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Indigenous knowledge on utilization aspects and nutritional profiling of selected edible wild fruits from Zambia

By

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DECLARATION

I Choolwe Mutelo hereby declare that the work contained in this dissertation is my original work, and has never been submitted for a degree at the University of Zambia or any other academic institution of higher learning for examination. All materials published or unpublished contained in this document have been appropriately acknowledge.

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CERTIFICATE OF APPROVAL

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ABSTRACT

In recent years, the potential role of edible wild fruits has been recognized in the reduction of poverty and improving human health and nutrition. Edible wild fruits are an important source of household food security for the poor in both rural and urban communities. Edible wild fruits tend to be overlooked by policy-makers despite their significant contribution to food security, nutrition and health. The aim of this study was establish the nutritional composition and indigenous knowledge on utilization aspects of selected edible wild fruits Masuku (*Uapaca kirkiana*), Impundu (*Parinari curatellifolia*), Intugulu (*Afromomum africanum*) and Imfungo (*Anisophyllea Boehimii*). The study used a mixed method approach in data collection and analysis. A survey was used to establish indigenous knowledge based on utilization, nutritional and food safety aspects of selected edible wild fruits that included Masuku, Impundu, Intugulu and Imfungo. Detailed questionnaires and focused group discussions were used to collect data on these aspects. Established laboratory methods were used to profile their nutritional composition. Data from the survey and laboratory experiments were analysed using Statistical Package for the Social Sciences (SPSS version 22). The findings from this study revealed that Masuku, Impundu, Intugulu and Imfungo are mainly consumed raw. The reasons for consuming these fruits include satisfying hunger, snacking, sweetness, and sour taste. Processing of products such as jams, juices and fermented beverages was reported in isolated cases. The wild fruits under investigation were reported to have medicinal uses that include stopping diarrhoea, boosting the immune system, increasing blood levels and boosting appetite of the sick. Food safety concerns were reported for Intungulu and Masuku when consumed in excess. The Intungulu fruit was reported to cause stomach pain due to its high acidic nature while its seeds cause intestinal obstruction when consumed in excess. Excessive consumption of Masuku fruit was reported to cause stomach bloating and sores on the upper pallet of the mouth. All the four fruits investigated were found to contain considerable amounts of selected macro and micronutrients. Total ash content ranged from 2.51 ± 0.09 to 6.33 ± 0.57 g/100g DW, moisture content ranged from 12.25 ± 0.21 to 14.35 ± 0.91 % DW, crude protein content ranged from 11.15 ± 0.07 to 16.30 ± 0.280 g/100g DW, crude fat ranged from 0.89 ± 0.021 to 5.41 ± 0.62 g/100g DW and carbohydrates content ranged from 50.50 ± 2.12 to 56.50 ± 0.07 g/100g DW. Dietary minerals (calcium, magnesium, iron, copper, lead, manganese and zinc) range from 608 ± 57.98 to 953 ± 9.89 mg/kg DW, 529 ± 32.52 to 1206 ± 9.89 mg/kg DW, 14 ± 1.4 to 42.5 ± 2.10 mg/kg DW, 6.82 ± 1.01 to 13.5 ± 2.1

mg/kg DW, 0.26 ± 0.056 to 0.58 ± 0.02 mg/kg DW, 5.74 ± 0.106 to 78 ± 5.65 mg/kg DW, 1.60 ± 0.417 to 13 ± 1.41 mg/kg DW respectively. Vitamin A ranged from 52.5 ± 4.94 to 187.5 ± 13.4 mg/kg DW, vitamin B1 ranged from 68.58 ± 5.21 to 142.06 ± 36.50 mg/kg DW, vitamin B2 ranged from 0.001 ± 0.00 to 0.18 ± 0.28 mg/kg DW, vitamin B9 ranged from 1.235 ± 0.106 to 2.385 ± 0.106 mg/kg DW and vitamin C content ranged from 0.57 ± 0.000 to 0.95 ± 0.07 mg/kg DW. There were significant differences in Ash, Moisture, Crude protein, crude fat, carbohydrate, calcium, magnesium, iron, copper, manganese, lead zinc, vitamin A, vitamin B1, vitamin B2, vitamin B9 and vitamin C contents among these fruits ($p < 0.05$). The findings in this study suggest that fruits under investigation could serve as sources of macro and micronutrients in human nutrition. Indigenous knowledge revealed valuable data on utilization, nutritional, medicinal and food safety aspects of the fruits.

DEDICATION

I dedicate this thesis to my parents Friday Mutelo and Mary Mbulo Mutelo, who have been a source of inspiration and encouraged me when I thought of giving up.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemist
CSO	Central Statistical Office
FGD	Focused Group Discussion
FOSEZA	Food Security in rural Zambia
MCDP	1000 Most Critical Days Program
MMD	Minimum Dietary Diversity
NCDs	Non Communicable Diseases
ODK	Open Data Kit
RDA	Recommended Daily Allowance
RP-UFLC	Reverse Phase Ultra-Fast Liquid Chromatography
SPSS	Statistical Package for Social Scientists
WHO	World Health Organization
WRA	Women of Reproductive Age

CHAPTER ONE

1.0 Background

Growing of both wild fruits and domesticated fruits species in Sub-Saharan Africa can diversify crop production options for small scale farmers and can bring about substantial economic revenue, ecological and health benefits to the population at large (Fanzo et al., 2013). There are lot of indigenous fruit tree species in Sub-Saharan Africa. These fruits play a very vital role in nutrition and food security and the local people generate an income out of them (Akinnifesi, 2008). Sub-Saharan Africa has the most nutritionally insecure people, especially children and women who usually suffer from insufficient intake of protein and energy, and lack micronutrients (Chawafambira et al., 2020; WHO, 2017). Iron is one of the most common micronutrient that affects over 30% of the global population with children and women representing the majority of the affected in developing countries (WHO, 2015).

Considerable quantities of wild indigenous edible fruits are generally consumed in season when they are in abundance. However, a few of these fruits are preserved while the majority go to waste. Consumption of domesticated indigenous wild edible fruits should be encouraged in areas where they are available as a way of maintaining good health. According to Tonga - Kambikambi (2006), wild fruits such as Masuku and Mpundu have economic value on the market. Besides Masuku and Mpundu, other fruits such as Intungulu and Imfungo are commonly sold at various markets and generate substantial income for the local people.

Post-harvest handling of wild edible fruits mainly involves gathering, transportation and storage. The wild fruits are underutilized and go to waste due to the crude methods of harvesting. When harvesting, the fruits are bruised excessively thereby reducing their shelf life and quality, and this reduces the potential of income generation (Moombe, 2009). Additionally, further wastage comes about due to limited capacity of advertising and marketing of fresh fruits (Gebauer et al., 2016), and in some cases the supply of these fruits is more than the demand (Moombe, 2009). Some studies report that in developing countries (Zambia inclusive), about 25-50% of the nutrients in the fruit and quality are lost indirectly or directly from the farm to the fork. According to Akinnifesi (2008), such losses causes wastage of 55% of the collected fruits.

A wide variety of wild edible fruits are found throughout Zambia. These fruits are a good source of energy, minerals and ascorbic acid (vitamin C). Ascorbic acid is an antioxidant that is vital for the resistance to infections. The immune system can be boosted through the consumption of wild fruits due to the diverse array of nutrients they contain. It has been observed that some fruits are high in protein and oil possibly due to the edible nuts they contain (Rawat et al., 2011). Several neurodegenerative diseases associated with oxidative stress such as cancer, stroke and cardiovascular diseases are usually lowered by the consumption of fruits and vegetables. This is because fruits and vegetables have phytochemical such as polyphenols, carotenoids and ascorbic acid which have health benefits (Rawat et al., 2011).

Amongst the phytochemicals, polyphenols are the most renowned anti-inflammatory, antimicrobial, antiviral and antioxidant agents (Pandey and Rizvi, 2009). Besides the domesticated commercial fruits, the indigenous or wild fruits are equally getting serious attention as potential food supplements or being sold at a cheaper price in place of the domesticated fruits (Russo et al., 2013).

Due to an increase in degenerative diseases, people have become conscious of what they eat. Therefore, there has been an increase in the consumption of edible wild fruits when they are in season due to the health benefits associated with the consumption of these fruits. In the current investigation, Masuku (*Uapaca kirkiana*), Intugulu (*Afromomum africanum*), Impundu (*Parinari curatellifolia*) and Imfungo (*Anisophyllea boehimii*) wild fruits were studied. The study was carried out to establish indigenous knowledge based on utilization, nutritional, medicinal and food safety aspects of these fruits. The study further profiles their nutritional composition. There is limited published data on the nutritional composition and indigenous knowledge of these fruits.

1.1 Problem statement and justification

Due to urbanization, deforestation and an increase in population, most of the indigenous fruits and knowledge are being lost. Zambia is one of the most urbanized countries in Sub-Saharan Africa (United Nations, 2015). Thus, people are losing knowledge of indigenous edible wild food resources. According to Boedecker (2014), "by focusing on domesticated cultivators, the collective skills needed to identify and prepare wild foods has declined precipitously. Since species that contain energy and micronutrients become peripheral or abandoned, humans sometimes have starved in the midst of wild food plenty."

Nutritional and indigenous knowledge based on utilization of wild fruits such as Masuku, Intugulu, Impundu and Imfungo in Zambia has not been documented. Information on nutritional, consumption and utilization of the local indigenous fruits harvested from Zambia is very limited.

The change in lifestyle and eating habits particularly the consumption of sugar, oils and foods that are highly processed have equally contributed to the disease burden. Due to the shift in lifestyle and eating habits there has been an increase in the emergence of non-infectious diseases such as diabetes, heart disease, asthma and cancers in Zambia (CSO et al., 2013). Thus, if nutritional profiling of these fruits is done along with placing effective nutritional interventions, there is a likelihood that their consumption may improve. This ultimately may help to mitigate nutritional insecurity and most likely lower the burden of NCDs. Furthermore, increased consumption of these fruits will help to improve the household income of the rural households involved in the harvesting of these fruits.

1.2 Objectives

1.2.1 Main objective

The main objective of the study was to establish the nutritional composition and indigenous knowledge on utilization aspects of selected edible wild fruits (Masuku, Impundu, Intugulu and Imfungo) from Nchelenge district in Zambia.

1.2.2 Specific objective

1. To establish indigenous knowledge on utilization aspects, consumption patterns, consumer preference and attitude towards the selected edible wild fruits (Masuku, Impundu, Intungulu and Imfungo) from Zambia.
2. To determine the nutritional composition of the selected edible wild fruits from Zambia.

1.3 Research questions

1. What are the key features in utilization and consumption pattern of the selected edible fruits (Masuku, Impundu, Intugulu and Imfungo) of rural communities of Nchelenge district in Zambia?
2. What is the nutritional composition of the selected edible fruits (Masuku, Impundu, Intugulu and Imfungo)?

CHAPTER TWO

2.0 Literature review

2.1 Role of wild edible fruits in household food and nutrition security

Wild fruits are still abundant in many rural areas of developing countries (Tuyizere et al., 2021). Bvenura et al., (2017) suggests that hunger and malnutrition incidences could be reduced if the wild fruits are incorporated in the diets of families in Sub-Saharan Africa. Wild fruit trees are a cheap and an easy source of food during drought periods. Different fruiting season may ensure a consistent supply of fruits each year, regardless of the season (Akinnifesi et al., 2004). Harsh climate conditions do not affect the growth of wild fruits because they adapt to any climate condition as opposed to exotic species (Chatepa et al., 2018).

Edible wild fruits play a vital role during periods of famine and when food becomes scarce because they become the main source of food to supplement diets in better times. Most of the edible wild fruits are generally harvested just before or during the hunger period in the Sub-Saharan region (Akinnifesi et al., 2004). The very fact that edible wild fruits and nuts are harvested and utilized during the hunger periods suggests that these foods are central to the livelihoods of the marginalised groups in Sub-Saharan Africa.

When wild fruits are available, they reduce food insecurity by about one third during times when food is scarce (Moombe et al., 2009). According to Mithöfer et al, (2011) the chances of falling below the poverty threshold is 70% in periods were there is hunger. Wild fruits would likely reduce the levels of being vulnerable to food insecurity during these periods.

The role of wild fruits in food security could be seen from the way these fruits are utilized. Wild fruits and nuts are sometimes pounded and mixed with cereal flour to make soft porridge (*Nshima*) which is a staple food in most of the Southern Africa region countries (Moombe et al., 2009).

Wild fruits also contribute greatly to household food security because they provide nutrition and food when agriculture labour demands are high. The widespread malnutrition in Africa can be reduced because a number of wild fruits that have been studied are excellent sources of vitamin C (Akinnifesi, 2008). For example, the vitamin C content of pulp from Baobab (*Adansonia digitate*) is 5.13g which is 10 times more than the same amount of weight from oranges (Akinnifesi, 2008).

2.2 Role of wild edible fruits in household income

In southern Africa, wild fruits are an important source of income especially for the less privileged people (Mithöfer et al, 2011). Wild edible fruit trees in Zimbabwe represent 20% of the plants used by rural households (Moombe et al., 2009). Wild fruit collection has a higher profit return compared to crop production enterprises according to Moombe et al., (2009). The contribution of wild fruits to the socio-economic development is substantial in that the fruits generate income for most of the rural communities (Akinnifesi, 2008). So many people are employed to harvests wild fruits when the fruits are in season and the fruits are sold to generate income (Leakey, 1999). Wild fruits are usually in seasons when income from agriculture is generally low, and therefore the selling of the fruits is critical for household income during this period (Akinnifesi, 2008).

