrients which were considered in this study are tannins, phytic acid and oxalates. This factors have the effect of reducing nutrients availability in the body and can be harmful beyond certain thresholds. The results are summarized in Table 4.4 below.

Table 4.4: Concentration of tannins, phytic acid and oxalic acid in bamboo shoots (fwb)

Bamboo species	Tannin content (% g/100g CE)	Phytic acid (mg/100g)	Oxalic acid (% g/100g)
B. vulgaris	0.024±0.001[a]	2,700±100[a]	1.2±0.1[a]
D. giganteus	0.030±0.001[a]	2,400±300[a]	1.0±0.1[b]
Y. alpina	0.007±0.001[b]	830±70[b]	0.7±0.0[c]

Mean values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are mean ± SD, n=6. CE=Catechin Equivalent.

The tannin content ranged from 0.007-0.024% CE and there was significant difference between the exotic species (*B. vulgaris* and *D. giganteus*) and the indigenous species of *Y. alpina* ($p \leq 0.05$). The exotic species contained more than three times the amount found in the indigenous. Wang et al. (2009) reported up to 1.71% of tannins in bamboo species known as *Fargesia yunnanensis* growing in China. When the tannin content is high, it contributes to an offensive taste of bamboo shoots (Xia-bo, 2006). The species tested in this study however, showed values lower than 0.03% in the raw shoots, implying that they could possess better taste than those with high tannin content. The tannin values found in the species tested were even lower than found in some common edible plants. For example, Omobolanle and Moses (2013) reported 0.88% in fresh *Amaranthus*, whereas 0.1% has been reported by other authors in the same vegetable (Gupta, Lakshmi, Manjunath & Prakash, 2005). Mosha. Gaga, Pace, Laswai and Mtebe (1995) on their part reported 1.27% tannins in cabbages and 0.49% in sweet potato. Since tannins are water soluble (Muhammed & Manan, 2015), the levels in bamboo shoots may even reduce further during boiling and this may improve the taste.

On the phytic acid content, there was a significant difference between the exotic and the indigenous species ($p \leq 0.05$). *B. vulgaris* showed the highest concentration of 2.7% followed by *D. giganteus* at 2.4 and 0.8% in *Y. alpina*. The values obtained in this study are higher than those reported by Sarangthem and Singh (2013) who found 30.7 and 36mg/100g in *Bambusa balcooa* and *Dendrocalamus hamiltonii*, respectively. Mina, Giri and Shantibala (2014) found phytate content of 25.9 and 66.4 mg/100g in five *Dendrocalamus* and *Bambusa* spps, respectively. The samples tested in the current study contains significantly high levels of phytic acid which may have been caused by differences in soil constituents. Phytic acid in the salt form (phytate) is the carrier of phosphorus in plants and is not digestible by non-ruminants because they lack the enzyme phytase. It is also prevalent in many other foods. Pearl millet genotypes were found to contain 354-796 mg/100g (Abdalla, Tinay, Mohamed & Abdalla, 1998) and 600-1,000mg/100g in whole wheat flour (Stevenson, Phillips, O'sullivan, & Walton 2012). Due to the adverse effect of this anti-nutrient in the diet, it is preferable to choose a processing method that can reduce their content and thereby improve mineral bioavailability and prevent associated nutritional disorders.

The oxalic acid also showed significant difference between the species, with values ranging 0.7-1.2% ($p \leq 0.05$), whereby *B. vulgaris* had the highest. In a random testing of some food conducted in Vietnam, bamboo shoots were found to contain up to 0.3% oxalic acid (VietNam News, 2013). There are other vegetables that are also known to contain high levels of oxalic acid. Mosha et al. (1995) reported about 0.4% in sweet potato and peanut greens whereas spinach, rhubarbs and amaranth are reported to contain 0.32-1.26%, 0.28-1.34 and 1.59%, respectively (Noonan & Savage, 1999). High concentration of oxalic acid is also found in chocolate, pepper, sesame and green tea and it is recommended that high oxalate food should be consumed with high calcium food to reduce the chance of oxalates being absorbed in the body (Yoshihide, Shigeki & Ryuichi, 1984). Regular consumption of high oxalate food over long periods of time could result to kidney stones and urinary tract problems.

4.8 Conclusion

The results of this study show that the shoots of bamboo species grown in Kenya are as rich in important macro-nutrients such as proteins, carbohydrates and fibre as found in similar species that are edible in countries such as India and China. The cultivated ones are richer particularly in calcium, magnesium and zinc content compared to others reported from other parts of the world and can thus aid in minimizing mineral deficiency in humans today. The shoots were found to possess high levels of polyphenols and flavonoids and indicated their potential for contributing to human health as important antioxidants. It was found that the amount of anti-nutrients which were found in the shoots were generally lower than those found in most common vegetables and therefore the bamboo shoots could provide alternative source of nutrients of better availability to the body.

CHAPTER FIVE

PHYSICOCHEMICAL PROPERTIES AND ANTIOXIDANT ACTIVITY OF THE UPPER AND LOWER PORTIONS OF THE BAMBOO SHOOT (*Yushania alpina* spp.)

5.1 Introduction

The species of *Y. alpina* is found growing naturally in clumps and unlike those of the giant bamboo species, its shoots are relatively slender. These shoots are edible and are harvested after the onset of rain between April and June each year when they are about 60 cm tall. The harvesting however, is traditional with no scientifically guided approach that will ensure that the most nutrient-rich part of the shoot is obtained. It was hypothesized that there is no variation of nutrients and other bio-actives within the shoot of this indigenous species. Other species have been reported to show differences in composition of some constituents within the same shoot. Thammawong, Nei, Roy, Nakamura and Shiina (2009) found variation in sugars between different sections of the shoot of *Phyllostachys pubescens* Mazel from the apex to the bottom. It has also been reported that the age of the shoots affects the concentration of nutrients and other biochemical constituents of *D. asper, D. strictus* and *B. tulda*, particularly for proteins, phenolics, fiber and carbohydrates (Pandey & Ojha, 2013). However, little information is available on these aspects of the shoot and more research on bamboo shoots from different agro-ecological regions as a food resource has been recommended (Satya et al., 2012). The objective of this study therefore, was to determine the distribution of physicochemical properties and antioxidant activity within the shoots of the *Y. alpina*, in order to establish the section of the shoot that is most nutritionally beneficial to the body and thus maximize its usage as a functional food for human health. The species was chosen for the study because it is consumed particularly in the Mt. Elgon region whereas the other two are yet to be accepted for food.

5.2 Methodology

5.2.1 Sample acquisition

About 60 shoots of *Y. alpina* with near uniform heights of about 60 cm were randomly harvested during a peak season in May 2013. The shoots were obtained in the same locality of about one acre at Kaberwa forest at Mt. Elgon region in Western Kenya where clumps of the bamboo grow naturally. Mt Elgon region was chosen because some consumption of the shoots had been reported, unlike in other highland areas with same species where no report was available about local communities consuming the shoots. The shoots were carefully and randomly selected to ensure they were of almost similar height. They were cut and transported the same day in the evening by road without removing the outer leaves. In the morning they were received at the Food Science Laboratory of Jomo Kenyatta University of Agriculture and Technology. The outer leaves were removed and each of the soft shoot was divided into two parts, making the upper and the lower portions. The upper part was 15 cm long from the apex after peeling, and the lower portion was the remaining part up to the soft part easily cut by a knife as standardized based on local practice. Figure 5.1 shows the sketch of the upper and lower portions.

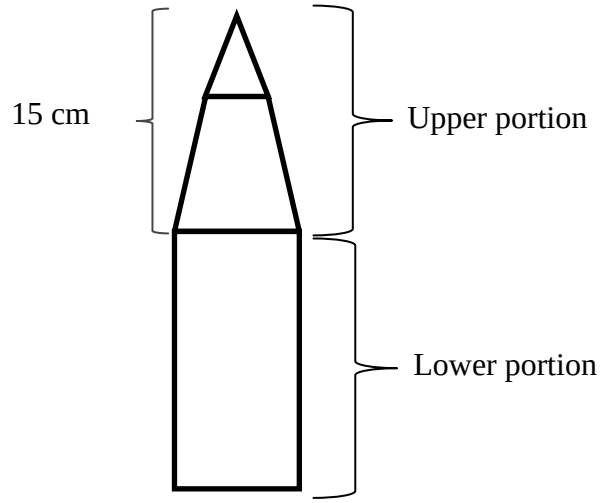


Figure 5.1: Sketch of the upper and lower portions of shoot

Color determination was done from the outer side after de-sheathing and 10 shoots were measured. As for moisture content determination, 10 shoots of the upper and

lower portions were chopped with a knife into small pieces for homogeneity and determination of moisture content made for each. The rest of the shoots were chopped and dried in an air-circulating oven at optimum temperature of 70ºC for 24 hr (Santosh et al., 2010). After drying, the upper and the lower portions were ground separately using a bench type sample mill (model SK-M10R, Japan) to pass a sieve of 0.84 mm for uniformity and homogeneity of the sample powder. Each portion was well homogenized and packaged in sealable polyethylene bags and kept at 5°C until analysis. As for other parameters, a minimum of three determinations were done for each of the upper and lower portion under consideration and results expressed on dry weight basis (dwb). The three determinations were deemed adequate because about 40 shoots had been reduced into a homogenous powder.

5.2.2 Determination of proximate composition

Proximate composition was determined using the AOAC methods describe section 4.3 sub-sections 4.3.1-4.3.6.

5.2.3 Determination of minerals

Minerals were determined by wet method of digestion and inductively coupled plasma spectroscopy as described in section 4.3.7.

5.2.4 Determination of vitamins

5.2.4.1 Determination of thiamine and riboflavin

The AOAC method (1995) was used with slight modification according to European Standards (2003). Two grams of the sample were mixed with 20 ml of 0.1 N HCl and heated in boiling water for 60 min. The pH was adjusted to 4.0 and 100 mg of taka-diastase was added, mixed and incubated at 40°C for 18 hr. The digest was made to 50 ml with 2 % acetic acid and centrifuged at 5,000 rpm for 10 minutes and the supernatant was taken and micro-filtered with 0.45µm membrane ready for HPLC analysis as follows.

In case of thiamine pre-column derivatization was done by mixing 1 ml of the enzymatically-treated sample was mixed with 1 ml of alkaline potassium hexacyanoferrate III solution. The mixture was vortexed for about 10 seconds and

allowed to stand for about 1 min for the reaction to take place. Exactly 20 µl of the oxidized thiochrome form were injected form was injected into the HPLC (Shimadzu LC-10A) with a reverse phase C18 column of 250 x 4.6 mm, and fluorometric detection at Ex 365 nm and Em 435 nm (Shimadzu RF 1501). The mobile phase for thiamine was methanol: acetate buffer of pH 4.4 (40:60). Sample solution for riboflavin was injected into the HPLC without derivatization and the mobile phase was methanol: water: acetic acid (40:59.5:0.5) at UV wavelength of 270 nm (Shimadzu SPD-10A). Thiamine hydrochloride and riboflavin were used to prepare standard solutions for quantification by comparing the peak areas of the samples with the prepared standard.

5.2.4.2 Determination of vitamin C

Vitamin C content in the samples was determined by HPLC according to method of Vikram, Ramesh, and Prapulla (2005). Approximately 10 g were homogenized with 20 ml of 0.8% *m*-phosphoric acid for 30 min and centrifuged at 10,000 rpm for 10 min at 4°C. The supernatant was micro-filtered with a 0.45 µm filter and injected into HPLC (Shimadzu LC-10A) with a photo diode array detector (Waters PDA 2996) set at 266 nm. Separation was achieved using a reverse phase C18 column of 150 x 4.6 mm and 0.8% *m*-phosphoric acid at a flow rate of 0.5 ml/min and L-ascorbic acid was used as a standard.

5.2.4.3 Determination of β-carotene

Extraction of β-carotene was done busing a mortar and pestle, partitioned with petroleum spirit, and isolated using an open column chromatography of 30 x 2.54 cm which was packed with silica gel of mesh 200-400 (Rodriguez, Delia, & Kimura, 2004). About 2 g of ground bamboo sample was weighed and put in to a mortar. Nearly 1.5g of Celite no. 503 was added and carotenoids extracted by grinding with a pestle using up to 50 ml cold acetone (refrigerated at 4°C for 2 hours). The mixture was filtered using a funnel fitted with a wool plug into a 50 ml volumetric flask and the residual washed with acetone until devoid of color. The acetone extract was transferred into a 250 ml separating funnel containing 40 ml of petroleum spirit.

About 150 ml of distilled water was added slowly along the wall without shaking to remove acetone.

Carotenoids were allowed to move from the acetone fraction into the petroleum spirit. The lower aqueous fraction was removed and discarded. Same amount of water was added again to wash off acetone completely. Again the lower fraction was removed and the petroleum fraction containing carotenoids was removed by filtering with funnel containing anhydrous sodium sulfate (a small wool plug was used to hold the sodium sulfate in the funnel). The separating funnel was washed with some petroleum spirit and the washings collected via the anhydrous sodium sulfate in the funnel. The filtrate was concentration using a rotary vacuum evaporator at 40°C to about 1 ml which was then separated in an open column packed with silica gel 60 (mesh 200-400) using petroleum spirit and 50 ml corrected. β-carotene standards (1-10 ppm) were prepared and absorbance values of sample extracts and standard solutions were read at 450 nm using a Uv-Vis spectrophotometer (Shimadzu UV-1601pc, Kyoto, Japan). Quantification was calculated using the standard curve.

5.2.5 Determination of soluble sugars

Soluble sugars were extracted using the method of Osborne and Voogt (1978). About 10 g of sample were refluxed with 50 ml of 96% (v/v) ethanol for 1 hr at 100ºC. The extract was filtered and the residue washed with 80% v/v ethanol. The filtrate was evaporated to dryness in a rotary vacuum evaporator at 60ºC and the dry residue was re-constituted with 10 ml distilled water and defatted using diethyl ether. Sample was micro-filtered with 0.45 μm filter and 20 μl injected into the HPLC (Shimadzu LC-10A) equipped with a refractive index detector (Shimadzu RID-6A). The mobile phase consisted of acetonitrile:water (80:20) at a flow rate of 0.5 ml/min on NH_2 column of 250 x 4.6 mm. Quantification was done using standard solutions of sucrose, glucose and fructose at the concentration range of 0.3-1% g/100ml

5.2.6 Determination of total polyphenols, flavonoids and antioxidant activity

The determination of total polyphenols, total flavonoids and antioxidant activity was carried out as described in section 4.4.

5.2.7 Measurement of color

Color was measured using a spectrophotometer model NF 333 (Nippon Denshoku, Japan) using the CIE L*a*b* color scale. The color of the sample was measured and expressed in terms of Hunter's L* (lightness), a* (redness/greenish) and b* (yellowness). Hue angle and chroma values were computed from a* and b* values using the formulas (i) and (ii) as shown below.

i) Chroma value= $(a^{*2}+b^{*2})^{0.5}$

ii) Hue angle= $\tan^{-1}(b^*/a^*)$

5.2.8 Data analysis

All samples were analyzed at least in triplicates and data presented as mean ± standard deviation as described in section 4.6.

5.3 Results and discussion

5.3.1 Nutrient composition

5.3.1.1 Proximate composition in upper and lower portions

The proximate composition was determined for the upper and the lower portions of the shoot and results are shown in Table 5.1.

Table 5.1: Proximate composition of upper and lower portions (% g/100g dwb)

Parameter	Upper Portion	Lower Portion
Protein	33.4±3.0[a]	33.0±1.3[a]
Fat	2.0±0.2[a]	2.0±0.1[a]
Ash	17.1±0.1[a]	11.8±0.3[b]
Fibre	23.9±0.2[b]	30.7±0.2[a]
Carbohydrates	23.6±3.1[b]	17.3±1.3[a]

Mean values within each row followed by different letters differ significantly at $p \leq 0.05$. Values are mean ±SD, n=3

There was no significant difference ($p \leq 0.05$) in protein and fat content between the two portions. Ash content differed significantly between the two portions with the upper one containing 17.1 % dwb compared to 11.8% in the lower. Analysis of similar species from three different sites in Ethiopia revealed protein content of 25.9-38.9%, fat content of 0.64-1.50% and ash content of 14.2-17.1% on dry weight basis (Feleke, 2013). These values compare well with the findings of this study even though their focus was not in different sections of the shoot. Fibre and carbohydrates contents were also found to have significant differences between the two portions ($p \leq 0.05$), where fibre content in the upper and the lower portions were 23.9 and 30.7% dwb, respectively. Higher fibre content observed in the lower portion is due to toughening near the base as the culm develops for structural support (George & Marya, 2001). The findings of the current study concurs with Pandey and Ojha (2013) who reported that older shoots had more fibre but with decreased proteins and phenolics,

5.3.1.2 Mineral composition in the upper and lower portions

The upper portion of the shoot was found to contain about 17.1% ash which was significantly different ((p≤0.05) from the lower part which contained 11.8% dwb as shown in Table 5.1. Comparison of specific minerals contained in the upper and the lower portions, as shown in Table 5.2, indicates presence of significant differences (p≤0.05) for all except iron.

Table 5.2: Composition of minerals in upper and lower portions (mg/100g dwb)

Type of Mineral	Upper portion	Lower portion
Calcium	267.0±4.0[a]	106.0±1.0[b]
Magnesium	430.0±42.0[a]	127.6±7.1[b]
Potassium	3,590.0±200.0[a]	2,760.0±120[b]
Phosphorus	763.0±17.0[a]	481.0±1.0[b]
Zinc	5.2±0.3[a]	3.8±0.2[b]
Manganese	3.0±0.2[a]	2.0±0.1[b]
Iron	2.6±0.2[a]	2.2±0.2[a]
Copper	1.2±0.1[a]	0.4±0.0[b]

Mean values within each row followed by different letters differ significantly at p≤0.05. Values are mean ± SD, n=3

The results show that the upper portion contains large quantities of all major minerals and that their concentration reduces towards the lower part of the shoot. The concentration of calcium, magnesium and copper in the upper portion was more than double the content in the lower part. Potassium, which is the major mineral in the shoot, was found to be about 1.3 times higher in the upper portion than in the lower. This observation was consistent with the fact that the portions had shown significant difference (p≤0.0.05) in the crude ash content. Erdal and Baydar (2005) observed that in a growing plant, nutrients with high metabolic activities such as, K, P and N move from older tissues to a newly growing part of the plant. This might be one of the reasons for the high concentration of these minerals in the upper apex. Therefore, selecting the top portion of the shoot during harvesting time will ensure that the shoot cooked has the capacity to boost the intake of minerals and assist towards meeting the recommended daily allowance (RDA) for calcium, magnesium and

potassium, which are 1,000 mg, 350 mg, and 2,000-6,000 mg, respectively (Silverman et al., 1999). RDA values however vary depending on age, gender and body weight.

