NUTRITIONAL VALUE OF SELECTED WILD EDIBLE INDIGENOUS FRUITS OF SOUTHERN AFRICA AND THEIR COMMERCIAL POTENTIAL

BY

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DISSERTATION CONTENTS

PART A

PREAMBLE

DECLARATION

By submitting this dissertation titled "Nutritional value of selected wild edible indigenous fruits of southern Africa", I declare that the entirety of the work contained therein, is my own original work, and that I am the sole author thereof (save to the extent explicitly otherwise stated). Reproduction and publication by the University of Johannesburg will not infringe any third party rights. I declare that I have not previously submitted this dissertation for obtaining any qualification**.**

Signature: …………………….

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DEDICATION

I devote this dissertation to the memory of my father, who ensured I continue my studies even when he is gone, my mother, my step-father, my daughter and my husband.

RESEARCH OUTPUTS/CONFERENCE CONTRIBUTIONS

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ABSTRACT

Food and nutrition security is a complex issue which influences the livelihoods of communities and impacts the economy of nations. Southern Africa harbours a diverse range of wild edible indigenous fruits, which have provided populations with food for years. However, there is a lack of comprehensive data regarding the nutrient content of these indigenous plants, but most are anticipated to have potentially good nutritional value. The purpose of this study was to compile a comprehensive list of wild edible indigenous fruits consumed in southern Africa, as well as available data on their nutritional qualities, in order to identify existing knowledge gaps with regards to their nutritional qualities. Selected plants were further evaluated for their proximate composition mineral, vitamin, and amino acid content, as well as the total energy value (caloric value). A total of 60 species, distributed in 35 families was captured. The families Cucurbitaceae and Anacardiaceae had the most species (7 spp.) and more coverage in terms of minerals and proximate value than other families. Interestingly, the study showed that the mineral elements potassium and calcium were present in substantial amounts in most fruits ranging from 521.946 to 14289.451 mg/kg. Even though most fruits were high in only one mineral element, *Cordyla africana* had the highest content of six minerals (i.e. Al, Fe, Mn, Pb, Se and Zn). The following fruits had the highest proximate values (shown in brackets): *Carissa macrocarpa* (ash at 20.42 mg/100g), *Syzygium guineense* (fat at 7.75 mg/100g), *Phoenix reclinata* (fibre at 29.89 mg/100g), *Halleria lucida* (protein at 6.98 mg/100g) and (carbohydrates at 36.98 mg/100g). The high protein content in *Halleria lucida* was exhibited by the highest amino acid content for histidine. Most fruits showed the presence of vitamin C but not vitamin A. Only *Dovyalis longispina* (902.88 mg/100g), *Manilkara mochisia* (25.307 mg/100g), *Garcinia livingstonei* (11.197 mg/100g) and *Syzygium guineense* (1.742 mg/100g) displayed significant amounts of vitamin A. Overall, the study showed that most wild edible fruits have good nutritional value, however, these fruits require more scientific scrutiny in order to thrive in the commercial markets.

KEY WORDS:

Nutrition, indigenous fruits, mineral, proximate, vitamin, southern Africa

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LIST OF ABBREVIATIONS

AACC, American Association of Cereal Chemists

ACL, Amarula Cream Liqueur

ADF, acid detergent fibre

AOAC, Association of Official Analytical Chemists

ARC, Agricultural Research Council

CBD, Convention of Biological Diversity

DNA, Deoxyribonucleic acid

EBSCO, Elton B. Stephens Co

EC, fruits from Mqanduli in the Eastern Cape

FAO, Food and Agricultural Organisation

FMOC, Flourenylmethyl chloroformate

FSA, Flora of southern Africa

HPLC, High Performance Liquid Chromatography

ICP-OES, Inductively Coupled Plasma Optical Emission Spectrometry

IPUF, Indigenous Plant Use Forum

JSTOR, Journal Storage

NEL, fruits from Nelspruit

NEMBA, National Environmental Management: Biodiversity Act (2004)

NRF, National Research Foundation

RDA, Recommended Dietary Allowance

SADC, Southern African Development Community

SPE, Solid Phase Extraction

TFA, Triflouoroacetic acid

UJ, University of Johannesburg

UNICEF, United Nations International Children's Emergency Fund

USDA, United States Department of Agriculture

WHO, World Health Organization

PART B

STRUCTURED STUDY

CHAPTER 1

The general introduction of the wild edible indigenous fruits

1.1 An overview of the prominence of wild edible indigenous fruit plants

Botanically speaking, a ‘fruit’ is a seed-bearing structure derived from a mature ovary in flowering plants, as a result of fertilization of the ovum (Lewis, 2001). This therefore means that structures such as bean/pea pods (legumes), tomatoes, grains (maize, rice, rye, wheat, etc.), for example, are all fruits. In common usage on the other hand, a ‘fruit’ normally refers to the fleshy, seed-bearing structures of plants, that are edible when raw and often sweet or sour, such as apples, bananas, kiwis, oranges, pineapples, and strawberries. In this study, the word ‘fruit’ is used in the latter sense.

Globally, there are a wide variety of wild edible indigenous fruits that are not as utilized and well-known as some of the exotic fruits. Indigenous knowledge is important for future research and commercialization of underutilized species, correspondingly, ethnobotanical research has led to the development of new products, such as cosmetics, medicine, rubber, and beverages (Cotton and Wilkie, 1996; Choudhary et al., 2008). Even though indigenous plants have such beneficial products, when humans overexploit the resource, the plants can become extinct. It is therefore imperative to obtain information about popular uses of wild edible plants before this knowledge disappears, hence, the crucial need to study such knowledge systems, and find innovative ways to instil them to future generations (Pieroni et al., 2005; Hadjichambis et al., 2008). For as long as people have occupied the planet, they have eaten culturally and traditionally important indigenous fruits, such as the baobab, desert date, black plum, and tamarind (Cemansky, 2015). It has been well documented that ancient people of India relied

[1] Definition Indigenous fruits: fruits that are of southern African origin and are found diversely in the wild.

heavily on wild fruit plants such as *Solanum nigrum* L. (which they call *makoi*) for survival (Saleem et al., 2009), moreover, extending their utilization to medicinal purposes, for relief of itching, pain, burns, etc. (Atanu et al., 2011; Sharma et al., 2017). Apart from their traditional use as food, indigenous wild plants have more advantages as they are already adapted to the environment, therefore contributing to water conservation and other ecosystem aspects (Cemansky, 2015). They are also less adversely affected by insect attack, compared to exotic fruit trees, such as *Malus domestica* Borkh. (Way et al., 1991). Best of all, indigenous wild plants are adapted to withstand competition from other plants and weeds (Maundu et al., 1999).

The population of southern Africa comprises a wide variety of ethnic groups; therefore, preservation of their deep-rooted indigenous knowledge is vital for the survival of future generations. South Africa alone includes major ethnic groups such as the Bapedi (North Sotho), Basotho (South Sotho), Amandebele, Emaswati, Batswana, Vatsonga, Vhavenda, Amaxhosa, and Amazulu (Davenport and Saunders, 2000); therefore, the country is richly diverse in tradition and has immense indigenous knowledge. Since ancient times, the people of southern Africa consumed a wide variety of fruits (both indigenous and exotic), some of which have gained substantial recognition in the commercial market, for example, *Sclerocarya birrea* (A.Rich.) Hochst. (marula) and *Opuntia ficus-indica* (L.) Miller (prickly pear) (Mokgolodi et al., 2011; Shackleton et al., 2011). Attention has been given almost exclusively to the marula fruit, whereby both the raw and ripe pulp of the fruit is used to prepare juices, jams, dried fruits, and alcoholic drinks (Hiwilepo-van Hal, 2013). The Amarula cream liquor (ACL) (made from the marula fruit) has gained significant recognition on a global scope, becoming the world's best-selling beverage in its category (Distell Annual Report, 2005) and winning a gold medal at the San Francisco World Spirits Competition for 3 years (2006, 2014, and 2017).

1.2 The contribution of wild edible indigenous fruits to alleviate nutrition and food insecurity

Most foods from the wild play an important part in supplying nutrition during periods of food scarcity, playing the role of, for example; snacks in emergency demands. This statement is supported by Maundu et al. (1999), who affirms that indigenous food plants make supplemental and emergency contributions to household food supplies. Some of these foods add flavour to staple food, which then increases appetite (Manyafu, 1970). Even though some fruits, such as *Opuntia ficus-indica* and *Diospyros mespiliformis* L., produce unpleasant sharp taste, as well as side effects, such as dry mouth, stomach cramps, and constipation, there have been no records of mortalities captured (Fentahun & Hager, 2009). It is worth noting that the inclusion of these fruits in a diet is dependent on their seasonal accessibility, nonetheless, there is a large extent of availability in spring and summer and most of the fruits can be dried for extended accessibility (Amarteifio and Mosase, 2006; Isabelle et al., 2010).

Scientific research has validated that some of these fruits are beneficial sources of nutrients. For example, a study conducted to assess a number of wild edible indigenous African fruits noted that *Azanza garckeana* (F. Hoffm) Exell & Hillc. (Mutchwa), *Parinari curatellifolia* Benth. (mobola plum), *Strychnos spinosa* Lam. (spiny monkey orange), *Trichilia emetica* Vahl (natal mahogany), and *Ximenia caffra* Sond. (sour plum), gave the highest levels of fibre (45.3 g/100g), carbohydrates (88.2 g/100g), fat (31.2 g/100g), protein (17.0 g/100g) and ash (11.2 g/100g) respectively (Saka and Msonthi, 1994). It appears that there are still many more un-researched wild edible fruits that are anticipated to have potentially efficient nutritional value. According to Mc Burney et al. (2004), researchers have deserted wild food plants in focus of wild medicinal plants, perhaps anticipating that the food plants are of poor nutritional value.

The Food Agricultural Organisation (FAO) (2011) estimates that, of a total of 300,000 known plant species, only 10,000 have been used for human food since the origin of agriculture. Of these species, only about 150-200 have been commercially cultivated, of which only four (rice, wheat, maize, and potatoes) supply 50% of the world's caloric intake. The above statistics therefore indicates that many plants with potential to improve food and nutrition security are not yet mainstreamed (Fanzo et al., 2013). Presently, malnutrition is a major health problem in Africa (Guled et al., 2017; WHO, 2017), reporting an increase from 50.4 to 58.5 million nutrition stunted children between the year 2000 to 2016, therefore indicating that the use of wild indigenous fruits could have an effect on combating malnutrition and improving food security (Maundu et al., 1999).

1.3 Wild edible indigenous fruits: Economic considerations

Indigenous wild fruits are sometimes sold in urban markets, in competition with popular exotic fruits (Leakey and Ajayi, 2007), which are well supported by nutritional research since ancient times. Exotic fruits such as *Musa acuminata* x *balbisiana* (banana), native to South Asia, have further expanded to the world markets, through distribution and cultivation, ensuring that high yields are available for business (Wong et al., 2001). As yet, these demands are less evident in the expansion of markets for wild indigenous fruits, rendering indigenous fruits suitable only for smallholder farmers (Poole, 2004; Schreckenberg et al., 2006).

Recent reports have recognised that indigenous fruits can make a contribution to reducing poverty in rural households (Garrity, 2004; Russell and Franzel, 2004), therefore leading an interest to the establishment of this study. Although the popularity of these wild forms of fruits is minimal, it is recommended that special attention should be paid to them, in order to maintain and improve this important source of food supply (Manyafu, 1970; Cemansky, 2015).

During the last two decades, the food sector has failed to keep pace with the population growth rate (Abdalla, 2007). The demand and shortages have usually been overcome by massive food imports. The Southern African Development Community (SADC) region alone, is facing growing food insecurity, with a decline in exports and escalating food imports (FAO, 2017). Bates (1981) argues that agricultural policies in most African countries are created only to cope with political problems, whose backgrounds lie outside the agricultural sector, and apart from this, population pressures and rapidly expanding urbanisation are some of the biggest barriers to accomplishing food security in southern Africa (Abdalla, 2007).

In countries such as Botswana, when arable agriculture fails in poor rainfall years, indigenous fruit trees bridge the income gap and improve food security for rural households (Mojeremane and Tshwenyane, 2004). In Zimbabwe, food security was found to be among other factors that are escalated by climate change, but to which indigenous fruits are used or are available to overcome these lean times (Mithöfer and Waibel, 2004). Studies have shown that using simple procedures such as osmotic dehydration for preservation of underutilised indigenous fruits such as *Irvingia gabonensis* Baill. (African mango) and *Ficus sycamorus* L. (fig), can be very effective for generating income for small-scale commercial production, thereby contributing to sustainable rural development (Aworh, 2015). The nutritional content analysis, however, through new research could prove that these fruit plants have more to offer (McBurney, 2004).

1.4 Aims and objectives of the study

The underlying objective of this study is to determine the nutritional properties of selected wild indigenous fruits consumed by communities in southern Africa. For the selection of fruits, a comprehensive literature review was conducted. The survey also established plants that have not been previously tested for their nutritional value.

Specific objectives

- Compile a comprehensive list of wild indigenous fruits of southern Africa from the literature;
- Conduct a gap analysis of all southern African wild indigenous fruits tested for nutrition;
- Identify selected plant species with knowledge gap in respect to nutritional qualities;
- Generate nutritive potential data of selected species with respect to their proximate, minerals, vitamins and amino acid composition; and
- Determine the energy value (caloric value) per species.

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CHAPTER 2

Ethnobotanical survey of the indigenous fruits of southern Africa

2.1 Introduction

According to Aiyeloja and Bello (2006), the term ethnobotany was coined by John Harshburger in 1986 in his study of plants, used by primitive and aboriginal people. However, Teketay and Eshete (2004), states that the term refers to the study of plants in relation to people, focusing on the use of plants by ancient and modern communities, and by surveying basic information from local users of the plants. Modern science has developed the field of ethnobotany from simply listing useful indigenous plants, to a new scientific data with appropriate methodology, and documenting for sustainable use. Therefore, this contributes not only to future referencing but also to conservation management (De Albuquerque et al., 2009).

The investigation of wild food plants is multidisciplinary; it does not only involve ethnobotany or botany, but includes disciplines such as nutrition, medicine, analytical chemistry, phytochemistry, and anthropology (Ogoye-Ndegwa, 2003; Kindscher et al., 2012; Shad et al., 2013; Vitalini et al., 2013). Nevertheless, most scholars only focus their studies on one or two of these disciplines, often leading to the inadequate inclusion of the commercialisation of food plants and/or their utilization. Surprisingly, for some of the investigated species, there is a repetition of similar data throughout the literature over time (McBurney, 2004), for example, the studies and tests conducted on *Sclerocarya birrea*, creating the misconception that the research of “wild fruits” is advanced and that attention is given to their nutrition (Eromosele et al., 1994; Jaenicke and Thiong'o, 1999; Shackleton et al., 2002; Mariod and Abdelwahab, 2012; Magaia, 2015).

This chapter presents research findings of an ethnobotanical survey of indigenous fruits of southern Africa, based on available literature. In this study, southern Africa should be understood as the flora of southern Africa (FSA) region, which comprises five countries, namely; Botswana, Lesotho, Namibia, South Africa, and Eswatini (Swaziland) (Goldblati, 1978). South Africa alone boasts a wide range of biodiversity, including countless wild fruits, which can be studied and utilized to bridge food insecurity (Klopper, 2010). For the reason that there are many mineral elements found in fruits, only 5 were reviewed namely; calcium, iron, potassium, phosphorus and magnesium, as they are essential for fluid balance, maintenance of bones and teeth, muscle contractions, and nervous system. Vitamin C (ascorbic acid) was the only vitamin scrutinized (for literature survey) as it is the most common vitamin present in fruits.

2.2 Methodology

2.2.1 Literature survey

The literature survey was compiled through data collection. Databases/search engines, such as; EBSCO, Google Scholar, JSTOR, Scopus, etc. were searched using scientific species name, nutritional value, chemical composition, etc. (as keywords), as described by Tariq et al., 2017. For any obstacle in finding complete information regarding research studies, the corresponding author and co-authors of articles were contacted through e-mails and ResearchGate. The data was then summarized into a table comprising; scientific name, common name, nutritional value and references. Species with information gap were reviewed three times to confirm accuracy. Figure 2.1 demonstrates the process depicted to complete the survey.