A study that was carried out in Malawi, Mozambique and Zambia by (Akinnifesi, 2008) revealed that during the hunger period, 25-50% of households depend on wild fruits for income and survival. Another study by Moombe et al., (2009) revealed that the marketing of wild fruits is a good source of income that enables households to sustain their families, alleviate the levels of poverty and improve the standards of living. Most rural communities in Southern Africa alleviate poverty through generation of income by selling wild fruits (Akinnifesi, 2008).

Wild fruits have great potential to boost rural incomes and employment opportunities greatly. In Sub-Sahara Africa, a few wild fruit products have great market penitential. According to (Akinnifesi, 2008), there are five wild fruits that have high trade potential in Southern Africa and they generate high income because they are widely traded in the region. These fruits include Masuku (*Uapaca kirkiana*), Impundu (*Parinari curatellifolia*), Mahulu-hulu (*Strychnos cocculoides*), Matobo (*Azanza garckeana*) and Tumbulwa (*Flacourtia indica*). The five fruits mentioned above are traded fresh and are an important source of income that is used for purchasing food, paying rentals, transport, school fees and other basic household goods (Moombe et al., 2009).

2.3 Indigenous knowledge on wild fruits

Traditional medicine is used by 80% of the world's population for primary healthcare (Mander and Le Breton 2006; Moombe et al., 2009). A study by Moombe et al., (2009) revealed that 63% of households in rural communities use wild fruit trees, roots, tree barks, leaves and fruits for medicinal purposes. Intungulu (*A. boehmii*) (67%), Masuku (*U. kirkiana*) (44 %) and

Impundu (*P. curatellifolia*) (36%) are among the most medically utilized wild fruit trees (Moombe et al., 2009). Anecdotal evidence suggests that traditional medicine in rural areas is preferred because people consider it to be more effective and further, indigenous knowledge on the use of wild fruit trees is passed on from one generation to the other.

2.4 Consumer attitude towards wild fruit

One of the issues that affect the attitude of the consumer towards wild fruit is the belief and perception in the ownership of these fruits. In some communities it is believed that wild fruits are owned by ancestral spirits, and therefore it is a taboo to utilise them for trade (Moombe et al., 2009).

Consumer attitude towards wild fruits is propelled by the desire for satisfying hunger, sweetness and nutritional value (Akinnifesi, 2008). To fulfil such desires, wild fruits are consumed either raw or processed. According to (Akinnifesi, 2008) few people consume both raw and processed wild fruits. The attitude of consumers towards these fruits is most likely attributed to limited knowledge on the possible utilization options.

Wild fruits are perceived differently in various cultural setting. In some cultures, exotic species of fruits have marginalised wild fruits while in others, wild fruits play a pivotal role in diets (Akinnifesi, 2008). Tuyizere et al., (2021) reported that there has been a drastic decline in the consumption of wild fruits. Factors such as urbanisation and westernisation of African diets have been linked to the low consumption of wild fruits (Bvenura et al., 2017). Other authors reported that the population of wild fruits has been declining due to environmental disasters, development, agriculture expansions and conservation exclusion (Akinnifesi, 2008; Mithöfer et al, 2011).

According to Moombe et al., (2009) consumer of exotic fruits regard quality (texture, taste and flavours) more than the price. Another study revealed that consumers of Masuku preferred to buy the fruits clean, sorted, graded and properly packaged (Kalaba et al., 2009). The buying behaviour for wild fruits is also influenced among others by appearance, size, pest infestation, price, packaging, source and storage (Akinnifesi, 2008). Other factors that influence the consumption on wild fruits are the colour and freshness. According to Tuyizere et al., (2021) the attitude of consumers on wild fruits is also influenced by the characteristics of the fruit.

Some wild fruits cause stomach pains when eaten, some cause sores in the mouth, diarrhoea, constipation and sometimes loss of appetite.

In the following sections, detailed reviews on nutritional, utilization, consumption, health and medicinal aspects of Masuku, Intungulu, Impundu and Infungu fruits studied in the current investigation are presented.

2.5.1 Masuku

Masuku (*Uapaca kirkiana*) comes from the family of *Euphorbiaceae* and is locally known as Masuku in the four Zambian languages (Tonga, Tumbuka, Kaonde, Nyanja and Bemba). The common name universally used is Wild loquat (Tonga - Kambikambi, 2006).

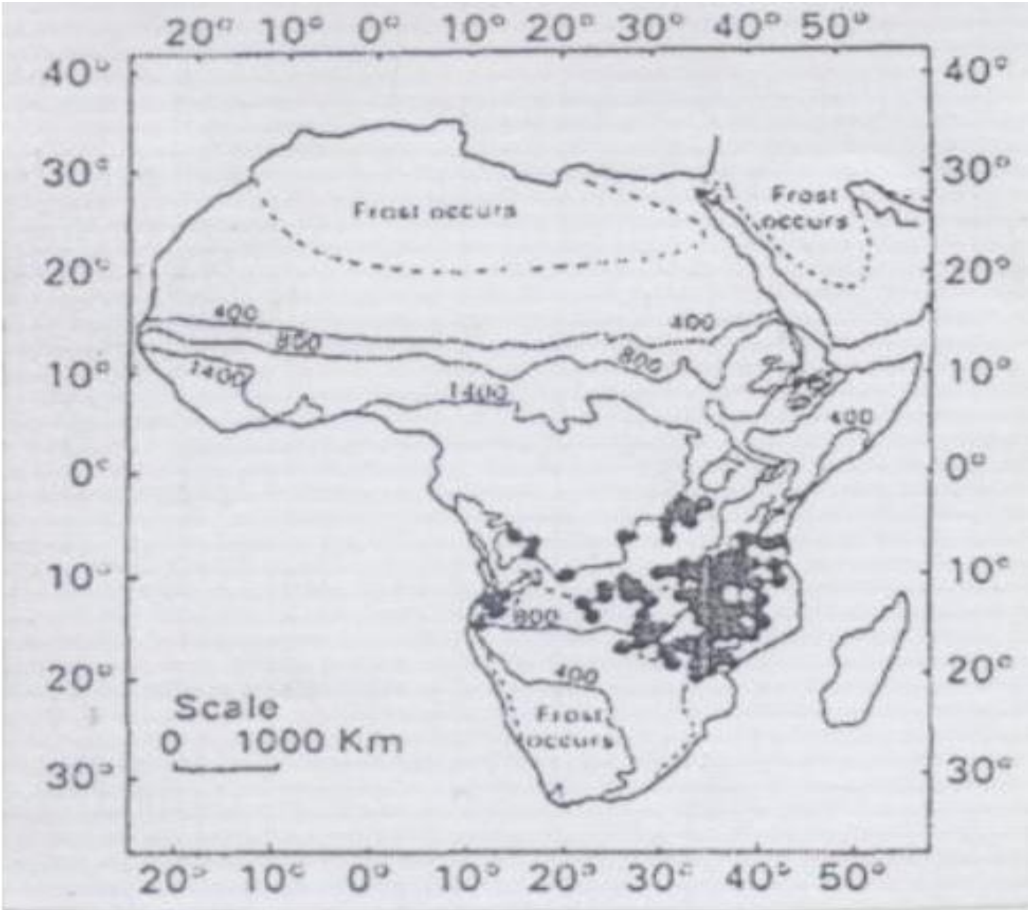
2.5.2 Description of Masuku

Masuku is a medium larger tree that grows over 10 m high with a lot of branches and brown black bark. This plant has big green leaves and flowers that are yellow in colour. The plant either carries male or female flowers. The fruit usually have a diameter of 2.5 cm and contains about three seeds in them (Tonga - Kambikambi, 2006).

2.5.3 Distribution of Masuku

Masuku is the most widespread species of the *Uapaca* genus in southern Africa (Moombe et al., 2009). It is found in the secondary miombo woodlands, lowland forests such as open woodlands, clearings and gaps, and amongst rocks at medium altitudes with good rainfall of about 800–1200 mm/year (Akinnifesi, 2008). According to Moombe et al., (2009), the geographical distribution of this tree in southern Africa covers the following countries; Congo, Angola, Zambia, Malawi, Zimbabwe, Tanzania, Mozambique and Burundi as shown in Figure 1.

In Zambia this fruit is found in many parts of the country and mostly in places where there is an annual rainfall of about 1,500 mm. This plant was found in several districts including Chama, Mumbwa, Mkushi, Katete, Sinazongwe and Kawambwa during a survey in 2006 October and December when the fruit was in season (Tonga - Kambikambi, 2006).



Source: Moombe et al., 2009.

Figure 1 Masuku (*Uapaca kirkiana*) species distribution.

2.5.4 Utilization and consumption of Masuku

In Southern Africa, Masuku is made into different products such as jam, squash, refreshing juice, sweet beer, porridge, cake, wine and is also eaten raw (Akinnifesi, 2008). Masuku jam is ranked fifth while wine seventh among fruit products, and the tree is ranked first among indigenous fruit trees in Malawi (Leakey, 1999; Mithöfer et al, 2011; Moombe, 2009; Akinnifesi, 2008).

In Zambia Masuku is usually eaten fresh as a snack and also used to make sweet beer and a yoghurt like food prepared by adding curd to its pulp (Tonga - Kambikambi, 2006).

2.5.5 Nutritional value of Masuku

The nutritional value of Masuku fruit found in the woodlands of Zambia has not yet been documented. According to Tonga – Kambikambi (2006), data on the nutritional value of

Masuku fruits found in Zambia is limited. However, the nutritional profiles of Masuku harvested from other countries in Africa have been reported.

According to a research that was carried out in Malawi by Saka et al., (2007), the proximate analysis of Masuku fruit revealed the following nutrient compositions: Water 72g/100g, crude protein 1.8g/100g, fat 1.1g/100g, fiber 8.4 g/100g, ash 2.2 g/100g, potassium 13.68 mg/100g, magnesium 1.106 mg/100g, phosphorous 0.555 mg/100g, iron 0.431mg/100g, sodium (g/g) 0.365mg/100g, calcium 0.033 mg/100g. Ascorbic acid 16.8 mg/100g. The fruit has also been reported to have the caloric value of 1456KJ/100g and the pH of its pulp to be around 5.05 (Saka et al., 2007).

A similar study on Masuku conducted in Tanzania revealed the following nutrient compositions: Protein 7.0%, fibre 14.9%, fat 2.4%, ash 5.4%, total carbohydrates 70.2%, reducing sugars 98.6 mg/100g, vitamin c 430.8 mg/100g, minerals; iron 0.09%, sodium 0.34%, potassium 3.09%, calcium 0.72%, magnesium 0.17% and phosphorous 0.48% (Karaan et al., 2006).

Akinnifesi et al., (2004) characterised the fruit pulp of Masuku from the Miombo woodlands of Malawi based on the chemical composition and reported the following compositions: Dry matter 58.1%, ash content 4.5%, protein content 17.0%, fat content 22.9%, fibre 8.1% and carbohydrate 47.5%.

2.6.1 Intugulu

Intungulu (*Afromomum africanum*) comes from the family of *Zingiberaceae* and is locally known as Intugulu in the four Zambian languages (Kaonde, Bembas, Tonga); Nthungulu (Nyanja). The common name is Wild cardamom (Tonga - Kambikambi, 2006).

2.6.2 Description of Intungulu

Intungulu is a perennial grass like plant that almost looks like ginger. The flowers come out from underground stem. The onion shaped fruits are bright red outside while the acid pulp inside is white. It has a hard cover, and measures 7 cm in length. It contains many small 2-3 mm long seeds that are brown with yellow growing points (Tonga - Kambikambi, 2006).

2.6.3 Distribution Intugulu

Intungulu is one of the widespread species of the edible indigenous fruits in southern Africa (Moombe et al., 2009). It is found in the secondary miombo woodlands, lowland forests such as open woodlands, clearings and gaps, and amongst rocks at medium altitudes with good rainfall of about 800–1200 mm/year (Akinnifesi, 2008). The geographical distribution of this tree in southern Africa covers the following countries; Congo, Angola, Zambia, Malawi, Zimbabwe, Tanzania, Mozambique and Burundi (Moombe et al., 2009).

The plant is usually found in areas where there is an annual rainfall of about 800 to 1,500 mm. According to a survey carried out by Tonga - Kambikambi, (2006) it was found that this fruit mostly grows in Mumbwa, Kawamba and Mkushi districts of Zambia.

2.6.4 Utilisation and consumption of Intugulu

The fruit is eaten fresh as a snack and also used to make jam. Intungulu is usually preferred by the elderly folk because of its sour taste (Tonga - Kambikambi, 2006). The leaves and stems if crushed have a spicy ginger like flavour and the seeds can be dried and used as a substitute for pepper (Moombe et al., 2009). Despite people consuming this fruit, seeds and leaves, the nutritive value of this plant is not known or has not been documented (Tonga - Kambikambi, 2006).

2.6.5 Nutritional value of Intugulu

The nutritional value of Intungulu is still unknown. Published data on the nutritional value of this fruit is very limited. The current investigation therefore seeks to fill this knowledge gap.

2.7.1 Impundu

Impundu (*Parinari curatellifolia*) comes from the family of *Chrysobalanaceae* and its fruits are locally called by different names such as Impundu (Bemba), Mpundu (Tonga), Imbula (Tonga) and Mphundu (Nyanja) in Zambia. The common names for this fruit are Mbola plum, Fever tree and Hissing tree (Tonga - Kambikambi, 2006).

2.7.2 Description of Impundu

Impundu is an evergreen, medium sized and mushroom shaped tree with a brownish-grey bark. The leaves are oval and green in colour; the flowers are brown yellowish. The tree grows up to

20 m high. When the fruits are ripe they become red-brown in colour, round, scaly and speckled. The fruits are sweet in taste, fleshy and contain fibrous pulp and one to two seeds enclosed in a hard stone. The seeds are very rich in oil and contain a single nut the size of a groundnut (Tonga - Kambikambi, 2006).