5.3.1.3 Vitamins content

The vitamins which were found in the shoots of *Y. alpina* are shown in Table 5.3. Significant difference ($p \leq 0.05$) was noted in the content of thiamine, vitamin C and β-carotene. The upper portion contained more thiamine and vitamin C, while β-carotene was significantly more in the lower. Sood et al. (2013) reported vitamin C content of 5.3 mg/100g in fresh bamboo samples.

Table 5.3: Composition of vitamins in upper and lower portions (mg/100g dwb)

Parameter	Upper portion	Lower portion
Thiamine	0.22 ± 0.02^{a}	0.18 ± 0.01^{b}
Riboflavin	0.84 ± 0.02^{a}	0.73 ± 0.07^{a}
Vitamin C	7.82 ± 0.38^{a}	5.12 ± 0.24^{b}
β-Carotene	0.99 ± 0.03^{a}	1.57 ± 0.12^{b}

Mean values within each row followed by different letters differ significantly at $p \leq 0.05$. Values are mean ± SD, n=3

5.3.1.4 Sugar Content

The results obtained in the current study are shown in Table 5.4 below and indicates that Fructose was found to be the dominant sugar in the upper portion and varied significantly from 2.19 to 0.62% in the lower portion ($p \leq 0.05$). However, sucrose content was not significantly different between the two portions.

Table 5.4: Comparison of sugars in upper and lower portions (% g/100g dwb)

Parameter	Upper portion	Lower portion
Fructose	2.19 ± 0.19^{a}	0.62 ± 0.06^{b}
Glucose	0.65 ± 0.10^{b}	0.77 ± 0.08^{a}
Sucrose	0.68 ± 0.06^{a}	0.58 ± 0.06^{a}

Mean values within each row followed by different letters differ significantly at $p < 0.05$. Values are mean ± SD, n=3

Other researchers found significant difference in sugar content between the four portions of shoots measured from the apex to the basal part of *Phyllostachys pubescens* Mazel, where higher glucose, fructose and total sugars were found at the basal part of the shoots underground (Thammawong et al., 2009). However, results of the current study indicate that there was no significant difference in sucrose content in different portions of the shoots, which had just emerged from the ground. This findings nevertheless, showed higher fructose content near the apex where there is very high vegetative growth and photosynthesis. Since plant food is manufactured by the plant leaves and trans-located to different parts of the plant, it is likely that some soluble sugars may be higher at the upper part of the shoot where the leaves are more than at the lower part.

5.3.1.5 Total polyphenols and flavonoids content of upper and lower portions

The total polyphenol and flavonoid contents were determined and results are shown in Table 5.5.

Table 5.5: Total polyphenol and flavonoid contents (mg/100g dwb)

Parameter	Upper portion	Lower portion
Polyphenol*	2,760±14.0[a]	2,590±4.0[a]
Flavonoid**	2,460±20.0[a]	2,010±15.0[b]

Mean values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are mean ± SD, n=3 *Gallic acid equivalent; ** Quercetin equivalent

Total polyphenol content was 2,590-2,760 mg/100g dry weight basis and there was no significant difference between the upper and the lower portions. However, the total flavonoid content varied significantly ($p \leq 0.05$) between the two portions, where the upper portion contained 2,460 mg/100g dwb compared to 2,010 mg/100g dwb in the lower part. Polyphenols and flavonoids are very important bioactive compounds which are known for their strong anti-oxidative and anti-inflammatory properties (Nongdam et al., 2014; Singh, Bora & Singh 2012). The findings in this study shows that it would be more advantageous to consume the upper part of the shoot for better health benefits.

5.3.1.6 Antioxidant activity of upper and lower portions

It was also observed that the upper portion had higher antioxidant activity with LC_{50} of 1.0 mg/ml compared to LC_{50} of 5.0 mg/ml in the lower portion as shown in Figure 5.1. This high inhibition against the DPPH radical may be due to synergic effect caused by higher vitamin C, polyphenol and flavonoid contents observed in the upper portion of the shoot. This finding also further confirms that the upper portion of the shoot be chosen for consumption.

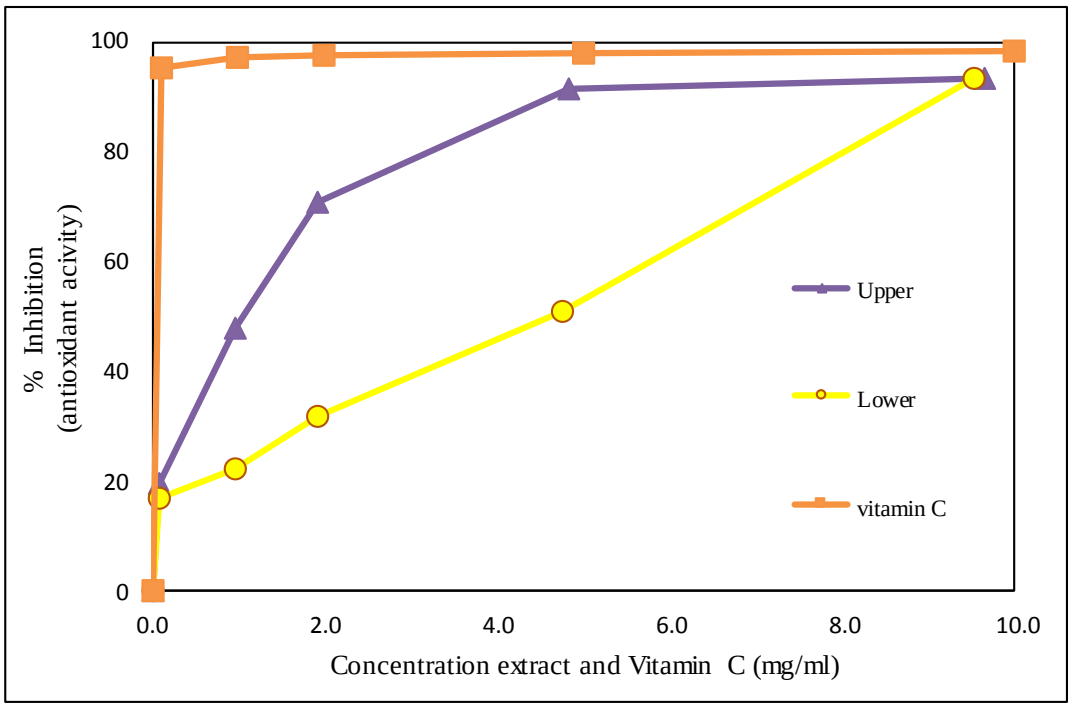


Figure 5.2: Antioxidant activity of the extracts of the upper and the lower portions of *Y. alpina* (mg/ml dwb)

The results obtain in this work demonstrate that bamboo shoots can compete very well with other vegetables in providing protective properties against diseases that results from oxidative stress in the body. Ouedraogo et al. (2011) reported LC_{50} value of between 1.23-2.73mg/ml in extracts of four species of *Amaranthus*.

5.3.2 Colour variation in the upper and lower portions

Colour is an important quality parameter in the food industry. It has been used to indicate the stage of maturity of fruits whose colour change with ripening. In the fresh vegetable market, the colour could be used to indicate the quality products such

as cabbages, kales, spinach and others. In this study the aim was to check whether the colour of the upper portion differs with the lower one and whether the difference could be used to identify better quality shoots.

The L*a*b* Hunter's values were applied for colour measurement where the L* value measures the lightness or brightness of a substance and ranges from 0 for black surface to 100 for white. Hue angle indicates whether the object is red, orange, green, blue or violet and ranges from 0 to 359°, whereas chroma or saturation value is a measure of colour intensity and defines a range from pure colour (100%) to gray colour (0%) at a constant lightness (Ali, Shahin, Zahra & Alireza, 2008). The results for colour variation are shown in Table 5.6. Significant difference between the upper and the lower portions ($p<0.05$) was noted for L*, b*, Hue angle and chroma values. The upper portion with L* value of 82.1 was therefore, found to be brighter than the lower portion. Negative values of a* and positive values of b* were also observed, indicating that the colour was in the yellow-greenish region, which was confirmed by the value of Hue angle. The chroma value shows that greenish-yellow colour was stronger in the lower portion than the upper. This means that the colour near the tip is more whitish than the lower part. These results are consistent with the fact that the lower portion was found to contain more β-carotene than the upper, and thus influencing the apparent colour. Grading by colour sorting is a common practice in the food industry today, in order to separate items which are discoloured, toxic or not at the stage of maturity required (Shabbir, 2016).

Table 5.6 Colour variation between upper and lower portion

Parameter	Upper portion	Lower portion
L*	82.1 ± 2.1^{a}	74.6 ± 2.7^{b}
a*	-1.34 ± 0.12^{a}	-1.35 ± 0.11^{a}
b*	14.0 ± 1.4^{b}	22.1 ± 2.0^{a}
Hue angle	66.4 ± 0.7^{b}	68.4 ± 0.4^{a}
Chroma value	14.1 ± 1.4^{b}	21.9 ± 2.2^{a}

Mean values within each row followed by different letters differ significantly at $p\leq0.05$. Values are mean ±SD, n=10

5.3.3 Conclusion

The upper portion of the shoot of *Y. alpina* was found to contain more nutrients than the lower. It was also found to contain higher polyphenols and flavonoids, and exhibited higher antioxidant activity than the lower. The colour of the upper portion was brighter than the lower part, and this implies that whiter shoots are potentially rich in nutrients and are thus superior to the greenish ones. A difference in distribution of nutrients within the shoot was therefore observed. Furthermore, the result of the present study provides important baseline information on *Y. alpina* as valuable vegetable source, as well as potential nutrient supplement.

CHAPTER SIX

EFFECT OF TRADITIONAL PROCESSING METHODS ON PHYSICOCHEMICAL PROPERTIES OF PROCESSED BAMBOO SHOOTS (CASE OF *Bambusa vulgaris)*

6.1 Introduction

Application of heat in food preparation is a common practice. The process of cooking makes the food soft and tastier and improve both its palatability and digestibility particularly of proteins (Deol & Bains, 2010). This is principally because most foods before cooking are hard, bitter and sometimes contain some anti-nutrient factors. Different food preparations methods and cooking time regimes have been known to have varying effect on the quality of nutrients present (Fabbri & Crosby, 2016). Bamboo shoots can be boiled for 1-4 hours and or sometimes soaked before boiling to remove the bitterness (Nongdam et al., 2014). Thus, depending on the method adopted, cooking can results in loss of nutrients and functionality of the food constituents in the body. Bamboo shoots are known to be rich in nutrients, dietary fiber and important phytochemicals while at the same time containing undesirable toxic compounds and hardness which can be softened through boiling. Improvement in the processing methods of the shoots will lead to better consumer appeal which will then boost demand for bamboo-based food products. This will in turn cause many farmers to plant bamboo for food use beside other known uses of the plant.

The objective of this study was to determine the effect on the physicochemical properties of the shoots processed with ash of bean stalks as used traditionally in the study site and compare with the effect of sodium chloride (table salt) which has been previously utilized in cooking shoots by Pandey et al., 2014. These researchers observed that boiling shoots in NaCl solution contributed in lowering the cyanogen content in the shoots of some *B. vulgaris* species but at the same time reduced the

nutrient composition of the shoots. It can also be noted that that utilization in food processing of ash of bean's stalks, a by-product of bean harvesting, has not been reported previously despite the fact that it is practiced traditionally by community such as *Sabaot* in Kenya as leant through the focus group discussion in Chapter 3. In this chapter therefore, the effect of these processing methods on the quality of the shoots was determined and the best conditions utilized in development of some bamboo value-added products. One species namely *B. vulgaris* was chosen for this study due to its ease of availability and proximity to the processing laboratory. It was also easy to compare the results with those published by Pandey et al., 2014 who also used it for their study.

6.2 Methodology

6.2.1 Sample acquisition and treatments

About 40 shoots of *B. vulgaris* were randomly harvested from a private farm in Murang'a County and immediately transported to the Laboratory of Food Science in Jomo Kenyatta University of Agriculture and Technology (JKUAT). The sampling farm is situated about 20 km from the laboratory and therefore there was no need of cooling the samples during transportation. At the laboratory, the outer leaves of the shoots were removed and each shoot cleaned with water and left to dry at room temperature for about 1 hour. Brine solutions were prepared using NaCl (Kensalt brand purchased from a local supermarket) and Ash of dry stalks of "Kifamu" or Rosecoco bean (KARI GLP-2) obtained from a private farm in Limuru.

The ash was prepared by burning the dry stalks and empty pods to ashes and then incinerating in a muffle furnace at 500°C for 2 hours to increase its solubility. The stalks were by-products of bean harvesting and their photo is shown in Figure 6.1. Three concentrations of NaCl and ash namely, 1, 2 and 5% were prepared as a percentage of the water volume used. The choice of 1, 2 and 5% concentrations was based on the work done by Pandey and Ojha (2014) who used NaCl at 1, 5 and 10% for 10, 15, 20 and 25 min to reduce the level of cyanogenic glycosides in some *Bambusa* spps. Nongdam et al. (2014) also reported boiling sliced shoots for 60 min

to remove bitterness. The ash was dissolved in hot water and solution filtered with cotton wool to remove insoluble matter. The ratio of shoots to brine used was 1:2.

Plate 6.1: Stalks of *"Kifamu"* bean (Photo taken in April 2015)

Three batches of 10 shoots each were sliced with a slicer to a thickness of approximately 1 cm, mixed well and packed. The brine was allowed to boil, filtered in the case of ash to remove the insoluble ash and then shoots were added and boiled as indicated earlier. A control was incorporated where shoots were boiled in plain water for the same period of time. Once the samples were removed from the boiling water bath, they were cooled immediately by dipping the beaker into a trough containing cold water to prevent further cooking. Ten pieces of the fresh shoots from each batch were measured for color, firmness and moisture immediately and the rest of the samples were packaged in ziplock polyethylene bags and stored at -20°C for other analyses. Figure 6.1 shows the flow of the processing activities described above.

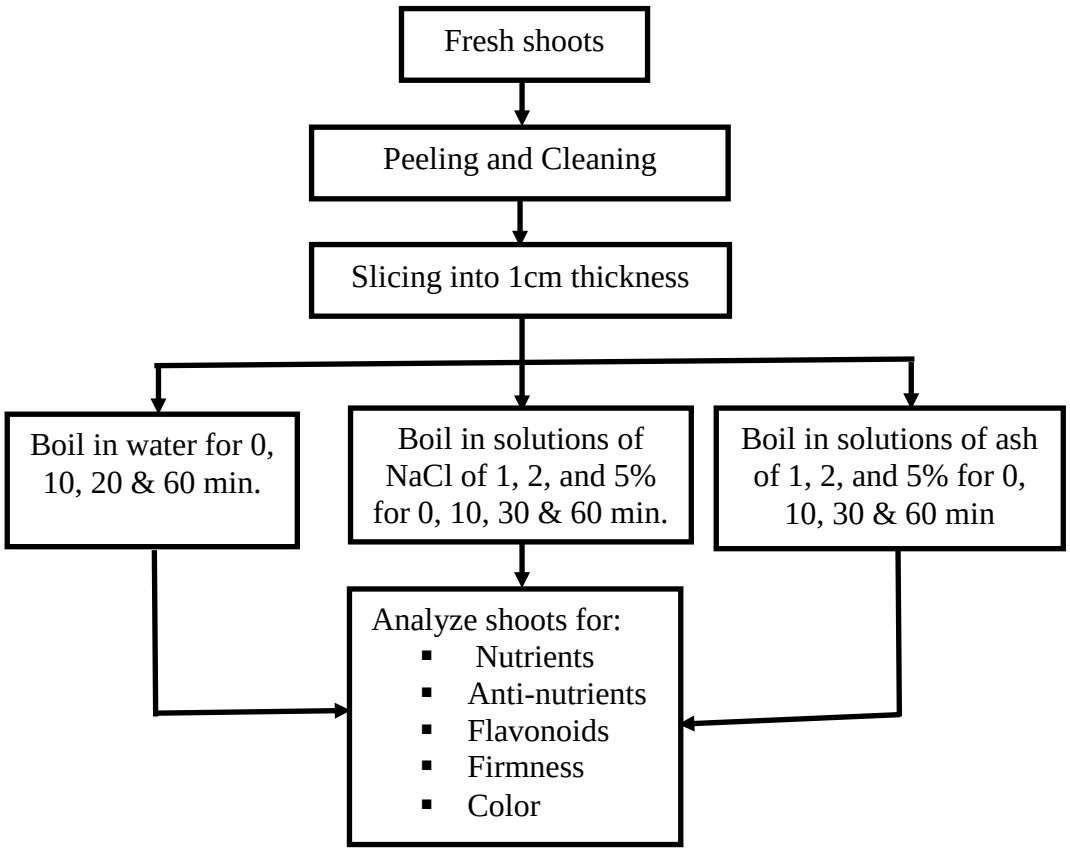


Figure 6.1: Flow diagram for treatment of shoots

6.2.2 Proximate analysis

Proximate composition was determined by AOAC methods as described in section 4.3 sub-sections 4.3.1-4.3.6.

6.2.3 Mineral analysis

Five grams of each sample were weighed, charred and incinerated for 6 hours at 550°C in a Muffle furnace. The ash was then dissolved in 1N HCl and diluted appropriately for the elements. Minerals (Ca, Mg, Zn and Fe) were determined using Atomic Absorption Spectrophotometer (Model Shimadzu AA 6200, Kyoto, Japan) whereas K was analyzed by Flame Photometer (Model AFP 100, Biotech Engineering Management Company Ltd, Germany).

6.2.4 Determination of Total flavonoid content

Total flavonoids were determined as described in section 4.4 sub-sections 4.4.2.

6.2.5 Measurement of colour

Colour was determined using Hunters L* a*b* values as described in section 5.2.7.

6.2.6 Quantification of anti-nutrients

Tannins, oxalates and phytic acid were determined as described in section 4.5 sub-section 4.5.1- 4.5.3.

6.2.7 Measurement of pH of brines of ash and NaCl

The pH was determined using a pH Meter (Hanna Instruments, Model H1 8519N, Portugal) calibrated by pH buffer solutions of 4.0, 7.0 and 9.2.

6.2.8 Determination of firmness of shoots

Firmness of the shoots was determined by Rheometer (Model Sun Rheo 100, Japan). A piercing plunger fixed to the Rheometer was made to penetrate 8 mm through a sliced shoot of 1 cm thickness at speed of 100 mm/min and the amount of force used (Newtons) determined. The Rheometer was first calibrated by measuring different loads up to 10 KN and getting the corresponding peak height on the recorder (Shimadzu C-R1B). The calibration curve was used to calculate the force in Newtons

6.2.9 Data analysis

All samples boiled in brine solutions of ash and NaCl were analyzed in triplicates for each of the three batches and data expressed as mean ± SD (standard deviation). Data were subjected to statistical analysis using STATA/SE (Version 12.0) statistical/data analysis software. Two way analysis of variance (ANOVA) was performed and means were separated using Bonferroni's multiplevariate analysis of variance at 95% confidence interval.