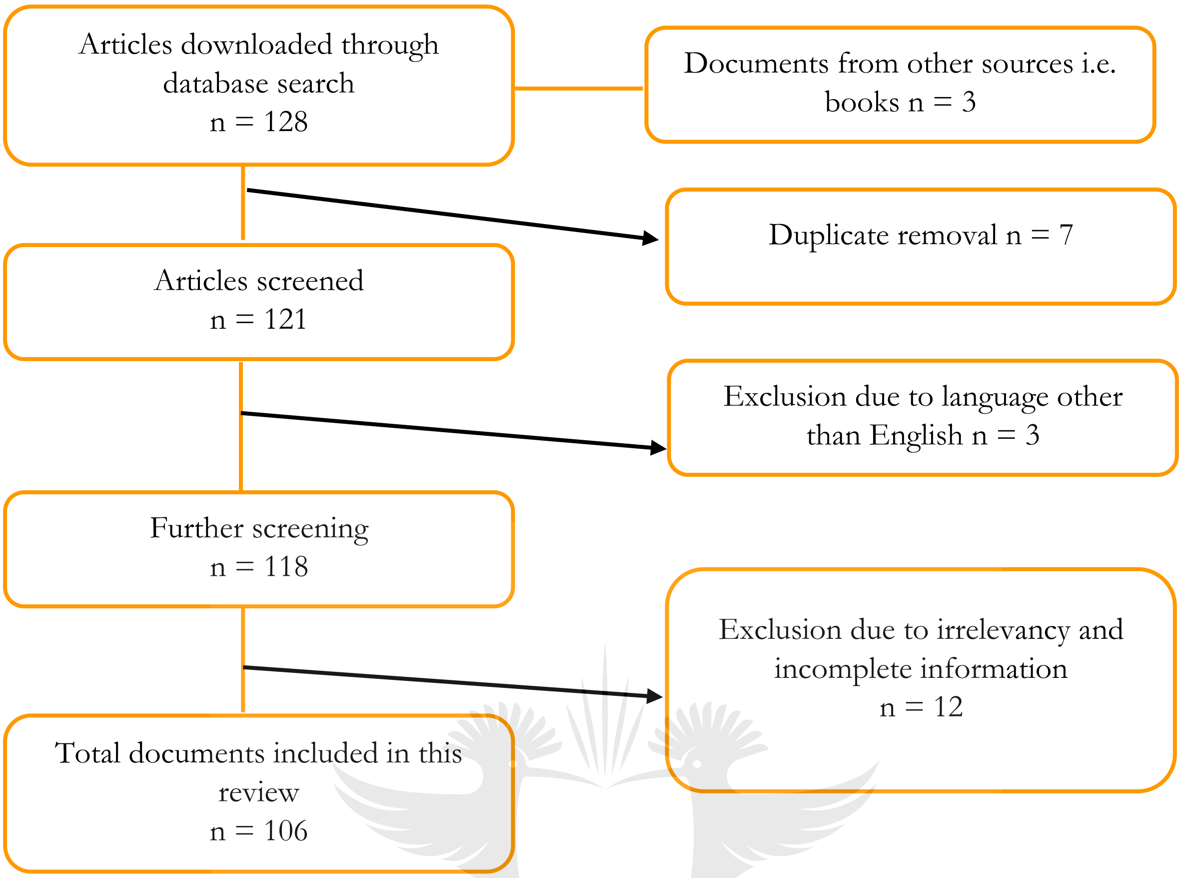

Figure 2.1 Flow diagram depicting major steps throughout the review process

2.3 Results and discussions

The ethnobotanical survey reviewed the wild edible indigenous fruits of southern African plants, in order to assess their nutrition knowledge gap. A total of 60 plant species, distributed in 35 families were captured. Detailed information including scientific names, common names, was recorded on the various nutritional aspects (minerals, proximates, vitamin C and amino acids), as well as the references shown in Table 2.1. The family Cucurbitaceae and Anacardiaceae comprises the highest number of species (7 spp.), followed by Sapotaceae (3 spp.), Annonaceae, Apocynaceae, Ebenaceae, Euphorbiaceae, Flacourtiaceae, Malvaceae, Vitaceae (2 spp.) and all other families were represented by 1 species each (as seen in Figure

2.2). Interestingly, in a study by Rampedi (2010), on the commercial potential of indigenous plants of Limpopo, Ebenaceae had the highest number of species used traditionally for beverage production. Plants belonging to one of the most popular families (Cucurbitaceae) were the most covered in terms of knowledge scope, nevertheless, this was expected as the family includes popular species such as *Coccinia sessilifolia* (Sond.) Cogn. (red gherkin) and *Cucumis anguria* L. (gherkin), that are commonly used in hamburgers recipes (Witepski, 2011).

Rosaceae is arguably one of, if not the most important families in terms commercial fruits (e.g. apples, peaches, plums, cherries, pears, apricots, etc.) (Zibadi and Watson, 2004), but not very well represented in terms of indigenous fruits in this region. The other family worth mentioning is Solanaceae, which is also economically important and includes many agricultural crops (such as potatoes, tomatoes, eggplant, peppers, etc.), medicinal plants (*Capsicum frutescens* L, *Withania somnifera* (L.) Dunn, etc.), but in this study, only one indigenous fruit was captured (*Solanum retroflexum* Dunal) (Sharada et al., 1993; Chen et al., 2003).

Interestingly, unlike in other ethnobotanical surveys, in which the family Fabaceae features a high number of species (e.g. Ajao et al., 2018), in this study the family showed the least species. Ethnobotanical surveys referred to here are mostly of an ethnomedicinal nature, for which Fabaceae is better known. However, the under-representation of the family Fabaceae does not come as a surprise since the legumes (the type of fruits typical of the family) were excluded from the study.

Table 2.1 - List of edible fruits; common names; minerals; proximate; vitamin C; amino acids; and references

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Anacardiaceae															
Harpephyllum caffrum Bernh.	Wild plum	✓	✓	-	-	✓	✓	-	✓	-	✓	-	-	-	Moodley et al., 2012; Wilson and Downs, 2012
Lannea edulis (Sond.) Engl.	Wild grape	✓	✓	-	✓	-	✓	✓	✓	✓	✓	-	-	-	Malaisse and Parent, 1985
Sclerocarya birrea (A.Rich.) Hochst.	Marula	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	✓	-	Eromosele et al., 1991; Eromosele et al., 1994; Jaenicke and Thiong'o, 1999; Aganga and Mosase, 2001; Mariod and Abdelwahab, 2012; Magaia et al., 2013a; Magaia et al., 2013b
Searsia undulata (Jacq.) T.S.Yi, A.J.Mill. & J.Wen.	Taaibos	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Searsia discolor E. Mey. ex Sond.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Searsia pentheri Zahlbr.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Searsia dentata Thunb.	Nana berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Annonaceae															
Annona senegalensis Pers.	Wild custard apple	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Eromosele et al., 1991; Yisa et al., 2010
Hexalobus monopetalus (A.Rich.) Engl. & Diels	Shakama plum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apocynaceae															
Ancylobotrys capensis (Oliv.) Pichon	Wild apricot	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Carissa macrocarpa (Eckl.) A.DC.	Natal plum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Wehmeyer, 1966; Moodley et al., 2012; Wilson and Downs, 2012; Augustyn et al., 2018
Sarcostemma viminale (L.) R.Br.	Caustic bush	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arecaceae															
Phoenix reclinata Jacq	Wild date palm	-	-	-	-	-	✓	-	-	-	-	-	✓	-	Cunningham and Wehmeyer, 1988
Asteraceae															
Chrysanthemoides monilifera (L.) Norl.	Bietou	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Capparaceae															
Boscia albitrunca (Burch.) Gilg & Gilg-Ben.	Emigrant's tea/ Caper bush	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caryophyllaceae															
Pollichia campestris Aiton	Waxberry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Celastraceae															
Salacia kraussii (Harv.) Harv.	Ibontsi	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	Magaia et al., 2013a; Magaia et al., 2013b; Magaia, 2015
Chrysobalanceae															
Parinari curatellifolia Benth.	Mobola plum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Saka and Msonthi, 1994; Benhura et al., 2012; Ogungbenle and Atere, 2014

Taxon	Common name	Nutrients													Reference
		Minerals					**Proximate**						**Vitamin**	**Amino acids**	
		Ca	**Fe**	**K**	**P**	**Mg**	**P**	**F**	**Fat**	**A**	**C**	**M**	**C**		
Clusiaceae															
Garcinia livingstonei T.Anderson	African mangosteen	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	Maundu et al., 1999; Wilson and Downs, 2012; Joseph et al., 2017
Cucurbitaceae															
Acanthosicyos horridus Welw. ex Hook.f.	Nara	-	-	-	✓	-	✓	-	-	-	✓	-	-	✓	Van damme et al., 1922; Van damme and Van Den Eynden, 2000
Acanthosicyos naudiniana (Sond.) C.Jeffrey	Gemsbok cucumber	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Citrillus lanatus (Thunb.) Matsum. & Nakai	Tsamma	-	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	Anhwange et al., 2010; Fila et al., 2013; Velempini and Perkins, 2008
Coccinia sessilifolia (Sond.) Cogn	Red gherkin	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Wehmeyer, 1966
Cucumis anguria L.	Gherkin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cucumis metuliferus E.Mey. ex Naudin	Jelly melon	✓	✓	-	✓	✓	✓	✓	✓	✓	✓	✓	-	-	Odhav et al., 2007
Cucumis myriocarpus Naud	-	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	Flyman and Afloyan, 2007
Ebenaceae															
Diopyros mespiliformis Hochst. ex A.DC.	Jackal berry	-	-	-	-	-	✓	✓	✓	✓	✓	✓	-	✓	Ezeagu et al., 1996; Petzke et al., 1997; Codron et al., 2007
Euclea crispa (Thunb.) Gürke	Bush guarri	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Euphorbiaceae															
Bridelia mollis Hutch.	Velvet sweet berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Uapaca kirkiana Müll.Arg.	Sugar plum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	Malaisse and Parent, 1985; Saka and Msonthi, 1994
Fabaceae															
Cordyla africana Lour.	Wild mango	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flacourtiaceae															
Dovyalis caffra (Hook.f. & Harv.) Sim	Kei-apple	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Wehmeyer, 1966
Dovyalis longispina (Harv.) Warb.	Natal Kei-apple	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Flacouritia indica (Burm.f.) Merr.	Governor's plum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	Saka and Msonthi, 1994
Hydnoraceae															
Hydrona africana Thunb.	Jakkalskos	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-	Bolin et al., 2010
Iridaceae															
Romulea rosea (L.) Eckl.	Frutangs	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lauraceae															
Cryptocarya wyliei Stapf	Red quince	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loganiaceae															
Strychnos spinose Lam.	Green monkey apple	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	-	Saka and Msonthi, 1994

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Malvaceae															
Azanza garckeana (F. Hoffm) Exell & Hillc.	Snot apple	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Saka and Msonthi, 1994; Mojeremane and Tshwenyane, 2004; Maundu et al., 1999; Nkafamiya et al., 2016; Roger et al., 2012; Jacob et al., 2016
Morella serrata Lam.	Lance-leaf wax berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mesembryanthemaceae															
Carpobrotus edulis (L.) L.Bolus	Sour fig	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Moraceae															
Ficus sycamorus L.	Sycamore fig	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Acipa et al., 2013; Nkafamiya et al., 2016
Myrtaceae															
Syzygium cordatum Hochst.ex C.Krauss.	Water-berry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Maliehe, 2015
Syzygium guineense (Willd.) DC	Water-berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Olacaceae															
Ximenia americana L.	Blue sour plum	✓	✓	-	-	✓	✓	-	✓	-	✓	-	-	-	Eromosele et al., 1991; Eromosele et al., 1994; Wilson and Downs, 2012; Magaia et al., 2013a

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Polygalaceae															
Nylandtia spinosa (L.) Dumort.	Skilpadbessie	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhamnaceae															
Bechemia discolor (Klotzsch) Hemsl.	Brown ivory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Ohiokpehai, 2003; Feyssa et al., 2012
Ziziphus mucronata Willd.	Buffalo-thorn	✓	✓	✓	✓	✓	✓	✓	-	✓	-	-	-	-	Aganga and Mosase, 2001; Aganga and Mesho, 2008; Ondiek et al., 2010
Rosaceae															
Rubus rigidus Sm.	Wild bramble	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rubiaceae															
Vangueria infausta Burch.	Wild medlar	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	Saka and Msonthi, 1994; Legwaila et al., 2011; Magaia et al., 2013b; Ohiokpehai, 2003
Sapindaceae															
Pappea capensis Eckl. & Zeyh.	Jacket-plum	-	✓	-	-	-	-	✓	-	-	-	-	✓	-	Karau et al., 2012; Osuga et al., 2006
Sapotaceae															
Englerophytum magalismontanum (Sond.) T.D.Penn.	Stamvrug	-	-	✓	-	-	-	-	-	-	-	-	✓	✓	Rampedi, 2010
Manilkara mochisia (Baker) Dubard	Lowveld milkberry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mimusops zeyheri Sond.	Transvaal red milkwood	✓	-	-	✓	✓	✓	✓	✓	✓	✓	-	-	✓	Chivandi et al., 2011

Taxon	Common name	Nutrients													Reference
		Minerals					Proximate						Vitamin	Amino acids	
		Ca	Fe	K	P	Mg	P	F	Fat	A	C	M	C		
Scrophulariaceae															
Halleria lucida L.	White olive	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Solanaceae															
Solanum retroflexum Dunal	Nightshade	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	Maundu et al., 1999; Nesamvuni et al., 2001; Njeme et al., 2014
Tiliaceae															
Grewia flava DC.	Velvet raisin bush	-	-	-	-	-	-	-	-	-	✓	-	-	-	Ohiokpehai, 2003
Verbenaceae															
Lantana rugosa Thunb.	Chameleon's berry	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Vitaceae															
Rhoicissus tomentosa (Lam.) Wild & R.B. Drumm.	Wild grape	-	-	-	-	-	✓	-	-	-	-	-	-	-	Codron et al., 2006
Rhoicissus tridentata (L. f.) Wild & Drum.	Bushman's grape	-	-	-	-	-	-	-	-	-	-	-	-	-	-

✓Marks nutrient record, - Marks no record

Ca: calcium, Fe: iron, K: potassium, P, phosphorus, Mg, magnesium, F: Fibre, A: ash, C: carbohydrates, M: moisture

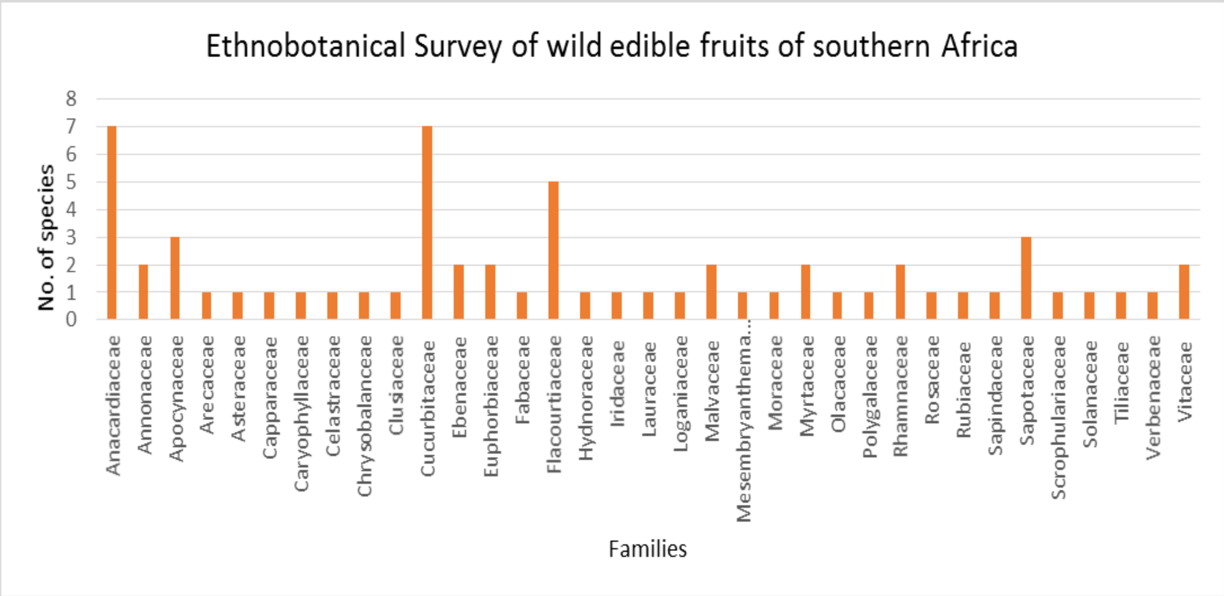

Figure 2.2 Bar chart of the ethnobotanical survey of wild edible fruits of southern Africa

Even though Anacardiaceae is one of the most utilized family, it showed a large nutrient knowledge gap, for example, none of the *Searsia* species (i.e. *Searsia undulata, Searsia discolor, Searsia pentheri*. and *Searsia dentata,* have previously been tested for their nutritional content. Nevertheless, the very well known fruit, *Sclerocarya birrea* (marula), was tested the most. This review shows that this fruit has been of interest for a number of years, as exemplified by the number of publications covering its nutrition (Eromosele et al., 1991; Eromosele et al., 1994; Jaenicke and Thiong'o, 1999; Aganga and Mosase, 2001; Magaia et al., 2013a; Magaia et al., 2013b). This therefore clarifies the success of the marula fruit in the commercial markets. Overall, these results are a demonstration that a well-studied fruit can be of interest to investors, in consequence, accumulating its strength in the retail markets.