2.7.3 Distribution Impundu

The Miombo woodland has approximately 650 species of the woody plant flora, many of which are edible. Of the estimated 33 edible wild fruit species in Zambia, 82% are found in miombo. Impundu is among the most common edible wild fruits that have been exploited for both cash and consumption (Chatepa et al., 2018).

The fruit matures from October to March and the tree is widespread in dried parts of Tropic Africa. It is found almost throughout Zambia and Zimbabwe and in the northern parts of Namibia and Botswana. The pleasant tasting fruits has a variety of uses and forms a part of the staple diet in Southern Africa (Tonga - Kambikambi, 2006).

2.7.4 Utilisation and consumption of Impundu

In Southern Africa, Impundu is made into jams, butter, alcoholic drinks or juices, or the fruits are grinded into fruit powder for mixing with other foods, for example the preparation of porridge (Lesten et al., 2018; Akinnifesi, 2008). Oil is also extracted from its nuts. Impundu is also eaten as a snack when food is plenty and in times of famine it becomes the main source of food (Akinnifesi, 2008).

Juice making is most preferred by women processors in Tanzania followed by jam and wine, probably because juice making is affordable and simple Moombe et al., 2009). The processing of this fruit into wine and jam in Malawi is done in order to add variety to the food when the fruit is out of season (Moombe et al., 2009).

In Zambia, Impundu is consumed as a snack, it is also made into porridge and sometimes processed into a delicious syrup. Nuts obtained from the seeds are used as relish, but oil can also be extracted from them. The oil from the seeds has a potential for being commercialized (Tonga - Kambikambi, 2006). According to Akinnifesi et al., (2004), Impundu fruit extracts are used for the treatment of heart diseases like hypertension or are used as cardiac tonic. Other parts of the tree such as the leaves are used to treat anaemia and inflammation (Akinnifesi et al., 2004).

2.7.5 Nutritional value of Impundu

The nutritional value of Impundu (*Parinari curatellifolia)* as reported by (Chatepa et al., 2018) is as follows: Dry matter ranged from 88.66 ± 0.15 to 99.31 ± 0.04% for pulp and peels, and fruit respectively, protein ranged from 3.90 ± 0.03 to 15.61 ± 0.05% for pulp and kernel respectively, crude fat ranged from 2.02 ± 0.47 to 46.05 ± 0.19% for pulp and kernels respectively, ash content was reported as 2.46 ± 0.09%, crude fibre ranged from 1.58 ± 0.04 to 21.39 ± 0.28% for kernels / nuts and whole fruit respectively, carbohydrate content ranged from 34.34 ± 0.21 to 84.95 ± 0.14%. Minerals in the fruit pulp were reported as follows in mg 100 g^{-1} DW: potassium ranged from 712.65 ± 12.02, magnesium ranged from 213.06 ± 8.25, copper ranged from 6.26 ± 0.00, zinc ranged from 17.57 ± 0.67, iron ranged from 295.49 ± 0.68, phosphorus ranged from 405.23 ± 2.17 and manganese 24.27 ± 0.58. However, there is very limited data on the nutritional value of Impundu fruit harvested from Zambia.

2.8.1 Imfungo

Imfungo (*Anisophyllea Boehimii*) comes from the family of *Anisophylleaceae* and the fruits in Zambia is locally known as as Mfungo (Kaonde), Imfungo (Bemba), Fungo (Tumbuaka) and Mufungo (Lozi) and Muhoto (Nyanja) (Tonga - Kambikambi, 2006).

2.8.2 Description of Imfungo

Imfungo plant grows up to 16 meters and it is usually green or semi-green with a short crooked trunk. The leaves are usually thin and leathery with fine hairs on both sides and the vines are very thin and clear. The small flowers are cream coloured and grow on woolly stalks. The plum like fruits are up to 3.5 cm long and ripen red-yellow. The pale yellow fleshy is tasty and contains one very hard seed (Tonga - Kambikambi, 2006).

2.8.3 Distribution of Imfungo

According to a research which was carried out in the Miomba woodlands by Akinnifesi et al., (2004), Imfungo was only known in Zambia as an edible wild fruit and in terms of preference it score eight among the most preferred indigenous edible fruits.

Imfungo is very popular and is sold at Zambian markets. This fruit is usually found in areas where there is a lot of rainfall such as the Copperbelt and rarely found in Southern , Western and Eastern provinces due to less rainfall (Tonga - Kambikambi, 2006).

2.8.4 Utilisation and consumption of Imfungo

The utilization and consumption of Imfungo only takes place in between September and December when the fruits ripen. The edible parts of the plant are fruit itself and the seeds. The fruit is mainly eaten as a raw snack and sometimes it is made into a porridge by boiling it in water. When the fruit is soft enough, the water is sieved and then boiled for the second time with mealie-meal. The biggest challenge is that the fruit is highly perishable, it is easily infested with maggots but can be preserved by sun drying and used in future (Akinnifesi et al., (2004).

2.8.5 Nutritional value of Imfungo

There are considerable amounts of protein (28-31%) and oil (56-61%) in the nut. The fruit contains vitamin C, which is higher than the majority of the citrus fruits except the orange (Tonga - Kambikambi, 2006). Published data on other nutrients is very limited.

2.9.1 Medicinal aspects of Masuku, Intungulu, Impundu and Imfungo fruits

Literature on medicinal aspect of Masuku, Intungulu, Impundu and Imfungo is limited. However, studies on the other wild fruits have revealed a number of medicinal properties that may beneficial to human health. There is pragmatic evidence that wild fruits have a protective effect against diabetes, hypertension, stroke, coronary heart disease and cancer. (Chua-Barcelo, 2014) reported a number of medicinal uses in 12 wild fruits: "*Antidesma bunius* (A. bunius) for diabetes and body cleansing; *V. myrtoides* for eye sight, diabetes, antioxidant, flu, anti-cancer; *S. sparsifolia* for flu, cough and hypertension; *R. fraxinifolius* for stomatchache, sore eyes, urinary tract infection and cough; *G. binucao* for "agas nginao" (conceiving mothers' cravings), cough, flu and arthritis; *Amomum lepicarpum* for loose bowel movement; *Solanum betacea* for anti-cancer; *R. edulis* for good source of vitamin C; *Elaegnus triflora* for cough; *S elegans* for lung problem (respiratory); *Alipinia vanoverberghii* for loose bowel movement and *M. pendula* for cough and colds."

Another study by Sharma et al., (2017) on wild fruits of Uttarakhand in India revealed that *Punica granatum* rind is used as a traditional remedy against diarrhoea, dysentery and intestinal parasites; *Ficus palmate* is beneficial in the disease of lung and bladder; *Prunus armeniaca* kernels can be used as an alternative treatment for cancer; *Pyracantha crenulata* medically has cardio-tonic, coronary vasodilator and hypertensive properties. According to Sharma et al., (2017) *Pyracantha crenulata* has been used traditionally for cardia failure, myocardial weakness, paroxysmal tachycardia, hypertension and also as an appetizer and pain killer. The antioxidants present in the *Pyracantha crenulata* help in reducing the ill-effect of free-radical's in the body, maintain blood-pressure and reduce the levels of cholesterol (Sharma et al., 2017).

CHAPTER THREE

3.0 Material and methods

3.1 Fruits utilization and consumption survey

3.1.1 Research design

A cross sectional study design which followed a mixed approach method was deployed. The mixed approach was used because qualitative and quantitative method of research complement each other on giving pragmatic evidence and it also helps to avoid bias. This design enabled to effectively collect data on utilization, nutritional knowledge, food safety aspects and indigenous knowledge of the selected edible wild fruits in Nchelenge district Luapula province of Zambia. The cross-sectional design was utilised in addressing objective one (1) of the study, which is, to establish indigenous knowledge on utilization aspects, consumption patterns, consumer preference and attitude towards the selected edible wild fruits (Masuku, Impundu, Intungulu and Imfungo).

3.1.2 Target population

Elderly women, adult men, female and male teenagers whose age ranged between 16 - 85 years were the target population in order to have a representation of all age groups in the survey and reduce bias.

3.1.3 Study site, sampling procedure and sample size

Study site

The study was conducted in Mulwe ward of Nchelenge district, Luapula Province of Zambia between June and July 2020. Mantapala has 7 villages that includes Semiwe, Sekeza, Sikazwe, Inkana, Champo, Bupina and Mulwe. The study site was an operational area for the Food Security in rural Zambia (FOSEZA) project for which domestication of wild fruits as a way of ensuring food security was one of its goals. The study site is located in Luapula province, one of the areas of Zambia with households with a low resilience to food and nutrition security. According to First 1000 Most Critical Days Program (2019) baseline results for hunger and access to food report indicates that Nchelenge district household reports 21.2% of low resilience to lean season and environmental shocks.

3.1.4 Sampling procedure

Multi-stage sampling technique was used to select participants in this study. The selection was done in four stages as follows:

Stage 1. Nchelenge district was purposively selected as it was the operational area for the FOSEZA project.

Stage 2. Mulwe ward was purposively selected as it was the operational area for the FOSEZA project.

Stage 3. Four (4) villages out of seven (7) villages in the selected ward were randomly selected by listing down the 7 villages on a piece of paper and the names of the villages were separated from each other by cutting them into small pieces and folding them. The pieces of paper with names of the villages that were folded were placed in plastic bag and shaken. The researcher picked four papers out of the seven villages.

Stage 4. From the four villages, using the random sampling technique, households were selected from the updated village register provided by the headman. Using the table of random numbers, the households were randomly selected to arrive at the sample.

3.1.5 Sample size calculation

The following formulae was used to determine the minimum sample size:

$N = (Z)^2 \pi (1- \pi)/ ME^2$

Where N = required sample size

Z = z value of desired level of confidence

π = population proportion of interest (households reporting low resilience to lean seasons and environment shocks) MCDP (2019)

ME = Acceptable margin of error

Z= 1.96=95% confidence interval (CI)

$\pi = 0.212$

$ME = 0.05^2$

$N = (1.96)^2\ 0.212\ (1- 0.212)/ 0.05^2$

Minimum sample Size = 257

The minimum sample size was adjusted at 5% for attrition and non-response biases to get 270.

3.1.6 Survey instrument and pretesting

A semi-structured questionnaire (Appendix 2) focussing on social demographics of respondents, utilization, nutritional knowledge, food safety aspects and indigenous knowledge of selected wild fruits (Masuku, Impundu, Intugulu and Imfungo) was developed in the XLS format and deployed on the Open Data Kit (ODK) software for collecting, managing and using data.

Data was also collected by means of a Focused Group Discussion (FGD) using the same questionnaire but mainly focussing on utilization, food safety aspect and indigenous knowledge of these fruits. The FGD was conducted at Mantapala village where the participants were divided into three groups, comprising 12 individuals in each group. The FDGs were interactive and flexible in order to allow the respondents adequate time to provide relevant details on a topical subject under discussion.

The questionnaire was pretested among non-participating households with similar characteristics in a nearby village were the project was being carried out. Pretesting was done on 20 households.

3.2 Nutritional analysis of fruits

3.2.1 Fruit samples

The different types of edible wild fruits (Masuku, Impundu, Intungulu and Imfungo) were harvested from Nchelenge district Luapula Province Zambia in 2019 when the fruits were in season. These fruits were harvested at different times as they matured at different times.

3.2.2 Sample preparation and storage

The fruit samples were thoroughly cleaned and washed with tap water to remove debris. They were allowed to drain at room temperature. The clean fresh fruit samples were immediately frozen at -80^{o}C and freeze dried to obtain dried materials that were packaged in airtight packages awaiting further analysis.

3.2.3 Chemical composition

Chemical composition analysis of the wild fruits involved the analysis of crude moisture, crude fat, crude protein and total ash. Crude moisture, crude fat, crude protein and total ash were determined using the association of official agriculture chemistry methods which are 934.01, 920.39 (A), 984 (A – D), 942.05 and 978.10 respectively (AOAC, 2006). The total carbohydrate was calculated by the difference.

The selection of vitamins and minerals was based on nutritional requirements for women of reproductive age (WRA) who are nutritionally vulnerable because of the physiological demands of pregnancy and lactation. Mostly the requirement of nutrients for pregnant and lactating women is higher than adult men (FAO, 2021). The Minimum Dietary Diversity for WRA (MDD-W) indicates whether or not women of 15-49 years have consumed at least five out of ten defined food groups the previous day or night (FAO and FHI 360, 2016). Micronutrients such as vitamin A, thiamine, riboflavin, niacin, vitamin B6, folate, vitamin B12, vitamin C, calcium, iron and zinc are needed in high amounts for WRA because of the physiological demands (Martin-Prével et al., 2015). Calcium, magnesium, iron, copper, lead, manganese and zinc were analysed using the standard method 947.27 (AOAC, 2012). Vitamin C was analysed by titration of dichlorophenol-indophenol (DPI) (Tibuhwa, 2012), while vitamin A was determined using the standard method 2001.13 (AOAC, 2012). Vitamin B1, vitamin B2 and vitamin B9 were analysed using reverse phase Ultra-Fast Liquid Chromatography (RP-UFLC) (Heudi et al., 2006); Sami et al., 2014). All the parameters under investigations were analysed in duplicates. For more details on the methods used, refer to appendix 1.

3.3 Statistical analysis

Statistical analysis was performed using SPSS version 22. Descriptive statistics were generated as mean, frequencies, ± standard deviation (SD) and percentages to summarize dependent variables. Values at $p < 0.05$ were considered statistically significant. The data was analysed as follows:

- The demographic and socio economic, consumer preference, the frequency of consumption, months when each fruit is in season, the methods of utilization, respondent’s attitude of towards the wild fruits, nutritional knowledge of the wild fruits, the proximate component analysis, mineral content and vitamin content of the selected edible wild fruits were analysed using descriptive and frequency statistics.