6.3 Results and discussion

6.3.1 Effect of treatment conditions on nutrients

6.3.1.1 Effect on moisture content

The effect on the moisture content after processing the shoots is shown in Table 6.1. The results showed that both boiling time and NaCl concentrations did not have significant difference ($p \leq 0.05$) on moisture content of the shoots ($p=0.20$). However boiling shoots in ash extracts was observed to have significant difference on moisture content ($p=0.00$). It increased with boiling time but reduced with when the ash concentrations was raised.

Table 6.1: Effect of NaCl and ash on moisture content (%) during boiling of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	90.5 ± 0.1^{ab}	93.9 ± 0.4^{ab}	93.7 ± 0.6^{ab}	94.3 ± 0.2^{ab}
1% NaCl	90.5 ± 0.1^{ab}	94.7 ± 0.1^{a}	94.2 ± 0.5^{ab}	94.8 ± 0.1^{a}
2% NaCl	90.5 ± 0.1^{ab}	92.3 ± 0.4^{ab}	93.4 ± 0.7^{ab}	93.4 ± 1.2^{ab}
5% NaCl	90.5 ± 0.1^{ab}	92.3 ± 2.1^{ab}	92.3 ± 4.3^{b}	92.1 ± 2.5^{ab}
0% ash	90.5 ± 0.1^{d}	93.9 ± 0.4^{ac}	93.7 ± 0.6^{abc}	94.3 ± 0.2^{a}
1% ash	90.5 ± 0.1^{d}	93.6 ± 0.2^{abc}	94.6 ± 0.1^{a}	94.5 ± 0.4^{a}
2% ash	90.5 ± 0.1^{d}	93.2 ± 0.4^{abc}	92.8 ± 0.3^{bc}	94.7 ± 0.7^{a}
5% ash	90.5 ± 0.1^{d}	92.5 ± 1.1^{bc}	92.8 ± 0.4^{bc}	92.0 ± 1.1^{b}

Mean values within each row and column followed by different letter in the group label are significantly different at $p \leq 0.05$. n=9, two way anova

6.3.1.2 Effect on protein content

The protein content of the processed shoots is shown in Table 6.2. Both boiling time and NaCl as well as ash were observed to have significant difference ($p \leq 0.05$) on protein content ($p=0.00$). The control registered the least effect reducing from 32 to 22% (dwb). On the other hand, NaCl and ash at high concentrations caused the

greatest decrease in the protein content after 60 min boiling. Different concentrations of ash and NaCl in boiling solutions resulted in significant differences ($p \leq 0.05$) where the

Table 6.2: Effect of NaCl and ash on protein content (% dwb) during boiling of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	32.0 ± 2.5^{b}	28.9 ± 2.9^{bg}	26.3 ± 1.5^{fg}	22.0 ± 0.6^{df}
1% NaCl	32.0 ± 2.5^{b}	17.3 ± 1.7^{ad}	15.3 ± 0.9^{ac}	14.2 ± 0.6^{ac}
2% NaCl	32.0 ± 2.5^{b}	21.8 ± 0.9^{df}	15.8 ± 0.6^{ac}	8.5 ± 0.6^{e}
5% NaCl	32.0 ± 2.5^{b}	17.6 ± 0.4^{ad}	11.4 ± 0.9^{ce}	6.8 ± 0.5^{e}
0% ash	32.0 ± 2.5^{a}	28.9 ± 2.9^{ad}	26.3 ± 1.5^{bd}	22.0 ± 0.6^{bc}
1% ash	32.0 ± 2.5^{a}	25.8 ± 1.7^{ad}	18.3 ± 1.7^{bd}	14.3 ± 0.3^{bc}
2% ash	32.0 ± 2.5^{a}	22.5 ± 2.5^{bc}	16.2 ± 1.3^{fg}	11.1 ± 0.5^{e}
5% ash	32.0 ± 2.5^{a}	19.2 ± 0.9^{cg}	18.3 ± 1.3^{ef}	10.3 ± 0.8^{e}

Mean values within each row and column followed by different letter in the group label are significantly different at $p \leq 0.05$. n=9, two way anova

protein content reduced with increase in ash and NaCl concentrations. NaCl however produced greater loss of protein than the ash. Pandey and Ojha (2014) observed even higher reduction of protein at 5% NaCl where *D. asper* spp. lost over 80% protein after just 10 min. Loss of protein during cooking has been reported in shoots and potatoes (FAO report, 1990; Singhal et al., 2013) where 5.5% decrease in protein occurred. Bamboo shoots stored for up to 10 days were also found to have reduced protein content from 3.10-3.71 to 2.17-2.60% compared to fresh ones. Canning and fermentation have also been reported to reduce the protein content to 1.93 and 2.6% respectively for the same samples (Singhal et al., 2013). Loss of protein during boiling has also been reported in other foods. Lola (2009) found that protein decreased from 4.03 to 2.98 % in *S. biafrae* and from 4.63 to 3.68% in *S. nigrum* after boiling for 15 minutes. In yam tubers however, the reduction was not statistically significant (Wanasundera & Ravindran, 1992).

Loss of protein with increased boiling time may be attributed to acidic solution whose pH was found to be 5.0-5.3 for NaCl solutions and 11.5-12.7 in solutions of

ash extract. When the net charge of a protein is zero, the protein is least soluble and will precipitate out. This pH when the solubility of the protein is at minimal is known as isolectric point (IEP) and is 5.5-8.0 for most proteins (Alberts, Bray & Johnson, 1998). Below the IEP, the proteins are positively charged whereas above the IEP, the proteins are negatively charged. Proteins are most soluble when they carry a positive charge but are soluble also when negatively charged (Zidani, Fahloul & Bacha, 2012). In the present study, NaCl was found to cause more leaching out of protein than the ash which had an alkalined pH with noted significant differences ($p \leq 0.05$) between various concentrations of NaCl, ash extract and boiling time.

6.3.1.3 Effect on crude ash content

Crude ash contains the mineral elements of a plant material. The content of crude ash in the different shoots boiled in the ash of the bean's stalks and NaCl was investigated. As shown in Table 6.3, boiling time, NaCl and ash concentrations had significant difference ($p \leq 0.05$) on crude ash content of the shoots ($p=0.00$).

Table 6.3: Effect of NaCl and ash treatment on crude ash content (% dwb) of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	10.2 ± 0.2^{a}	6.9 ± 0.3^{c}	6.0 ± 0.3^{c}	6.6 ± 0.3^{c}
1% NaCl	10.2 ± 0.2^{a}	19.6 ± 0.0^{b}	18.0 ± 0.6^{b}	18.7 ± 0.4^{b}
2% NaCl	10.2 ± 0.2^{a}	19.3 ± 1.5^{b}	23.6 ± 1.3^{d}	25.5 ± 0.5^{d}
5% NaCl	10.2 ± 0.2^{a}	40.1 ± 1.0^{f}	38.1 ± 0.9^{ef}	35.9 ± 1.6^{e}
0% ash	10.2 ± 0.2^{a}	6.9 ± 0.3^{b}	6.0 ± 0.3^{b}	6.6 ± 0.3^{b}
1% ash	10.2 ± 0.2^{a}	13.8 ± 0.0^{c}	16.6 ± 0.3^{d}	14.1 ± 0.2^{c}
2% ash	10.2 ± 0.2^{a}	12.3 ± 1.1	13.9 ± 0.5^{c}	18.9 ± 0.4
5% ash	10.2 ± 0.2^{a}	17.2 ± 0.8^{d}	21.9 ± 1.2	23.8 ± 0.6

Mean values within each row and column followed by different letter in the group label are significantly different at $p \leq 0.05$. n=9, two way anova

In the control (no NaCl or ash) the crude ash content reduced sequentially from 10.2% to about 6.0% representing about 40% leaching. On the other hand, shoots boiled in ash were found to increase the crude ash content significantly ($p \leq 0.05$) indicating an uptake of the minerals from the solution during boiling. Table 6.5

below shows some of the minerals present in the ash that was applied in the processing tests. Shoots boiled in NaCl similarly indicated significant difference ($p \leq 0.05$) between the raw and those boiled for 10 minutes, where the shoots seems to take up the salt. The uptake of the ash (containing minerals) and NaCl by the shoots can be said to be due to osmotic pressure where the boiling solution had higher concentration of solutes than the shoots whose moisture content was over 90% as shown in Table 6.1 above.

6.3.1.4 Effect on crude fibre content

Fibre is an important constituent of a food sample and bamboo shoots are known to be excellent sources. The effect on fibre after cooking the shoots in ash and NaCl was investigated and results are shown in Table 6.4.

Table 6.4: Effect of NaCl and ash on crude fibre content (% dwb) during boiling of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	29.4 ± 3.7^{c}	32.1 ± 1.9^{cf}	32.3 ± 0.9^{cf}	37.4 ± 0.4^{f}
1% NaCl	29.4 ± 3.7^{c}	20.8 ± 0.3^{e}	16.4 ± 0.7^{de}	10.2 ± 1.0^{abd}
2% NaCl	29.4 ± 3.7^{c}	14.2 ± 0.5^{abde}	14.5 ± 0.8^{bce}	7.7 ± 1.0^{a}
5% Nacl	29.4 ± 3.7^{c}	13.6 ± 0.2^{abd}	9.7 ± 0.4^{ab}	8.8 ± 0.7^{ab}
0% ash	29.4 ± 3.7^{ab}	32.1 ± 1.9^{ad}	32.3 ± 0.9^{ad}	37.4 ± 0.4^{d}
1% ash	29.4 ± 3.7^{ab}	25.1 ± 1.9^{abc}	24.8 ± 1.2^{abc}	27.4 ± 2.9^{abc}
2% ash	29.4 ± 3.7^{ab}	27.1 ± 2.4^{abc}	25.2 ± 0.2^{abc}	21.2 ± 2.3^{c}
5% ash	29.4 ± 3.7^{ab}	28.7 ± 1.0^{abc}	23.8 ± 1.4^{bc}	24.4 ± 2.8^{abc}

Mean values within each row and column followed by different letter in the group label are significantly different at $p \leq 0.05$. n=9, two way anova

The results indicate that boiling time, NaCl and ash concentrations had significant difference ($p \leq 0.05$) on crude fibre content of shoots. NaCl was found to reduce the fibre content with the loss increasing with increase in NaCl concentration and boiling time ($p=0.00$). One percent salt reduced the fibre from 29.4 to 10.2% whereas 5% NaCl reduced it to 8.8% after 60 minutes. Higher concentration of NaCl and prolonged boiling caused significant loss of fibre from the shoots. The control shows that boiling the shoots in plain water does cause a significant difference ($p \leq 0.05$) in

crude fibre content where it increased. A similar observation was made by Deol and Bains (2010) that boiling increases the dietary fibre content. It was also observed that crude fibre did not change much in shoots boiled in 1 and 5% ash solutions even after 60 min ($p=0.00$). Boiling in water was reported not to significantly affect the fibre content in the shoots (Kumbhare & Bhargava, 2007).

Increase in ash and NaCl concentrations was observed to cause significant loss of fibre ($p \leq 0.05$) as can be seen within columns in the table. Boiling food will generally result in some loss of nutrients. Zhang et al. (2011) made the same observations whereby after boiling shoots for 10 minutes, a significant reduction of protein, soluble sugars and ash by about 38% was found. In the current study, the loss of fibre in samples treated with NaCl solution is evident and there is no proper explanation of this occurrence. Nevertheless, it may be possible that the chloride ions in the boiling water were responsible for the leaching out of the fibre. The Swedish turnip was found to have lost about 40% of its fibre during boiling and this leakage of fibre into processing water was also reported with canned foods (FAO, 2016).

6.3.1.5 Mineral content in the ash of bean's stalks

The mineral content of the ash of the beans's stalks which was used for making the brine solutions was determined and Table 6.5 shows the content of some of the minerals found in the ash. Potassium, Calcium and magnesium were the main constituents at 173.7, 83.0 and 29.5 mg/g, respectively.

Table 6.5: Mineral content in ash of bean stalks (*Kifamu* bean) used for brine solution

Mineral	Content (mg/g)
Potassium	173.7±2.1
Sodium	1.4±0.0
Calcium	83.0±1.8
Magnesium	29.5±0.5
Phosphorus	10.0±0.3
Iron	7.5±0.2
Zinc	0.1±0.0

6.3.1.6 Effect of treatment conditions on mineral content in the shoots

The change in Ca, Mg, K, Zn and Fe contents during cooking with ash and NaCl solutions was evaluated and is shown in Figures 6.2-6.6.

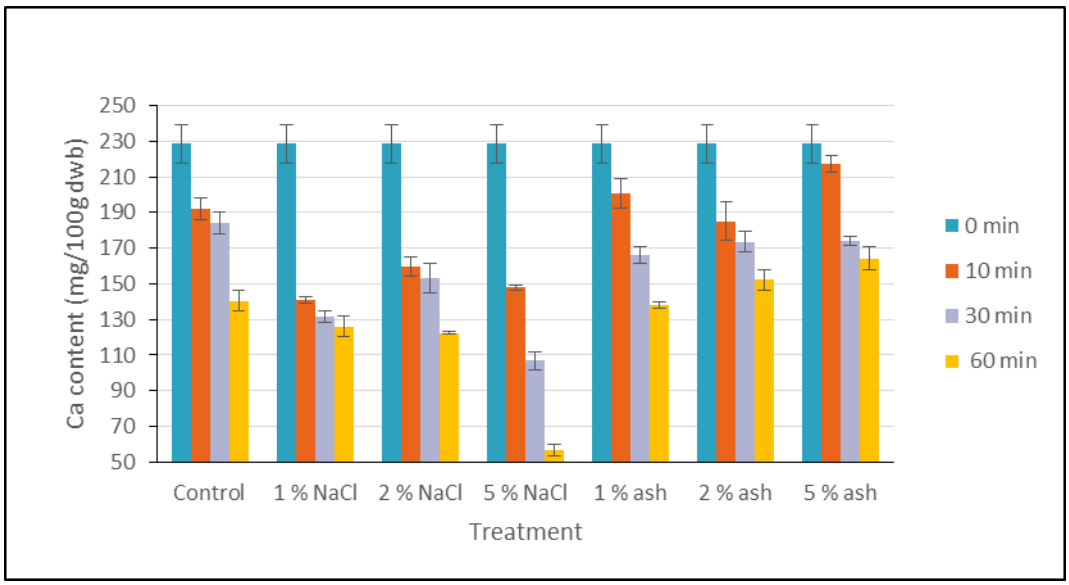


Figure 6.2: Effect of treatment conditions on Ca content of the shoots

Figure 6.2 above shows the effect on Ca content during boiling of shoots in different concentrations of NaCl and ash. It was noted that boiling time and variation of NaCl concentration reduced Ca content significantly ($p \leq 0.05$) in the boiled shoots ($p=0.00$) (see table in Appendix 1.5a). Ca content in shoots boiled in NaCl reduced significantly from about 230 mg to about 150 mg/100g (dwb) after boiling for only 10 minutes. On the other hand, the ash concentration and length of boiling was observed to have no significant difference ($p \leq 0.05$) at $p=0.18$. After boiling for 60 minutes, Ca content decreased to 170 mg for the 5% ash treatment compared to 140 mg for the control and about 50mg/100g (dwb) for the 5% NaCl solutions. The more the ash used, it was observed, the more the Ca absorbed by the shoots from the solution during boiling.

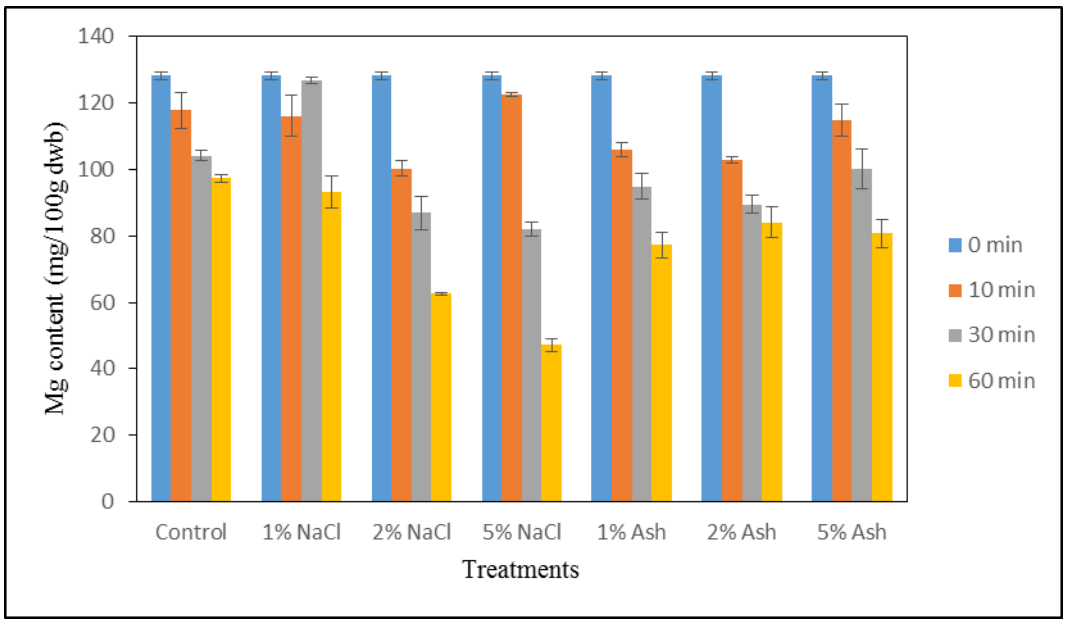


Figure 6.3: Effect of treatment conditions on Mg content of the shoots

The effect of the treatment conditions on Magnesium (Mg) content is indicated in Figure 6.3 and Appendix 1.5b. Boiling time and variation in NaCl concentration was found to have significant difference ($p \leq 0.05$) on Mg content in the shoots ($p=0.00$). Mg content reduced significantly when boiled in 2 and 5% NaCl reducing from about 128 mg to 65 and 50 mg/100 g respectively after boiling for 60 minutes. It was however observed that boiling time and ash concentrations did not have significant difference in Mg content of the shoots ($p=0.09$).