Only two species, *Grewia flava* (Tiliaceae) and *Rhoicissus tomentosa* (Vitaceae) were tested for only one nutrient. However, it was depicted that the nutrient analysis was just a basis of another continuous study, which is featured in another discipline, i.e. zoology (Ohiokpehai, 2003). Surprisingly, fruits belonging to 12 of the 35 families had previously not been tested for any nutritional content, namely: Asteraceae, Capparaceae, Caryophyllaceae, Ebenaceae, Euphorbiaceae, Iridaceae, Lauraceae, Mesembryanthemaceae, Polygalaceae, Sapotaceae, Scrophulariaceae and Verbenaceae.

Results emanating from the minerals literature survey indicates that the number of species studied, are at a similar range for most nutrients. Figure 2.3 demonstrates that iron and phosphorus were tested the most (25 spp.) followed by calcium and magnesium (24 spp.), and potassium with 22 species. For proximate value, proteins were tested the most, with 28 spp., followed by fibre and fat with 24 spp., ash with 23 spp., and the least tested was moisture with 15 spp. The possible explanation for the high number of studies of protein analysis could be due to the fact that proteins play a significant role in enzyme activity, DNA processes and are the building blocks of life (Marieb, 2015).

Vitamin C was second least tested nutrient, with only 14 out 62 species having been screened. This was surprising, as fruits are known to have relatively high ascorbic acid content (Devaki and Raveendran, 2017). Vitamin C plays a role as an immune-stimulating effect, for example, it is important for defence against infections such as common colds. However, according to literature, vitamin C was of least concern, meaning most studies focus on other nutrients than ascorbic acid. Amino acids were the least tested, with only 11 fruits. *Garcinia livingstonei*, *Luffa cylindrical* and *Vangueria infausta* were the only fruits tested for all nutrients, except for the two least tested nutrients (namely vitamin C and amino acids). The fact that amino acid analysis can be expensive and requires technical machinery such as the HPLC, could explain the large knowledge gaps for this nutrient. Nevertheless, this does not make amino acids insignificant, as they play a crucial role in biological processes and are the building blocks of protein, thus significant for analysis (Wu, 2009).

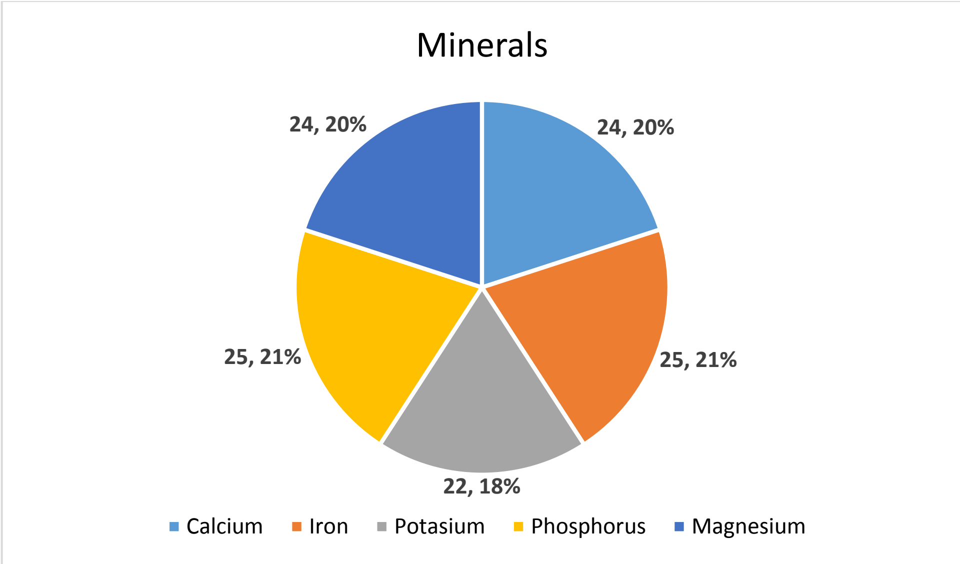

Figure 2.3 Pie chart of the nutrients of wild edible fruits of southern Africa

In total, 29/62 (47%) of the species showed nutrition knowledge gap, these fruits had the most unavailable data among the rest. Excluding the aforementioned 29 fruits, there are still many fruits that have one or more nutrient untested i.e. *Carpobrotus edulis*. The sour fig showed a large nutrition gap, but comprehensive data regarding its medicinal potential (Van der Watt and Pretorius, 2001; Omoruyi et al., 2012). The fact that there are numerous fruits that were not studied, can possibly be attributed to geographical and availability constraints.

2.4 Conclusions

In conclusion, the results obtained demonstrate that there is a large nutrition knowledge gap, which can solely be filled by evaluating the nutritional value of these fruits. It is evident that species that are well studied, are already commercialised and their nutrition have been of immense interest in old and recent literature. The results obtained are expected to promote research of the wild indigenous fruits and encourage the utilization of those that are highly nutritive.

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CHAPTER 3

The macronutrient composition of the wild edible indigenous fruits of southern Africa

3.1 Introduction

According to Nieman and Lee (2003), nutrition assessment is the best way to determine whether or not people's nutritional needs are effectively being met. Nutrition analysis of wild edible indigenous fruits provides quality, quantity, and evidence-based information for future research, planning, commercialization and utilization, all together aiming at eradicating hunger, poverty and reducing the burden of malnutrition in southern Africa.

The proximate technique is a system of food analysis that is divided into five constituents, i.e. ash, moisture, proteins, fats and carbohydrates (AOAC, 2005). Although the proximate procedure does not give complete nutritional information (i.e. minerals, vitamins and amino acids), it is a low-cost analysis that is used to track deviations from the quality of foods (Hart and Fisher, 2012). There are additional ingredients that may fall under one of the five constituents, for example, carbohydrates in proximate analysis include dietary fibres, sugars, and sugar alcohols (Doublecz, 2011). Several wild fruits are a good source of carbohydrates, proteins, and fats that may be lacking in some human diets (Saka and Msonthi, 1994). Since proximate analysis for proteins is quantitative, it only gives the total nitrogen content, therefore, it is essential to further analyse the amino acids of the wild fruits for more accurate results.

The moisture content refers to the content of water in the fruit, which sometimes indicates the length of the period of freshness and storage (Rockland and Nishi, 1980). High moisture content, coupled with high temperatures (among other factors), can predict the shelf life of fruits, because these two factors contribute effectively to microbial growth (Hammond et al., 2015). According to a study conducted by Magaia et al. (2013), the pulp of *Adansonia digitata* L. (baobab) showed the highest moisture content at, 88.5 g/100g, than most studied fruits, meaning that this fruit could be more susceptible to microbial activity, and would have a shortened shelf life if commercialized (Isengard, 2001).

A healthy diet requires an intake of at least one or more fruits a day, as most fruits are high in dietary fibre. Previous studies have proven that people who consume high levels of dietary fibre, have a reduced risk of fatal coronary artery disease and nonfatal myocardial infarction (Rimm, 1996). Studies have shown that some indigenous fruits have much higher fibre content than some cultivated fruits, for example, *Azanza garckeana* (snot-apple) was reported to have a fibre content of 45.3 g/100g (Saka and Msonthi, 1994) compared to 28 g/100g in *Prunus domestica* L. (prune) (USDA, 2018), which is commercialized and promoted as a "natural" laxative (El-Dakak, 2013). Rural communities with abundant *Azanza garckeana* trees can bridge this daily diet requirement and improve digestive metabolism (Gidenne, 2010).

Amino acids are a combination of two organic substances that combine an amide and an acid, and are the building blocks of proteins (Galli, 2007). Amino acids are essential to the human body in order to undertake biological processes, which give cells their structure, as well as to transport and store nutrients. There are twenty amino acids that the body cannot survive without; these are divided into essential and non-essential amino acids. Nine essential amino acids are found in the human body are namely: leucine, isoleucine, lysine, methionine, phenylalanine, tryptophan, valine, threonine and histidine. Essential amino acids are said to be indispensable, as they cannot be synthesized by the body and can only be obtained from food (Ha and Zemel, 2003). The body can synthesize non-essential amino acids, such as arginine, alanine, serine, asparagine, aspartate, glutamic, glycine, ornithine, tyrosine, proline and cysteine. According to Nechet (2010) of the fruitarians network, many people think there are no amino acids found in fruits. This study therefore compares the results of the selected wild edible indigenous fruits to the World Health Organization (WHO) recommended daily intake, to see if there are substantial amino acids in fruits. This lays the significance of testing fruits for proteins, among other macronutrients. This chapter presents the research findings based on the proximate values, amino acids, and energy content of the selected wild edible indigenous fruits of southern Africa. This chapter provides the material and methods in section 3.2, results and discussion in section 3.3, the conclusion in section 3.4 and the references in section 3.5.

3.2 Materials and methods

3.2.1 Fruit samples for evaluation

a) Selected fruits for analysis

Fourteen types of wild edible fruits were selected (based on availability and knowledge gap), and collected randomly across southern Africa. Prof. Annah Moteetee of the University of Johannesburg, Botany and Plant Biotechnology Department, authenticated the plant species for further evaluation. The species tested are listed in Table 3.1.

Table 3.1 - List of species and collection site

#	Species	Collection site
1	*Carissa macrocarpa*	Johannesburg, Gauteng
2	*Carpobrotus edulis*	Capetown, Western Cape
3	*Cordyla africana*	Nelspruit, Mpumalanga
4	*Dovyalis caffra (EC)*	Mqanduli, Eastern Cape (ARC)
5	*Dovyalis caffra (NEL)*	Nelspruit, Mpumalanga (ARC)
6	*Dovyalis longispina*	Nelspruit, Mpumalanga (ARC)
7	*Englerophytum magalismontanum*	Nelspruit, Mpumalanga (ARC)
8	*Garcinia livingstonei*	Nelspruit, Mpumalanga (ARC)
9	*Halleria lucida* L.	Johannesburg, Gauteng
10	*Manilkara mochisia*	Venda, Limpopo
11	*Pappea capensis*	Nelspruit, Mpumalanga (ARC)
12	*Parinari curatellifolia*	Nelspruit, Mpumalanga (ARC)
13	*Phoenix reclinata*	Barberton, Mpumalanga
14	*Syzygium cordatum*	Nelspruit, Mpumalanga (ARC)
15	*Syzygium guineense*	Nelspruit, Mpumalanga (ARC)

b) Processing of fruits

The edible part of the fruits (pulp and peel) were carefully removed from the seed. The material was homogenised using a mortar and pestle (Saka & Msonthi, 1994). The fruits were then freeze-dried, except for the samples that were analysed for moisture content.

3.2.2 Proximate analysis

a) Moisture content determination

Moisture was determined using the procedure described in American Association of Cereal Chemists (AACC) Method 44 – 15A (1999). Moisture crucibles were dried in a forced draught oven at 103^{0}C for 1 hour. The crucibles were then cooled in a desiccator for about 10 minutes. The crucibles were weighed and 2 g of sample was weighed into the crucibles and dried in a forced draught oven for 4 hrs at 103^{0}C. The samples were cooled for 10 minutes and weighed. The moisture content percentage was calculated as follows:

$$\% \text{ moisture} = \frac{[(\text{mass food} + \text{tin}) - (\text{mass tin})] - [(\text{mass dry food} + \text{tin}) - (\text{mass tin})] \times 100}{[(\text{mass food} + \text{tin}) - \text{mass tin}}$$

b) Protein content determination

The micro Kjeldahl method described by the Association of Official Analytical Chemists (AOAC) (1990), was used. Two grams (2 g) of each sample was mixed with 10 ml of concentrated sulphuric acid (H_2SO_4), in a heating tube. One tablet of selenium catalyst was added to the tube and the mixture was heated inside a fume cupboard. The digest was transferred into a 100 ml volumetric flask and made up with distilled water. Ten millilitre portion of the digest was mixed with equal volume of 45% NaOH solution and poured into a Kjeldahl distillation apparatus. The mixture was distilled and the distillate was collected into a 4% boric acid solution, containing 3 drops of indicator. A total of 50 ml distillate was collected and titrated as well. The sample was duplicated and the average value was taken. The nitrogen content was calculated and converted to percentage protein by using a protein conversion factor of 6.25. This was given as:

$$\% \text{ nitrogen} = \frac{(100 \times W \times N \times 14 \times Vf)\ T}{100 \times Va}$$

Where; W = Weight of the sample, N = Normality of the titrate (0.1N), Vf = Total volume of the digest = 100 ml, T = Titre value and Va = Aliquot volume distilled.

c) Ash content determination

To determine the ash content which is the substance remaining after oxidative combustion of all the organic matter in food, the AACC method 08 – 01 (1999) was used. Crucibles were dried in an oven at 100^{0}C for 5 hours and allowed to cool in order to be weighed. Two grams of each samples was weighed into the crucibles. The crucibles with samples were then placed on a tripod and heated until the samples are charred. The charred samples were then put in a muffle furnace and heated at 550^{0}C for 5 hrs. The samples were removed and cooled in a desiccator until room temperature and then weighed. Percentage ash was calculated as follows:

$$\% \text{ ash} = \frac{(\text{mass ash} + \text{crucible}) - (\text{mass crucible}) \times 100}{(\text{mass food} + \text{crucible}) - (\text{mass crucible})}$$

d) Fat content determination

Crude fat was determined by extracting the sample using petroleum ether, according to the AACC method 30 – 25 (1983) of the Soxhlet test apparatus. The petroleum ether was then removed from the collection flask at low temperature volatilization before oven drying. The residue fat was dried in an oven at 100^{0}C for 30 minutes. Percentage of fat was calculated using the following formula:

$$\% \text{ fat} = \frac{[(\text{mass of beaker} + \text{mass of extracted fat}) - (\text{mass of beaker})] \times 100}{\text{mass of sample}}$$

e) Fibre content determination

Crude fibre was determined by first weighing the filter bag (W_1), then 0.5 g of dried sample (W_2), that was ground to pass a 1mm screen, and directly added into a filter bag. A blank bag was weighed and included in digestion, in order to determine blank bag correction (C_1). The bags were sealed within 0.5 cm from the pen edge, using the heat sealer. The bags were placed in a bag suspender. About 2000 ml of temperature acid detergent solution was added into the ANKOM Fiber Analyzer vessel and the suspender was covered. The fibre analyser vessel was set for 60 minutes. Approximately 2000 ml of hot water was added and the samples were agitated again. The samples were rinsed for 3-5 minutes with water, until a neutral pH was reached. Excess water was pressed out from the bags. The bags were then placed in a beaker and covered with acetone for 3 minutes. The bags were removed and pressed again to remove excess acetone. The bags were dried in the oven at 105˚C, for at least 2 hours. The bags were cooled to ambient temperature and weighed (W_3).

$$\% \text{ ADF (as is basis): } = \frac{[W_3 - (W_1 \text{ x } C_1)] \text{ x } 100}{W_2}$$

f) Carbohydrates determination

The available carbohydrate content in the samples was calculated by difference as follows:

% carbohydrate = 100 – (% moisture + % ash + % crude protein +% crude fat + % crude fibre)

3.2.3 Amino acid analysis

Amino acid compositions of the fruit samples were determined at the Agricultural Research Council (ARC) - Irene Analytical Research Laboratory, Pretoria, South Africa, using high-performance liquid chromatography (HPLC), following the procedure of Einarsson et al. (1983). Briefly, milled samples (700 mg) were hydrolysed using an equal volume of 6 N HCL solution and an internal standard (a-amino-b-guanidino propionic acid), for 24 h at 1150˚C and left to cool. The hydrolysate was transferred to an Eppendorf tube and centrifuged at 3000 rpm for 10 min, after which the supernatant (protein hydrolysate) was filtered (0.45 mm). The protein hydrolysate was dried under nitrogen gas and derivatized using FMOC reagent (9-flourenylmethyl chloroformate) and borate buffer. After a few seconds, the mixture was extracted with pentane. The derivatized extract was analysed on HPLC using fluorescence detectors (Schoeffel FS 970, Perkin-Elmer LS-4 and Shimadzu RF-530 at excitation and emission wavelengths of 260 and 313 nm respectively). A mixture of HPLC grade acetonitrile, methanol and acetic acid (10:40:50, v/v/v) was used as the eluent and varied linearly to acetonitrile: acetic acid (50:50, v/v) over 90 min. Oven temperature was kept at 40˚C while the gradient flow initiated at 3 min at 1.3 mL/ min flow rate. The flow rate was later increased to 2 mL/min for 0.5 min at the end of the gradient. Using calibration curves from amino acid standards (Sigma Aldrich, Germany), the concentration of the amino acids in the samples were then determined.