- Multiple response was employed to analyse the reason of consumption.
- Thematic analysis method was used to analyse qualitative data from two FGDs by summarising the responses from the following themes: months when each fruits are in season, method of utilization, indigenous knowledge on medicinal uses and food safety concerns on the consumption on the four selected wild fruits. Then the data was compared among the two groups and a conclusion was made from each theme.
- One-way Analysis of Variance (ANOVA) was applied to compare means of the chemical components of the four selected edible wild fruits.

3.4 Ethical clearance

Ethical clearance was obtained through the framework of the FOSEZA project that started its project activities in 2016. All the participants who were above 18 years old were requested to give consent to participate in the study. For the participants below the age of 18, consent was taken from their parents/guardians. All those who did not consent did not participate in the study.

CHAPTER FOUR

4.0 Result

4.1 Indigenous knowledge on utilization aspects

Demographic and socio economic characteristics of respondents, Indigenous knowledge, medicinal uses, food safety concerns, nutritional knowledge of respondents on consumption and preferences of the wild fruits under investigation are presented in sections 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6 and 4.1.7.

4.1.1 Demographic and socio economic characteristics of Masuku, Imfungo, Intungulu and Mpundu

The total number of respondents was 306 across the age distribution that ranged between 16-83 years. The social demographics are summarized in Table 4.1. The demographics include gender, marital status, educational level and occupation.

The respondents in the survey were both male and female. There were more females (69.9%), (n=214) than males (30.1%), (n=92) and the mean age was 31.99 years.

The respondents under investigation reported varied marital status. The majority (82%) were married, while the remaining reported being widowed (8.5%), divorced (4.9%), single (3.3%) and separated (1.3%).

The occupation of the respondents was divided into six categories, namely; not employed, self-employed, farmer, employed and farming, pensioner and other. The majority (76%) of the participants were farmers, followed by those who were self-employed (43%), not employed (23%), employed and practice farming (4%), and other categories (0.7%) and the lowest number of participants were pensioners (0.3%).

The levels of education of the respondents was categorised into fourteen classes as follows; none, grade 1, grade 2 grade 3, grade 4, grade 5, grade 6, grade 7, grade 8, grade 9, grade 10, grade 11, grade 12 and certificate. The majority (25.2%) learnt up to grade 7 and 21.2% learnt up to grade 9 while 4.6% did not attain any education. Very few respondents went up to grade 12 (7.5%) and only 1% had a certificate/diploma.

Table 4. 1: Social demographics

Characteristic of the respondent	Number of respondents (N=306)	% respondent
Gender		
Male	92	30.1
Female	**214**	**69.9**
Marital status		
Married	**251**	**82**
Single	10	3.3
Divorced	15	4.9
Widowed	26	8.5
Separated	4	1.3
Education level		
None	14	4.6
Grade 1	1	0.3
Grade 2	5	1.6
Grade 3	13	4.2
Grade 4	11	3.6
Grade 5	18	5.9
Grade 6	20	6.5
Grade 7	**77**	**25.2**
Grade 8	31	10.1
Grade 9	65	21.2
Grade 10	14	4.6
Grade 11	13	4.2
Grade 12	23	7.5
Certificate/Diploma	1	0.3
Occupation		
Not employed	23	7.5
Self-employed (Business)	43	14.1
Farmer	**223**	**76.1**
Employed and farming	4	1.3
Pensioner	1	0.3
Other	2	0.7

4.1.2 Consumer preference towards the consumption of Masuku Imfungo Intungulu and Mpundu

Ranking of the selected edible wild fruits (Masuku, Imfungo, Intungulu and Mpundu) by consumers in Nchelenge district of Luapula province of Zambia revealed varying perceptions. Table 4.2 presents the consumers ranking of edible wild fruits under investigation. Out of the four selected wild fruits consumed, Masuku was the most preferred fruit or the most commonly consumed wild fruit. The respondents ranked Masuku first with an overall percentage score/rank of 35%, followed by Imfungo (29.7%), Intungulu (22.5%) and Impundu (12%) respectively.

Table 4. 2: Ranking of consumption preference of selected wild fruits

	Rank	
Name of wild fruit	Score % (N)	Score
Masuku	35% (107)	1
Imfungo	29.7% (91)	2
Intungulu	22.5% (69)	3
Impundu	12.7% (39)	4

4.1.3 Frequency of consumption of selected wild fruits

Table 4.3 summarises the frequency of consumption of Impundu, Imfungo, Intugulu and Masuku when each of these fruits are in season. Masuku was reported to be consumed daily by 49.7% of the respondents, followed by Imfungo (37.9%), Intungulu (35.3%) and Impundu (25.5%) respectively.

Table 4. 3: Frequency of consumption of selected wild fruits

Name of Fruit	Frequency of consumption % (N)				
	Daily	2 days/week	4 days/week	6 days/week	Never
Impundu	25.5 (78)	40.2 (123)	12.4 (38)	4.2 (13)	17.6 (54)
Imfungo	37.9 (116)	33.1 (103)	19.6 (60)	5.2 (16)	3.6 (11)
Intungulu	35.3 (108)	36.6 (112)	17.3 (53)	6.9 (21)	3.9 (12)
Masuku	49.7 (152)	25.8 (79)	15.7 (48)	5.6 (17)	3.3 (10)

4.1.4 Months when each fruits are in season

Figure 2 shows the months when the selected wild fruits are in season. Most of the respondents in the survey reported that Impundu is in season around June (20.8%), July (19.2%) and 10.6% were not sure. For Imfungo, respondents reported that the fruit is in season in October (15.8%), November (24.3%), December (17.7%) while 10.3% did not know when the fruit is in season. Intungulu was reported to be in season around June (37.9%), July (27.4%) while 2.6% of the respondents were not sure. The majority of the respondents reported that Masuku is in season around October (12.8%), November (25.2%), December (24.6%) while 6.9% of the respondents did not know when these fruits are in season.

However, data from the FGD collectively revealed that Impundu is in season around June, Imfungo in October and November, Intungulu in May and June, and Masuku in October respectively. The data is reliable because the majority of the respondents that participated in the FGD were elderly men and women.

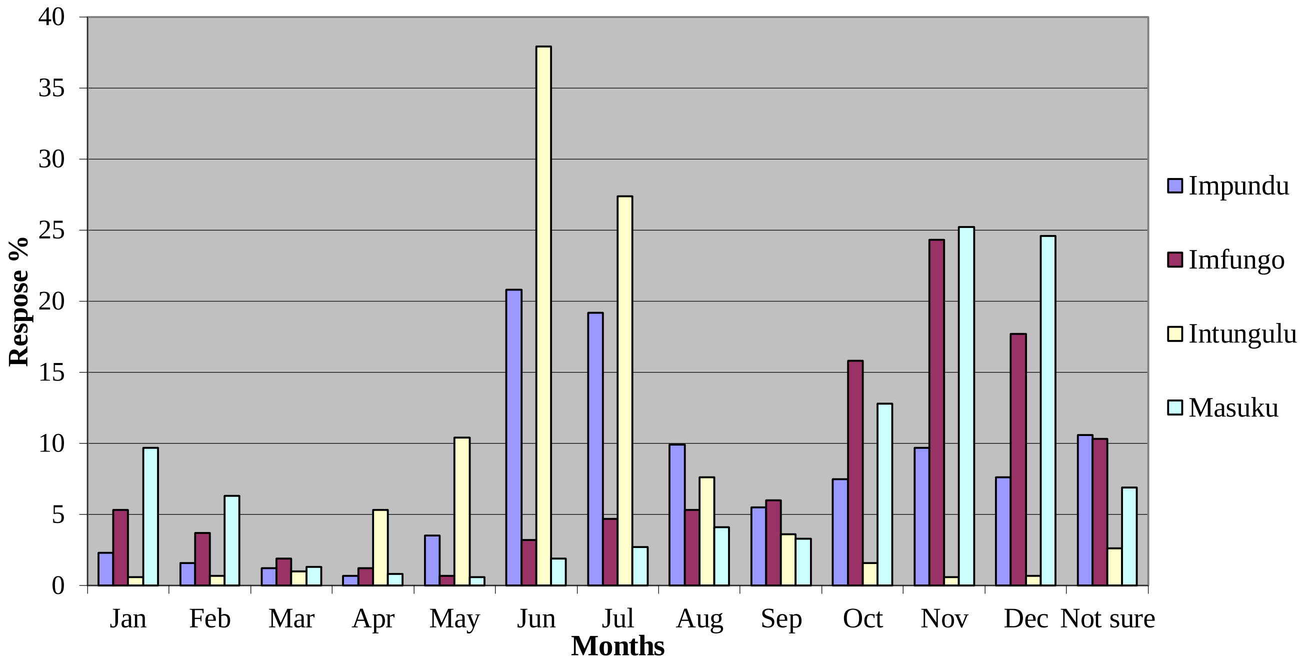


Figure 2 Months when each fruits are in season

4.1.5 Reasons for the consumption of each wild fruit

Figure 3 presents the reasons why respondents like consuming the wild fruits. The most common reasons given by the respondents for the consumption of the selected wild fruits under investigation was the fruits sweet taste. The reasons given for the consumption of Impundu include sweetness (52.9%), snack (22.3%), satisfying hunger (21.8%), and sour taste (3.0%). For Imfungo, the main reasons for consumption were sweetness (52.5%), snack (20.1%), sour taste (17.2%) and satisfying hunger (10.2%). For Intungulu, the reasons for consumption in descending order is sour (55.5%), sweetness (21.2%), snack (17.3%) and satisfying hunger (6.1%). The reasons for the consumption of Masuku were sweetness (63.6%), satisfying hunger (17.9%), snack (17.2%) and sour taste (1.2%).

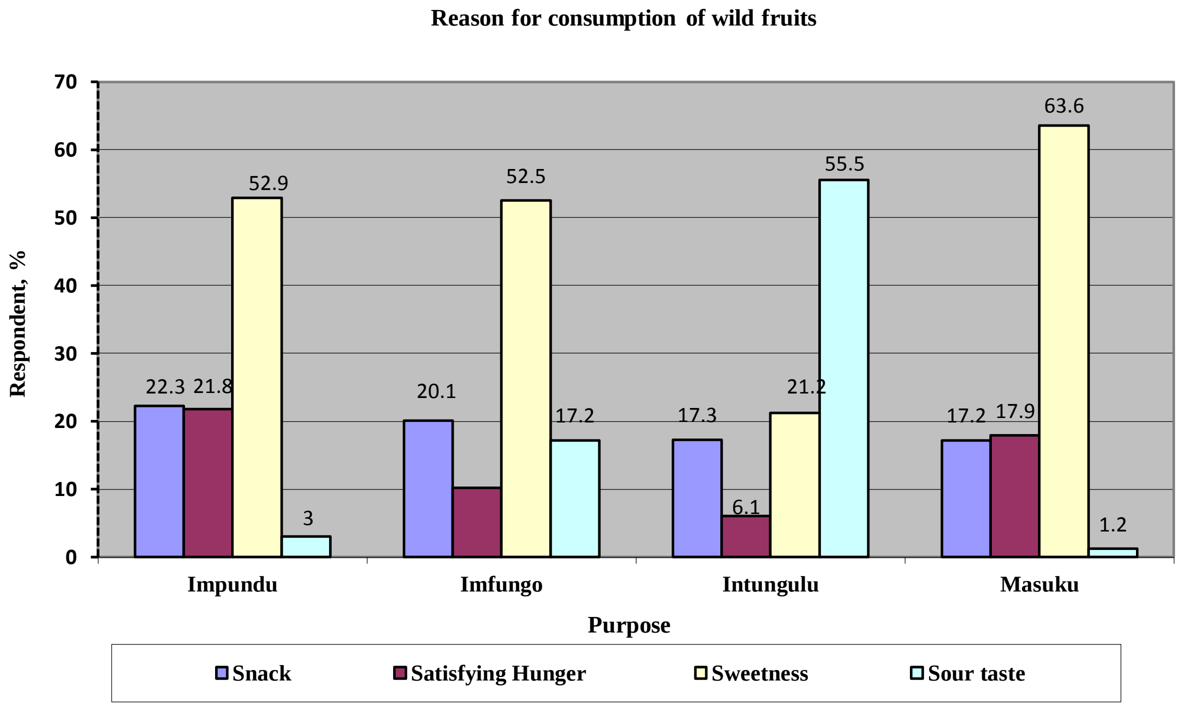


Figure 3 Reasons for consumption of wild fruits

4.1.6 Methods of fruit utilization

Based on the results obtained from the survey, the selected wild fruits (Masuku, Imfungo, Intungulu and Mpundu) are consumed raw, dried, fermented/pickled or as processed juice/jam (Figure 4). Most of the respondents consumed these fruits raw, followed by consuming them in form of juice/jam, then fermented/pickled and lastly dried. Impundu is mostly consumed raw (69.2%), juice/jam (14.3%), fermented/pickled (10.7%) and dried (5.8%) respectively. Imfungo is consumed raw (87.8%), juice/jam (6.1%), fermented/pickled (4.6%) and dried (1.4%). For Intungulu, it is mostly consumed raw (93.3%), juice/jam (3.7%), fermented/pickled (2.1%) and dried (0.9%). The consumption of Masuku followed this order; raw (95.9%), fermented/pickled (1.9%), juice/jam (1.3%) and dried (0.9%) respectively.

Findings from the FGD on how these fruits are utilized and consumed revealed that Impundu is processed and used as follows: the fruit is put in a mortar and mashed, the mashed fruit is removed from the mortar and sun dried for half a day for the mashed fruit to be sweetened. Thereafter, water is added to the mashed fruit to make a paste or drink. Impundu was also reported to be used in the processing of wine. After the crushing or pounding of the fruit, the crushed fruit is boiled and sieved and left in a container for 2-3 days for fermentation to take place, the longer it is fermented the stronger the wine. The fruit is also crushed, dried and pounded to powder which is used to cook a soft porridge by combining it with cassava meal, maize meal or millet meal.