On potassium (K), both NaCl and ash extract of beans' stalks and boiling time were found to significantly affect the concentration of K in the shoots. Figure 6.4 below and appendix 1.5c show that there was significant difference ($p \leq 0.05$) in K content in shoots processed in NaCl solutions and plain water ($p=0.00$) . The control, 1 and 2% NaCl treatments lost about 50% of the K after boiling for 60 min. The 5% NaCl significantly ($p \leq 0.05$) reduced K content in the shoots from the initial 4,000 mg/ 100g to about 1,460 mg and 1,230 mg/ 100 gdwb after heating for 30 and 60 minutes respectively. Boiling time and ash concentrations were found to have significant

difference (p=0.00) on K content in the processed shoots. The 1% ash increased

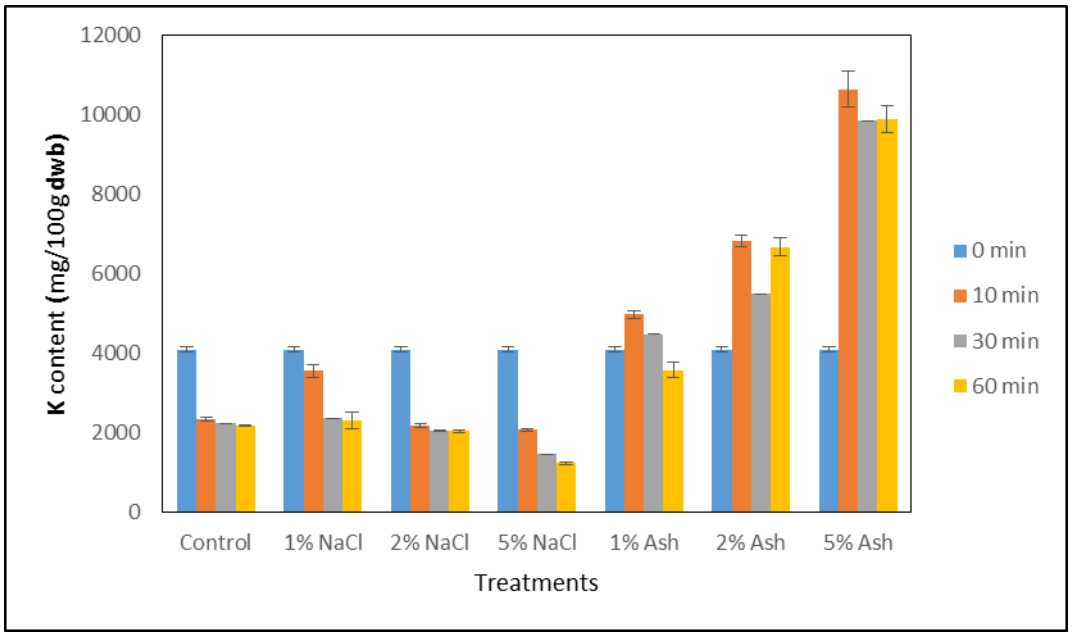


Figure 6.4: Effect of the treatment conditions on K content of the shoots

K content from about 4,000 mg to about 5,000 mg/100 g dwb after boiling for 10 minutes. The 2% ash increased the content to 6,800 mg whereas 5% tremendously raised the amount of K in the shoots to about 10,600mg/100 g dwb. The ash of the beans' stalks was found to contain about 174 mg/g of potassium (Table 6.5) and this appears to be absorbed by the shoots during boiling. Potassium is a vital electrolyte in the body helping to maintain normal blood pressure and a steady heartbeat. Generally bamboo is said to provide up to 18% of the daily K requirement and cooking the shoots in ash extract can therefore improve available K and thus promote healthy living.

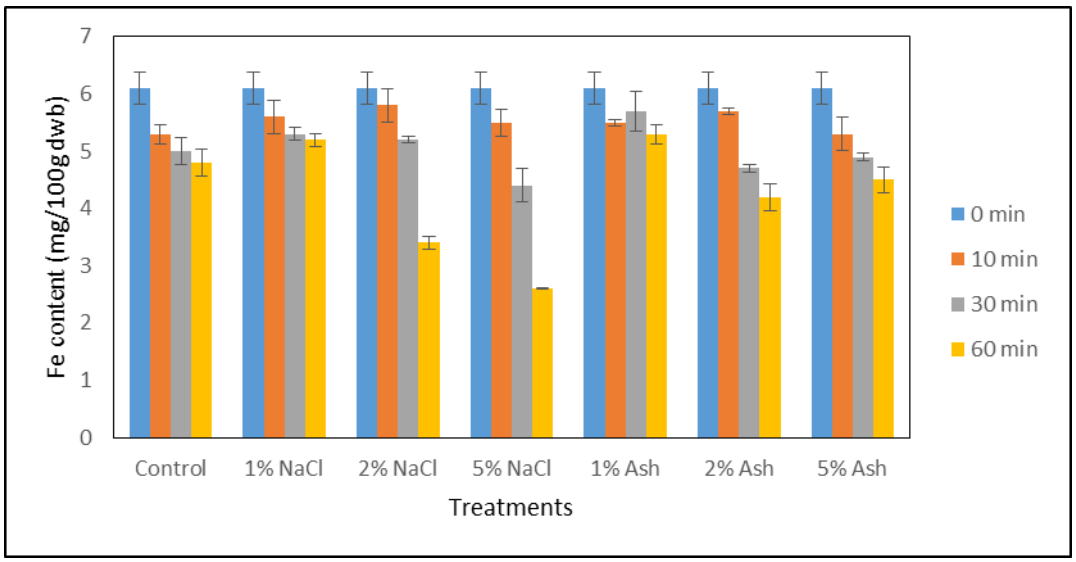


Figure 6.5: Effect of the treatment conditions on Fe content of the shoots boiled at different time intervals

The effect of the processing conditions on Fe content of the shoots is shown in Figure 6.5 and Appendix 1.5d. Both boiling time and NaCl were found to have significant difference in Fe content of the shoots (p=0.00). The 2 and 5 % NaCl caused a significant difference ($p \leq 0.05$) with Fe content reducing from 6.1 mg to 3.5 and 2.5mg/100g, respectively. On the other hand it was observed that boiling time and ash extract had no significant difference (p=0.33) on the Fe content in the processed shoots.

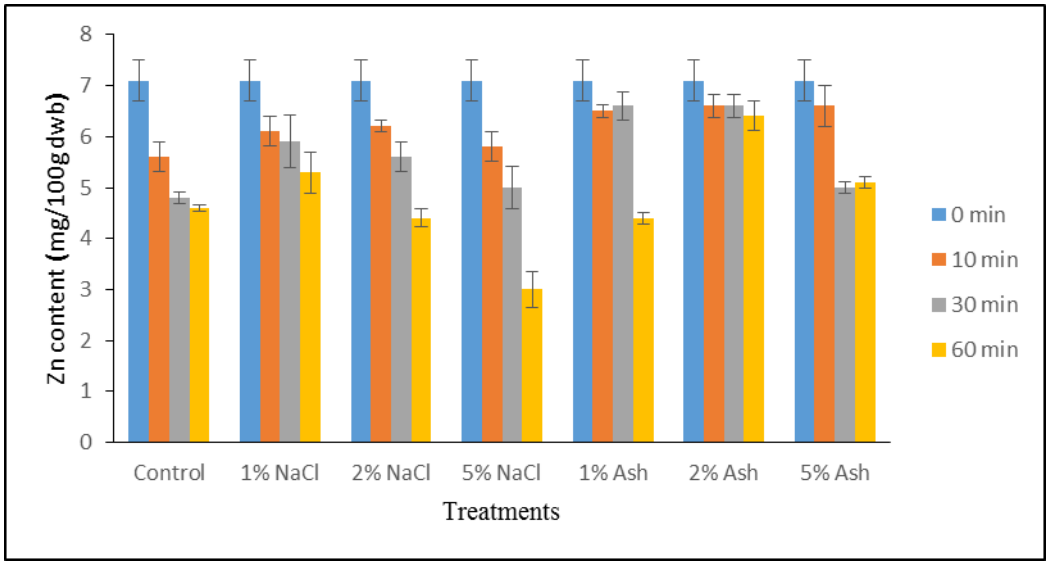


Figure 6.6: Effect of the treatment conditions on Zn content of the shoots boiled at different time intervals

Zinc content was observed to be affected by the boiling time, ash and NaCl concentration (p=0.00) as shown in Figure 6.6 and Appendix 1.5e. The treatment of the shoots with 2% ash reduced Zn content from about 7.1 to about 6.5mg/100 g dwb after boiling for 60 min. Treatment with 2% NaCl solutions on the other hand showed significant loss of Zn similar to the control which reduced from 7.1 to about 4.5 mg/100g dwb after boiling for 60 min. The contribution of the ash therefore in retention of Zn in the shoots is notable.

The results shows that NaCl resulted in significant leaching out of minerals as boiling time was increased compared to just boiling in plain water. This observation was also made by Pandey and Ojha (2014) who found significant reduction of minerals in *B. bambos* whose K reduced from 320 mg/100g to 60 mg/100g after boiling in 5% NaCl for only15 min. On the other hand, the ash gave the best retention of minerals in the shoots even under prolonged cooking. Busie, Wasiu and Alfred (2015) reported loss of iron and zinc through leaching in boiled cassava. Pressure cooking and boiling was also reported to cause significant losses of Fe and Ca in green cowpea (Deol & Bains, 2010). Generally when bamboo shoots are boiled, the brew is discarded because it contains the leached out anti-nutrients and this also results into loss of minerals which have dissolved into the boiling solution from the shoots. Loss of micronutrients in this way is undesirable because it renders the food being cooked be of lesser nutritional value. Minerals are very vital in the body. In terms of gender, women are more susceptible than men to mineral deficiency particularly calcium and iron and they are prone to osteoporosis condition especially after menopause (Noonan & Savage, 1999).

6.3.2 Effect of Treatment conditions on total flavonoids in boiled shoots

Flavonoids are a group of antioxidants and are vital in the body because they consume the peroxide radicals that are produced by tissues due to oxidative stress. Figure 6.7 and Appendix 1.6, show the effect of ash and NaCl on flavonoid content in the bamboo shoots during boiling.

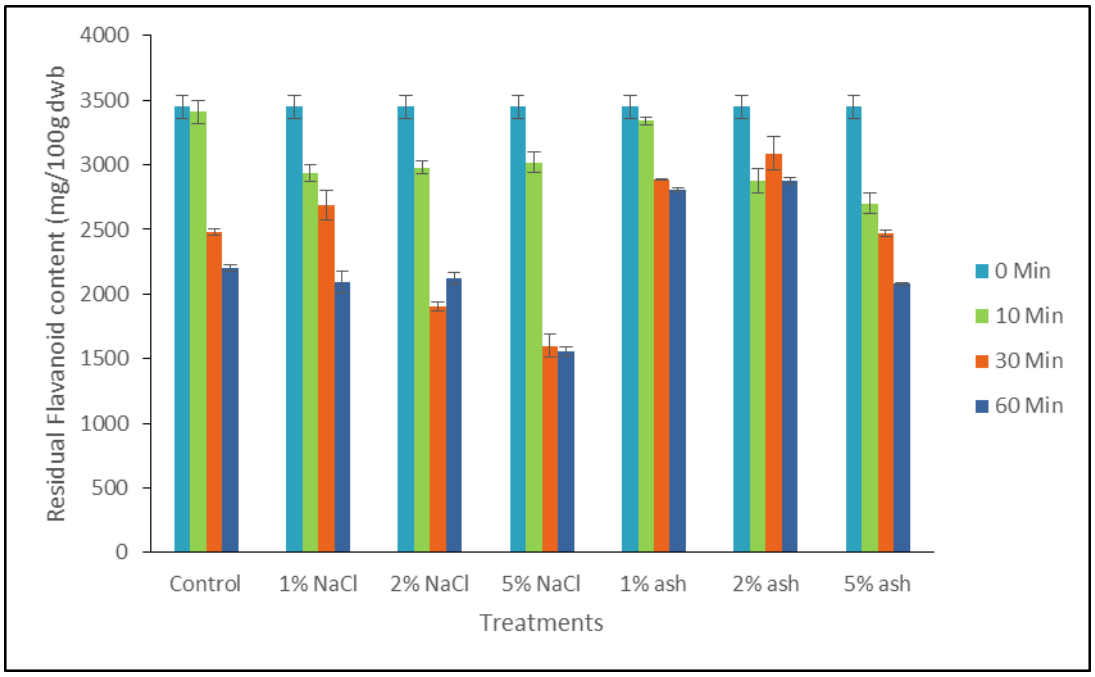


Figure 6.7: Effect of treatment conditions on flavonoids content of shoots

The results indicate that boiling time, NaCl and ash concentrations caused significant difference ($p \leq 0.05$) in flavonoids content in the shoots ($p=0.00$). Boiling shoots in water for 60 min caused about 40% loss of flavonoids whereas 5% NaCl caused more than 50% loss of flavonoids within the same cooking time. It was noted however that 1 and 2% ash recorded the least reduction of flavonoids at about 17% after 60 minutes. Thus NaCl caused significant loss of antioxidants than the ash. These findings agree with Settharaksa, Jongjareonrak, Hmadhlu, Chansuwan and Siripongvutikorn (2012) who observed that flavonoids retention in spices heated at 100°C was higher above pH 6 (found to have maximum retention) but lower below that pH, with the reduction being more severe in acidic conditions than alkaline. Thus the effect of pH of the solutions used in the boiling test in the current study appears to have influenced greatly the flavonoids retention and therefore the antioxidant capacity of the shoots. Loss of antioxidants due to boiling food has also been reported by other researchers. Jimenez-Monreal, Garcia-Diz, Martinez-Tome, Mariscal and Murcia (2009) found that cooking vegetable in water reduced antioxidants by about 50% thus making that cooking method unpopular. Zhang et al.

(2011) also found significant decrease of antioxidants in shoots boiled for 10 minutes. On the other hand use of ash in food preparation provides a promising intervention to prevent loss of value of food rich in antioxidants. These findings are important given the increasing cancer cases in Kenya and the world at large resulting in many deaths (Jemal, Bray, Melissa, Ferlay & Ward, 2011). Highly active free radicals and their uncontrollable production in the body are responsible for the numerous pathological processes such as cell tumor and heart complications (Olajire & Azeez, 2011). Prevention of destruction of antioxidants in the food through application of the ash will therefore help in improving food value and promote good health to its consumers.

6.3.3 Effect of treatment conditions on anti-nutrients in boiled shoots

Anti-nutrients are chemical compounds that bind with some important nutrients rendering them unavailable to the body. In this study tannins, phytic and oxalic acids were considered and the effect of the processing conditions on these anti-nutrients is shown in Figures 6.8, 6.9 and 6.10 below.