3.2.4 Determination of energy value

The sample calorific value was calculated in kilocalories (kcal) by multiplying the energy factor composition (4, 4, and 9) by percentage protein, carbohydrates and fats respectively (FAO, 1968; Asibey-Berko and Tayie, 1999; USDA, 1999). The conversion factors are equivalent to the physiological energy, which is the energy value remaining after losses due to digestion and metabolism (USDA, 1999).

3.2.5 Statistical Analysis

The results were statistically analyzed by using the Statistica statistical software for proximate analysis. Results were shown as means of ± standard deviation. One way Analysis of Variance (ANOVA) with Fisher Least Significant Difference (LSD) were used to analyze the means between the fifteen fruit samples type. The difference of mean values was analyzed by Fisher Least Significant Difference (LSD) tests. The significance difference of the samples were determined at confidence level above 95% ($p<0.05$).

3.3 Results and discussion

3.3.1 Proximate

Table 3.1 displays the proximate values of the selected wild edible indigenous fruits of southern Africa. Results showed a significant difference $p \leq 0.05$, between the proximate values, obtained from the fifteen fruit samples. The proximate content was obtained from the pulp and skin of the fruit. Statistically, the moisture content showed a significant difference, ranging from 19.61 g/100g to 88.11 g/100g. The moisture content of *Carpobrutus edulis* was significantly lower than that of other fruits. These results may be attributed to the high content of pectin, which is a very sticky gel-like substance that did not evaporate at the prescribed temperature (Mohnen, 2008). *Englerophytum magalismontanum* showed the highest moisture content (88.11 g/100g), followed by *Syzygium guineense* (82.41 g/100g) and *Syzygium cordatum* at 81.78 g/100g. The levels of moisture obtained from the pulp and skin of *S. guineense* and *S. cordatum* were highly comparable (expressed by consecutive letter superscripts ‘m’ and ‘n’), possibly because the fruits are from the same genus, and the fact that their common name ‘water-berry’ advocates their high water content.

Table 3.2 - List of edible plants; common names; and proximate value

Species	Proximate g/100g						Energy kJ/100g
	Ash	Fat	Fibre	Moisture	Protein	Carbohydrates	
Carissa macrocarpa	20.28±0.12^{l}	0.87±0.05^{h}	4.68±0.22^{f}	52.48±0.00^{e}	1.96±0.00^{f}	21.57±0.01^{l}	**101.95±0.00^{k}**
Phoenix reclinata	4.23±0.23^{g}	1.44±0.00^{j}	29.89±0.00^{o}	48.92±0.00^{d}	4.08±0.01^{k}	11.44±0.00^{g}	**75.04±0.01^{g}**
Parinari curatellifolia	3.69±0.00^{de}	0.25±0.00^{c}	8.88±0.00^{j}	63.39±0.01^{f}	2.61±0.00^{i}	21.18±0.00^{k}	**97.37±0.01^{j}**
Garcinia livingstonei	5.85±0.00^{i}	0.69±0.01^{f}	4.80±0.00^{g}	81.59±0.00^{l}	2.16±0.00^{g}	4.64±0.00^{c}	**33.41±0.00^{c}**
Cordyla africana	1.97±0.00^{a}	3.55±0.00^{l}	3.06±0.00^{c}	71.48±0.01^{i}	0.004±0.02^{a}	19.94±0.00^{j}	**111.73±0.00^{l}**
Dovyalis caffra (EC)	3.90±0.00^{f}	0.73±0.00^{g}	3.44±0.00^{d}	79.30±0.00^{k}	0.83±0.00^{b}	11.80±0.00^{h}	**57.09±0.00^{d}**
Dovyalis caffra (NEL)	2.50±0.00^{b}	0.003±0.02^{a}	2.48±0.00^{b}	79.26±0.00^{j}	1.56±0.00^{c}	14.20±0.02^{i}	**64.27±0.00^{f}**
Dovyalis longispina	6.73±0.01^{j}	1.49±0.00^{k}	1.88±0.01^{a}	70.51±0.00^{h}	1.94±0.00^{e}	30.91±0.00^{n}	**144.81±0.00^{m}**
Carpobrotus edulis	8.76±0.00^{k}	0.21±0.00^{b}	11.46±0.00^{l}	19.61±0.03^{a}	3.45±0.00^{j}	10.97±0.00^{e}	**59.57±0.00^{e}**
Syzygium cordatum	3.79±0.00^{ef}	0.34±0.00^{e}	7.64±0.00^{i}	81.78±0.00^{m}	0.83±0.00^{b}	5.62±0.03^{d}	**28.86±0.02^{b}**
Syzygium guineense	3.34±0.00^{c}	7.74±001^{n}	3.84±0.00^{e}	82.41±0.00^{n}	1.66±0.00^{d}	1.01±0.00^{a}	**80.34±0.00^{h}**
Pappea capensis	3.42±0.02^{c}	5.11±0.00^{m}	16.51±0.00^{n}	45.63±0.00^{c}	4.33±0.01^{l}	25.00±0.00^{m}	**163.31±0.00^{n}**
Englerophytum magalismontanum	2.05±0.00^{a}	0.31±0.00^{d}	5.60±0.00^{h}	88.11±0.00^{o}	0.83±0.00^{b}	3.10±0.00^{b}	**18.51±0.00^{a}**
Manilkara mochisia	3.65±0.00^{d}	1.38±0.00^{i}	12.77±0.00^{m}	43.03±0.00^{b}	2.19±0.00^{h}	36.98±0.00^{o}	**169.10±0.00^{o}**
Halleria lucida	5.06±0.00^{h}	1.44±0.00^{j}	10.13±0.01^{k}	64.98±0.00^{g}	6.98±0.00^{m}	11.41±0.00^{f}	**86.52±0.01^{i}**

Values are expressed as means ± standard deviations (n= 3).For all the values within a column, different letter superscripts mean significant differences (P<0.05).

The results obtained show that the stamvrug and the water-berries could make good fruit juice products. The low levels of moisture for *Phoenix reclinata* were highly predictable, as the fruit has a seed/nut-like nature. Statistically, *Carissa macrocarpa* was observed to have the highest ash content at 20.28 g/100g and *Cordyla africana* to have the lowest at 1.97 g/100g. For other species, this value significantly varied between 2.05 g/100g to 8.76 g/100g. The results for *S. guineense* and *P. capensis* were statistically similar (expressed by a 'c' superscript), with a concentration of 3.34 g/100g and 3.42 g/100g, respectively. The levels of fat for the fifteen fruit samples ranged significantly between 0.003 and 7.74 g/100g. *Syzygium guineense* showed the highest fat content than all other fruits at 7.74 g/100g, while *Dovyalis caffra* from Nelspruit recorded the lowest fat content of 0.003 g/100g. The results for the two *Syzygium* species were significantly incomparable, as *S. cordatum* showed a low 0.34 g/100g content of fat. Overall, the results obtained are in agreement with Wang et al. (2014), proving that most fresh fruits are a poor source of fat.

The proximate fibre value was the third highest amount captured in this study, at 29.89 g/100g, and it was recorded in *Phoenix reclinata*. This may be due to the fact that the fruit is seed or nut-like in nature. According to Whitbread (2019), seeds such as walnuts, sesame seeds, chia seeds and almonds possess a high fibre content, therefore added in food products such as muesli. The findings, shown in table 3.1 indicate that wild edible indigenous fruits could be a good component for weight loss and reducing the risk of cardiovascular disease. The Recommended Daily Allowance (RDA) for fibre is 18 to 35 g (Ganong, 2003), implying that 100 g of *Phoenix reclinata* fruit is adequate to meet the daily fibre requirements of the body.

Statistically, *Manilkara mochisia* recorded the highest carbohydrate content of 30.91 g/100g while *Syzygium guineense* was the lowest at 1.01 g/100g. In a holistic view, all samples from the *Dovyalis* genus contained higher levels of available carbohydrates compared to those from the *Syzygium* family. The carbohydrate content for *Cordyla africana* (19.94 g/100g) was higher than its commercial counterpart *Mangifera indica*, at 15 g/100g (USDA, 2018). Even though the carbohydrate nutrient is not ideal for weight loss, carbs play a very significant role in supplying the body with energy. There was a substantial level of carbohydrates in *Carissa macrocarpa* at 21.57 g/100g, however, the values for moisture and fat were still low. Nevertheless, the low fat and moisture contents are necessary for the storage quality of the fruit.

As shown in Table 3.1, the protein levels of the fruits ranged significantly from 0,004 to 6.98 mg/100g. The highest protein value was recorded in *Halleria lucida* (6.98 g/100g), followed by *Pappea capensis* (4.33 g/100g) and *Phoenix reclinata* (4.08 g/100g). According to Ganong (2003), the Recommended Dietary Allowance (RDA) of protein for children, adult males, adult females, pregnant women and lactating mothers are 28, 63, 50, 60 and 65 g respectively. If 100g of *H. lucida* provides 6.98 g of proteins, this indicates that fruits could be poor sources of proteins. In order to assess and confirm the nutritional quality of the protein in the 15 samples, the amino acid analysis was further conducted.

3.3.2 Energy

The energy values were measured from 18.51 to 169.10 kJ/100g. *Manilkara mochisia* was well above all fruits, but not far from *P. capensis* at 163.31 kJ/100g, illustrating that these fruits have high calorific value. According to Johnson et al. (2008), high energy density foods tend to include foods that are high in fat and have a low water content. This statement was found correct, as *P. capensis* showed a high content for fat (5.11 g/100g), and a low moisture content of 45.63 g/100g.

3.3.3 Amino acids

The amino acid profile of the fifteen wild edible indigenous fruits are summarized in Table 3.2, containing both essential as well as the non-essential amino acid patterns. Arginine and serine were the most abundant amino acids in *D. longispina* and the highest recorded compared to all fruits, at 3.31 and 1.14 g/100g, respectively. Arginine plays an important role in the removal of ammonia from the body, during cell division and in synthesizing nitric oxide for blood pressure regulation (Andrew and Mayer, 1999; Gokce, 2004; Frezza and Mauro, 2015). Correspondingly, the high *H. lucida* protein concentration was exhibited by a high histidine concentration, at 1.56 g/100g, thus showing alignment between the proximate and the amino acids results.

Both *Dovyalis* species were on par at 0.07, 0.08 and 0.09 g/100g for HO-proline, which is a precursor of proline. Noteworthy, was the fact that all fruits listed in table 3.2 showed a methionine content below 0.10 g/100g, except for, *D. longispina*, *P. capensis* and *P. reclinata*. *Pappea capensis*, *Parinari curatellifolia*, and *Phoenix reclinata* were comparable for glutamic acid at 1.10, 1.63 and 1.07 g/100g, respectively.

The amino acid composition of the wild edible indigenous fruits of southern Africa was compared to the World Health Organization standard protein recommended daily requirements for adults (WHO, 2007). The requirement for lysine has received most attention given its nutritional importance as the likely limiting amino acid in staple foods, such as wheat. The highest lysine captured was 0.77 g/100g for *P. capensis*. The jacket-plum meets and exceeds the required daily intake (0.0003 g/100g or 13 mg/kg) recommended by WHO in figure 3.1. In fact, the lysine content of all fruits tested is significantly higher than the lysine content required within 24 hours in adults.

Table 3.3 - List of edible plants; common names; amino acids

Taxon	Amino acids (g/100g)							
	C. macrocarpa	*C. edulis*	*C. africana*	*D. caffra* (EC)	*D. caffra* (NEL)	*D. longispina*	*E. magalismontanum*	*G. livingstonei*
Arginine	0.35	0.30	0.29	0.39	0.50	3.31	0.39	0.47
Serine	0.20	0.22	0.28	0.24	0.33	1.14	0.32	0.32
Aspartic acid	0.43	3.34	0.47	0.45	0.66	0.52	0.80	0.62
Glutamic acid	0.48	0.51	0.64	0.57	0.75	0.62	0.71	0.74
Glycine	0.17	0.37	0.22	0.19	0.26	0.24	0.24	0.31
Threonine	0.17	0.16	0.22	0.20	0.28	0.23	0.21	0.26
Alanine	0.21	0.16	0.34	0.28	0.40	0.29	0.29	0.36
Tyrosine	0.05	0.10	0.14	0.04	0.04	0.16	0.38	0.47
Proline	0.15	0.18	0.24	0.19	0.28	0.25	0.26	0.28
HO-Proline	0.40	0.14	0.19	0.07	0.08	0.09	0.16	0.06
Methionine	0.07	0.05	0.05	0.04	0.08	0.10	0.09	0.08
Valine	0.17	0.14	0.29	0.22	0.31	0.27	0.31	0.37
Phenylalanine	0.14	0.12	0.21	0.18	0.24	0.22	0.22	0.28
Isoleucine	0.14	0.12	0.23	0.16	0.22	0.21	0.23	0.27
Leucine	0.23	0.18	0.31	0.27	0.36	0.36	0.35	0.46
Histidine	0.14	0.18	0.26	0.08	0.08	0.16	0.24	0.28
Lysine	0.30	0.26	0.53	0.27	0.28	0.55	0.54	0.67

Table 3.3 continued

Taxon	**Amino acids (g/100g)**						
	H. lucida	*M. mochisia*	*P. capensis*	*P. curatellifolia*	*P. reclinata*	*S. cordatum*	*S. guineense*
Arginine	0.55	0.30	0.51	0.25	0.67	0.52	0.38
Serine	0.64	0.21	0.46	0.44	0.31	0.23	0.36
Aspartic acid	0.62	0.34	0.75	0.51	0.81	0.55	0.55
Glutamic acid	0.85	0.45	1.10	1.63	1.07	0.58	0.62
Glycine	0.46	0.20	0.38	0.27	0.31	0.22	0.29
Threonine	0.30	0.17	0.31	0.25	0.27	0.19	0.23
Alanine	0.40	0.23	0.41	0.65	0.36	0.31	0.34
Tyrosine	0.27	0.11	0.22	0.18	0.19	0.14	0.19
Proline	0.27	0.19	0.34	0.24	0.23	0.19	0.21
HO-Proline	0.07	0.06	0.14	0.17	0.06	0.11	0.08
Methionine	0.08	0.05	0.15	0.05	0.11	0.06	0.07
Valine	0.39	0.23	0.37	0.32	0.37	0.25	0.30
Phenylalanine	0.31	0.15	0.30	0.22	0.27	0.20	0.24
Isoleucine	0.30	0.17	0.29	0.23	0.24	0.19	0.23
Leucine	0.47	0.28	0.48	0.34	0.42	0.32	0.39
Histidine	1.56	0.23	0.63	0.27	0.31	0.12	0.62
Lysine	0.58	0.37	0.77	0.46	0.58	0.49	0.61

The biological functions of lysine include; support for healthy growth and development as well as the maintenance of healthy immune function, particularly with regard to antiviral activity (Li et al., 2007). According to Nechet 2010, most foods may have substantial lysine content, but show a limited methionine content. In this study, *P. reclinata* showed a substantial methionine content of 0.11 g/100g and a significant lysine content of 0.58 g/100g.

As displayed in Figure 3.2, the WHO required methionine intake is 0.00015 g/100g (15 mg/kg) per day, therefore implying that wild edible indigenous fruits such as *P. reclinata* can provide sufficient protein nutrients in one fruit. *Dovyalis caffra* from the Eastern Cape (EC) and Nelspruit (NEL) showed equal values for tyrosine and histidine, at 0.04 and 0.08 g/100g respectively. Even though the two amino acids differ in functions, as tyrosine is non-essential and histidine is an essential amino acid, they have a cross link and a role in cytochrome c oxidase (McCauley et al., 2000).