Data from the FGD revealed that Imfungo is processed when the fruit is ripe. The fruit is washed, pressed by hands added to water to make a drink. The waste is thrown away. The drink made from Imfungo is also added to porridge to improve palatability. Imfungo is also eaten in order to rehydrate the body because it contains a lot of water.

FGD respondents reported that Intugulu is eaten raw. The fruit is not processed into any juice, jam, fermenting or dried.

Masuku is washed peeled and eaten while the seeds are discarded. This fruit is only consumed when it is ripe.

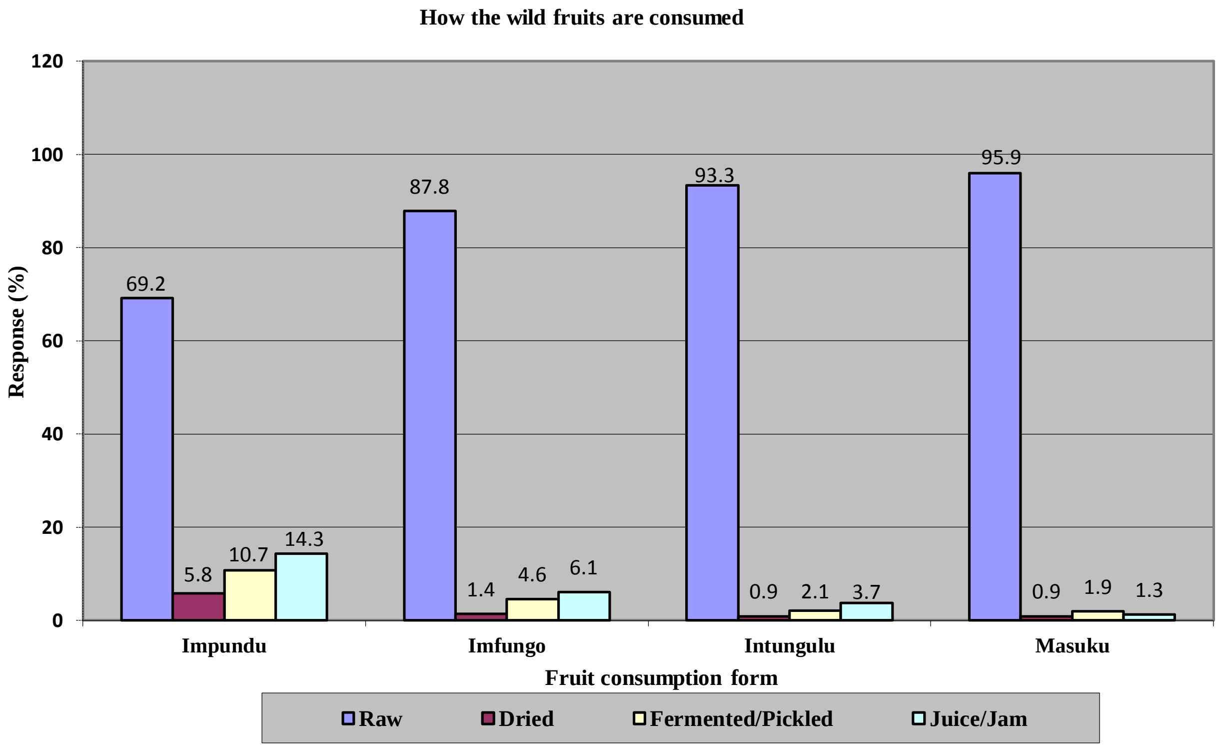


Figure 4: How wild fruits are consumed

4.1.7 Respondents attitude towards wild fruits

Table 4.4 summarises the attitude of respondents towards wild fruits. The majority of the respondents disagreed that wild fruits are poor people's food (58.8%). Most of the respondents disagreed (62.7%) that wild fruits are not nutritious. About 73.5% of respondents disagreed that wild fruits are not safe. Some of the respondents disagreed (67%) that wild fruits are only important when there is poor harvest, implying that these fruits are important even when the harvest is good. The majority of the respondents agreed (68.6%) that wild fruits boosts household income. About 81% of the respondents disagreed that wild fruits are not tasty. Most of the respondents disagreed (72%) that wild fruits are better than domestic fruits.

Table 4. 4: Attitude towards wild fruits

	Respondents opinion, % (n=306)			
Variable	**Agree**	**Not sure**	**Disagree**	**Total**
Wild fruits are poor people's food	38.2 (117)	2.9 (9)	58.8 (180)	100
Wild fruits are not nutritious	29.1 (89)	8.2 (25)	62.7 (192)	100
Wild fruits are not safe	23.5 (72)	2.9 (9)	73.5 (225)	100
Wild fruits are only important when there is poor harvest	28.4 (87)	4.6 (14)	67 (205)	100
Wild fruits in season boost household income	68.6 (210)	2.9 (28.4)	28.4 (87)	100
Wild fruits are not tasty	18.3 (56)	0.7 (2)	81 (248)	100
Wild fruits are better than Domestic fruits	25.8 (79)	2 (6)	72 (221)	100

4.1.8 Indigenous knowledge on medicinal uses of selected wild fruits

Responses from the semi-structured questionnaire and FGD showed that wild fruits are perceived to have medicinal properties. FGD revealed that Imfungo is used to boost the immune system and blood levels in the body of the sick. Impundu is given to diarrhoea patients in paste preparation to stop the running stomach. The respondents also believe that Masuku is rich in vitamins and boosts the immune system. Intungulu is known to increase or boost appetite to persons who have lost appetite due to an illness.

4.1.9 Food safety concern on the consumption of selected wild fruits

Information on the food safety concerns of the fruits under investigation was collected from the FGD in which the respondents composed of elderly men and women. Intungulu was reported to cause stomach pain if eaten in excess as the fruit is generally acidic in nature. Its seeds were reported to cause intestinal obstruction when eaten in excess. Masuku was reported to cause stomach blotting when eaten in excess while its seeds cause sores on the upper palate of the mouth during mastication. No food safety concerns were reported for Imfungo and Impundu.

4.1.10 Respondents nutritional knowledge of selected wild fruits

Figure 5 presents the findings on nutritional knowledge of the selected wild fruits. About 56.2% of the respondents agreed that wild fruits protect the human body against diseases, 68.6% of the respondents agreed that wild fruits are a source of vitamins and minerals, 54.6% agreed that wild fruits are a good source of energy while 50.7% agreed that wild fruits have medicinal value.

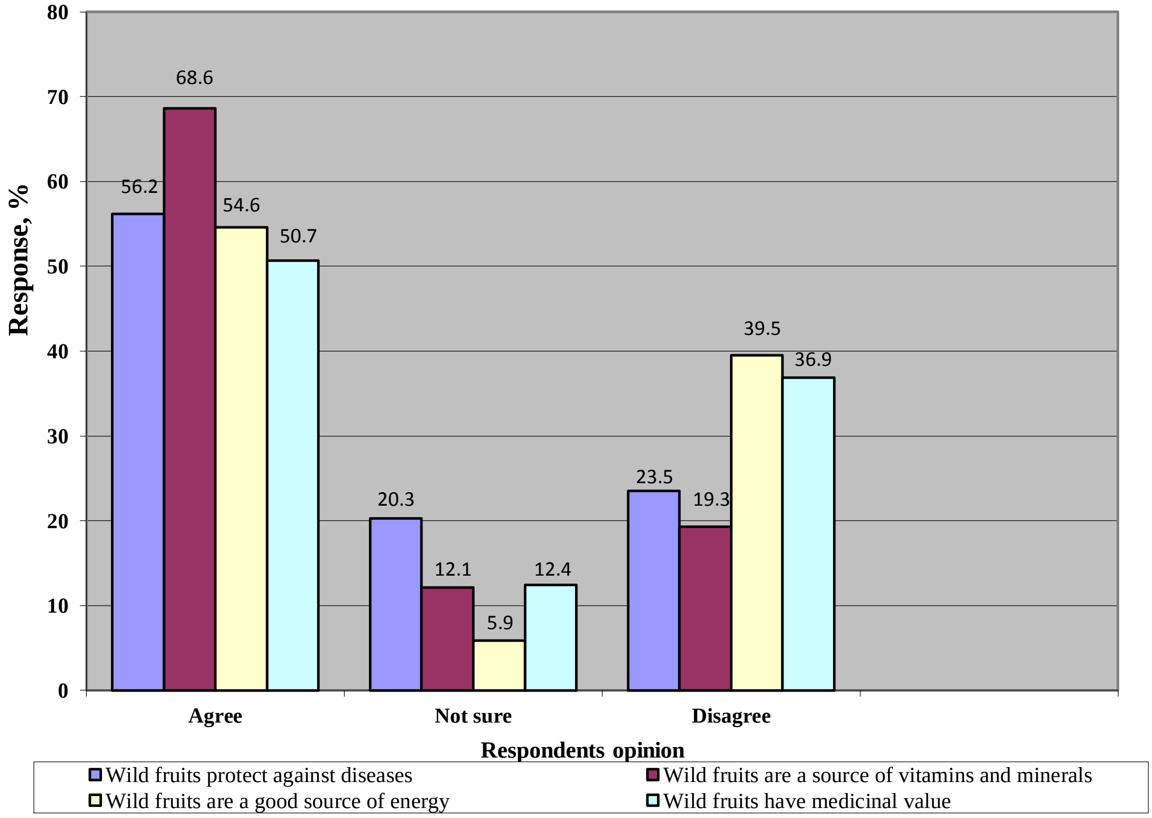


Figure 5. Nutritional Knowledge of respondents on Masuku, Imfungo, Intungulu and Mpundu

4.2 Nutritional composition of fruits

4.2.1 Proximate composition of the four selected wild fruits

A summary on the total ash, moisture, crude protein, crude fat and carbohydrates of the four selected wild fruits are presented in Table 4.5.

Total ash content of the fruits under investigation ranged from 2.51 ± 0.09 to 6.33 ± 0.57 g/100g DW. Intungulu recorded the highest ash content (6.33 ± 0.57 g/100g DW), followed by Masuku (3.88 ± 0.01 g/100g DW), Impundu (2.76 ± 0.091 g/100g DW) and Imfungo (2.51 ± 0.09 g/100g DW) respectively. There was a significant difference (P=0.001) among the four fruits in total ash at 95% confidence interval level.

The moisture content of the fruits under investigation ranged from 12.25 ± 0.21 to 14.55 ± 0.91% DW. Masuku recorded the highest moisture (14.55 ± 0.91% DW), followed by Impundu (12.90 ± 0.14 % DW), Imfungo (12.55 ± 0.07 % DW) and Intungulu (12.25 ± 0.21% DW) respectively. There was a significant difference (P= 0.043) among the four fruits in total moisture content at 95% confidence interval level.

Crude protein content of the fruits under investigation ranged from 11.15 ± 0.07 to 16.30 ± 0.280 g/100g DW. Imfungo recorded the highest protein content (16.30 ± 0.280 g/100g DW), followed by Impundu (14.3 ± 0.00 g/100g DW), Intungulu (13.55 ± 0.21 g/100g DW) and Masuku (11.15 ± 0.07 g/100g DW) respectively. There was a significant difference (P= 0.000) among the four wild fruits in the crude protein at 95% confidence interval level.

Crude fat of the fruits under investigation ranged from 0.89 ± 0.021 to 5.41 ± 0.62 g/100g DW. Imfungo recorded the highest crude fat content (5.41 ± 0.62 g/100g DW), followed by Impundu (4.05 ± 0.13 g/100g DW), Intungulu (1.83 ± 0.007 g/100g DW) and Masuku (0.89 ± 0.021 g/100g DW) respectively. There was a significant difference (P= 0.000) between the four fruits in crude fat at 95% confidence interval level.

Carbohydrate content of the fruits under investigation ranged from 50.50 ± 2.12 to 56.50 ± 0.07 g/100g DW. Impundu and Intungulu recorded the highest carbohydrate content (56.50 ± 0.07 g/100g DW) and (56.50 ± 2.12 g/100g DW), followed by Masuku (53 ± 000 g/100g DW) and Imfungo (50.50 ± 2.12 g/100g DW) respectively. There was a significant difference (P= 0.043) between the four wild fruits in the carbohydrate content at 95% confidence interval level.

Table 4. 5: Proximate composition (g/100g DW) of the fruit flesh of the four wild fruit

	Wild Fruits				
Property	Impundu	Imfungo	Intungulu	Masuku	P-Value
Ash	2.76 ± 0.091[a]	2.51 ± 0.09[b]	6.33 ± 0.57[c]	3.88 ± 0.01[d]	0.001
Moisture	12.90 ± 0.14[a]	12.55 ± 0.07[b]	12.25 ± 0.21[c]	14.55 ± 0.91[d]	0.043
Crude Protein	14.3 ± 0.00[a]	16.30 ± 0.280[b]	13.55 ± 0.21[c]	11.15 ± 0.07[d]	0.000
Crude Fat	4.05 ± 0.13[a]	5.41 ± 0.62[b]	1.83 ± 0.007[c]	0.89 ± 0.021[d]	0.000
Carbohydrates	56.50 ± 0.07[a]	50.50 ± 2.12[b]	56.50 ± 2.12[c]	53 ± 000[d]	0.043

Mean ± SD based on duplicate analysis for each of the four fruits

Values except moisture content are expressed in dry weight basis, DW = Dry weight

Means ±standard deviation, n = 2. For each parameter, means with same superscripts were not significantly different ($p < 0.05$).