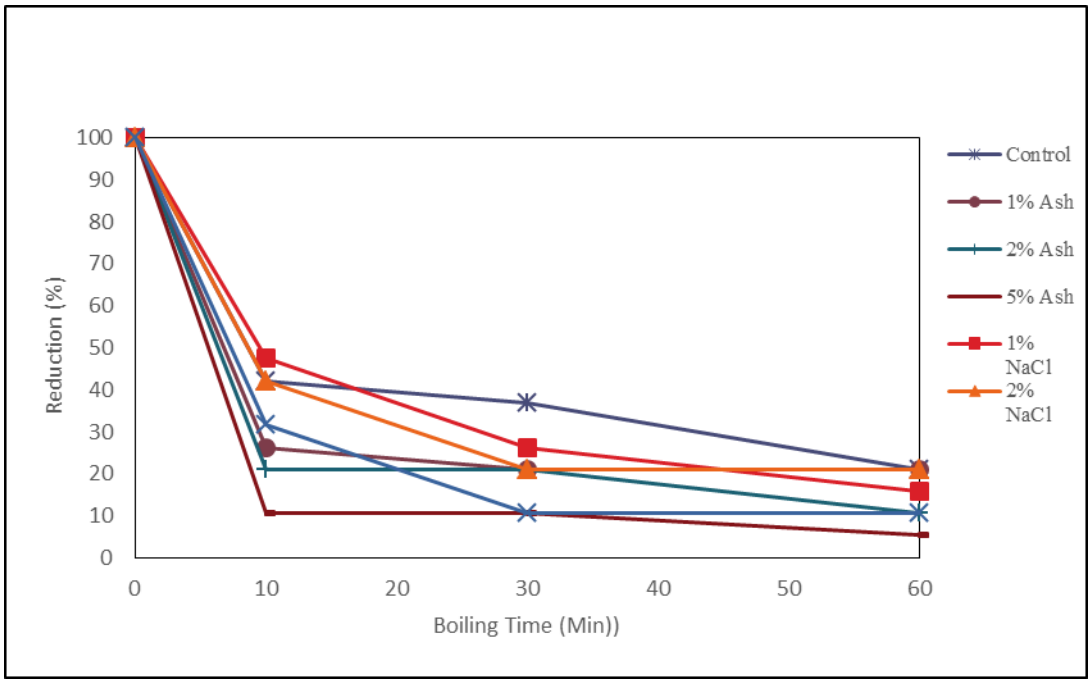


Figure 6.8: Effect of treatment conditions on tannin content of shoots

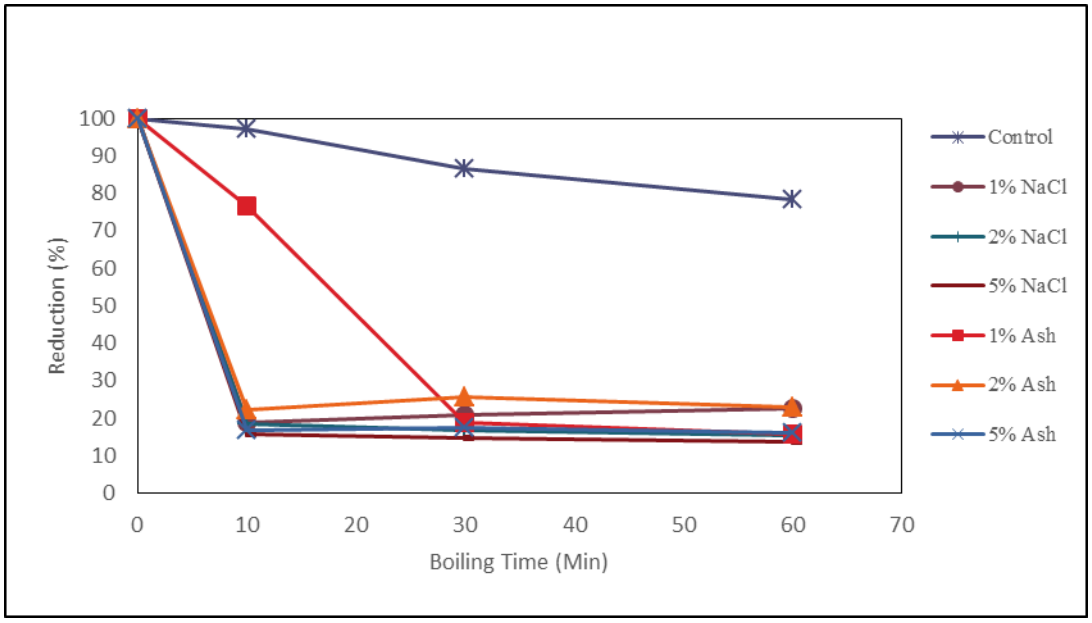


Figure 6.9: Effect of treatment conditions on phytic acid content of shoots

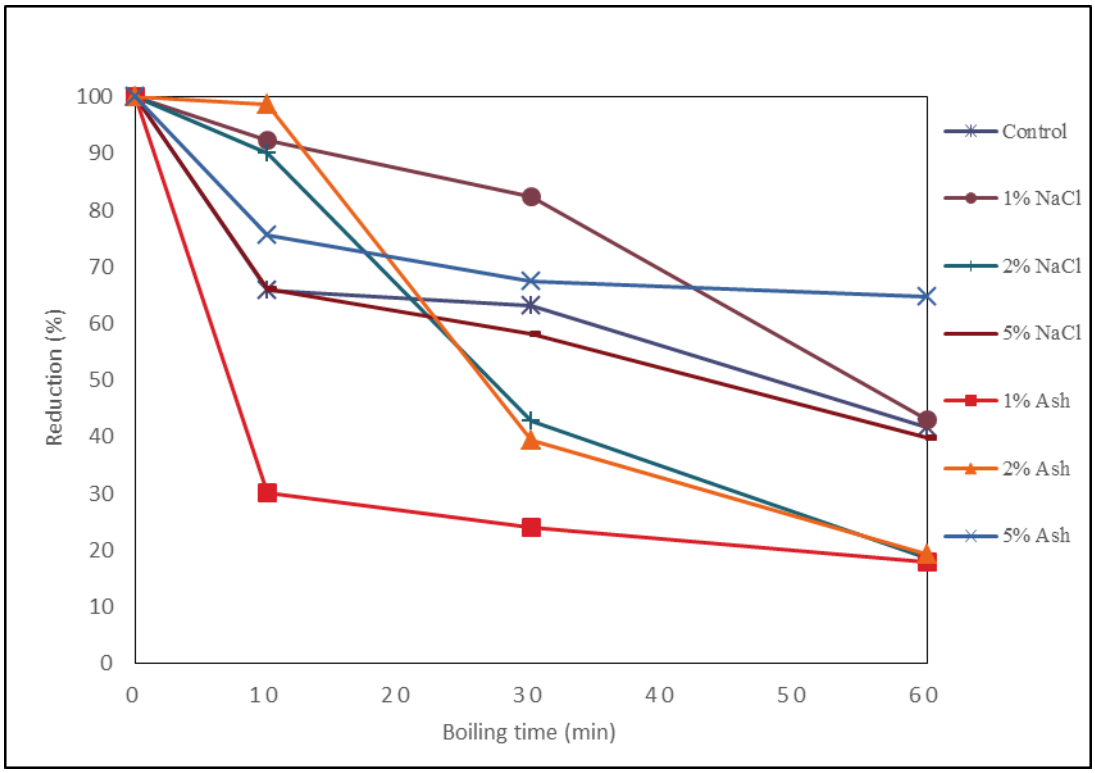


Figure 6.10: Effect of treatment conditions on oxalic acid content of shoots

The effect of ash and NaCl on the tannin content in the shoots is shown in Figure 6.8. Reduction in tannin content in the shoots of *B. vulgaris* was very drastic after the first 10 min of boiling for all the treatments, recording more that 50% reduction in the shoots. At the end of 60 min all the samples had lost more than 70% of the tannins with 2 and 5% ash reducing the levels by about 80 and 90%, respectively.

On the other hand both NaCl and ash at concentrations of 1-5% resulted in reduction of phytic acid content by about 80% within the first 10 min of boiling as shown in Figure 6.9. NaCl at low concentrations gave better results than ash at similar concentrations although higher NaCl concentration recorded the best results in phytic acid reduction. High NaCl concentration has been reported to dissociate phytic-protein complex that is formed due to direct electrostatic interaction at low pH and low cation concentration, thus enhancing the leaching of phytic acid into the boiling water (Cheryan & Rackis, 1980). Phytic acid is said to be heat-resistant and not easily destroyed by boiling (Schlemmer, Frolich, Prieto & Grases, 2009) and this finding is consistent with the observation from this study where the control showed little change in the phytic acid content reducing by less than 5% after 10 minutes and only by about 20% after 60 minutes.

Oxalic acid content was also affected by boiling shoots in NaCl and ash solution as shown in Figure 6.10. Ash was found to be more effective in reducing the oxalic acid content than NaCl. One percent ash reduced it by 70% after 10 minutes whereas after 60 minutes, both1, 2% ash and 2% salt achieved about 80% reduction. Generally 5% NaCl and ash respectively had less effect on oxalic acid content compared to lower concentrations. The reason behind this occurrence is not clear but, it might be that high concentration of solutes in the boiling solution prevented oxalates from leaching out from the shoots. This explanation can be supported by the fact that shoots boiled in plain water had better reduction of oxalic acid than those boiled in higher concentrations of salt and ash.

Boiling food has been reported by several researchers to decrease anti-nutrient content in foods though to varying extent. Lola (2009) found that boiling for 15 minutes reduced tannins by 29.3 and 39.8%, phytic acid by 22.3 and 23.6%, whereas

oxalic acid decreased by 21.7 and 20 % in *Solanum biafrae* and *Solanum nigrum,* respectively. The nature of the food material however, appears to influence the effect of boiling in plain water. In the current study, phytic acid in the control sample reduced by a mere 20% even after boiling for 60 min. Sallau, Mada, Ibrahim and Ibrahim (2012) on the other hand reported that there was about 85% reduction in phytic acid after boiling leaves of *Moringa oleifera* for only 15 minutes. Significant destruction of phytates, tannins and trypsin inhibitors in green cowpea and ground nuts has also been observed by Deol and Bains (2010) and Ndidi et al. (2014), respectively during boiling. Chai and Liebman (2005) also reported that boiling reduced soluble oxalates in vegetables by 30-87% and that it was more effective by boiling than by steaming or baking. A similar observation was made by Noonan and Savage (1999) who recommended that high oxalate food should be cooked. Generally soluble oxalate is more dangerous than the insoluble ones because it is more readily absorbed by the body, thus predisposing one to development of kidney stones. This free oxalate binds to calcium and precipitate in urine to form kidney stones, a condition that is becoming increasingly more common in men between the age of 30 and 50 years in industrialized countries (Hughes & Norman, 1994).

The results of this study shows that boiling alone may not always remove all the anti-nutrients and therefore a combination of methods such use of ash and NaCl as well as prolonged cooking will go a long way in freeing the food from toxins. Onwuka (2006) made the same observation after finding out that combining soaking and boiling up to 80 minutes gave better reduction of toxicants in pigeon peas and cowpeas rather than just soaking or boiling alone.

6.3.4 Effect of drying shoots on cyanogenic glycoside content

Palatability and toxicity of bamboo shoots is affected by bitterness which is said to be due to cyanogenic glycosides present in most varieties of bamboo shoots. These compounds are however volatile and were determined for both the fresh and dried shoots. The results are shown in Tables 6.6.

Table 6.6: Composition of total cyanogenic content (mg/kg) in shoots of two bamboo species growing in Kenya

Bamboo species	Fresh Samples	Dried @ 70° C	Reduction on drying (%)
Dendrocalamus giganteus	1,340±23[a]	270.0±18.9[a]	79.9
Bambusa vulgaris	1,050±27[b]	37.6±2.9[b]	96.4

Values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=3

On drying the fresh samples the hydrogen cyanide content reduced significantly in the two species of bamboo as shown in Table 6.7. *D. giganteus* reduced by about 79.9% whereas *B. vulgaris* decreased by about 96.4%. Drying can therefore be an effective method of reducing the toxin levels and compares well with boiling where Caasi-Lit, Mabesa and Candelaria (2010) reported a reduction of 75-98% after boiling in water. Ras (2007) did not detect any cyanide in samples which had been dried. Generally the amount of cyanide permissible is 500mg/kg (Anon, 2005; FAO, 2005). Most bamboo shoots contain amounts higher than 500mg/kg and therefore requires appropriate processing techniques to remove or reduce the toxic level.

6.3.5 Effect of various treatment conditions on physical properties of shoots

6.3.5.1 Effect on Colour

The colour of a food item is very important because it can attract or put off a prospective consumer. The effect of ash and NaCl on colour was investigated and is shown in Tables 6.7, 6.8, 6.9, 6.10 and Figure 6.16 below. More data in graphical format is shown in Appendix 1.7(a-d).

Table 6.7: Effect on L* value of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	79.7±3.6^{b}	79.5±0.9^{b}	72.9±4.2^{c}	72.2±4.3^{c}
1 % NaCl	79.7±3.6^{b}	80.6±1.3^{c}	75.6±2.4^{ce}	71.4±5.2^{a}
2 % NaCl	79.7±3.6^{b}	81.5±3.6^{e}	78.1±1.6^{a}	71.2±4.9^{ad}
5% Nacl	79.7±3.6^{b}	80.4±1.8^{a}	76.5±1.7^{a}	72.2±4.8^{d}
0% ash	79.7±3.6^{b}	79.5±0.9^{b}	72.9±4.2^{c}	72.2±4.3^{c}
1% ash	79.7±3.6^{b}	72.9±1.7^{c}	68.2±7.2^{ce}	55.3±6.6^{a}
2 % ash	79.7±3.6^{b}	64.1±1.5^{e}	53.5±2.3^{a}	50.0±6.5^{ad}
5% ash	79.7±3.6^{b}	53.7±2.3^{a}	49.7±1.8^{a}	43.8±4.1^{d}

Values within each row and column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=8, two way anova

Table 6.8: Effect on a* value

Treatment	**Boiling time (Min)**			
	0	**10**	**30**	**60**
0% NaCl	1.4±0.2^{a}	3.5±0.4^{ad}	1.1±0.1^{a}	7.7±0.6^{bc}
1% NaCl	1.4±0.2^{a}	2.8 ±0.4^{cd}	4.1±0.4^{cd}	6.9±0.7^{b}
2% NaCl	1.4±0.2^{a}	3.6±0.3^{ad}	1.7±0.2^{bc}	5.1±0.7^{b}
5 % NaCl	1.4±0.2^{a}	2.9±0.4^{bc}	1.4±0.4^{be}	4.3±0.5^{e}
0% ash	1.4±0.2^{a}	3.5±0.4^{ad}	1.1±0.1^{a}	7.7±0.6^{bc}
1% ash	1.4±0.2^{a}	5.8±0.5^{cd}	5.1±0.4^{cd}	9.9±0.8^{b}
2% ash	1.4±0.2^{a}	3.6±0.4^{ad}	8.5±0.4^{bc}	10.1±0.9^{b}
5% ash	1.4±0.2^{a}	8.3±0.6^{bc}	10.4±0.5^{be}	13.7±0.7^{e}

Values within each row and column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=8, two way anova

Table 6.9: Effect on b* value of shoots

	Boiling Time (Min)			
Treatment	**0**	**10**	**30**	**60**
0% NaCl	15.1±2.3^{e}	21.8±1.9	25.7±3.6^{b}	30.5±1.3^{abc}
1 % NaCl	15.1±2.3^{e}	22.6±2.0^{abc}	27.6±1.9^{ad}	28.1±4.3^{abcd}
2 % NaCl	15.1±2.3	24.1±3.0^{b}	26.2±1.5^{b}	33.8±3.4^{a}
5% Nacl	15.1±2.3^{d}	22.9±1.9^{c}	29.3±1.9^{b}	32.4±3.1^{a}
0% ash	15.1±2.3^{e}	21.8±1.9^{d}	25.7±3.6^{b}	30.5±1.3^{abc}
1% ash	15.1±2.3^{e}	31.2±2.3^{abc}	32.9±2.9^{ad}	31.1±1.0^{abcd}
2 % ash	15.1±2.3^{e}	30.5±1.6^{abc}	39.6±2.7^{d}	32.7±3.2^{ad}
5% ash	15.1±2.3^{e}	32.3±2.7^{acd}	35.4±2.4^{d}	28.4±1.3^{bc}

Values within each row and column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=8, two way anova

Table 6.10: Effect on hue angle of shoots

Treatment	**Boiling time (Min)**			
	0	**10**	**30**	**60**
0% NaCl/ash	66.5±1.4^{a}	63.9±1.4^{ab}	68.8±1.4^{abe}	60.0±3.7^{bcde}
1% NaCl	66.5±1.4^{a}	65.3±2.7^{abde}	64.3±3.5^{abe}	60.9±4.8^{c}
2% NaCl	66.5±1.4^{a}	64.1±1.6^{ab}	67.9±1.7^{bcde}	65.7±2.4^{cd}
5 % NaCl	66.5±1.4^{a}	65.0±2.8^{cde}	68.6±2.1^{cd}	65.0±1.8^{cde}
0% ash	66.5±1.4^{a}	63.9±1.4^{ab}	68.8±1.4^{abe}	60.0±3.7^{bcde}
1% ash	66.5±1.4^{a}	63.5±2.1^{abde}	64.3±6.3^{abe}	57.4±3.5^{c}
2% ash	66.5±1.4^{a}	65.4±2.8^{ab}	61.1±1.4^{bcde}	58.4±2.8^{cd}
5% ash	66.5±1.4^{a}	58.9±2.9^{cde}	57.9±1.5^{cd}	51.7±4.4^{c}

Values within each row and column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=8, two way anova

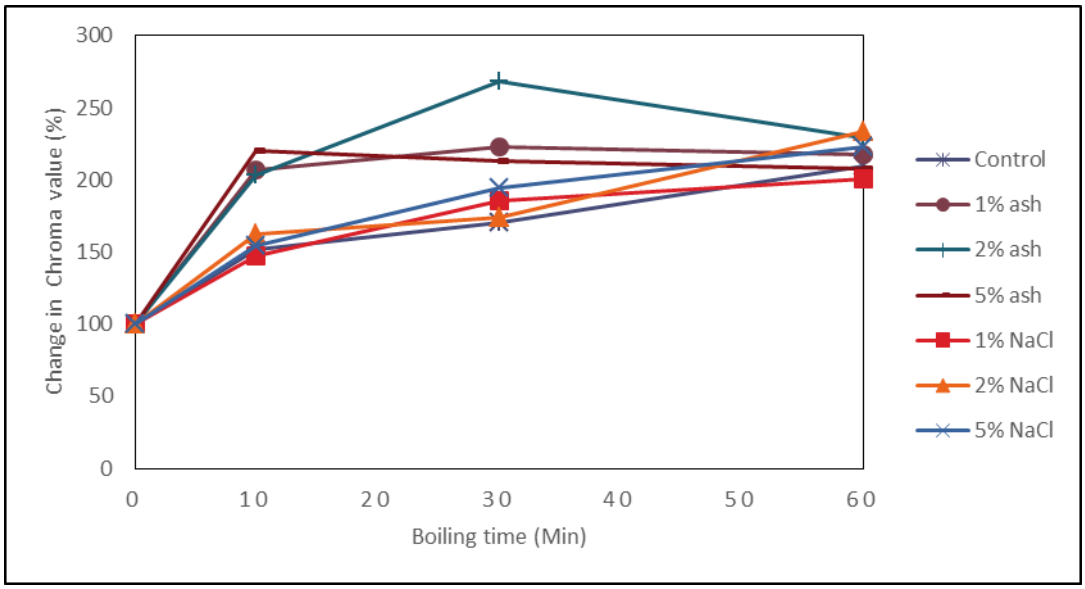


Figure 6.11: Effect on chroma value of shoots

Results of L* value (Table 6.8 and Appendix 1.7a) indicated that there was a significant difference ($p \leq 0.05$) in the shoots treated with ash and NaCl concentrations and boiled at different time regimes ($p=0.00$). The samples treated with ash of 1, 2 and 5 % had significantly high reduction in L* value compared to the control and samples boiled in NaCl solutions. It was observed that the higher the concentration of ash, the higher the loss of brightness where, 5% ash caused about 33% reduction in L* after 10 minutes and about 45% at the end of 60 minutes. One percent ash reduced the L* value by about 10% after boiling for 10 minutes and by about 33% after 60 minutes.

The a* value which indicates redness was also greatly affected by treatment with ash solutions as shown in Table 6.8 and Appendix 1.7b. The boiling time, ash and NaCl concentrations had significant difference in a* value ($p=0.00$). Tremendous increase in a* value was observed when the amount of ash increased making the shoots more the reddish. The 5% ash increased the a* value by more than 800% after 60 minutes of boiling whereas 1 and 2% ash increased it by about 600% after 60 minutes. NaCl solution had lesser effect on color and even 1% ash caused more redness than the 5% NaCl.

The change in b* value (yellowness) is shown in Figure 6.9 and Appendix 1.7c. There was significant difference ($p \leq 0.05$) in color change between the control samples and the boiled ones ($p=0.00$). The ash caused intense yellowness after 10 min of boiling though it reduced significantly after 30 min. The salt and the control on the other hand showed significantly steady increase in yellowness from 0 to 60 minutes of boiling and for these samples, the change in b* value was about 100%. The results showed that color change can be controlled when the shoots are boiled in plain water or in salt solutions. If a deeper yellow is desired, then the ash would be more preferable though prolonged boiling up to 60 minutes resulted into significant loss of yellowness particularly for 2 and 5 % ash which caused darkening of the shoots.

The hue angle on the other hand was also found to be affected significantly by the boiling time, NaCl and ash concentration ($p=0.00$). It reduced with increasing concentration of ash in the boiling water as shown in the Table 6.10 and Appendix 7b. The 5% ash caused up to 25% reduction compared to 15% caused by 1-2% ash after 60 minutes. Generally 2 and 5% NaCl had little but significant effect on the hue angle. Reduction in hue angle implies loss of yellowness.

On Chroma value or sharpness of the color (Figure 6.11), it was observed that the ash caused significant increase ($p \leq 0.05$) of about 100-120% after 10 minutes and stabilized more or less up to 60 minutes. On the other hand, a 40-60% increase was observed in the control and NaCl-treated shoots after 10 minutes increasing gradually up to 80-120% at the end of 60 minutes. Likewise chroma was significantly affected by the solutes in the boiling water as well as length of boiling.

Coloration of food during processing may be a desirable effect, whereas other times it may cause poor aesthetic value of the food. To most people the sense of taste is often fooled by the sense of sight, because many believe that how the food looks has a bearing on its taste. Indeed people associate particular colours with particular tastes. For example, yellow may be linked to bananas whereas red may be perceived to have the taste of apples or grapes. The current study shows colour development occurred during boiling for all the treatments including the control. Colour change in

the control could have been caused by maillard reactions due to proteins and sugars present in the bamboo shoots. The pH also plays a role in colour change in foods (Bello, Palacios, Segovia & Monzo, 2013) and it can be deduced that the solution of the ash which was found to have a pH of 11-12 could have accelerated the big color development witnessed in all the samples containing ash. However, non-enzymatic browning is said to be influenced by many parameters such as pH, moisture, and chemical composition in general (Bastos, 2012). Low concentration of ash and NaCl appears desirable in producing acceptable effect on coloration of the food products. For many years, Sodium in form of common salt (table salt) has been used as a colour controller to reduce undesirable chemical reactions in foods such as lipid oxidation and enzymatic browning (Henney, Taylor & Boon, 2010). In this study the ash shows potential in controlling the colour of bamboo shoots during cooking.