Lysine requirement measured using different approaches

Type of study	Lysine requirement (mg/kg per day)	Reference
Nitrogen balance	12	*1–3*
	17	*5, 7–9*
$[^{13}C]$leucine oxidation studies		
24-hour multi-level lysine intakes	29	*11*
24-hour multi-level lysine intakes 21-day adaptation	31	*12*
$[^{13}C]$lysine oxidation studies		
Fed state only, multi-level lysine intakes	>20 <30	*17*
24-hour multi-level lysine intakes	30	*18, 19*
$[^{13}C]$phenylalanine oxidation studies		
Fed state only, multi-level lysine intake	37	*14, 15, 10, 16*
	45	
	37	
	35	
$[^{13}C]$leucine oxidation studies		
Leucine retention from wheat (postprandial protein utilization)	18–23	*24, 25*
Recommendation	**30**	

Figure 3.1 Recommended lysine requirement per day

Type of study	Methionine or cysteine requirement (mg/kg per day)	Reference
Nitrogen balance: methionine only	13	*1, 2, 3*
Re-evaluation of nitrogen balance: methionine only	30	*5, 7*
$[^{13}C]$methionine oxidation studies		
Fed state, single intake, no cysteine	13	*62*
Fed state, single intake, variable cysteine	6–13	*73*
Fed state, variable methionine and cysteine	6–13	*74*
$[^{13}C]$phenylalanine oxidation studies		
Fed state, multi-level intakes, no dietary cysteine	13	*63*
$[^{13}C]$leucine oxidation studies		
24-hour multi-level intakes	15	*64*
24-hour multi-level intakes	16	*65*
Obligatory amino acid losses	13	*8, 61, 66*
Recommendation (see assumptions in text)		
Methionine	**10.4**	
Cysteine	**4.1**	
Total sulfur amino acids	**15**	

Figure 3.2 Recommended methionine requirement per day

Even though *S. guineense* and *S. cordatum* are different species, they were on par for most amino acids compared to the study of proximate values, this is possibly because they belong to the same genus.

3.4 Conclusions

In this study, it was evident that all the fifteen studied fruits contain detectable amounts of the proximates and the amino acids tested. The proximate results, based on an overall effect of sample type, were found to be significantly different at $p < 0.05$. This signifies that some indigenous fruits exhibit a very high value, which sometimes supersede its commercial counterpart, while others can be quiet low. This study has shown that indigenous fruits have much higher nutrients than some cultivated fruits. For example, *H. lucida* (white olive) was reported to have a higher protein content of 2.6 g/100g (USDA, 2018) compared to *Psidium guajava* L. (guava) at 2.6 g/100g (USDA, 2018), which stated to have the highest protein compared to other commercialized fruits. Another example is *Phoenix reclinata* (wild date palm) (at 29.89 g/100g) versus *Malus domestica* (apple) (at 2.4 g/100g) which is known to have a high fibre content. Holistically, this study proved that indigenous fruits possess high nutrition content compared to some commercialized fruits.

It was observed that most fruits exhibited an amino acid value that is lower than 1.00 g/100g, however, these results were significantly higher than the daily required intake, meaning the fruits are a good source of protein. All the fruits were considerably higher than the required pattern of amino acid requirements for adults. Overall, no fruit was found to be more superior to the other fruits in every aspect, some fruits showed the highest content of one macronutrient, but the lowest amounts of another.

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CHAPTER 4

The micronutrients of the selected wild edible indigenous fruits of southern Africa

4.1 Introduction

Annually, South Africa loses billion of rands in gross domestic product (GDP) due to vitamin and mineral deficiencies (UNICEF, 2004; Ruzicka, 2017). Faced with this problem, deficiencies of essential nutrients continuously increase the risks of illness/death by suppressing the immune system and increasing vulnerability to numerous diseases (Magaia, 2015). Nevertheless, good health can only be achieved by eating a well-balanced diet, with adequate amounts of minerals and vitamins among other nutrients.

Minerals are nutritional chemical elements of the periodic table, required for the functioning of the body, in order to sustain life (Heber et al., 2016). Most minerals in the human diet are obtained by the ingestion of plants and animals, or in the form of consuming water (Soetan et al., 2010). Minerals are broadly classified as macro (major) or micro (trace) elements. Potassium, magnesium, calcium, sodium, and phosphorus, alongside chlorine and sulphur, are the main quantity elements or macro-minerals, as they are required in amounts greater than 100mg/dl, to maintain the human body's physiochemical processes (Rosborg, 2016). The trace elements or micro-minerals, are required in smaller quantities – less than 100mg/dl (Eruvbetine, 2003; Harris, 2014).

According to Mann and Truswell (2017), mineral elements are required to maintain the human body's metabolism and biochemical processes. Minerals work together to ensure a smoothly functioning body, for example, calcium, phosphorus, and magnesium harden the teeth and strengthen the bones (Abrams and Atkinson, 2003). The fact that the deficiency of minerals can lead to illness symptoms, disease susceptibility, and eventually mortality (Soetan et al., 2010), is proof that minerals are essential to the human body. For example, the lack of calcium may lead to retarded growth and possibility of loss of bone mass. Fruits such as *Cordia sinensis* Lam., *Grewia tenax* (Forssk.) Fiori and *Hyphaene compressa* Gaertn. retain an exceptionally high calcium content (1250 mg, 2750 mg and 3100 mg), they can therefore be used as a source of calcium (Maundu et al., 1999).

Some minerals are ionized in body fluids, or they are bound to organic compounds in formation of phospholipids and hormones. For example, iron is essential to the oxygen-binding heme of haemoglobin, while sodium and chloride ions are the major electrolytes in blood (Marieb, 2015). Low levels of iron may lead to anaemia, which is a major health problem in many parts of East Africa, particularly in women. Previous studies have shown that wild indigenous fruits can have higher mineral content than their cultivated counterparts. For example, *Ziziphus mauritiana* Lam. (Chinese date tree) showed higher iron content (6.30 mg/100g) (Eromosele et al., 1991; Rieger, 2006) in comparison to the exotic commercialised *Prunus armeniaca* (apricot) (USDA, 2018) at 0.39 mg/100g, therefore showing that it has the potential to combat nutrition deficiencies in suffering African countries (Maundu et al., 1999). Another comparative study revealed that *Glycosmis pentaphylla* (Retz.) DC. (orange-berry) had appreciably higher iron content (5.28 mg/100 g) than cultivated fruits such as, pomegranate (0.30 mg/100 g) and guava (0.26 mg/100 g) (USDA, 2018), therefore supporting the opinion that indigenous fruits possess substantial amounts of minerals.

In some areas of Africa, the soils are deficient in iodine; therefore, the diet is also deficient in this mineral. The deficiency of iodine causes goitre and mental retardation in children. This deficiency can be prevented by importation of foodstuffs grown in other areas where there is no iodine deficiency, and by using iodised salt (Weng et al., 2008). Even though the mesocarp of fruits have a slightly lower iodine content in comparison to green vegetables (Haldimann et al., 2005), the seed oils of some wild fruits exhibit a high iodine content e.g. *Blighia sapida* K.D. Koenig (Ackee) at 87.6 g/100g (Eromosele and Eromosele, 1993).

Vitamins are valuable organic compounds that are required in limited amounts for growth and good health (Marieb, 2015). In the absence of vitamins, all the carbohydrates, proteins, and fats that humans eat would be un-synthesised, as vitamins function as coenzymes. The B vitamins act as coenzymes in the oxidation of glucose (Bolander, 2008; Marieb 2015) and low levels of riboflavin, commonly known as vitamin B2, can lead to eye and skin disorders. Most vitamins are not made in the body, so they ought to be ingested as foods or vitamin supplements. Vitamin C (ascorbic acid) is readily obtainable from fruits and fresh vegetables, it is a great antioxidant, essential for collagen synthesis, and it protects the immune system from disease susceptibility (McDowell., 2013). Wild fruits such as baobab (*Adansonia digitata*) and marula (*Sclerocarya birrea*) are exceptionally rich in the vitamin C (270 mg and 179 mg respectively) (Maundu, 1999) than most fruits. Deficiency of vitamin C leads to muscle weakness, joint, and muscle aches, bleeding gums, and leg rashes. Prolonged deficiency may cause scurvy, which is a rare but potentially severe illness (Agarwal et al., 2015). According to Beattie and Geiger (2017), as early as 1564 citrus fruits have been used empirically for the prevention and treatment for scurvy therefore, consumption of wild fruits that are rich in vitamin C could assist in prevention of scurvy, especially in rural areas where wild fruits are freely available (Carpenter, 1988; Kucich and Wicht, 2016). Among the above mentioned vitamins, is vitamin A (retinol) which is produced by the conversion of beta-carotene in the body, for this reason, beta-carotene and substances like it are called provitamins (Kimura et al., 1990). The lack or deficiency of vitamin A may lead to dry-eye disease (xerophthalmia), night-blindness, and eventually complete blindness. Children who are deficient in vitamin A are more likely to die from infectious diseases than healthy children who take vitamin A supplements or nutrients (Akhtar et al., 2013). According to Stommel and Haynes (1994), *Lycopersicon cheesmann* (Riley) (wild tomato) is a good source of beta-carotene (an inactive form of vitamin A), such fruits are mostly yellow-orange pigmented and have been found to have significantly high carotenoid levels (Saini, 2015). Such wild fruits are important contributors to healthy diets and in reducing the onset of chronic diseases (Khoo et al., 2011).

This chapter presents the research findings based on the minerals, vitamin A and vitamin C of the selected wild edible indigenous fruits of southern Africa. This chapter provides the material and methods in section 4.2, results and discussion in section 4.3, conclusions in section 4.4 and the references in section 4.5.

4.2 Materials and Methods

4.2.1 Mineral analysis

a) Microwave digestion

The samples were digested using microwave digestion (CEM One Touch™ Technology, CEM Technologies, and USA). Approximately 0.5 g of each sample was weighed into Teflon tubes (MARSXpress - High Throughput Vessels), and mixed with 10 mL HNO^3. A blank solution consisting of just the digesting acid (i.e. without sample) was prepared and digested along with the samples. Temperature conditions of the microwave-digester were as follows; temperature program was 25 – 170 °C for 10 min and 170 °C- 240 °C for another 10 min at 1000 W, followed by immediate ventilation at room temperature for 20 min. The resulting solutions were cooled and made up to the mark with Milli-Q water (Millipore, Bedford, MA) in a 50 mL volumetric flask.

b) Inductively coupled plasma optical emission spectrometry (ICP-OES) analysis

Stock and working standard solutions were prepared by using ICP - OES standard solutions of each metal to be analysed. The concentrations ranged from 0.1 – 40 μg/mL and the samples were analysed for aluminium (Al), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), phosphorus (P), lead (Pb), selenium (Se) and zinc (Zn). The triplicate samples were then analysed on an ICP-OES equipment (Spectro ARCOS, Spectro Analytical Instruments, Kleve, Germany) instrument, under the instrumental conditions presented in Table 4.1 and at wavelengths associated with foods (Table 4.2). Results obtained are expressed as mg/kg dry weight of the sample.

Table 4.1 - ICP OES working conditions

Parameters	**Conditions**
RF power (emission intensity)	1200 W
Nebulizer type	Concentric
Nebulizer flow	0.5 L/min
Gas (as 600 kpa)	Argon
Plasma gas flow	10 L/min
Auxiliary gas flow	0.5 L/min
PMT volts	600 V
Sample flow	0.9 mL/min
Rinse time	5 min

Table 4.2 - Detection wavelengths (Nölte, 2003)

Element Detection	**wavelength (nm)**
Al	396.152
Ca	317.933
Fe	259.940
K	766.490
Mg	285.213
Mn	257.610
P	178.287
Pb	220.353
Se	196.026
Zn	206.200

4.2.2 Vitamin A and C analysis

a) Standard preparations

The vitamin standard solutions were prepared in ultra-pure water (for water-soluble vitamins) or methanol (for fat-soluble vitamins) and stored in the dark at 4 °C. The stock standard solutions for vitamin A and C was prepared by dissolving 25 mg of ascorbic acid in a 25 ml volumetric flask and adding HPLC grade methanol to the mark and three calibration standards for each standard was prepared to establish the linearity of each vitamin.

b) Extraction of water- and fat-soluble vitamin

One gram of the respective samples was weighed into centrifuge tubes and 4 mL solution of [0.01% Triflouoroacetic acid (TFA) (pH 3.9): HPLC grade methanol (50:50 v/v)] was added to them. The mixtures were vortexed, centrifuged (14 000 × g, 4 ◦C for 15 min), and the supernatants evaporated to dryness in a rotary vacuum evaporator. The residues were further reconstituted with 1 mL solution of 0.01% TFA: HPLC grade methanol, 50:50 (v/v) and filtered through a 0.45 μm filter prior to HPLC analyses.

b) Determination of water-soluble vitamin

Mobile phase was prepared with methanol/water in the ratio 60/40 and 0.01% TFA was used to adjust the pH of the mobile phase. A 25 mg standard stock solution was prepared in 25 ml volumetric flasks and made up to the mark with HPLC grade methanol. A series of standard solutions was then prepared from the stock solution into 25 ml volumetric flasks. The standards were loaded into the auto sampler of the HPLC with the samples and chromatographed at wavelength of 254 nm using a mobile phase flow of 1 ml/min.

c) Determination of fat-soluble vitamin

The mobile phase was prepared the same way as for water-soluble vitamins, the only difference is that the determination was done at the wavelength of 280 nm. Both separations used a C_{18} reverse column with 5µm particle size with I.D. 460 x 250 mm and a UV detector.

4.3 Results and discussion

The results presented in table 4.3, demonstrate the contents of the minerals that were tested in the selected wild edible indigenous fruits. Similar to Amarteifio and Mosase's study (2006), which analysed the selected wild edible indigenous fruits in Botswana and Ca, K, and Mg were the most abundant elements in this study. Calcium is essential to bone structure and function, the highest level of this mineral (14289.451 mg/kg) was recorded for *C. edulis* while *E. magalismontanum* gave the lowest calcium content (409.899 mg/kg). According to Del Valle et al. (2011), children between the ages of 4-8 years require 1,000 mg/d of calcium, as they are in crucial stage of growing and development, this mineral is a building block for strong, healthy bones and teeth. In this study 14289.451 mg/kg of calcium was recorded for sour fig, meaning 100g of sour figs, will have 428 g extra of calcium. Therefore supporting the statement that wild edible indigenous fruits could bridge nutrition gap in rural communities.

Potassium is essential for its ability in conducting electrolytes and structuring of red blood cells in order to maintain a well-functioning metabolism (Marieb, 2015). In this study, it was observed that K was higher in indigenous fruits compared to some popular cultivars i.e. bananas contain 3580 mg/kg of potassium (USDA, 2018). Magnesium, the element that maintains nerve and muscle function, was the third highest, at 2283.531 mg/kg in *Syzygium cordatum*. The levels of Al and Mn were relatively low compared to other elements. *Carpobrotus edulis* recorded the lowest value of Mn at 0.026 mg/kg. The data report shows that the richest plant source of Fe is *Cordyla africana* (186.922 mg/kg) followed by *Syzygium* *cordatum* at 54.378 mg/kg. *Cordyla africana* also had the highest mineral concentrations for Al, Mn, Pb, Se, and Zn (176,229; 164.660; 216.735; 368.982 and 191.007 mg/kg respectively), making it the richest in minerals in this study. Trumbo et al. (2001) states that the required daily intake of iron, for children between 4-8 years of age is 10 mg/d, meaning 100g of the wild mango possess 8.69 mg extra of iron content.

Table 4.3 - List of edible plants; and minerals

Taxon	Minerals (mg/kg)									
	Al	**Ca**	**Fe**	**K**	**Mg**	**Mn**	**P**	**Pb**	**Se**	**Zn**
Apocynaceae										
Carissa macrocarpa	ND	1282.353	10.827	13123.299	922.297	ND	1022.747	130.848	273.102	19.483
Arecaceae										
Phoenix reclinata	ND	585.644	ND	6901.835	1122.170	ND	879.849	116.688	301.610	23.454
Chrysobalanceae										
Parinari curatellifolia	6.804	3851.677	3.715	10534.429	1564.415	ND	508.863	109.316	283.483	19.698
Clusiaceae										
Garcinia livingstonei	ND	461.061	ND	10757.725	879.517	6.794	1197.016	118.403	348.736	23.696
Fabaceae										
Cordyla africana	176.229	717.850	186.922	8124.226	550.903	164.660	825.814	216.735	368.982	191.007
Flacourtiaceae										
Dovyalis caffra (EC)	9.354	521.946	ND	7372.560	610.308	ND	889.712	119.910	321.403	25.998
Dovyalis caffra (NEL)	25.257	530.0585	2.281	8477.686	570.429	ND	929.047	132.536	308.215	ND
Dovyalis longispina	35.0001	1502.603	29.534	ND	983.414	103.950	1409.130	124.218	354.640	30.035
Mesembryanthemaceae										
Carpobrotus edulis	ND	14289.451	9.436	11431.741	2247.921	0.026	843.657	108.331	241.450	17.384
Myrtaceae										
Syzygium cordatum	15.571	2503.536	54.378	14270.842	2283.531	8.941	1390.744	114.766	296.930	19.349
Syzygium guineense	11.871	1725.049	22.627	ND	1548.621	ND	1242.661	118.065	262.356	ND
Sapindaceae										
Pappea capensis	34.601	2517.1647	26.092	9772.178	1044.511	1.183	1251.268	110.743	336.452	20.880
Sapotaceae										
Englerophytum magalismontanum	108.561	409.899	26.534	8464.409	776.848	50.439	717.611	130.771	285.951	25.308
Manilkara mochisia	12.515	2039.926	ND	10782.053	1086.346	ND	892.509	101.017	342.581	ND
Scrophulariaceae										
Halleria lucida L.	57.326	2031.613	7.384	ND	1260.667	4.096	1778.510	110.703	302.874	23.309

ND = Not detected

Al: Aluminium, Ca: calcium, Fe: iron, K: potassium, Mg: magnesium, Mn: manganese, P: phosphorus, Pb: lead, Se: selenium, Zn: zinc

For all fruits, the lead contents were ranging from 101.017 mg/kg to 216.735 mg/kg. Lead is regarded as a toxic mineral especially in children, however, there are no precise records indicating the safest level of lead intake (Rossi., 2008). *Halleria lucida* recorded the highest phosphorus content (1778.510 mg/kg) while *Parinari curatellifolia* was at the lowest at 508.863 mg/kg. When comparing the phosphorus content of *H. lucida* and *Prunus domestica* at 16 g/100g (USDA, 2018), this shows wild indigenous fruits contain significantly high micronutrients than some exotic fruits.