4.2.2 Mineral content

The mineral contents (mg/kg DW) of the wild fruits sample are presented in Table 4.6. The minerals analysed were calcium, magnesium, iron, copper, lead, manganese, and zinc.

Calcium content of the fruits under investigation ranged from 608 ± 57.98 to 953 ± 9.89 mg/kg DW. Impundu recorded the highest calcium content (953 ± 9.89 mg/kg DW), followed by Masuku (768 ± 11.31 mg/kg DW), Imfungo (619 ± 48.08 mg/kg DW) and Intungulu (608 ± 57.98 mg/kg DW). The difference in the calcium contents of the four fruits were found to be statistically significant ($P = 0.002$) at 95% confidence interval level.

The magnesium content of the fruits under investigation ranged from 529 ± 32.52 to 1206 ± 9.89 mg/kg DW. Intungulu recorded the highest magnesium content (1206 ± 9.89 mg/kg DW), followed by Masuku (1005.5 ± 14.84 mg/kg DW), Impundu (673.5 ± 31.80 mg/kg DW) and Imfungo (529 ± 32.52 mg/kg DW). The difference in the magnesium contents of the four fruits were statistically significant ($P = 0.00$) at 95% confidence interval level.

The iron content of the fruits under investigation ranged from 14 ± 1.4 to 42.5 ± 2.10 mg/kg DW. Impundu recorded the highest iron content (42.5 ± 2.10 mg/kg DW), followed by Masuku

(26 ± 1.4 mg/kg DW), Intungulu (25 ± 12.7 mg/kg DW) and Imfungo (14 ± 1.4 ± 8.13 mg/kg DW). The difference in the iron contents of the four fruits were statistically significant (P = 0.051) at 95% confidence interval level.

The copper content of the fruits under investigation ranged from 6.82 ± 1.01 to 13.5 ± 2.1 mg/kg DW. Intungulu recorded the highest copper content (13.5 ± 2.1 mg/kg DW), followed by Impundu (10.88 ± 0.007 mg/kg DW), Imfungo (7.465 ± 0.81 mg/kg DW) and Masuku (6.82 ± 1.01 mg/kg DW). The difference in the copper contents of the four fruits were statistically significant (P = 0.017) at 95% confidence interval level.

Lead content of the fruits under investigation ranged from 0.26 ± 0.056 to 0.58 ± 0.02 mg/kg DW. Impundu recorded the highest lead content (0.58 ± 0.02 mg/kg DW), followed by Imfungo (0.46 ± 0.056 mg/kg DW), Masuku (0.45 ± 0.07 mg/kg DW) and Intungulu (0.26 ± 0.056 mg/kg DW). The difference in the lead contents of the four fruits were found to be statistically significant (P = 0.018) at 95% confidence interval level.

Manganese content of the fruits under investigation ranged from 5.74 ± 0.106 to 78 ± 5.65 mg/kg DW. Imfungo recorded the highest manganese content (78 ± 5.65 mg/kg DW), followed by Intungulu (64.50 ± 6.36 mg/kg DW), Impundu (6.13 ± 0.325mg/kg DW) and Masuku (5.74 ± 0.106 mg/kg DW). The difference in the manganese contents of the four fruits were statistically significant (P = 0.00) at 95% confidence interval level.

The zinc content of the fruits under investigation ranged from 1.60 ± 0.417 to 13 ± 1.41 mg/kg DW. Intungulu recorded the highest zinc content (13 ± 1.41 mg/kg DW), followed by Imfungo (11.49 ± 0.72 mg/kg DW), Masuku (1.80 ± 1.55 mg/kg DW) and Impundu (2.7 ± 0.01 mg/kg DW). The difference in the zinc contents of the four different fruits were statistically significant (P = 0.00) at 95% confidence interval level.

Table 4.6: Mineral (mg/kg DW) of the four wild fruits

	Wild Fruits				
Minerals	Impundu	Imfungo	Intungulu	Masuku	P-Value
Calcium	953 ± 9.89^{a}	619 ± 48.08^{b}	608 ± 57.98^{c}	768 ± 11.31^{d}	0.002
Magnesium	673.5 ± 31.80^{a}	529 ± 32.52^{b}	1206 ± 9.89^{c}	1005.5 ± 14.84^{d}	0.00
Iron	42.5 ± 2.10^{a}	14 ± 1.4^{b}	25 ± 12.7^{c}	26 ± 1.4^{d}	0.051
Copper	10.88 ± 0.007^{a}	7.465 ± 0.81^{b}	13.5 ± 2.1^{c}	6.82 ± 1.01^{d}	0.017
Lead	0.58 ± 0.02^{a}	0.46 ± 0.056^{b}	0.26 ± 0.056^{c}	0.45 ± 0.07^{d}	0.018
Manganese	6.13 ± 0.325^{a}	78 ± 5.65^{b}	64.50 ± 6.36^{c}	5.74 ± 0.106^{d}	0.00
Zinc	1.60 ± 0.417^{a}	11.49 ± 0.72^{b}	13 ± 1.41^{c}	2.7 ± 0.01^{d}	0.00

Mean ± SD based on duplicates analysis for each of the four types of wild fruits

Means ± standard deviation, n = 2. For each parameter, means with same superscripts were not significantly different ($p < 0.05$).

DW = Dry weight

4.2.3 Vitamin content

The vitamin content (mg/kg DW) of the wild fruits analysed were vitamin A, B1, B2 B9 and vitamin C. The results are presented in Table 4.7.

The vitamin A content ranged from 52.5 ± 4.94 to 187.5 ± 13.4 mg/kg DW among the fruits under investigation. Imfungo recorded the highest vitamin A content (187.5 ± 13.4 mg/kg DW), followed by Intungulu (115.3 ± 9.19 mg/kg DW), Impundu (106 ± 4.24 mg/kg DW) and Masuku (52.5 ± 4.94 mg/kg DW) respectively. The difference in vitamin A contents of the four fruits was found to be statistically significant (P = 0.000) at 95% confidence interval level.

Vitamin B1 content of the fruits under investigation ranged from 68.58 ± 5.21 to 120.06 ± 5.380 mg/kg DW. Intungulu recorded the highest content in vitamin (120.06 ± 5.380 mg/kg DW), followed by Imfungo (108.10 ± 8.17 mg/kg DW), Impundu (81.31 ± 4.24 mg/kg DW) and Masuku (68.58 ± 5.21 mg/kg DW) respectively. The difference in vitamin B1 contents of the four fruits were found to be statistically significant (P = 0.03) at 95% confidence interval level.

The content of vitamin B2 ranged from 0.001 ± 0.00 to 0.18 ± 0.28 mg/kg DW of the fruits under investigation. Impundu recorded the highest vitamin B2 content (0.18 ± 0.28 mg/kg DW), followed by Intungulu (0.03 ± 0.003 mg/kg DW), Masuku (0.001 ± 0.00 g/100g DW) and Imfungo (0.001 ± 0.00 mg/kg DW). The difference in the vitamin B2 contents of the four fruits were found not to be statistically significant (P = 0.714) at 95% confidence interval level.

The vitamin B9 content of the fruits under investigation ranged from 1.235 ± 0.106 to 2.385 ± 0.106 mg/kg DW. Masuku recorded the highest vitamin B9 content (2.385 ± 0.106 mg/kg DW), followed by Imfungo (2.190 ± 0.169 mg/kg DW), Impundu (1.75 ± 0.35 mg/kg DW) and Intungulu (1.235 ± 0.106 mg/kg DW) respectively. The difference in the vitamin B9 contents of the four fruits were found to be significant (P = 0.019) at 95% confident interval level.

The vitamin C content of the fruits under investigation ranged from 0.57 ± 0.000 to 0.95 ± 0.07 mg/kg DW. Imfungo recoded the highest vitamin C content (0.95 ± 0.07 mg/kg DW), followed by Masuku (0.695 ± 0.063 mg/kg DW), Intungulu (0.610 ± 0.056 mg/kg DW and Impundu (0.57 ± 0.000 mg/kg DW) respectively. The difference in the vitamin C contents of the four fruits were found to be statistically significant (P = 0.008).

Table 4. 7: vitamin content (mg/kg DW) of the four wild fruits

Vitamins	Wild Fruits				
	Impundu	Imfungo	Intungulu	Masuku	P-Value
Vitamin A	106 ± 4.24[a]	187.5 ± 13.4[b]	115.3 ± 9.19[c]	52.5 ± 4.94[d]	0.000
Vitamin B1 (Thiamine)	81.31 ± 4.24[a]	108.10 ± 8.17[a]	120.06 ± 5.380[a]	68.58 ± 5.21[a]	0.03
Vitamin B2 (Riboflavin)	0.014 ± 0005[a]	0.00095 ± 0.00007[b]	0.00094 ± 0.00036[c]	0.0007 ± 0.0001[d]	0.016
Vitamin B9 (Folate)	1.75 ± 0.35[a]	2.190 ± 0.169[b]	1.235 ± 0.106[c]	2.38 ± 0.106[d]	0.019
Vitamin C	0.57 ± 0.000[a]	0.95 ± 0.07[b]	0.610 ± 0.056[c]	0.695 ± 0.063[d]	0.008

Mean ± SD based duplicate analysis for each of the four types of wild fruits.

Means ± standard deviation, n = 2. For each parameter, means with same superscripts were not significantly different ($p < 0.05$).

DW = Dry weight

CHAPTER FIVE

5.0 Discussion

The main objective of this study was to establish the nutritional composition and indigenous knowledge on utilization aspects of the edible wild fruits (Masuku, Impundu, Intungulu and Imfungo) from Nchelenge district in Zambia. The study showed that wild fruits are utilized in various ways and a comparison of the nutritional components was attempted between the four wild edible fruits, which revealed that wild fruits qualify as high macronutrients and micronutrients. The study was conducted between 2019 and 2020. The findings on the utilization aspect of the wild fruits under this study were consistent with Aknnifesi et al,. (2006), Akinnifesi et al., (2008), Kalaba et al., (2009), Mander et al., (2006) and other authors referred to in this section.

In terms of preference, Masuku was the most preferred and popular wild fruit among the fruits investigated, followed by Imfungo. A similar study covering 451 households in Malawi, Tanzania, Zimbabwe and Zambia showed Masuku to be the most preferred wild fruit amongst other fruits investigated (Akinnifesi et al., 2008). This study confirmed the anecdotal observation about the dominance of Masuku in terms of preference among the edible wild fruits in Zambia. The main reasons for consuming these fruits were sweetness, satisfying hunger and as snack. A study done elsewhere that Masuku, which among the fruits in the current investigation was consumed for its sweetness, satisfying hunger and as a snack (Kalaba et al., 2009).

The current investigation revealed that wild fruits, when in season, boost household income. This observation is in agreement with the study by Moombe et al., (2009) who reported an increase in households income for rural communities when fruits were in season. Further, wild fruits improve household food security because they are among the cheapest rich source of food for the poor and those that are malnourished (Akinnifesi et al., 2008; Seal et al., 2014).

Indigenous knowledge on utilization, food safety and nutritional aspects are relevant to the body of knowledge. The utilization of these fruits can be improved by passing the indigenous knowledge on how to preserve them by making of different products such as jams, fermented beverages and juices. To a lesser extent, processing of the fruits under investigation was reported by respondents in the current study. Previously, similar studies were conducted in Zambia, Tanzania, Zimbabwe, Malawi and Kenya on how the wild fruits are utilized besides eating them raw when ripe. A study by Kweisga and Mwanza (1995) reported that Masuku is processed into a brand wine called *Mulunguzi*. Packham (1993) reported the brewing of wine/fermented beverage from Masuku. In another study conducted in Tanzania, Tiisekwa et al (2004) reported that Masuku is processed into jam and juice. The fruits produce juice and jam of high quality acceptable to consumers. Leakey (1999) reported that Masuku is also processed into a cake apart from it being processed into a spirit (wine) locally called *Kachasu* and jams. Similarly, Akinnefidi et al (2006) highlighted the processing of a different wild fruit (*Stychnos*) into juice in Tanzania and *Parinari* nuts into oil in Zimbabwe.

With the current health prevailing challenges, wild fruits could likely be a source of medicine. In rural areas, there are claims that wild fruits boost the immune system, blood levels, increase appetite, reduces diarrhoea and protect the body against disease. It is evident from this study that wild fruits are an important source of medicine to households in rural communities. Several medicinal applications were reported by respondents for fruits under investigation. As previously reported by Mander et al., (2006); Karaan et al., (2006), traditional medicines are used as primary health care and 80% of the world population rely on them. According to Lucy and Le Breton, (2008), healing properties of wild fruit tree species is tied to cultural beliefs and these fruit trees are used to self-medicate a range of minor ailments.

In general, there is some nutritional knowledge on the four wild fruits in rural communities of Nchelenge District. However, this knowledge is based on speculations. Most of the participants speculated that the four wild fruits under investigation are nutritionally rich. Validated research on nutritional composition of these fruits combined with sensitization on the health benefits of the fruits would increase the consumption, improve health and food security of rural communities.

The study analysed some of the nutrients (protein, fat, carbohydrates, vitamin A, vitamin B1, vitamin B2, vitamin B9, vitamin C, calcium, iron, and zinc) that important for child development, growth and WRA who are generally vulnerable as summarized Michaelsen et al., (2000) and Martin-Prével et al., (2015). Minerals (magnesium, copper, lead and manganese) were also analysed.

The findings for the proximate composition in the current investigation revealed that Impundu, Imfungo, Intungulu and Masuku contain considerable amounts of carbohydrates that ranged from 50.50 ± 2.12 to 56.50 ± 0.07 g/100g DW. A similar study by Karaan et al., (2006) on the carbohydrate content of Masuku revealed a higher value (70.2 g/100g) than what was observed in the current study. Another study by Benhura et al., (2012) on Impundu revealed the carbohydrate content that ranged from 73.6 ± 0.5% to 75.0 ± 1.0. This suggests that the four fruits could serve as sources of energy especially in resource constrained communities of Nchelenge district. Previous studies have shown that consumption of carbohydrates gives the body the necessary energy to drive cellular metabolism (Okello et al., 2018).