6.3.6 Effect of treatment conditions on the firmness of shoots

The hardness of a food item affects the ability to chew and the mouth feel. Due to the high fibre content of bamboo shoots which affects the texture, the effect of ash and NaCl on hardness was investigated and results are shown in Figure 6.12.

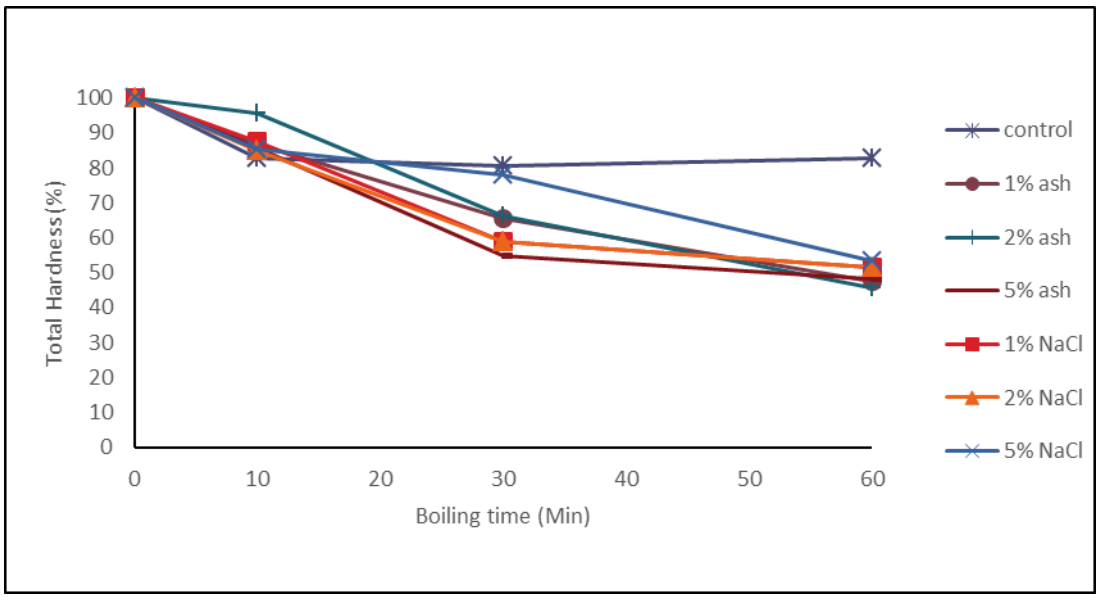


Figure 6.12: Effect of treatment conditions on texture of shoots

Total hardness was also affected significantly by boiling and treatments (p=00). The control reduced by about 15 % after boiling for 60 minutes compared to up to 40-50 % reduction observed in samples cooked in ash and NaCl solutions. Generally, both ash and NaCl at low concentrations showed better softening power which was achieved by 30 min of boiling. Addition of solutes in cooking water is said to raise the boiling point of the water and thus accelerating the cooking process.

This study shows that even though NaCl contributes to softening of the food, it however caused degradation and loss of some important nutrients and phytochemicals. It has also been recommended that consumption of NaCl should also be minimized to less than 5g/day because too much of it leads to increased risk of cardiovascular diseases (EU, 2012). The ash of the bean's stalks and pods on the other hand has been proved in this work to have potential in improving nutrients retention and also contributing to softening of the shoots.

6.5.6 Conclusion

The study showed that boiling bamboo shoots in plain water may not remove all anti-nutrients and may lead to loss of important nutrients through leaching. Cooking bamboo shoots with extract of the ash of beans' stalks would help to reduce loss of nutrients, improved the mineral content and retained antioxidants and therefore making the processed shoots healthy food. On the other hand cooking with NaCl especially at high concentration reduce the value of the shoots through loss of important nutrients, phytochemicals and important functional properties. Both NaCl and ash at low concentrations are effective in reducing anti-nutrients and softening of shoots during boiling. The ash at low concentration has the effect of reducing brightness and increasing the redness of the shoots which impacts on consumer appeal. The best treatment condition was therefore found to be 1-2% of ash and NaCl.

CHAPTER SEVEN

PROCESSED BAMBOO SHOOTS, ASSOCIATED VALUE-ADDED PRODUCTS AND EVALUATION OF CONSUMER ACCEPTABILITY

7.1 Introduction

The processing of bamboo shoots into palatable, delicious and value-added products is the sure way of ensuring that the bamboo as a food resource penetrates the consumer market in Kenya. In the current section, bamboo shoots were processed using innovative methods as outlined in the preceding chapter where 1 and 2% NaCl and ash were selected as giving products with desirable physicochemical properties. These shoots and dried powder of *B. vulgaris* were incorporated into other food products which were tested for consumer acceptance. The products which were made are boiled shoots, deep-fried shoots, biscuits and porridge.

7.2 Methodology

7.2.1 Materials

The shoots of *Bambusa vulgaris* were obtained from a private farm in Murang'a County, NaCl and plain finger millet flour were purchased from a local shop whereas, ash was obtained by burning beans' stalk waste as described in section 6.2.1. The powder of *B. vulgaris* was obtained by drying the shoots at 70°C for 24 hours and grinding with a mill to pass a sieve of 0.84 mm.

7.2.2 Processing of boiled and boiled deep-fried shoots

Shoots were processed using concentrations of NaCl and ash at 0, 1 and 2 % by boiling for 60 minutes. The shoots obtained were also deep-fried and used to make puree as shown in Figure 7.1. The puree was then utilized as an ingredient for biscuit making.

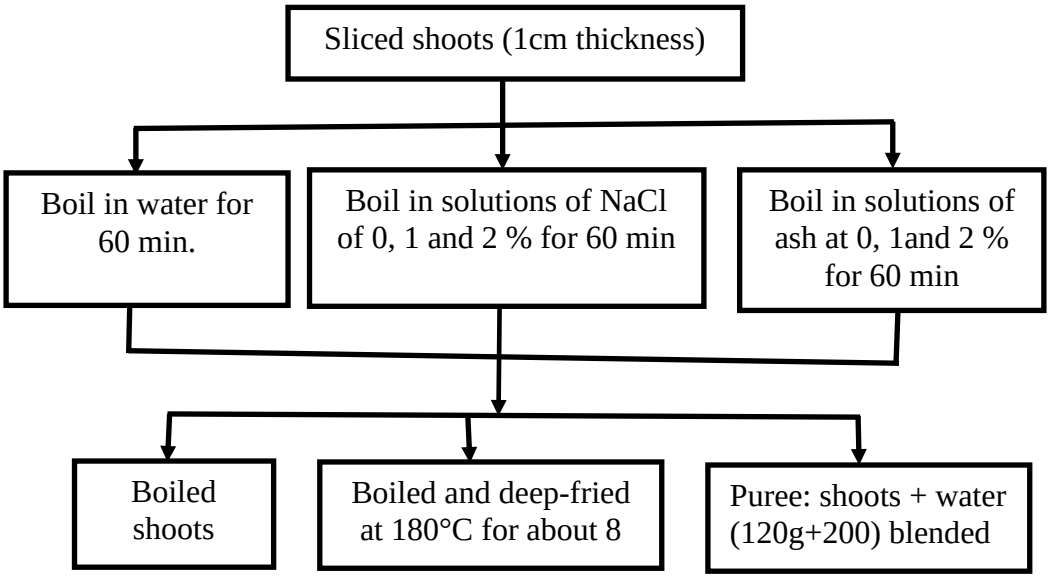


Figure7.1: Diagram for production of boiled shoots, deep fried shoots and puree

7.2.3 Production of biscuits (1kg) with shoots' puree and dry powder of *B. vulgaris*

To make a batch of 1kg, purees prepared as shown in Figure 7.1 were added to the biscuit mix reducing flour and water amount to make two formulations, one with 100g and another with 200g of puree. A control containing no shoots was also formulated. Figure7.2 below shows how the biscuits were made. The reference biscuit mix formula which was modified for the experiments is shown in Table 7.1. The production of biscuits using the powder of *B. vulgaris* is shown in Figure 7.3.

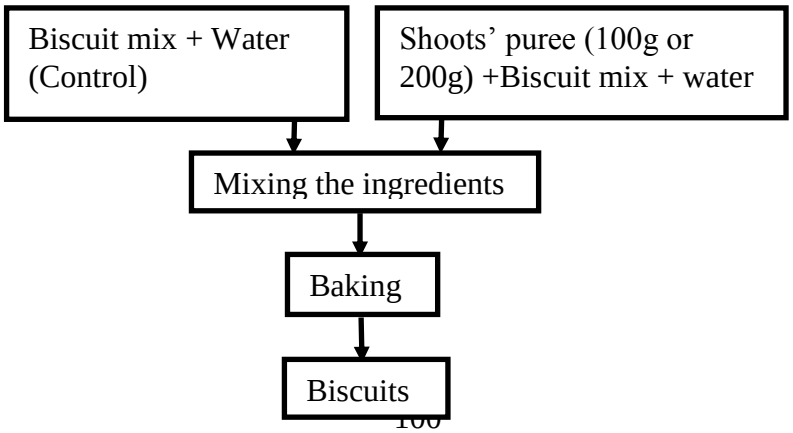


Figure7.2: Production of biscuits using processed shoots of *B. vulgaris*

Table 7.1: Original recipe for biscuits, modified for formulation of bamboo biscuits

S/No	Materials	Quantity (g)
1	Wheat flour	1,000
2	Sugar	450
3	Shortening	300
4	Baking powder	40
5	Salt	3.4
6	Vanilla	5
7	Water	Approx. 190 ml

Sugiyama and Koaze (1985)

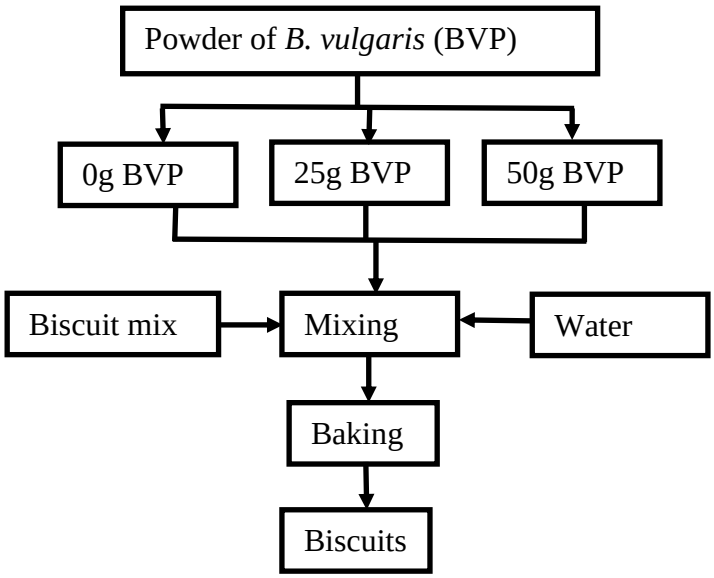


Figure7.3: Biscuits with powder of *B. vulgaris*

7.2.4 Enrichment of raw finger millet porridge with bamboo shoot powder

Raw non-fermented finger millet flour was mixed with bamboo shoot powder at 0, 5, 10 and 20% as shown in Figure 7.4. The porridges were prepared using conventional boiling method.

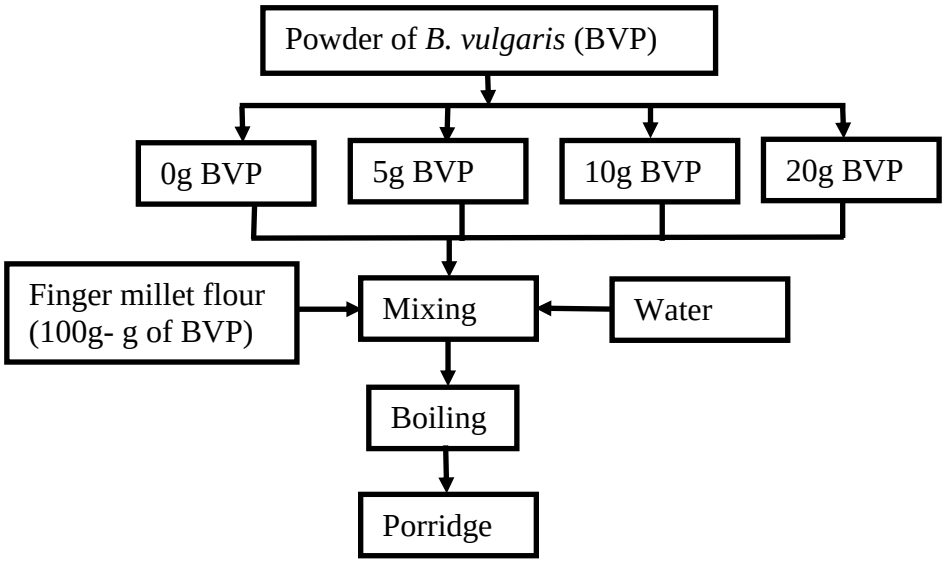


Figure7.4: Flow diagram for production of raw finger millet porridge enriched with *B. vulgaris* powder

7.2.5 Sensory evaluation

Sensory evaluation was conducted in the Food processing workshop of the Department of Food Science and Technology in JKUAT. Untrained panelist who were mainly students drawn from the University community at 11.00-12.00 noon and 3.00-4.00 pm assessed the products. The 7-point scale where 1 was "Like very much" and 7 was "Dislike very much" for biscuits and porridge containing BVP was used. As for the shoots and the biscuits with the shoots' purees, the 9-point scale was applied with 1 being "Like extremely" and 9 being "Dislike extremely". The evaluation was performed by different panelist whose number ranged 23-42 for different products.

The solid products were reduced into small pieces and set in different coded plates whereas the porridge was served in small coded cups of about 20 ml for each

panelist. Drinking water was provided in glasses for rinsing the mouths after tasting. The sensory attributes of the products being rated were colour (eye appeal), aroma, taste, texture, mouth feel and general acceptability as shown in the questionnaire attached (Appendix 1.4a-b). All evaluations were conducted under white light and at room temperature. Samples with a score of 1-3 for the 7-point and 1-4 for the 9-point were considered acceptable.

Scales used:

a) 7-point:

1) Like very much	2) Like moderately	3) Like slightly	4) Neither Like nor Dislike
5) Dislike slightly	6) Dislike moderately	7) Dislike very much	

9-point

1. Like Extremely	2. Like very much	3. Like moderately	4. Like slightly	5. Neither Like nor Dislike
6. Dislike slightly	7. Dislike moderately	8. Dislike very much	9. Dislike extremely	

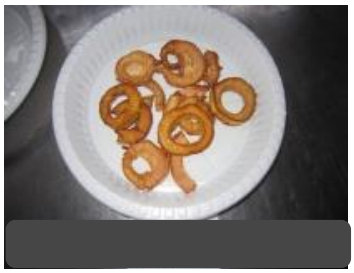
7.3 Data analysis

Data were subjected to statistical analysis using SPSS (Version 17.0) analytical software and expressed as mean ± SD (standard deviation). One way analysis of variance (ANOVA) was performed and Duncan's multiple range test at $p \leq 0.05$ was considered statistically different.

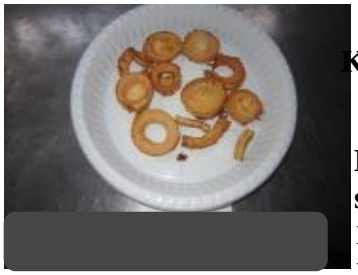
7.4 Results and discussions

7.4.1 Value added bamboo shoots products

Bamboo shoots of *B. vulgaris* species which were boiled with the NaCl and the ash extract were further processed into edible products. Below are some products which were made.



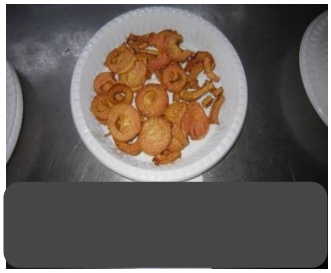
1A



1B

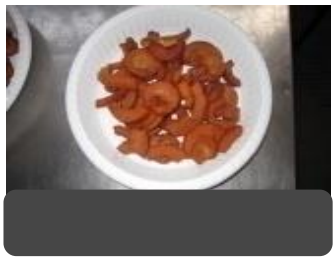
Key:

Boiled and deep fried shoots:
1A: 0% NaCl/ash
1B: 1% NaCl,
1C: 2% NaCl
1D: 1% Ash
1E: 2% Ash



1C

1D



1E

Plate 7.1: 1A-1E: Boiled and deep-fried shoots

Puree of control

Puree of shoots boiled with 1% NaCl

Puree of shoots boiled with 2% NaCl

Puree of shoots boiled with1% ash

Puree of shoots boiled with1% ash 2% ash

Plate 7.2: Purees of boiled shoots utilized to make biscuits

Plate 7.3: Some biscuits made with purees

0% BVP 2.5% BVP 5% BVP

Plate 7.4: Biscuits made with of *B. vulgaris* powder (BVP)

7.4.2 Sensory Evaluation of value-added products

7.4.2.1 Boiled and deep fried shoots

The shoots of *B. vulgaris* were processed by boiling in plain water as well as brine containing 1-2% of NaCl and ash for 60 minutes. These conditions were chosen because they showed better performance in terms of producing a product with desirable qualities. Both the boiled and boiled-deep fried shoots were then subjected to sensory evaluation by untrained panelists using the 7-point hedonic scale and the results are shown in Table 7.2.