The mineral contents of *Dovyalis caffra* samples from Mqanduli in the Eastern Cape (EC) differed slightly from the Nelspruit (NEL) samples. Figure 4.2 shows the comparison between the fruits from the two localities. The only significant difference was observed for the K content, where the Nelspruit Kei-apple had 1105.126 mg/kg higher than the Mqanduli Kei-apple (7372.560 mg/kg). The levels for the K contents in the Nelspruit Kei-apple (8477.686 mg/kg or 847.7686 mg/100g) were much higher in comparison to the 232 mg/100g obtained by Du Preez (2007).

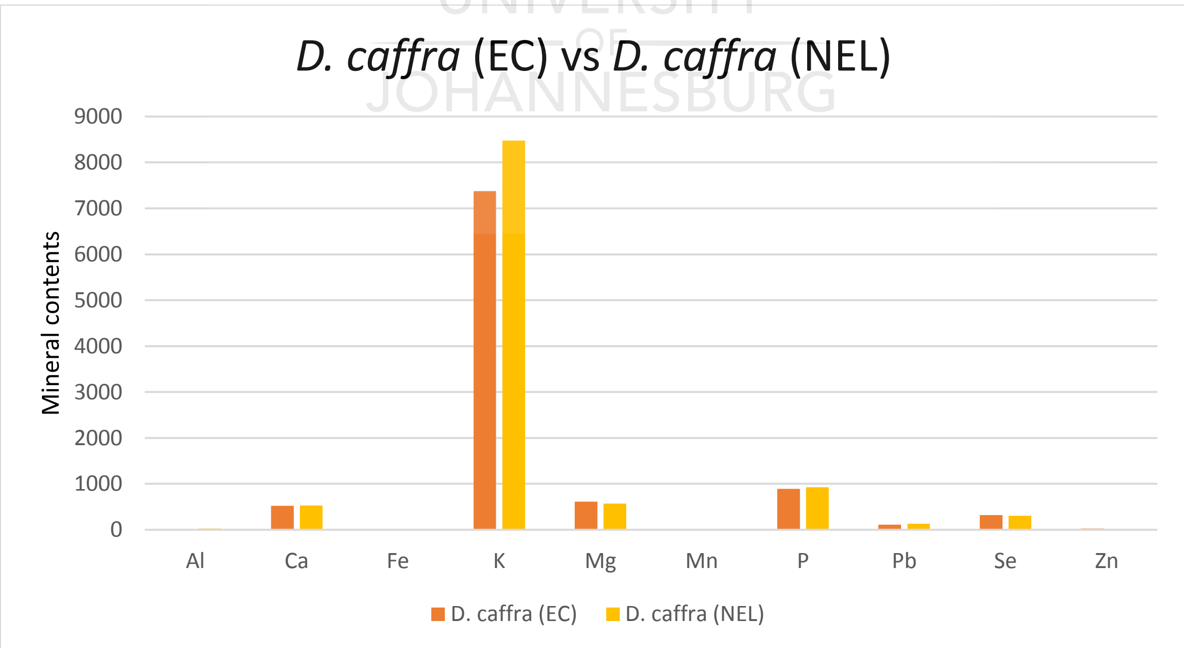

Figure 4.1 Mineral elements of *D. caffra* (EC) vs *D. caffra* (NEL)

The Mn content for both fruits was beyond detectable levels for the Eastern Cape and for the Nelspruit material. The comparative study between the two fruits revealed *D. caffra* from Nelspruit to be slightly superior in respect of mineral elements composition. When comparing *S. cordatum* and *S. guineense* in figure 4.2, the two species showed different mineral contents for Ca, K, Mg, and P. The concentrations for Se, a chemical component of glutathione peroxidase, was more or less similar in both fruits, differing by only a 34.574 mg/kg. Nevertheless, *S. cordatum* recorded the highest levels of Ca, K, Mg, Pb and Se compared to *S. guineense*. As for the latter species, the K content was below the detection limit of the instrument, for this element. The elements Al, Fe, Mn, and Zn were also below detection for both fruits. Statistically, the Ca values for both fruits were higher compared to some commercialised berries i.e. strawberries (160 mg/kg) and grapes (140 mg/kg) (USDA, 2018), as such, *S. cordatum* and *S. guineense* can serve as a good source of Ca and could be further processed for calcium nutritional products. The comparative study between the two fruits revealed that *S. cordatum* is richer in minerals compared to its relative *S. guineense* meaning, *S. cordatum* would be the best fruit for commercialization.

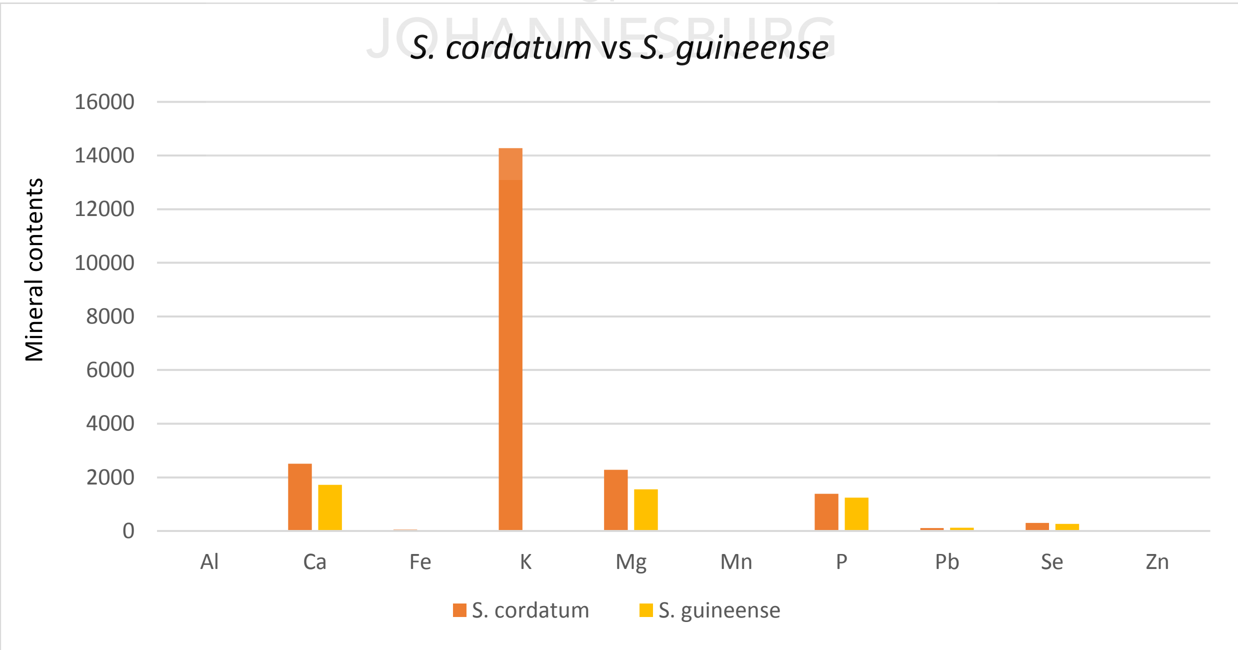

Figure 4.2 Mineral elements of *S. cordatum vs S. guineense*

Table 4.4 displays the summarized values for fat soluble vitamin A (retinol) and water soluble C (ascorbic acid), of the selected wild edible indigenous fruits of southern Africa. The quantity of all vitamins in all fruit samples is expressed as mg/100g. The extent of vitamin A in fifteen wild edible fruits ranged from 1.742 mg/100g to 902.888 g/100g. The content of vitamin A was found highest in *D. longispina*, followed by a good amount that was detected in the fruits of *Manilkara mochisia* (25.3067 mg/100g) and *Garcinia livingstonei* (11.197 mg/100g). Retinol plays a crucial role in the eyes, by detecting light and enhancing night vision in the retina and the lack of this vitamin causes night blindness (Ross, 2010).

The highest ascorbic acid content was found in *D. caffra* from the Eastern Cape at 8.3518 mg/100g and the lowest in *C. africana* at 0.1518 mg/100g. The amounts for the Kei-apple were high in this study but incomparable to those captured in a study conducted by Du Preez et al. (2003), which was 83 mg/100g. The Kei-apple from Nelspruit, showed lower quantities of ascorbic acid than the fruit from the Eastern Cape (1.569 mg/100g), however, both fruits showed absence of retinol. In this regard, solid phase extraction method should be used for best vitamin recovery. This technique removes irrelevant substances that would interfere with the analysis and then enhance the concentration of the targeted compounds to allow for trace level detection (Rodriguez-Mozaz et al., 2007).

The chromatogram (in Appendix A, Figure 6.14) showed that there is a presence of other ingredients in the samples, which showed interferences with both ascorbic acid (vitamin C) and retinol (vitamin A). According to Del Valle et al. (2011), 75 mg of vitamin C is required for a 14 – 18 year old female per day, meaning that 900 g of the Kei-apple from Manquli, Eastern Cape will be sufficient to be consumed in a period of 24 hours. The HPLC chromatogram of *Phoenix reclinata* (in Appendix B, Figure 6.1) indicated the presence of vitamin C and the absence of vitamin A. The amount of vitamin C in the wild date palm is 0.9535 mg/100g, which is lower than the 6.5 mg/100g recorded by Cunningham and

Wehmeyer (1988). The chromatogram showed the presence of the fat soluble vitamin A (indicated in red), however, the vitamin was not quantified. These results could be attributed to the fruit storage technique, nutrient levels in the soil and or the vitamin analysis technique.

Table 4.4 - List of edible plants; common names; and vitamins

Taxon	Common name	Vitamin mg/100g	
		A	**C**
Apocynaceae			
Carissa macrocarpa	Natal plum	ND	0.7737
Arecaceae			
Phoenix reclinata	Wild date palm	ND	0.9535
Chrysobalanceae			
Parinari curatellifolia	Mobola plum	ND	ND
Clusiaceae			
Garcinia livingstonei	African mangosteen	11.197	ND
Fabaceae			
Cordyla africana	Wild mango	ND	0.1518
Flacourtiaceae			
Dovyalis caffra	Kei-apple (EC)	ND	8.3518
Dovyalis caffra	Kei-apple (NEL)	ND	1.569
Dovyalis longispina	Natal Kei-apple	8	ND
Mesembryanthemaceae			
Carpobrotus edulis	Sour fig	ND	0.1536
Myrtaceae			
Syzygium cordatum	Water-berry	ND	1.576
Syzygium guineense	Water-berry	1.742	ND
Sapindaceae			
Pappea capensis	Jacket-plum	ND	1.2448
Sapotaceae			
Englerophytum magalismontanum	Stamvrug	ND	1.6319
Manilkara mochisia	Lowveld milkberry	25.3067	ND
Scrophulariaceae			
Halleria lucida L.	White olive	ND	0.521

ND = Not Detected

The jacket-plum showed a satisfactory amount for vitamin C (1.2448 mg/100g), which is 8 times greater than those of the wild mango (0.1518 mg/100g) and the sour fig (0.1536 mg/100g). *Syzygium cordatum* was separated on the HPLC system and vitamin C quantity was detected at 1.576 mg/100g. Surprisingly no ascorbic acid nor retinol were recorded for *Parinari curatellifolia*. Vitamin A was expected to elute within 1 minute and vitamin C within 4 minutes but no peak was detected within these periods. These results might be due to the low detection limit. Armbruster and Pry (2008) state that some contents are far above the low analytical limits therefore it is highly unlikely that action could take place. It is therefore important to fully characterise the performance of every test to maximise its performance. These results could also be attributed to parameters such as preservation time, or technical issues such as extraction method.

4.4 Conclusions

This study proved that the wild edible indigenous fruits are rich in Ca, K, and Mg. It was evident that some wild fruits possess higher mineral nutrients than some of the commercialized fruits when compared. Even though the results demonstrated satisfactory and consistent levels of the vitamins, the results were comparable to other studies, where vitamin C was a dominant source in most fruits. Overall, the chromatographs of the fruit samples show that the method used for analysis is selective for both vitamins therefore other methods can be explored in future studies.

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CHAPTER 5

Conclusions and recommendations

5.1 Introduction

The purpose of this study was to document the wild edible indigenous fruits of southern Africa and identify the knowledge gaps on the nutritional value of these fruits, then to assess the nutritional value of selected fruits. The underlying goal was to determine whether or not the fruits have received research attention, especially for their nutrition and how much nutrient content they possess. This chapter outlines concluding remarks from the research and provides recommendations for further studies.

5.2 Conclusions of research findings

5.2.1 The ethnobotanical survey of the wild edible indigenous fruits

The majority of the listed fruits had a large knowledge gap with regard to nutritional information and this study has provided identification and documentation of those that need attention. This study has added nutritional information which was previously lacking, in addition to ethnomedicinal information of indigenous plants. It was noted that some of the fruits surveyed are not indigenous i.e. *Opuntia ficus indica* (L.) Miller, *Rubus rigidus* Sm., *Langenaria siceraria* (Mol.) Standl. etc., but can be regarded as naturalised alien species since they have been growing in the region for many decades, such fruits were then removed in the list. Naturalised alien species are easily mistaken as native species, since they are aliens that reproduce consistently in the area, without any direct human intervention (Maroyi, 2012).

Based on the literature survey reported in Chapter 2, it can be concluded that most of the species which have been successfully commercialised, were supported with adequate background research, highlighting some of their marketable properties. In this regard, substantial research appears to play a big role in the utilization and marketing of wild edible indigenous fruits. The fruits investigated for nutrition were selected based on their nutrition knowledge gaps, availability, as well as quantity and quality of harvest. For example, the wild apricot (*Ancylobotrys capensis*) was harvested, but the quantity was low and the quality was poor (due to microbial invasion), therefore, this fruit was eliminated from this study. This challenge is anticipated to be one of the barriers for expanding nutritional data for wild edible indigenous fruits.

5.2.2 Macronutrients of selected wild edible indigenous fruits

The present study has examined the macronutrients of selected wild edible indigenous fruits, and attempted to estimate their dietary importance relative to some of the commercial fruits and also in relation to the dietary recommended daily allowance (RDA). The best combination of fruits to meet daily requirements would be *Phoenix reclinata* (fibre), *Syzygium guineense* (fat) and *Halleria lucida* (protein).

From the literature review a large knowledge gap for amino acids was depicted, the investigation of this nutrient was not filled for all fruits except for *S. cordatum* and *E. magalismontanum*, which were the only fruits previously tested (Rampedi, 2010; Maliehe, 2015). The most striking results were for lysine content of the jacket plum, where the jacket-plum met and exceeded the required daily intake recommended by WHO. This study also showed that most indigenous fruits have a high moisture content, meaning that adequate consumption can keep the body hydrated. These research findings also support their beverage production for future markets.

5.2.3 Micronutrients of selected wild edible indigenous fruits

This part of the study was essential for shedding light on the mineral nutrient potential of the fruits, as it quantified the minerals, indicating how they compare with dietary standards and the amount of fruits needed to bridge the nutrition gap per day. From these research findings, substantial vitamin C concentrations were observed and can be further extended to the commercialization of vitamin C products, such as tablets and juices. Nevertheless, literature indicates that these fruits possess even higher concentrations, therefore, with testing optimisation and improvement, the indigenous fruits could show elevated vitamin potential, as these fruits untapped commercialisation potential.