The moisture contents of the four fruits under this study were low (12.25 ± 0.21 to 14.35 ± 0.91 % DW) because the fruits were analysed on dry weight basis after freeze drying. A similar study revealed that wild fruits contain high moisture contents when they are fresh (Chatepa et al., 2018). Findings from Sibiya et al., (2021) revealed that fresh Impundu has a moisture content of 63.39 ± 0.01 %.

Impundu, Imfungo, Intungulu and Masuku had a protein content that ranged from 11.15 ± 0.07 to 16.30 ± 0.280 g/100g DW, and this range was lower than that for Masuku (17g/100g) reported by Akinnefidi et al (2004). Another study in Malawi by Chatepa et al., (2018) on Impundu revealed the protein content that ranged from 3.90 ± 0.003 to 15.61 ± 0.05%, an observation that is similar to the results obtained in this study. This high protein content of the four fruits under investigation suggests that these fruits could be used as a source of protein.

The fat content of the four fruits in this study ranged from 0.89 ± 0.021 to 5.41 ± 0.62 g/100g DW and this was similar to that found for Masuku (1.1 g/100g) by Chawafambira et al., (2020). Though the fat content in the studied fruits are considerably low, these fruits could be used as additional sources of dietary fat.

The ash content recorded gives an insight that the sample contained some nutritionally important minerals. The ash content in the found in the four fruits ranged between 2.51 ± 0.09 to 6.33 ± 0.57 g/100g DW, a range that was similar to the ash content (3.1g/100g) for Impundu that was studied in Zimbabwe by Benhura et al., (2012). This suggests that the wild fruits under investigation could contain important dietary minerals.

The mineral analysis revealed that the levels of calcium, magnesium and manganese were higher compared to the other minerals investigated. These minerals are very important to the body systems for disease prevention and control. Calcium is important for growth and maintenance of strong bones, teeth, muscular functions and normal physiological functions (Muhammad et al., 2011). Calcium was found to be abundant in all the wild fruits that were investigated and this is in agreement with a study conducted previously by Chatepa et al., (2018). Magnesium is essential in the structure stability of nucleic acid and intestinal absorption while its deficiency can cause severe diarrhoea and migraines in human beings (Achaglinkame et al., 2019). Iron is a vital element in the diet of female adolescents, pregnant women, infants and elderly people prevent anaemia and other diseases (Muhammad et al., 2011). The recommended daily allowance (RDA) of iron according to Muhammad et al., (2011) is 2-5 mg/day. The iron content in the four wild fruits under investigation was higher than results obtained by (Adepoju, 2009) for other wild fruits studied. On the contrary Seal et al., (2014); Okello et al., (2018); Chatepa et al., (2018) reported a higher iron content in comparison to the four wild fruits under investigation. It is however acknowledged that these fruits could be an addition sources of iron for the resource constrained communities of Nchelenge and other rural areas.

Copper was found in varying amounts for the four fruits in the current study. This mineral is a powerful pro-oxidant and helps in the oxidation of unsaturated fats and oils as well as ascorbic acid (Seal et al., 2014). The levels of lead in Impundu, Imfungo, Intungulu and Masuku were extremely low. The levels detected in the current study may not cause any health hazard in humans as they were below the maximum permissible limit of 30 mg/kg (Anyasor et al., 2014). Manganese was also detected in all the four fruits with Imfungo and Intungulu recording considerable amounts. This mineral plays a vital role in a number of physiological processes like activating enzymes in the breaking down of carbohydrates, cholesterol and amino acids (Okello et al., 2018). The Zinc content in Impundu and Masuku was similar to another wild fruit (*Grewia sapida*) studied by Seal et al., 2014), but Imfungo and Intungulu recorded higher amount.

Substantial amounts of vitamin A were present in all the four wild fruit types investigated. A similar study on other wild fruits (*Spondias mombin, Dialium guineense and Mordii whytii*) revealed the presence of β-carotene in all the three wild fruits (Adepoju, 2009). However, Vitamin C was found in low amounts in the four fruits investigated. Antioxidants such as vitamin C and carotenoids combined with dietary fibre have been associated with the prevention of diabetes mellitus, obesity, coronary heart disease and cancer (Adepoju, 2009). Vitamin C plays a critical role of decreasing the incidence of degenerative diseases as reported by (Okello et al., 2018). Low vitamin C in the human body has been associated with increased severity of respiratory tract infection and fatigue (Seal et al., 2014), while an increased intake of vitamin C from food has been reported to raise serum HDL-cholestrol and lowers serum triglyceride concentration (Anyasor et al., 2014). The four fruits were found to be good sources of vitamin B1 and B9 but had lower levels of vitamin B2. These findings therefore suggest that four fruits may likely have health promoting potentials.

CHAPTER SIX

6.0 Conclusion

The selected edible wild fruits (Impundu, Imfungo, Intungulu and Masuku) in Nchelenge district of Zambia are consumed mainly raw as snacks and partly as processed products (juices/jams, fermented/picked and dried). Indigenous knowledge revealed varying medicinal uses: Impundu paste stops diarrhoea; Intungulu helps to increase appetite of the sick, aid digestion of food and boosts immunity; Imfungo extract boost immunity and blood levels and Masuku is generally used to boost immunity of the sick. Intungulu and Masuku have food safety issues: Intungulu seeds may cause intestinal obstruction when eaten in excess while excess eating of its pulp may rise acid levels in the stomach; excessive consumption of Masuku may cause stomach blotting and sores on the upper palate of the mouth.

Generally, the people in the area have moderate nutritional knowledge and positive attitude towards these fruits. Overall, all the four fruits contain substantial amounts of selected macro and micro nutrients that can be used to supplement the dietary requirements of people in the area.

7.0 Recommendations

The government should come up with policy framework through the Ministry of Agriculture by promoting the sustainability of the edible wild fruits. Sustainability of these fruits can be achieved by domesticating the fruits and training communities on how to harvest, transport, and add value to the fruits after harvest.

Wild fruits should be incorporated in the strategies and programs aimed at improving household food security, poverty reduction and improving the nutritional health status of different communities in the country. This can be achieved if the Ministry of Health and Agriculture make joint programs.

The government through the Ministry of Agriculture needs to carry out more research on other wild fruits in order to improve the consumption of wild fruits. By so doing the wild fruits will become popular and their consumption will be improved.

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APPENDICES

APPENDIX 1 CHEMICAL COMPOSITION ANALYSIS METHODS, MINERAL ANALYSIS AND VITAMIN ANALYSIS.

AOAC official methods of analysis 934.01, 920.39 (A), 984 (A – D), 942.05, 978.10 and 974.27 respectively (AOAC, 2006) and (AOAC, 2012).

Proximate analysis

A: MOISTURE CONTENT DETERMINATION

Dishes were labelled according to the different type wild fruits. The dishes were weighed using the analytical balance. To the dishes that were weighted, 2 grams of the fruit were taken in duplicate and then weighed again accurately. The dishes were then placed in an oven for one hour at 120℃. Then the dishes were removed from the oven and cooled in a desiccator for 20-30 minutes. Thereafter, the samples were removed from the desiccator and weighed. The moisture percentage was calculated as follows:

$$\text{Moisture percentage} = \frac{B-C}{B-A} \times 100$$

Where

A= weight of dish in grams

B= weight of dish + sample in grams

B-A= weight of sample

C= weight of dry sample + dish

B: DETERMINATION OF CRUDE PROTEIN (KJELDAHL)

The sample were first ground and homogenised before carrying out the experiment. To the kjeldahl 0.2g of the sample was added, 12 ml of H_2SO_4, 1-2 g of the catalyst, then the content in the flask was mixed.

Digestion

The kjeldah flasks was then placed in the pre-heated digestion unit (180-230℃) and then the temperature was raised to 420℃ until the colour of the solution turned bright green, the process normally takes place within 1 hour 15 minutes. The temperature at the end of digestion was between 410 and 430°C. Then the acid digest was allowed to cool at room temperature and then 50ml of distilled water was added to the flask and mixed thoroughly.

Distillation

60ml of NaoH/thiosulphate solution was added to the cooled diluted digest. Thereafter, the kjeldahl was connected to the distillation unit and then the distillate was collected in the receiving flask containing 20ml boric acid indicator solution for 5 minutes.

Titration

The content from the receiving flask was then titrated with 0.05 N HCL until the trace the first pink colour shows. Separately a blank sample was taken following the same procedure as the sample, but using 5ml of distilled water.

The calculation of the nitrogen content. The nitrogen content of the sample was expressed as a percentage by mass.

$$\frac{1.4007 \times (V_S - V_B) \times M}{W}$$

Where,

V_S is volume, in millilitres of the HCL solution used in the determination.

V_B is volume, in millilitres of the HCL solution used in the blank.

M is the exact molarity of the HCL solution.

W is the mass, in grams, of the test portion.

Analyse each sample in double and round the result to the nearest 0.01 (g/100g sample)

Calculation of the crude protein content, expressed as a percentage by mass, is obtained by multiplying the nitrogen content by an appropriate conversion factor. For test samples with low fat 0.01 N HCL was used instead of 0.05N HCL.

C: ASH CONTENT DETERMINATION

In the past ignited crucibles were weighed to 4 decimal places. Approximately 2.00g of the wild fruit was weighed in the crucibles. The crucible was then placed in a muffle furnace and heated to 550°C for 4 hours. Then the crucibles were cooled in a desiccator for 30 minutes at room temperature. Afterward the crucibles were weighed and the ash percentage was calculated as follows:

$$\text{Ash percentage} = \frac{C-A}{B-A} \times 100$$

Where,

A= weight of ignited crucibles

B= weight of ignited crucibles + sample

B-A= weight of sample

C= weight of crucibles + sample

D: CRUDE FAT (SOXHLET METHOD)

Sample that had a moisture content above 10% were dried to a constant weight at temperatures between 95-100℃ under pressure ≤ 100 Hg for about 5 hours. Then 2g of the pre-dried sample were placed in the extraction thimble, with porosity permitting a rapid flow of ethyl ether. The sample were covered in a glass wool thimble. Weighing of the pre-dried boiling flask were done. Anhydrous ether was put in the boiling flask. Thereafter, the boiling flask, soxhlet flask and condenser was assembled. Extract in a soxhlet collector at the rate of 5 or 6 drops per second by condensation for about 4 hours. Then drying of the flask with the extracted fat in an air oven at 100℃ for 30 minutes, then it was cooled in the desiccator, and weighed. The calculation of fat content was as follows:

% fat on dry weight basis = (gram of fat in sample/ gram of dried sample) × 100

E: MINERAL CONTENT DETERMINATION

Reagents

All reagents used were analar or equivalent unless otherwise stated.

Hydrochloric Acid – AR Grade

Nitric Acid- AR Grade

Distilled water – Grade 2 purity (LWI 008)

Standards

High purity 100µg/mL multi-element standard stock was bought directly from a recommended supplier containing the above mentioned elements were used. The standard stock solution can also be prepared from spec pure metals/salts. The analyst ensured that the CRM (Certified reference material) standard had a valid shelf life and a certificate of analysis bearing a statement of traceability and a measurement uncertainty per element.

Equipment/Apparatus

1. Calibrated pipettes or burets- 0.01ml, 0.25ml, 0.050ml, 0.1ml, 0.5ml, 5.0ml, 10.0ml, 20.0ml, 50.0ml and 100.0ml.

2. Calibrated grade A volumetric glassware – 50ml, 100mls.

3. Standard laboratory glassware – 150mls tall form pyrex or PTFE beakers

4. Suitable electric hotplate with thermostatic control

5. Agilent 5100 ICP-OEs (Inductively Coupled Plasma- Optical Emission Spectrophotometry).

6. 1.5µm or less pore sized filter paper

7. Pipet filler

Preparation of 5% H=NHO3

Preparation of 1000mL of 5% NHO3 was based on the following equation using concentration 69% Nitric Acid.

$$C_1V_1=C_2V_2$$

Where;

C_1 = Concentration of Nitric Acid Stock Concentrate

V_1 = Desired Volume of Nitric Acid Stock Concentrate

C_2 = Desired Concentration of Nitric Acid Dilution Acid

V_2 = Desired Final Volume of Dilution Nitric Acid

69% x V_1 mL = 5% x 1000 mL

V_1 ml = 72.5mL

To make 5% NHO3 solution, 72.5mL of 69% stock concentrated Nitric Acid was added to 400ml of distilled water in a 1000mL volumetric flask. Top up to the mark 1000mL with distilled water and shake to make homogeneous.

Sample preparation

Approximately 1g of the sample was weighed and placed into a porcelain or ceramic crucible. The samples were placed in the muffle furnace set at 600℃ for four hours. After four hours of ashing, the crucibles from the furnace were removed and allowed to cool at room temperature. A few drops of distilled water were added slowly to the ash while ensuring that there was no puff of ash created. thereafter 5mL of Nitric Acid was added and boiled gently on a hot plate in the fume hood to dissolve the ash. The hot place was removed and left to cool in the fume hood. The cooled sample was filtered into 100mL volumetric flask and diluted to the volume with distilled water.