Table 7.2: Sensory evaluation of boiled and deep fried shoots of B. vulgaris

Cooked shoots	Colour	Aroma	Taste	Texture	Mouth feel	General acceptability
0% NaCl/ash, B	3.4 ± 0.3^{abc}	4.1 ± 0.2^{ab}	5.1 ± 0.2^{a}	3.8 ± 0.3^{a}	4.1 ± 0.3^{ab}	4.1 ± 0.2^{abc}
0% NaCl/ash, BF	2.9 ± 0.2^{abc}	2.8 ± 0.3^{c}	3.7 ± 0.2^{cde}	3.8 ± 0.3^{a}	3.6 ± 0.3^{ab}	3.2 ± 0.2^{bc}
1% NaCl, B	3.2 ± 0.2^{abc}	4.1 ± 0.2^{ab}	4.2 ± 0.3^{bc}	3.6 ± 0.2^{ab}	4.0 ± 0.3^{ab}	3.9 ± 0.2^{abc}
1% NaCl, BF	2.9 ± 0.2^{abc}	2.7 ± 0.2^{c}	3.2 ± 0.3^{de}	3.5 ± 0.3^{ab}	3.5 ± 0.3^{ab}	3.2 ± 0.2^{bc}
2% NaCl, B	3.3 ± 0.2^{abc}	3.6 ± 0.2^{ab}	4.3 ± 0.3^{abc}	5.6 ± 0.2^{ab}	3.7 ± 0.3^{ab}	3.8 ± 0.2^{bc}
2% NaCl, BF	2.7 ± 0.3^{bc}	2.8 ± 0.2^{c}	3.0 ± 0.3^{e}	2.9 ± 0.3^{b}	3.2 ± 0.3^{b}	2.9 ± 0.2^{c}
1% ash, B	3.5 ± 0.2^{ab}	4.0 ± 0.2^{ab}	4.6 ± 0.3^{ab}	3.6 ± 0.2^{ab}	4.1 ± 0.3^{ab}	5.0 ± 0.5^{a}
1% ash, BF	2.7 ± 0.3^{bc}	3.4 ± 0.3^{bc}	4.2 ± 0.3^{bc}	3.2 ± 0.2^{ab}	3.5 ± 0.3^{ab}	3.3 ± 0.2^{bc}
2% ash, B	3.7 ± 0.3^{a}	4.3 ± 0.3^{a}	4.8 ± 0.3^{ab}	4.0 ± 0.3^{a}	4.3 ± 0.3^{a}	4.2 ± 0.3^{ab}
2% ash, BF	2.5 ± 0.3^{c}	3.4 ± 0.3^{bc}	3.9 ± 0.3^{bcd}	3.3 ± 0.3^{ab}	3.7 ± 0.3^{ab}	3.3 ± 0.3^{bc}
p-value	0.015	0.000	0.00	0.124	0.175	0.007

Values within each column followed by different letters differ significantly at $p\leq0.05$. Values are presented as mean ±SD, n=29

Key: B means Boiled; **BF** means Boiled and Fried

Significant difference ($p\leq0.05$) was noted between shoots which were just boiled and those which were boiled and fried as indicated in Table 7.4. Generally all the boiled shoots scored an average of 4 (neither like nor dislike). When the shoots were deep fried, the consumer acceptance improved to a mean score of 3 (Like). Frying food is said to improve tremendously the palatability, aroma and color of food and even improve nutrient content (Fillion & Henry, 1998; Ghidurus, Turtoi, Boskou, Nikulita & Stan, 2010).

7.4.2.2 Biscuits enriched with boiled shoots

After boiling the shoots, the brew was drained and the shoots were blended with clean water to make the puree which was added into the dough of the biscuits at 100g and 200g respectively. The biscuits made were tested for consumer acceptance using the 9-point hedonic scale and the results are shown in Table 7.3.

Table 7.3: Sensory evaluation of biscuits with added puree of boiled *B. vulgaris*

Description of biscuits	Color	Aroma	Taste	Texture	Mouth feel	General acceptability
With no shoots (control)	2.4±0.2^{ab}	2.9±0.3^{a}	2.9±0.2^{a}	2.7±0.2^{a}	2.9±0.2^{a}	2.8±0.2^{a}
With 100g puree (0% NaCl/ash)	2.4±0.2^{ab}	2.7±0.2^{a}	2.6±0.2^{a}	2.7±0.2^{a}	2.8±0.2^{a}	2.9±0.3^{a}
With 200g puree (0% NaCl/ash)	2.5±0.2^{ab}	2.7±0.2^{a}	2.3±0.2^{a}	2.5±0.2^{a}	2.3±0.2^{a}	2.4±0.2^{a}
Boiled in 1% NaCl, 100g puree	2.3±0.2^{ab}	2.7±0.2^{a}	2.3±0.2^{a}	2.9±0.3^{a}	3.1±0.3^{a}	2.9±0.2^{a}
Boiled in 1% NaCl, 200g puree	2.2±0.1^{b}	2.9±0.2^{a}	2.7±0.2^{a}	2.4±0.2^{a}	2.7±0.2^{a}	2.8±0.2^{a}
Boiled in 2% NaCl, 100g puree	2.5±0.2^{ab}	2.4±0.2^{a}	2.2±0.2^{a}	2.2±0.2^{a}	2.6±0.2^{a}	2.5±0.2^{a}
Boiled in 2% NaCl, 200g puree	2.3±0.2^{b}	2.6±0.2^{a}	2.3±0.2^{a}	2.5±0.2^{a}	2.6±0.2^{a}	2.5±0.2^{a}
Boiled in 1% ash, 100g puree	2.2±0.2^{b}	2.7±0.2^{a}	2.5±0.2^{a}	2.6±0.2^{a}	2.9±0.3^{a}	2.8±0.3^{a}
Boiled in 1% ash, 200g puree	2.2±0.2^{b}	2.6±0.2^{a}	2.2±0.2^{a}	2.5±0.2^{a}	2.5±0.2^{a}	2.2±0.2^{a}
Boiled in 2% ash, 100g puree	2.9±0.3^{a}	2.8±0.3^{a}	2.7±0.2^{a}	2.3±0.2^{a}	2.8±0.2^{a}	2.7±0.3^{a}
Boiled in 2% ash, 200g puree	2.3±0.2^{ab}	2.3±0.2^{a}	2.2±0.2^{a}	2.3±0.2^{a}	2.3±0.2^{a}	2.3±0.2^{a}
p-value	0.28	0.09	0.05	0.07	0.07	0.07

Values within each column followed by different letters differ significantly at p≤0.05. Values are presented as mean ±SD, n=41

The results shown in Table 7.3 indicate that there was no significant difference (p≤o.05) between biscuits prepared from shoots of varying treatments. It was observed that different formulations of the biscuits were either liked moderately or liked very much. The best biscuits were however those containing 200 g puree of 1 and 2% ash content which scored a mean of 2 (like very much) for all quality parameters tested, particularly with respect to color, taste and texture. Mustafa, Naeem, Masood, and Farooq (2016) found that increase in ratio of bamboo powder to flour reduced the degree of likeness of the cookies in terms of aroma, taste and overall acceptability, with up to 5% bamboo shoot powder being most acceptable. The results of the current study shows that treatment of the shoots with the ash increased the palatability of the shoots and therefore higher amount of bamboo shoots may be incorporated. This would also boost the mineral content as shown in the preceding chapter.

7.4.2.3 Biscuits with *B. vulgaris* powder (BVP)

The results shown in Table 7.4 indicate that there was no significant difference ($p \leq 0.05$) between the biscuits containing different amounts of BVP. All the biscuits scored a mean of 2 (Like moderately) for all the parameters tested. Some respondents however reported slight after- taste for biscuits with 5% BVP.

Table 7.4: Sensory scores for biscuits fortified with BVP

Biscuits	Color	Aroma	Taste	Texture	Mouth feel	General acceptability
0% BVP	2.1±0.2[a]	2.2±0.2[a]	1.9±0.2[a]	2.1±0.2[a]	2.3±0.2[a]	2.0±0.2[a]
2.5% BVP	1.8±0.2[a]	2.1±0.2[a]	1.9±0.2[a]	2.0±0.2[a]	2.0±0.2[a]	2.1±0.2[a]
5% BVP	2.0±0.2[a]	2.8±0.2[a]	1.9±0.2[a]	2.0±0.2[a]	2.3±0.2[a]	2.1±0.2[a]
p-value	0.32	0.18	0.95	0.73	0.35	0.79

Values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=23

Scale: 1-7, with 1 (like very much) and 7 (dislike very much)

Biscuits have been made using the powder of *Bambusa balcooa* (Chouldhury et al., 2015) where up to 10% of the powder of boiled and dried shoots was found acceptable to consumers. However Mustafa et al. (2016) who had also boiled and dried the shoots into powder reported that overall acceptability was affected by high amount of the powder in cookies and observed that up to 5% of the powder was generally acceptable. These findings show that pre-treatment of the shoots before utilization is important since it will affect the quality of the final product.

7.4.2.4 Porridge enriched with *B. vulgaris* powder

The results for sensory evaluation tests for porridge are shown in Table 7.5. One category of porridge contained 1% sugar and the other was without sugar. Both were compared for consumer acceptance using the 7-point scoring scale with 1 being like very much and 7 representing dislike very much.

Table 7.5: Sensory scores for finger millet porridge fortified with BVP

% BVP in porridge	Color	Aroma	Taste	Texture	Mouth	General

					feel	acceptability
0, no sugar	1.7±o.2^{cd}	2.0±0.2c^{d}	2.0±0.2^{d}	1.9±0.2^{c}	2.1±0.2^{de}	2.1±0.2^{ef}
0 + sugar	1.2±0.1^{d}	1.7±0.2^{d}	1.2±0.1^{d}	1.6±0.2^{c}	1.5±0.1^{e}	1.4±0.1^{f}
5 + no sugar	2.3±0.2^{c}	2.8±0.4b^{c}	3.5±0.4^{bc}	2.2±0.2^{c}	2.7±0.3^{d}	2.7±0.2^{d}
5 + sugar	1.7±0.2^{cd}	2.0±0.2^{d}	2.0±0.2^{cd}	2.1±0.2^{c}	2.1±0.2^{de}	1.9±0.2^{ef}
10 + no sugar	3.7±0.3^{ab}	3.4±0.4^{ab}	5.1±0.3^{ab}	3.7±0.3^{b}	4.5±0.3^{bc}	4.1±0.2^{b}
10 + sugar	3.2±0.3^{b}	3.0±0.4^{b}	3.5±0.4^{b}	3.8±0.3^{b}	4.0±0.4^{c}	3.4±0.2^{c}
20 + no sugar	3.9±0.4^{ab}	4.0±0.4^{a}	5.7±0.3^{a}	4.3±0.4^{b}	5.2±0.4^{ab}	4.7±0.3^{ab}
20 + sugar	4.3±0.4^{a}	4.3±0.4^{a}	6.0±0.3^{a}	5.2±0.4^{a}	5.6±0.3^{a}	5.0±0.3^{a}
p-value	0.00	0.00	0.00	0.00	0.00	0.00

Values within each column followed by different letters differ significantly at $p \leq 0.05$. Values are presented as mean ±SD, n=23

The results show that there was no significant difference ($p \leq 0.05$) between the porridges contained 0-5% BVP and containing sugar for all the parameters evaluated, with the consumers rating then either like very much or like moderately. This category of ≤5% BVP was however significantly different from those containing higher amounts of BVP regardless whether they contained sugar or not. The dislike increased with increase in the amount of BVP and consumers reported bitterness of the porridge in this category, and therefore confirming that drying the shoots alone does not fully remove the bitter compounds (see Table 6.6).

7.4.3 Conclusion

Drying bamboo shoots only reduces but does not remove bitterness completely and therefore up to 5% of the powder could be incorporated into the porridge and biscuits. This therefore means that the shoots need pre-processing before drying if it is to be consumed either alone or with other foods. The technique of processing the shoots with the ash is a feasible venture given that the shoots which were boiled and fried were liked by consumers. The cookies made from this processed bamboo shoots also had better consumer acceptability compared to those boiled in NaCl or plain water. This method of food processing therefore, has potential to give products of high consumer appeal.

CHAPTER EIGHT

CONCLUSIONS AND RECOMMENDATIONS

8.1. Conclusions

Generally, the level of awareness on the potential benefits of bamboo as a food matrix is low among most Kenyans. Among the communities that utilize bamboo as food, there seems to be short supply with no data on consumption available. There is therefore hardly any consumption of the shoots in Kenya

The nutritional profile of three common bamboo species growing in Kenya was found to compare well with that of edible species found in Asia. The shoots also showed a big potential for utilization as human food for better health.

Utilization of the top part of the shoot of *Y. alpina* bamboo is more beneficial for consumption given that it is more nutrients dense compared to the lower part. This could have desirable impact at the community level since the top part was whiter than the bottom, which means that colour can be used as an indicator of appropriate harvesting time of the shoots.

The traditional practice of using ash extract from dry beans' stalks in bamboo processing was found to have potential for exploitation in the food industry as it can be used in low concentrations to improve the quality of processed bamboo shoots. This would also provide an alternative and economic use of the stalks which are a by-product of bean harvesting.

In terms of business opportunity, utilization of bamboo shoots as food is a feasible agribusiness venture. This is because the freshly processed shoots can be processed into edible form and a variety of value-added products of high consumer acceptability can be made.

8.2 Recommendations

The following recommendations are made for further research.

i. Conduct a sensitization and nutritional education sessions to create awareness and promote the use of bamboo shoots as human food.

ii. Investigate on the effect of other processing technologies on nutrients and anti-nutrient content of the common bamboo species grown in Kenya.

iii. Investigate on the mechanism involved in reduction of anti-nutrients in the bamboo shoots by the ash extract of beans' stalks and NaCl.

iv. Investigate possibility of utilizing ash extracts from other sources such as dry shelled maize cobs and other varieties of dry beans' stalks with the aim of finding alternative use of such by-products of maize and bean harvesting.

v. Define strategies for including bamboo in staple recipes and other value-added products.

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APPENDICES

Appendix 1.1: Questionnaire on consumption of bamboo shoots at Mt. Elgon

Interview form/guide for focus-group discussions

Date of Interview:……..

The purpose of the interview is to establish the situation of bamboo consumption in Mt Elgon region. The information obtained will be used solely for academic purposes.

Questions

1. Have you ever heard about bamboo shoots? (Yes/No)
2. Do you eat the bamboo shoots? Yes/No
3. Where do you get it from?
4. How do you prepare it?
5. How do you eat it?
6. Do you eat the exotic species?
7. Have you planted any indigenous or exotic species on your farm?
8. Have you ever received any formal training on growing bamboo?
9. What are the challenges you experience with bamboo growing?

Appendix 1.2: Interview form for survey at hotels and restaurants in Nairobi

Date: of Interview:…….

Name of the hotel/restaurant:……..

The purpose of the interview is to establish the status of bamboo shoots consumption in Nairobi especially those selling Asian dishes. The information obtained will be used solely for the purpose of this research.

Questions

1. Are you the proprietor, Manager or the Chef?
2. Do you serve bamboo shoots in your menu? (Yes/No)
3. If yes, what is the source of the bamboo shoots and how do you prepare them?
4. If no, why don't you serve the shoots?
5. If yes, what is the quantity of bamboo shoots that you serve your customers per week?
6. Would you be interested in getting the locally grown bamboo shoots?
7. If no, why?

Appendix 1.3: Raw data on consumption of bamboo shoots at hotels and restaurants in Nairobi

S/No	Status description of Hotel	No of hotels	Remarks
1.	Serving bamboo shoots	3	
2.	Once served but stopped	2	Restriction of importation
3.	Have never served shoots	3	Not heard about bamboo shoots, not sure whether they can sell
4.	Source through importing	5	
5.	Source locally	0	
6.	Can buy Kenyan bamboo shoots	5	
7.	**Quantity of shoots served per wk:**	5	
	<0.5Kg	2	
	0.5-1kg	0	
	>1kg<10kg	1	
	>10<15	0	

Appendix 1.4: Questionnaires used for sensory evaluation of products

Appendix 1.4a: Questionnaire on biscuits made with purees of processed bamboo shoots

Instructions

You are provided with **six samples of biscuits** labeled 1**A, 2A, 3A, 4A, 5A, and 6A.** In a scale of **1-9** shown in Table 1, kindly score the samples against the Parameters in Table 2. Fill the score in the spaces provided in Table 2.

Table 1. Scoring Scale (Hedonic Scale)

1. Like Extremely	2. Like very much	3. Like moderately	4. Like slightly	5. Neither Like nor Dislike
6. Dislike slightly	7. Dislike moderately	8. Dislike very much	9. Dislike extremely	

Please rinse your mouth with water in the glass provided before tasting the next biscuit.

Indicate your gender…..**Male/Female (**circle one)

Table 2. Scoring Sheet for the Biscuits

	Sample code					
Parameters	**1A**	**2A**	**3A**	**4A**	**5A**	**6A**
Color						
Aroma						
Taste						
Texture						
Mouth feel						
General appearance						
Comment						

Thank you for your kind participation.

Appendix 1.4b: Sample questionnaire for porridge, shoots and biscuits enriched with *Bambusa vulgaris* powder.

Introduction

You are provided with coded food samples. Kindly give a score for each parameter according to a scale of **1 to 7** as follows**:**

1. Like very much	2. Like Moderately	3. Like	4. Neither like nor dislike
5. Dislike	6. Dislike moderately	7. Dislike very much	

Please rinse you mouth after each sample before tasting the next.

Indicate: Male/Female

	SAMPLE CODE				
Parameter	**1A**	**2A**	**3A**	**4A**	**5A**
Color					
Aroma					
Taste					
Texture					
Mouth feel					
General acceptability					
General comment					

Thank you for your kind participation.