The mineral properties of *Halleria lucida*, *Phoenix reclinata*, and *Dovyalis longispina* among others, were analysed for nutrients for the first time, thus adding new knowledge to literature. Even though the results showed outstanding amounts of micro-minerals for most fruits, utilization and commercialization can be restricted to biodiversity policies and legislations, such as the National Environmental Management: Biodiversity Act (NEMBA) (2004) and the Convention of Biological Diversity (CBD) among others. These laws provide protection and sustainable uses of ecosystems as well as the equitable sharing of benefits, emanating from bioprospecting initiatives (Government of South Africa, 2015). Currently, there are many challenges in South Africa regarding the interpretation and implementation of these legislations. These policies and other international conventions that South Africa is party to, can also hinder plant collections and bioprospecting of these indigenous fruits.

5.3 Recommendations for future research

In the case that selected the species are further studied for commercialisation, cultivars with desired properties such as extended shelf life and enhanced growth should be considered. For example, literature highlights the difficulty in attempting to propagate the mobola plum from seeds, therefore new grafting techniques are needed for it to thrive in the commercial markets. Another example, is the natal plum, the fruit has growing commercial interest, however, its market growth could have been hindered by the fact that the fresh fruit can be easily damaged post-harvest, as it is thin skinned, and needs extra handling care (National Research Council, 2008). A study conducted by Rampedi (2010) advocates that the Kei-apple as well as African mangosteen exhibit commercial development potential. However, the most important decisive factor for commercialization highly depends on cultivation and preservation with which the Kei-apple could be limited by, as the fruit is very soft and fragile.

For vitamin analysis, it is recommended that solid phase extraction (SPE) is used, as it removes extraneous substances that could interfere with the analysis and therefore to allow for trace level detection for targeted compounds (Zdravkovic, 2017). Improved techniques will assist in retaining and enhancing some of the desirable nutrient characteristics noted in this study, as well others that weren't investigated in this project.

Future research can be extended to western Africa, sub-Saharan Africa and other African regions as a whole. From the 29 fruits that were depicted from the ethnobotanical survey, only a few were tested, leaving most fruits outstanding, therefore future studies are recommended to fill in the existing gaps. Moreover, the sensory analysis was not an objective for this study but some fruits indicated an array of aromas and flavours. This is also another aspect that can be investigated in future.

5.4 References

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PART C

APPENDICES

APPENDIX A

Some background information on the selected fruits including their morphology

Carissa macrocarpa

Figure 6.1 *Carissa macrocarpa*
Source: https://www.monrovia.com/plant-catalog/plants/695/tomlinson-natal-plum/

Carissa macrocarpa is a member of the Apocynaceae family and is indigenous to Kwa-Zulu Natal, thus popularly known as the natal-plum (Wehmeyer, 1966; Singhurst and Holmes. 2010). The plant has shiny leaves with thorns, and secretes a white milky sap which has been anticipated to be toxic, thus the genus is called Apocynaceae (Dogbane), which means 'it kills dogs easily' in Greek (Simpson, 2010). Nevertheless, studies have proven that the plant may be toxic except for the fruits which have numerous food uses (Carolus, 2004). This evergreen ornamental shrub grows up to 4 m high and has oval to sphere red fruits as seen on Figure 6.1. The taste of the fruit is described as a slightly sweet cranberry or a tart taste (Sparrow and Hanly, 2002). Numerous fruit recipes are available online, to make jams, sauces, cordial, pies and jellies (National Research Council, 2008; Van Wyk, 2011). During the fruiting period large quantities are sold along the roads of southern Kwa-Zulu Natal.

Phoenix reclinata

Figure 6.2 *Phoenix reclinata*
Source: https://www.worldwidefruits.com/genus-phoenix.html

Phoenix reclinata, commonly known as the wild date palm, is native of tropical and southern Africa (Von Fintel, 2004). It is one of the highly utilized palms of the Arecaceae family, after the domesticated date palm *Phoenix dactylifera* L. The wild date palm bears orange-brown oval-shaped fruits (Figure 6.2) that appear from February to April, however, the fruits of wild date palm are smaller than their well-known relative, the domesticated date palm (Aubrey, 2004; Kim, 2012). The wild date palm fruits are clustered and are about 2.5 cm in diameter, with a nut-like seed and they attract wildlife (Roodt, 1992). The fruits can be eaten raw or cooked, nonetheless, they are more popular in wine (palm wine) (Cunningham and Wehmeyer, 1988; Lim, 2012). The alcoholic beverage has been very famous among the people of Maputaland, KwaZulu-Natal Province, South Africa. According to Cunningham (1990), the palm wine generated R157 732 [US $145 113] in 1982. The wine was transported across the region and provided employment to 460-480 people. These profits can be increased if there is commercial interest of this plant, however, this is also highly dependent on the research status of the fruit.

Parinari curatellifolia

Figure 6.3 *Parinari curatellifolia*
Source: https://commons.wikimedia.org/wiki/File:Parinari_curatellifolia(fruit).jpg

The mobola plum (*Parinari curatellifolia*) belongs to the family Chrysobalanceae. *Parinari curatellifolia* has a mushroom-shaped canopy and occurs in woodlands and savannas throughout southern Africa (FAO, 1983). It is widespread in Zambia, Zimbabwe, and the low-lying region of South Africa. Its height can stretch up 15 to 12 m (ICRAF, 2010; DAFF, 2015). It blooms small white flowers that appear between July and November and bears oval-shaped fruits that are 25 to 50 mm long (Joulain et al., 2004; Maharaj and Glen, 2008). The fruits are yellow in colour, containig a rough skin with golden warts on surface (Figure 6.3), and a seed stone that contains the kernel/nut (Benhura et al., 2012). The nuts are rich in oils and can be mixed with vegetables as a substitute for almonds (Orwa et al., 2009). The fruits are eaten fresh as a snack, cooked as porridge, or fermented for beverages, such as juice or alcohol (Storrs, 1979). According to a study conducted by Prins and Maghembe (1994), *P. curatellifolia* requires partial or complete removal of the seed coat in order to achieve some germination.

Garcinia livingstonei

Figure 6.4 *Garcinia livingstonei*
Source: https://mygardenofdelights.com/catalog/product/gallery/id/51/image/54/

Garcinia livingstonei (African mangosteen) is a member of the Clusiaceae family, and the only one of the 400 species from the *Garcinia* genus found in Asia and Africa (National Research Council, 2008; Orwa et al., 2009). The African mangosteen is an evergreen shrub with a dense crown that can grow up to 10 m tall (Orwa et al., 2009). It has simple leathery leaves that vary in shape during its life cycle. It blooms flowers that are 6 to 14 mm and are white in colour. The plant bears orange berries (Figure 6.4) with 1 or 2 seeds (in June), that produce an acid sweet taste when ripe, and are later available in spring and summer (Rampedi, 2010). The fruits are edible, and can be eaten raw or cooked. The African mangosteen is one of the indigenous fruits used to make liquors using traditional methods (Coates-Palgrave, 2002).

Research has proven that there are health benefits from the African mangosteen i.e. the fruits are used for treating mumps (Kaikabo and Eloff, 2011; Joseph, 2017). According to the National Research Council (2008), there is a lot of potential in processing the fruit into food products, such as pulps and juices.

Cordyla africana

Figure 6.5 *Cordyla africana*
Source:
https://www.zambiaflora.com/speciesdata/imagedisplay.php?species_id=127230&image_id=8

Cordyla africana is a wild mango tree belonging to the legume family Fabaceae, and it can grow up to 10-25m tall (Ngobese et al., 2018). The wild mango occurs in low altitudes, along rivers and streams. Even though the wild mango belongs to a legume family, the fruits are only pod-shaped at their early stages, then become spherical when ripe (Figure 6.5). The ripe fruits are golden yellow in colour, thin-walled, with 1or 2 large seeds. The unripe fruits fall from the tree to the ground, in order to complete its ripening process and therefore germinate (Meyer, 2006).

Dovyalis caffra

Figure 6.6 *Dovyalis caffra*
Source: http://www.specialtyproduce.com/produce/Kei_Apple_13091.php

Dovyalis caffra, previously known as *Alberia caffra*, is a member of the wild peach family Flacourtiaceae, and is indigenous to Malawi, Mozambique, South Africa, and Zimbabwe (Sturtevant, 1919; National Research Council, 2008). *D. caffra* is a tall shrub that grows well in subtropical regions, with rainfall of 1,000-1,700 mm, it is drought resistant and can tolerate saline soil (National Research Council, 2008; Rampedi, 2010). The fruit is commonly known as the Kei-apple, however, it is more like an apricot in character. As seen on Figure 6.6, the sphere shaped fruits contain a fleshy pulp with 1 to 3 seeds, and a very acidic and or sour taste (Abdel-Fattah et al., 1975; Orwa et al., 2009). According to National Research Council (2008), the sourness of the fruit may have hindered the crop's wider acceptance however, in today's market, even the sourest fruit can be successful (e.g. lemons, grape-fruits etc.). Many people have used the fruit to make jams, juice and marmalades. The Pedi people of Limpopo, South Africa, add the Kei-apple juice into their sorghum or maize porridges (National Research Council, 2008). The species has a wide variety of fruits that taste differently i.e. this study therefore investigates fruits from different locations, consequently, the best can be promoted for commercial markets.

Dovyalis longispina

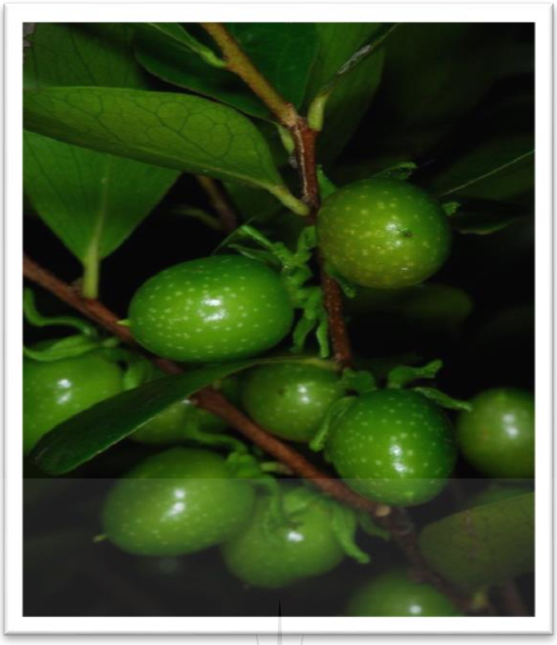

Figure 6.7 *Dovyalis longispina*
Source: https://za.pinterest.com/pin/575334921130776381/

Dovyalis longispina is commonly known as the natal apricot, belonging to the Flacourtiaceae family (Van Wyk and Gericke, 2000). The plant favours coastal regions for grown such as the Kwa-Zulu Natal coast. The leaves drop during flowering in summer, but new leaves re-appear immediately. As shown in Figure 6.7, fruits are green when raw, but delicious, edible, and red with white spots when ripe. The fruits attract birds to the garden. There are limited records on the natal apricots food use and other uses, however, this fruit has a delicious tomato-like taste, and is anticipated to be of good nutritional value. The plant has long, thin spines that make it an ideal plant for a security hedge, and it is also an attractive garden plant (Wild Flower Nursery, 2018).

Carpobrotus edulis

Figure 6.8 *Carpobrotus edulis*
Source: http://gardenboy.co.za/plants/plants_view.php?plant_id=267

Carpobrotus edulis, commonly known as the sour fig, belongs to the Mesembryanthemaceae family. The family includes succulents and other popular figs that are distributed all around the world (Vilà and D'Antonio, 1998). The sour fig is an undemanding succulent ground cover plant, which grows well in sandy soils (Watt and Breyer-Brandwijk, 1962). *Carpobrotus edulis* is known to grow in all soil types of coastal regions of South Africa, however, it is known as an alien invasive in Europe (D'Antonio, 1993; Delipetrou, 2006). The plant produces yellow to pink solitary flowers in August and September, that later produce ombre yellow and pink edible fruits (Figure 6.8), and a sticky/tart-like taste, thus called sour figs (Malan and Notten, 2006). The fruit can be eaten fresh or made into jam. The leaves are as edible as the fruits and are vastly used as a traditional remedy for treatment of sinusitis, diarrhoea, infantile eczema, tuberculosis and other internal chest conditions (Van Wyk, 1997). Even though the sour fig jam has gained popularity in Cape Town markets, its nutritional value remains unknown in literature. Sour figs can be easily grown from seed or by cuttings (Wisura and Glen, 1993), thus increasing its chances for agricultural purposes.

Syzygium cordatum

Figure 6.9 *Syzygium cordatum*
Source: Dr Ian Cock, St Lucia, South Africa, 2013

Syzygium cordatum is an evergreen, medium-sized tree of the Myrtaceae family, which grows up to a maximum of 20 m in height. The tree grows well near water and is native to the east and southern Africa (Orwa *et al*., 2009). The genus name, '*Syzygium'*, is derived from the Greek word 'syzgios' (paired), in description of the opposite leaves and twigs that grow from the same point. *Syzygium cordatum*, commonly known as the water berry, produces cream white to pinkish sweet scented flowers, that yield to deep pink or purple-black sweet berries, as seen in Figure 6.9 (Orwa et al., 2008). The fruits are ovoid in shape and contain a large amount of water, hence called water berry. The fruits are eaten fresh or made into a drink by soaking them in water for some hours (Palmer & Pitman, 1972; Tredgold, 1986). The fleshy fruit is edible, slightly acidic in flavour, and has a promising market in the beverage industry. The fruit has been used for making jam and/or jelly from a ripe fruit. Fruits are usually eaten by animals (monkeys, birds etc.) and they play a big role in seed dispersal (Carolus, 2004).

Syzygium guineense

Figure 6.10 *Syzygium guineense*
Source: http://www.africanplants.senckenberg.de/root/index.php?page_id=78&id=2118

Syzygium guineense, also known as water berry, is a widespread tree of Sub-Saharan Africa, belonging to the Myrtaceae family (Bankefa et al., 2014). The water berry is an evergreen tree that grows to about 15-30 m high (Orwa *et al*., 2009). As seen in Figure 6.10, the fruits are ovoid or ellipsoid drupes that are whitish-green when immature. They turn shiny purplish-black and become sweet and juicy after ripening. The ripe fruits are edible for humans, birds, and some wild animals (Orwa *et al*., 2009; Zenze, 2013).

Pappea capensis

Figure 6.11 *Pappea capensis*
Source: http://redlist.sanbi.org/species.php?species=3842-1

Pappea capensis, commonly known as the jacket plum, belongs to the litchi family Sapindaceae. The jacket plum is widespread in southern Africa and can grow up to 3.9 m tall, depending on the environmental conditions (Van Wyk and Gericke, 2000; Mng'omba et al., 2007). This evergreen plant has simple leaves that are oblong and wavy; and the edible fruits are used to make jam, jelly, and vinegar (Figure 6.11) (Fivaz and Robbertse, 1993; Venter and Venter, 1996). The seeds are rich in oil, and has the potential as a source of bio-fuel (Mng'ombaa et al., 2007). According to Palmer and Pitman (1972), the seedling growth is very slow, however, vegetative propagation is more preferable. The jacket plum seeds are rich in non-drying and viscous oil, which is used for making soap and oiling guns (Van Wyk and Gericke, 2000).

Englerophytum magalismontanum

Figure 6.12 *Englerophytum magalismontanum*
Source: http://pza.sanbi.org/englerophytum-magalismontanum

Englerophytum magalismontanum is a popular species of the Sapotaceae family, with about 22 native species that are differentiated by features such as their milky latex (Van Wyk 1997). The plant is widely distributed, ranging from the east coast of South Africa, all the way up to Zimbabwe (Van Wyk and Gericke, 2000). The fruits are densely crowded on the stem, hence the name stemvrag in Afrikaans. According to Coates-Palgrave (2002), the fruit is a small to medium (3-10 m), evergreen (Figure 6.12), and occurs on a variety of landscapes. *Englerophytum magalismontanum* possess small star-shaped brownish pink flowers that are unpleasantly scented and flower from June to December. The fruits are small-medium in size, red to pink in colour and ripen from December to January. The fruits are used for making syrup, jelly, jam, wine, vinegar and are sometimes distilled to produce an alcoholic drink known as mampoer (Van Wyk et al., 2000). Recipes for jam and vinegar are available in Rood's (1994) book, and these recipes can be further utilized for business ideas. The stamvrug is one of the essential species already involved in local subsistence trade and domestication trials.