Sample Analysis

Before running a plotted calibration curve, the calibration status of the equipment was check. Then the standards and reagent blank and the instruments were aspirated. The graph of intensity concentration for each element were plotted automatically by the instrument. The intensity vs Concentration calibration graph was accepted or rejected based in line with LP 08- procedure for selection and validation of Test Methods. Intensity vs concertation calibration graph had ≥ calibration standard points. The prepared sample was allowed to run against the plotted calibration curve at the respective instrument operating parameters for analyte of interest. Samples concentrations that exceeded the concentration of the highest standard of the calibration graph were diluted and repeated. QC's whose concentrations were close to the concentration of highest standards of the calibration graph were diluted and repeated. The concentration of each element were red from the instrument after inputting the dilution factor (where applicable). The element concentrations in the blank were subtracted from those of the sample. The calculation to obtain results was as follows:

$$\text{Mg/IL elements} = \frac{\mu\text{g/mL Element in solution x 100mL x Dilution Factor (where applicable)}}{\text{100mL (sample Volume)}}$$

The dilution factor was the number of times the sample aliquot was diluted. Dilution of the samples was performed when the initial concentration is greater than the highest calibration standard. Therefore, dilution enabled the sample concentration to fit in within the calibration curve.

G: WATER SOLUBLE VITAMIN IN FOOD SAMPLES USING UFLC UVVIS DETECTOR (VITAMIN B1, B2 AND B9)

Sample preparation

10g of the sample was added into 100ml of water. Then 150ml of water was added to the samples that formed a paste.

Samples were Sonicated for 3hrs

The samples were Filtered through a fluted filter paper followed by 0.45um microfiber filter.

The sample was collect 1ml for analysis.

Then 5ul of the sample was Inject into the column.

Method

Instruments and Software

A Shimadzu LC System LabSolution Software consisting of the following modules was used:

- Shimadzu UFLC CBM -20 A Communication Bus Module
- Binary Pump LC – 20AB, Pump and Vacuum Degasser DGU-20A_3
- High Performance Prominence Autosampler SIL – 20 AC 20Mpa with 100 µL Jet Weaver mixer
- Thermostatted Column Compartment CTO – 10 ASVPs
- Restex Pinnacle DBC C18 Column, 5µm 250× 4.6mm (Serial# 11061144T Lot# 110603P) made in USA.
- The UFLC analysis was developed and performed using Shimadzu UFLC Prominence LC system, Shimadzu SPD – 20 AV Prominence UVVIS Detector Infinity Peristatic Binary Pump with integrated vacuum degasser (DGU-20A_3) and 1 00 µL Jet Weaver mixer.

Reagents and materials

All the chemicals and solvents used were HPLC grade and highly purified water from a Milli Q water purification system (Millipore ELGA Purelab Option model, USA) was used. Acetonitrile ‘gradient grade was purchased from XILONG SCIENTIFIC and dibasic potassium phosphate was purchased from Fluka (Germany). O-Phosphoric acid was purchased from Fluka (Switzerland) and sodium hydroxide was purchased from Sigma (Germany). Standards of thiamine (B1), riboflavin (B2), folic acid(B9), and cyanocobalamine (B12) were purchased from Accustandard.

Instrument condition UFLC Shimadzu

Parameter
Column oven 25 °C
Acquisition rate 80 Hz
Data acquisition 205, 21 4, 220, 232, 266, 268, 280 nm
Flow cell 60 mm path 10 mm path
Injection volume 5 µL (Needle with wash, flush port active for 3 seconds)
Sample thermostat 5 °C

Mobile phase
Mobile phase A 25 mM HK_2PO_4, pH 7.0
Mobile phase B Acetonitrile
Gradient At 0 min & 1 %B
At 5 min & 1 %B
At 15 min & 30%B
At 20 min & 30%B
At 20.1 min & 1 %B

Post run time 5 minutes 1 minute
Flow rate 1.0 mL/min

H: VITAMIN C CONTENT DETERMINATION

Exactly 50mg of ascorbic acid was weighed into a 100cm^3 mark, it was the standard solution. Approximately 20g of the sample was weighed to the nearest 0.001g and ground to pass through a 1mm mesh sieve. The sample was transferred into a 250cm^3 round bottom flask. 25cm^3 of chloroform was added at ambient temperature and then the round bottom flask was placed in an ultrasonic bath for 2 minutes. Exactly 100cm^3 of 5% oxalic acid was added, the contents of the flask were shaken vigorously, first by hand then mechanically for 5 minutes. The flask was then allowed to stand for 15 minutes, after which 10-15cm^3 of the upper phase was placed into a centrifuge tube and then centrifugation was done at the revolution of 5000 per minute for 2 minutes. Thereafter, 3cm^3 of supernatant was pipetted into a beaker containing 15cm^3 of 5% oxalic acid. Titration were then carried out with dichlorophenol-indophenol (DPI) solution under continuous agitation to the point where the solution turns into a light pink shade. The analysis was conducted in the same way with the reference standard with ascorbic acid standard solution (0.5mg/cm^3). Vitamin C was calculated as follows:

$$\text{Vitamin C (mg/kg)} = \frac{\text{DPI (smp)} \times \text{Ascorbic acid (mg/cm}^3\text{ of std.sol.)} \times V \times 1000}{\text{DPI (std)} \times A \times m}$$

Where,

DPI (smp) is the volume of DPI solution for the titration of the sample solution in cm^3

DPI (std) is the volume of DPI solution for the titration for the titration of ascorbic acid standard

V is the volume of the sample water extracted solution ($100cm^3$)

A is the sample aliquot ($3cm^3$)

M is the mass of the sample in grams.

I. VITAMIN A CONTENT DETERMINATION

Reagents and solutions

Reagents

a. Certified vitamin A acetate concentrate (USP)

- **All-*trans*-retinyl acetate**, vitamin A acetate ($C_{22}H_{32}O_2$), 328.5 g/mol, with a purity of at least 90% was used
- **All-*trans*-retinol**, vitamin A alcohol ($C_{20}H_{30}O$), with a purity of at least 90% was used
- Retinyl palmitate ($C_{36}H_{60}O_2$), 524.86 g/mol with a purity of at least 90%

b. **Acetic acid glacial**, AR

c. **Methanol**, HPLC grade

d. **Tetrahydrofuran** (THF), AR grade

e. **Haxane** (n-Hexane 95% for HPLC)

f. **Potassium hydroxide solution**, 50% (KOH)

KOH (500g) was slowly added to 500mL water contained in a 2-L thick walled Erlenmeyer flask. The KOH (100g) was added in 100g portions while the flask was being cooled with water. The flask was swirled gently to aid in the dissolution of the KOH. The solution was stored in a glass container with a cork stopper.

g. **Pyrogallic acid**, crystal AR grade

h. **2-propanol**, Analytical grade

i. **Inert gas**, e. nitrogen

j. **Water**, distilled

k. **Water**, HPLC grade

l. **Mobile phase**,

m. Acetone AR grade

Methonol (HPLC grade) was mixed with distilled water in the proportions 860 + 140 (by volume)

Vitamin A stock standard

USP standard was used. 50 mg of retinyl acetate concentration was put into a 100-mL volumetric flask. The weight was recorded to the nearest 0.1mg. The concentration was recorded in mg/g per USP certification (0.5mg/g). Small amounts of acetone (less than 3mL) was added to aid dissolution. The mixture was diluted to volume with ethanol. Then the mixture was stored at 4℃ in the dark. The standard is kept for two weeks.

Apparatus and equipment

HPLC, which consisted the following

- Pump, set to deliver a constant eluent volume flow rate of 1 ml/min.
- HPLC injector device.
- Colum, length 250mm, internal diameter 4,6 mm, packed with a stationary phase consisting of octadecyl (C_{18}) groups bonded to silica.
- UV detector, allowing the measurements of ultraviolet radiation at 328 nm, and equipped with integrator/data collection system.
- Water bath or hot plate.
- Rotatory vacuum evaporator, with water bath at 40℃.
- Elementary flask, 125mL with neck adapted for connecting reflux condenser
- Volumetric flask, 10mL and 500mL.
- Reflux condensers
- Autoclave

Preparation of sample

All the test portions that were drawn from the laboratory sample that were ground were passed through a sieve with 1mm.

Saponification

The hot plate was turn on to preheat. The cooling water flow started and adjusted to precool reflux condensers.

Working standards

Caution: A clear flask wrapped in aluminium was used.

a. High standard: 5mL of vitamin A stock standard was put into 125-mL Erlenmeyer flask using a pipet and then 25mL of ethanol (95%) was added.

Procedure

i. The sample was weighed (not more than 5g) to give approximately 50µg vitamin A into 125mL Erlenmeyer flask. To samples that has high sugar, 3mL of water was added and dispersed sample as a slurry. To the sample 40mL of 95% ethanol was added.

ii. A pea-sized (approximately 50mg) of pyrogallic acid (antioxidant) to standard and sample flask was added.

iii. All the flask were swirled to ensure that samples are thoroughly dispersed in the solution.

iv. While refluxing the nitrogen flow was turned on to ensure a nitrogen atmosphere.

vi. 10 mL of the 50% KOH solution was pipeted into each flask and immediately placed the flask on a hot plate under the reflux condenser.

v. Refluxing was done for 45minutes. Swirling of the flask was done every 10 minutes.

vi. The reflux flask was removed from the hot plate, stopper with corks, and quickly cooled the flask to room temperature using cold water.

vii. 10mL of glacial acid solution was pipeted out to neutralize KOH, then the solution was mixed well and the flask was left to cool to room temperature.

viii. The solution was quantitatively transferred into each flask to 100mL volumetric flask, using a 50:50 THF ethanol solution. The same solution was diluted to volume.

ix. The solution was mix thoroughly for 10 minutes using the stopper and invert volumetric flask.

x. The sample was allowed to set overnight in a refrigerator so as to allow fatty acid salts formed during saponification to precipitate.

xi. the HPLC system was turned on and allowed to warm up and equilibrate for a minimum of 30 minutes with mobile phase flowing: flow rate was 1.0mL/minute.

xii. The high vitamin A standard that went through saponification was injected into the HPLC system. The mobile phase was adjusted to achieve a resolution of 1.5 or better for cis and trans form. All trans retinol was elute in approximately 6 minutes or longer.

xiii. The standard was injected, then the detector sensitivity was adjusted to give peak heights of 50-90% of full scale for the high standard. Injection of the standard was repeated until peak height (s) were reproducible.

xiv. The sample solution was injected. In order to ensure consistent performance of the HPLC, a known standard solution was injected after every ninth sample and verified the peak height. (in cases were the retinol peak exceeded that of the high standard solution by more than 25%, the sample was diluted using 10mL 50% KOH solution, 40 mL 95% ethanol, 10 mL glacial acetic acid, and 40mL 50:50 THF: ethanol solution.

Calculation of vitamin A as retinol using USP standard

Response factor for Vitamin A (RF_A) was given by the equation below

$$RF_A = \frac{mg_{md} \times mL_{md} \times C_{md}}{PH_{md} \times 10{,}000}$$

Mg_{md} is mass (in mg) of USP standard reagent used

mL_{md} is mL of standard used

C_{md} concentration of USP vitamin A as retinol per certification (mg/g)

PH_{md} is peak height or area of standard from chromatogram.

APPENDIX 2 RESEARCH ON UTILIZATION AND CONSUMPTION FOR SELECTED EDIBLE WILD FRUITS

<u>Household Identification:</u>

Household ID…………………………….

District……………………………………

Village…………………………………….

Agricultural camp……………………….

SECTION 1: DEMOGRAPHIC AND SOCIAL ECONOMIC INFORMATION

	HOUSEHOLD HEAD		
1	Age		[ ]
2	Sex	1. Male 2. Female	[ ]
3	What is your marital status?	1. Single 2. Married 3. Separated 4. Divorced 5. Widowed	[ ]
4	What is the highest educational grade/level you have attained (specify)		
5	What is your occupation?	1. Not employed 2. Civil servant 3. Privately employed (NGOs, private companies) 4. Self-employed (business) 5. Farmer 6. Employed and farming 7. Pensioner 8. Other………………..	[ ]

SECTION 2: FRUIT UTILIZATION AND CONSUMPTION

1. In a scale of 1 to 4, would you rank the wild fruits (Impundu, Imfungo, Intungulu and Masuku) in order of preference?

Wild fruit type	Ranking
Impundu	
Imfungo	
Intungulu	
Masuku	

2. Frequency of consumption when fruits are in season

Wild fruit type	Frequency			
	Daily	2 days/week	4days/week	6days/week
Impundu				
Imfungo				
Intungulu				
Masuku				

3. Months when each of these fruits are in season

Wild fruit type	Months when there in season
Impundu	
Imfungo	
Intungulu	
Masuku	

4. Why do you consume each of the fruits?

Wild fruit type	Reason for Consumption			
	Snack	Satisfy hunger	Sweetness	Sour taste
Impundu				
Imfungo				
Intungulu				
Masuku				

5. How do you consume each of the fruits?

Wild fruit type	Consumption pattern			
	Raw	Dried	Fermented/pickled	Juice/jam
Impundu				
Imfungo				
Intungulu				

Masuku				

6. Altitude towards wild fruits (Impundu, Imfungo, Intungulu and Masuku)

Variable	**Agree**	**Not sure**	**Disagree**
Wild fruits are poor people's food			
Wild fruits are not nutritious			
Wild fruits are not safe			
Wild fruits are only important when there is poor harvest			
Wild fruits in season boost household income			
Wild fruits are not tasty			
Wild fruits are better than Domesticated fruits			

7. Nutritional knowledge of wild fruits (Impundu, Imfungo, Intungulu and Masuku)

Variable	**Agree**	**Not sure**	**Disagree**
Wild fruits protects against diseases			
Wild fruits are sources of vitamins and minerals			
Wild fruits are good source of energy			
Wild fruits have medicinal value			

SECTION 3 FOCUS GROUP DISCUSSION QUESTIONNAIRE (UTILIZATION OF WILD FRUITS)

	Seasons they are found	**Processing**	**Uses**	**Who consumes the fruit**	**Importance for food security**	**Physical hazards**
Mfungu						
Intungulu						
Masuku						
Mpundu (Lumembe)						