Appendix 1.5: Effect of treatment conditions on specific mineral content of the bamboo shoots boiled in ash and NaCl solutions

1.5a. Effect on Calcium content (mg/100g dwb)

	Boiling time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	228.7±18.8^{c}	192.1±10.2^{ce}	184.0±0.3^{de}	140.5±9.6^{ab}	0.00
1 % NaCl	228.7±18.8^{c}	140.6±3.1^{ab}	131.5±5.8^{ab}	126.0±9.9^{ab}	
2 % NaCl	228.7±18.8^{c}	159.4±9.2^{ade}	153.1±14.8^{ad}	122.5±1.6^{ab}	
5% NaCl	228.7±18.8^{c}	147.9±2.3^{ad}	106.8±8.8^{b}	56.8±5.8	
0% ash	228.7±18.8^{c}	192.1±10.2^{be}	184.0±0.3^{abe}	140.5±9.6^{f}	
1% ash	228.7±18.8^{c}	200.8±14.0^{eg}	166.1±7.6^{ad}	138.1±3.5^{f}	0.18
2 % ash	228.7±18.8^{c}	185.0±18.6^{abe}	173.7±10.1^{abd}	152.2±10.0^{df}	
5% ash	228.7±18.8^{c}	217.3±7.6^{cg}	174.0±4.1^{ab}	164.1±11.2^{ad}	

Mean values within each row and column sharing a letter in the group label are not significantly different at p≤0.05. n=9

1.5b. Effect on Magnesium content (mg/100g dwb)

	Boiling time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	128.2±3.8^{a}	117.9±9.3^{ae}	104.1±2.7^{ce}	97.3±1.8^{bc}	0.00
1 % NaCl	128.2±3.8^{a}	116.2±2.2	126.7±1.6^{a}	93.4±8.4^{bc}	
2 % NaCl	128.2±3.8^{a}	96.1±4.1^{bc}	83.9±8.6^{b}	62.7±0.7^{d}	
5% NaCl	128.2±3.8^{a}	122.5±1.1^{a}	81.9±3.7^{b}	47.1±3.6^{d}	
0% ash	128.2±3.8^{c}	117.9±9.3^{h}	104.1±2.7^{ab}	97.3±1.8^{abf}	0.09
1% ash	128.2±3.8^{c}	106.0±3.9^{bg}	94.9±6.4^{af}	77.3±6.8^{d}	
2 % ash	128.2±3.8^{c}	103.0±1.6^{ab}	89.4±4.7^{ef}	84.1±7.8^{df}	
5% ash	128.2±3.8^{c}	114.8±8.2^{gh}	100.2±10.7^{ab}	80.7±7.5^{de}	

Mean values within each row and column sharing a letter in the group label are not significantly different at p≤0.05. n=9

1.5c. Effect on Potassium content (mg/100g dwb)

	Boiling Time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	4,060±110^{d}	2,350±80^{abc}	2,240±50^{ab}	2,180±30^{ab}	
1 % NaCl	4,060±110^{bcd}	3,560±290^{cd}	2,370±290^{abc}	2,310±230^{abc}	0.00
2 % NaCl	4,060±110^{d}	2,170±75^{ab}	2,040±140^{ac}	1,710±50^{ab}	
5% Nacl	4,060±110^{cd}	2,070±50^{ab}	1,460±50^{a}	1,230±70^{a}	
0% ash	4,060±110^{ab}	2,350±80c	2,240±50^{c}	2,180±30^{c}	
1% ash	4,060±110^{ab}	4,980±100de	4,480±300^{bd}	3,580±350^{a}	0.00
2 % ash	4,060±110^{ab}	6,830±250^{f}	5,490±470^{e}	6,670±390^{f}	
5% ash	4,060±110^{ab}	10,650±780	9,850±450^{g}	9,890±570^{g}	

Mean values within each row and column sharing a letter in the group label are not significantly different at $p \leq 0.05$. n=9

1.5d. Effect on Iron content (mg/100g dwb)

	Boiling Time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	6.1±0.5^{a}	5.3±0.3^{abc}	5.0±0.4^{abc}	4.8±0.4^{bc}	0.00
1 % NaCl	6.1±0.5^{a}	5.6±0.5^{abc}	5.3±0.2^{abc}	5.2±0.2^{abc}	
2 % NaCl	6.1±0.5^{a}	5.8±0.5^{ac}	5.2±0.1^{abc}	3.4±0.2^{de}	
5% Nacl	6.1±0.5^{a}	5.5±0.4^{abc}	4.4±0.4^{be}	2.6±0.1^{d}	
0% ash	6.1±0.5^{d}	5.3±0.3^{abc}	5.0±0.4^{abcf}	4.8±0.4^{aef}	
1% ash	6.1±0.5	5.5±0.1^{bcd}	5.7±0.6^{bd}	5.3±0.3^{abc}	0.33
2 % ash	6.1±0.5^{d}	5.7±0.1^{bd}	4.7±0.1^{aef}	4.2±0.4^{e}	
5% ash	6.1±0.5^{d}	5.3±0.5^{abc}	4.9±0.1^{acef}	4.5±0.4^{ef}	

Mean values within each row and column sharing a letter in the group label are not significantly different at $p \leq 0.05$. n=9

1.5e. Effect on Zinc content (mg/100g dwb)

	Boiling Time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	7.1±0.7[a]	5.6±0.5[a]	4.8±0.2[a]	4.6±0.1[a]	
1 % NaCl	7.1±0.7[a]	6.1±0.5[a]	5.9±1.3[a]	5.3±1.3[a]	0.00
2 % NaCl	7.1±0.7[a]	6.2±0.2[a]	5.6±0.5[a]	4.4±0.1[a]	
5% NaCl	7.1±0.7[a]	5.8±0.5[a]	5.0±0.5	3.0±0.3	
0% ash	7.1±0.7[a]	5.6±0.5[c]	4.8±0.2[b]	4.6±0.1[b]	
1% ash	7.1±0.7[a]	6.5±0.2[a]	6.6±0.5[a]	4.4±0.2[b]	0.00
2 % ash	7.1±0.7[a]	6.6±0.3[a]	6.6±0.4[a]	6.4±0.5[a]	
5% ash	7.1±0.7[a]	6.6±0.6[bc]	5.0±0.2[bc]	5.0±0.2[bc]	

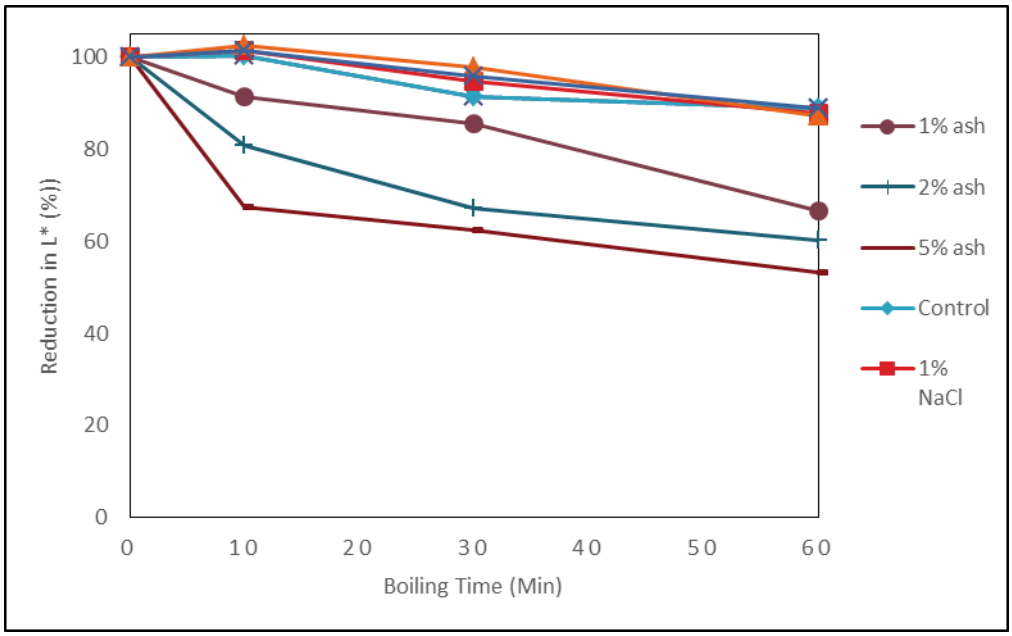
Mean values within each row and column sharing a letter in the group label are not significantly different at $p \leq 0.05$. n=9

Appendix 1.6: Effect on total flavonoids content of bamboo shoots boiled in NaCl and ash solutions (mg/100g dwb)

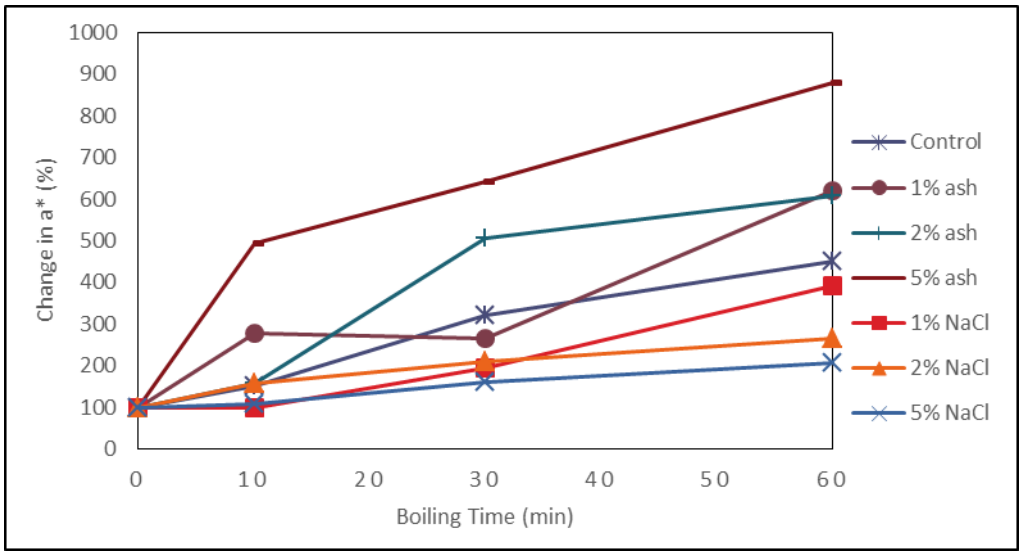
	Boiling Time (Min)				
Sample Treatment	**0**	**10**	**30**	**60**	**P value**
0% NaCl	3,450±150^{a}	3,410±160^{ac}	2,480±50b^{cf}	2,200±70^{bc}	
1 % NaCl	3,450±150^{a}	2,940±110^{d}	2,690±200^{df}	2,090±100^{bc}	
2 % NaCl	3,450±150^{a}	2,980±90^{d}	1,900±60^{be}	2,120±80^{bc}	0.00
5% Nacl	3,450±150^{a}	3,020±140^{dg}	1,600±150^{e}	1,560±60^{f}	
0% ash	3,450±150^{b}	3,410±160^{bg}	2,480±50b^{acf}	2,200±70^{f}	
1% ash	3,450±150^{b}	3,340±50^{beg}	2,890±10^{adeg}	2,810±30^{acd}	0.00
2 % ash	3,450±150^{b}	2,880±160^{acde}	3,090±200^{bdeg}	2,880±40^{ade}	
5% ash	3,450±150^{b}	2,700±140^{acd}	2,470±50^{acf}	2,080±20^{cf}	

Mean values within each row and column sharing a letter in the group label are not significantly different at $p \leq 0.05$. n=9

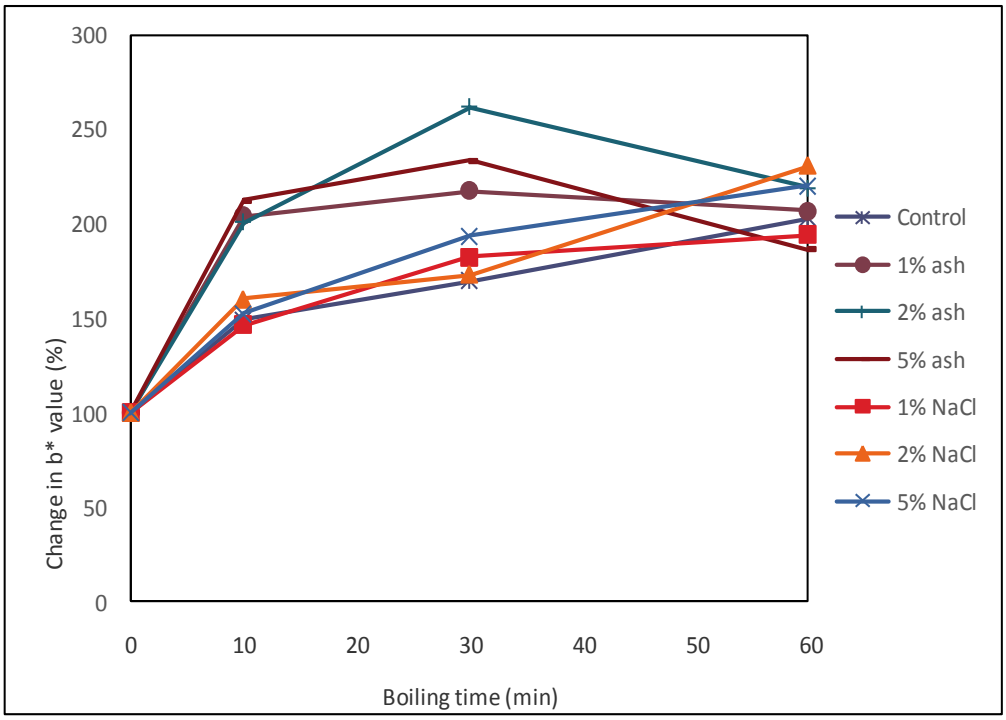
Appendix 1.7: Effect on color of bamboo shoots boiled in NaCl and ash solutions



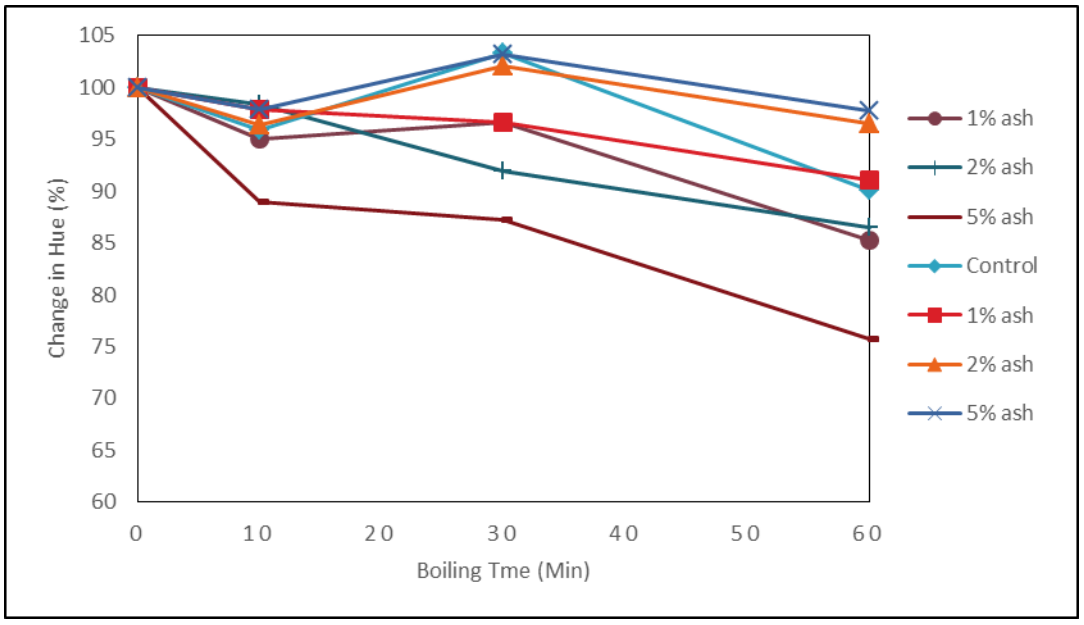
a) Effect of treatment conditions on L* value



b) Effect of treatment conditions on a* value



c) Effect of treatment conditions on b* value



d) Effect of treatment conditions on hue

Appendix 1.8: Publications

Journal of Food and Nutrition Research, 2015, Vol. 3, No. 9, 607-612
Available online at http://pubs.sciepub.com/jfnr/3/9/8

DOI:10.12691/jfnr-3-9-8

Compositional Characteristics of Young Shoots of Selected Bamboo Species Growing in Kenya and Their Potential as Food Source

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Abstract Bamboo shoots have been used for many years as food particularly in Asian countries. In Kenya however utilization of bamboo for food is largely unknown despite the frequent food shortages, high poverty level and widespread nutritional disorders. The objective of this study was to determine some compositional characteristics of three bamboo species namely, *Bambusa vulgaris*, *Dendrocalamus giganteus* and *Yushania alpina* growing in Kenya and show their potential as important food source. Proximate and mineral composition were determined using standard AOAC methods. Total polyphenol, flavonoids, antioxidant activity and anti-nutrient factors were also determined using established protocols. Results were expressed on fresh weight basis. The shoots were found to contain 1.9-3.6% of carbohydrates, 2.3-2.6% of protein, 91.2-92.3% of moisture, 1.6-2.6% of fiber, 0.14-0.17% of fat and 0.98-1.17% of ash. Mineral content in mg/100g were 20.2-31.8 of Ca, 53.4-103.0 of Mg, 51.4-67.4 of P, 288.8-362.6 of K, 0.3-1.3 of Mn and 0.9-1.5 of Zn. 3.0-16.1 mg/100g of total polyphenols and 53.1-288.4mg/100g of flavonoids were observed to be contained. Tannins, oxalates and phytic acid of 0.007-0.030%, 0.7-1.2% and 0.8-2.7%, respectively were found present. These findings provide vital baseline data for exploitation of bamboo shoots in nutritional interventions in Kenya.

Keywords: *bamboo shoots, proximate composition, minerals, polyphenols, flavonoids, anti-nutrients*

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Journal of Food and Nutrition Research, 2015, Vol. 3, No. 10, 675-680
Available online at http://pubs.sciepub.com/jfnr/3/10/10

DOI:10.12691/jfnr-3-10-10

Variation of Nutrients and Functional Properties within Young Shoots of a Bamboo Species (*Yushania alpina*) Growing at Mt. Elgon Region in Western Kenya

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Abstract Yushania *alpina* is an indigenous bamboo species growing at Mt. Elgon forest in Western Kenya and its young shoots are consumed by the local people as a vegetable. This study was done to determine some physico-chemical properties and their distribution within the shoot. Each shoot was divided into the upper and lower portions which were analyzed separately, and results were expressed in dry weight basis. On proximate composition, there was no significant difference ($p<0.05$) between the two portions in terms of moisture, protein, ash and fat content, which ranged 92.2-92.4% fresh weight, 33.0-33.4% dry weight basis (dwb), 17.0-17.1% dwb and 2.0% dwb, respectively. Significant difference was found in fiber and carbohydrates, whose content was 23.9 and 23.6% dwb in the upper portion compared to 30.7 and 17.3% dwb in the lower part, respectively. The upper portion contained Ca of 2,670, Mg of 4,300, K of 35,900 and P of 7,630 µg/g dwb, whereas the lower portion had Ca of 1,060, Mg of 1,270, K of 27,600 and P of 4,810 µg/g dwb. The upper portion was found to contain thiamine, riboflavin and vitamin C of 2.2, 8.4 and 78.2 µg/g dwb, respectively, whereas the lower part contained 1.8, 7.3 and 51.2 µg/g dwb, respectively. Fructose was found to differ significantly with the upper portion having 2.19 % against 0.62 % in the lower portion. Total polyphenol and flavonoid content of 27.6 and 24.6 mg/g dwb, respectively, were observed in the upper part compared to 25.9 and 20.1 mg/g dwb, respectively in the lower part. The upper portion was observed to exhibit better antioxidant activity with LC_{50} of 1 mg/ml compared to 5 mg/ml for the lower part, and higher Hunter's L* value.

Keywords: *Yushania alpina, bamboo, nutrients' distribution, minerals, polyphenol, flavonoids, antioxidant activity*

Cite This Article: Paul N. Karanja, Glaston M. Kenji, Simon M. Njoroge, Daniel N. Sila, Christine A. Onyango, Hiroshi Koaze, and Naomichi Baba, "Variation of Nutrients and Functional Properties within Young Shoots of a Bamboo Species (*Yushania alpina*) Growing at Mt. Elgon Region in Western Kenya." *Journal of Food and Nutrition Research*, vol. 3, no. 10 (2015): 675-680. doi: 10.12691/jfnr-3-10-10.