Manilkara mochisia

Figure 6.13 *Manilkara mochisia*
Source: https://www.mozambiqueflora.com/speciesdata/imagedisplay.php?species_id=143820&image_id=6

Manilkara mochisia (lowveld milk berry) is an evergreen shrub of the Sapotaceae family and it can grow up to 20 m high (FAO, 1983; Van Wyk, 2011). This low branched tree is common in dry woodlands. The flowers are white or light yellow, bearing yellow spherical fruits (Figure 6.13) that are sweet, juicy and soft, and edible when eaten raw. Inside the juicy pulp are 1 to 3 seeds which are discarded when eaten (Van Wyk, 2011). The plant has been a source of food and medicine for the communities of southern Africa and it is also common to in Tanzania (Willan, 1984) where it naturally receives between 508 and 1270 mm annual rainfall. The species grows well in coarse sandy soil. Willan (1984) observed that the lowveld milk berry flowers in November while fruit ripening takes place in March and June. The fruit has economic potential, and the bark shows prospect for medicine and fuel (FAO, 1983; Ruffo, 2002).

Halleria lucida

Figure 6.14 *Halleria lucida*
Source:
http://www.westafricanplants.senckenberg.de/root/index.php?page_id=47&id=3009#image=26634

Halleria lucida (white olive) is a cauiliflorous shrub of the Scrophulariaceae family that is found near rivers and streams of the eastern coast of South Africa, to the northern provinces (such as Limpopo) (Marloth, 1932). The *H. lucida* tree is an evergreen tree, single or multi-stemmed, with opposite leaves that are simple, and shiny (Van Wyk et al., 2000). It blooms nectar rich tubular flowers that are orange-red and regularly visited by sunbirds and sugar birds (Stirton, 1977). The flowers occur in autumn to summer and later followed by spherical green berries from August. As seen on Figure 6.14, the fruits turn black when ripe, in contrast with their common name, the 'white olive'. They possess many small black seeds that are in the fleshy part of the fruit. Even though the fruits are edible they tend to dry the mouth (Mbambezeli and Notten, 2002). The white olive may be of interest in the commercial markets, probably as pickled fruits.

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APPENDIX B

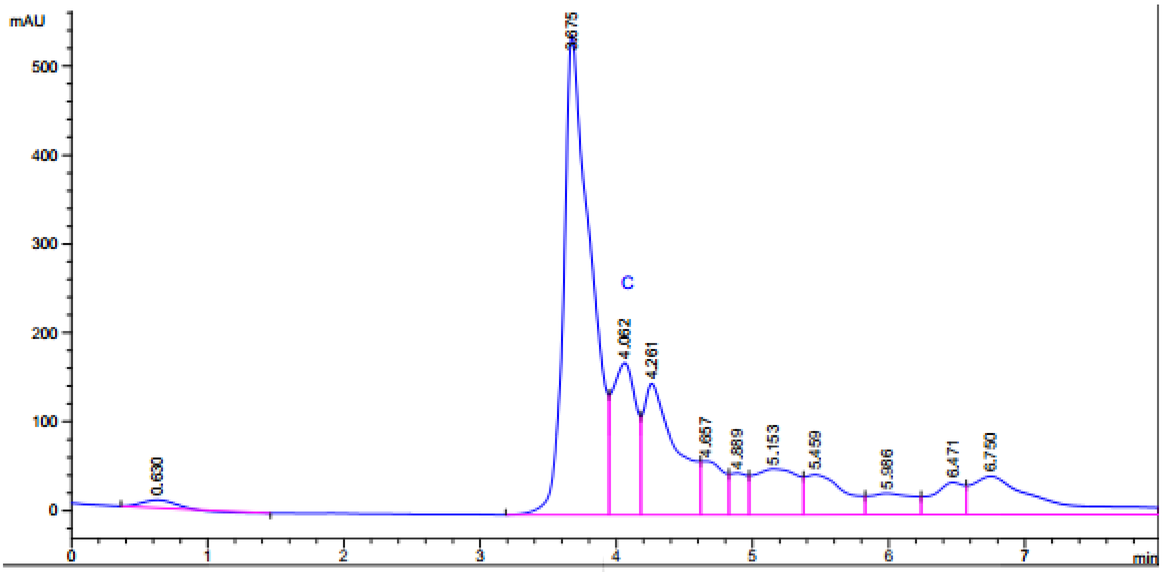

Figure 7.1 HPLC Chromatogram of *Phoenix reclinata* A

C = Ascorbic acid

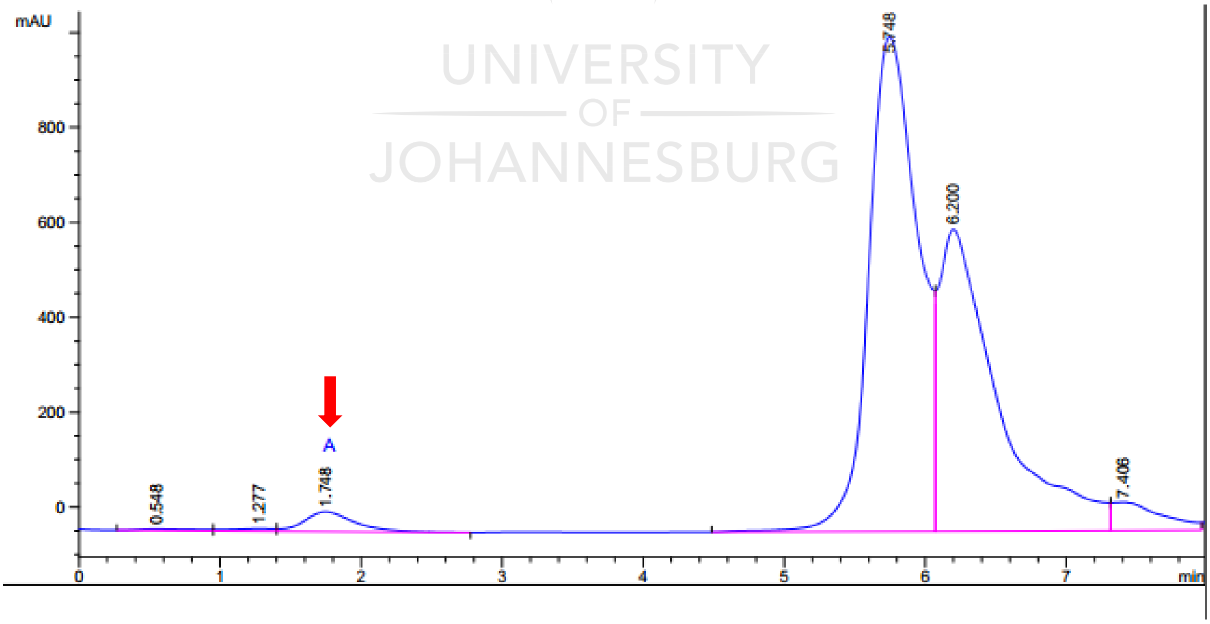

Figure 7.2 HPLC Chromatogram of *Phoenix reclinata* R

A = Retinol

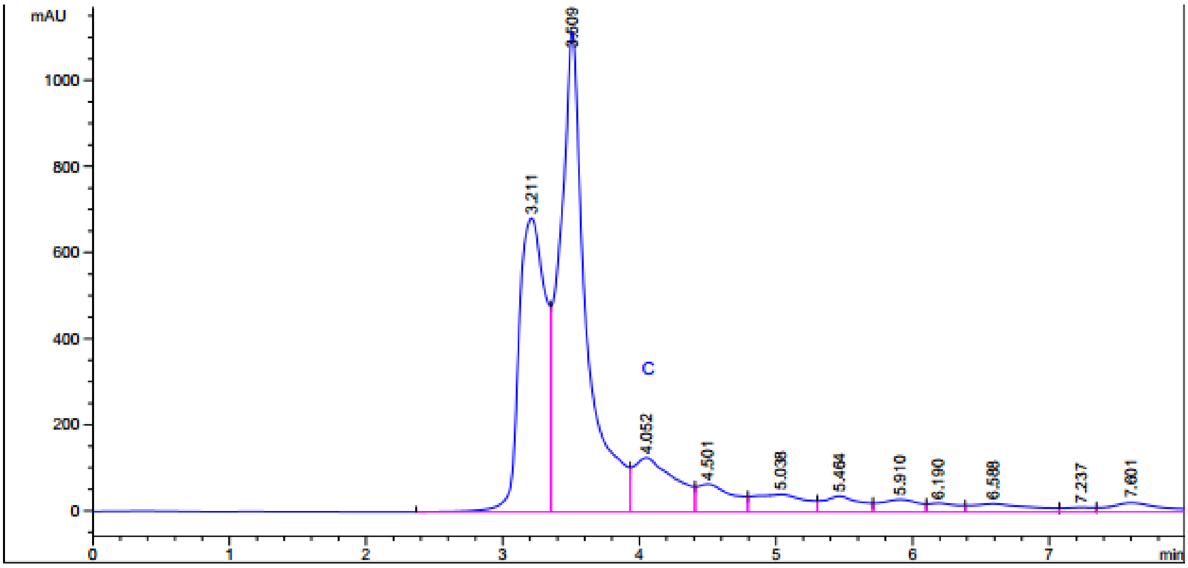

Figure 7.3 HPLC Chromatogram of *Pappea capensis*

C = Ascorbic acid

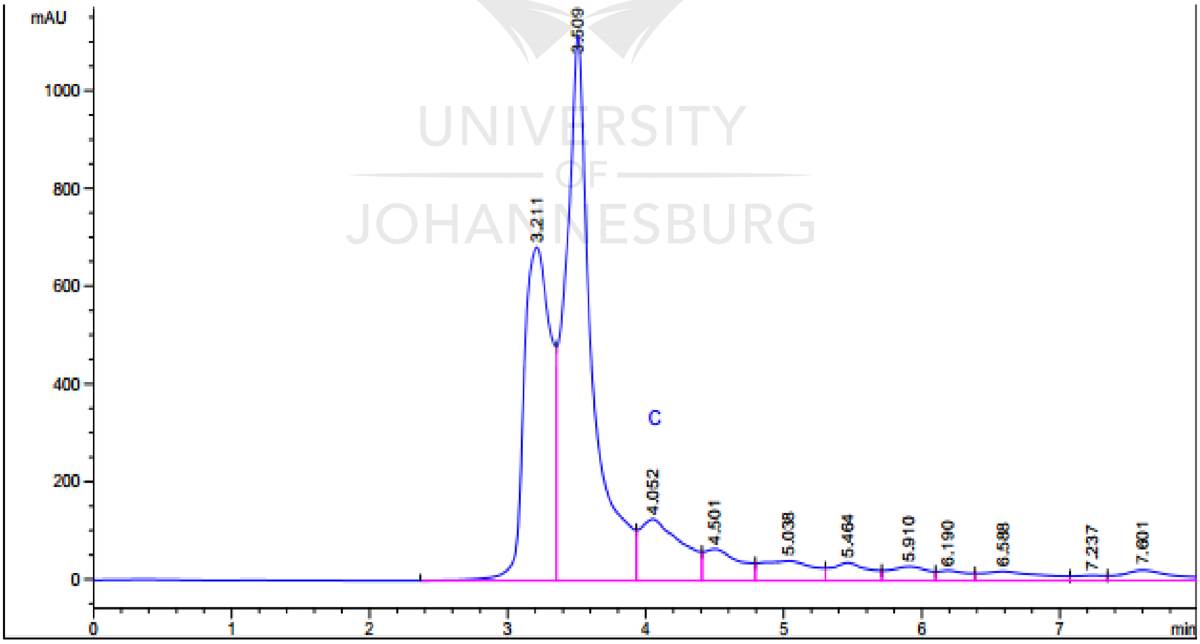

Figure 7.4 HPLC Chromatogram of *Syzygium cordatum*

C = Ascorbic acid

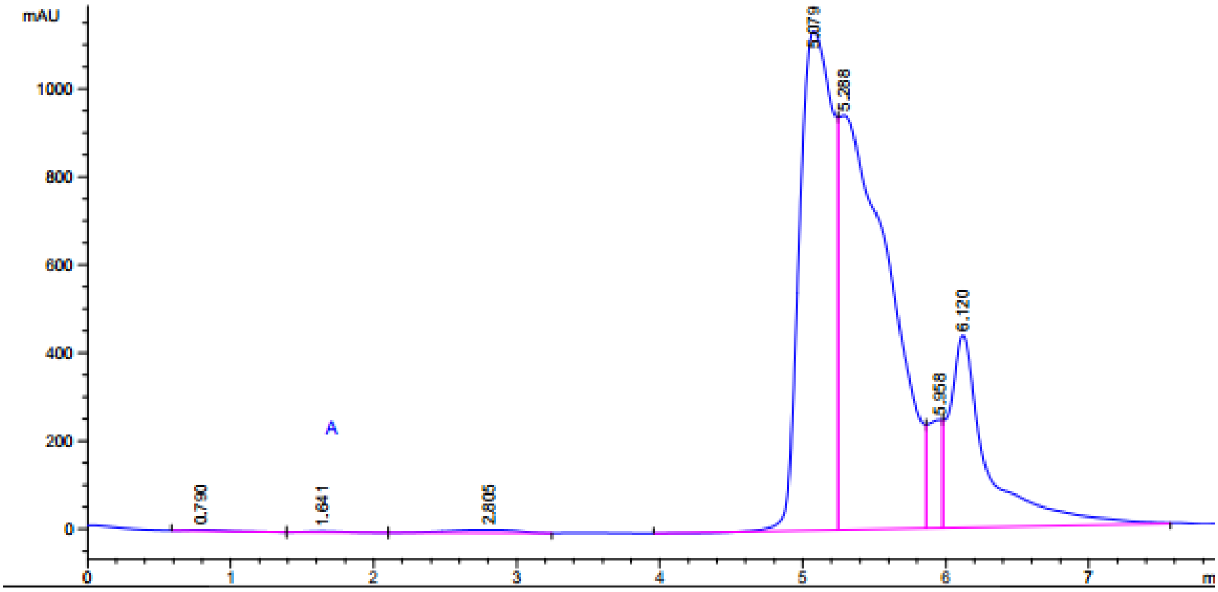

Figure 7.5 HPLC Chromatogram of *Syzygium guineese*

A = Retinol

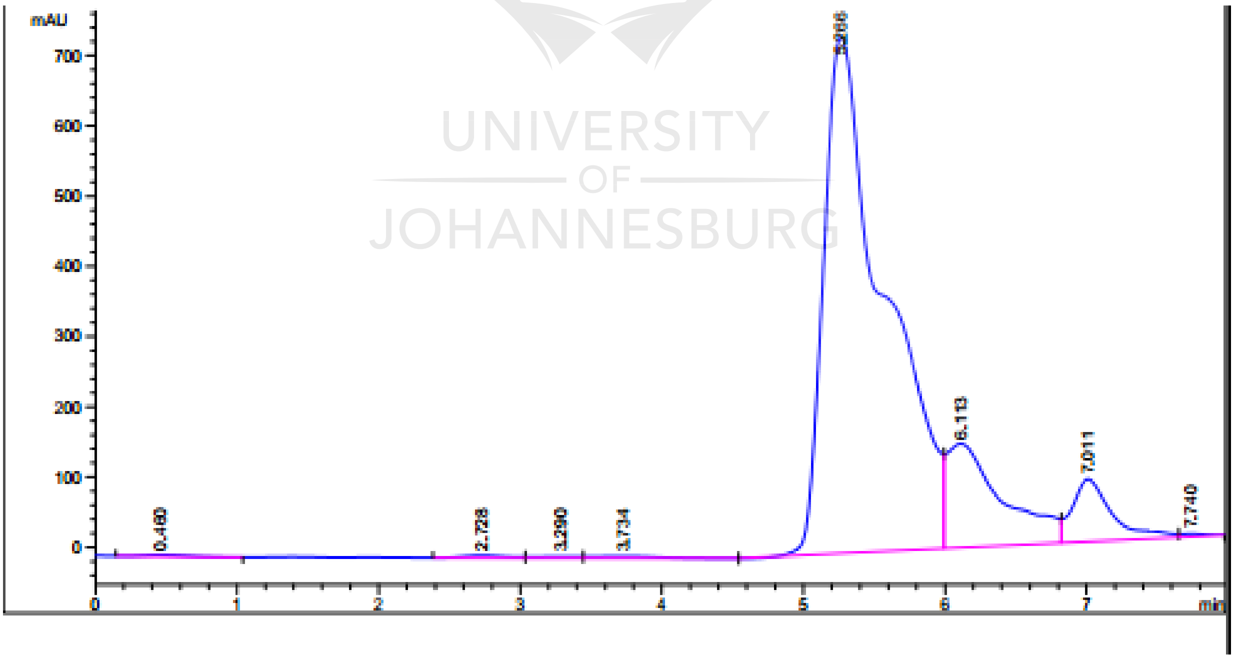

Figure 7.6 HPLC Chromatogram of *Parinari curatellifolia*

No Ascorbic acid or Retinol.

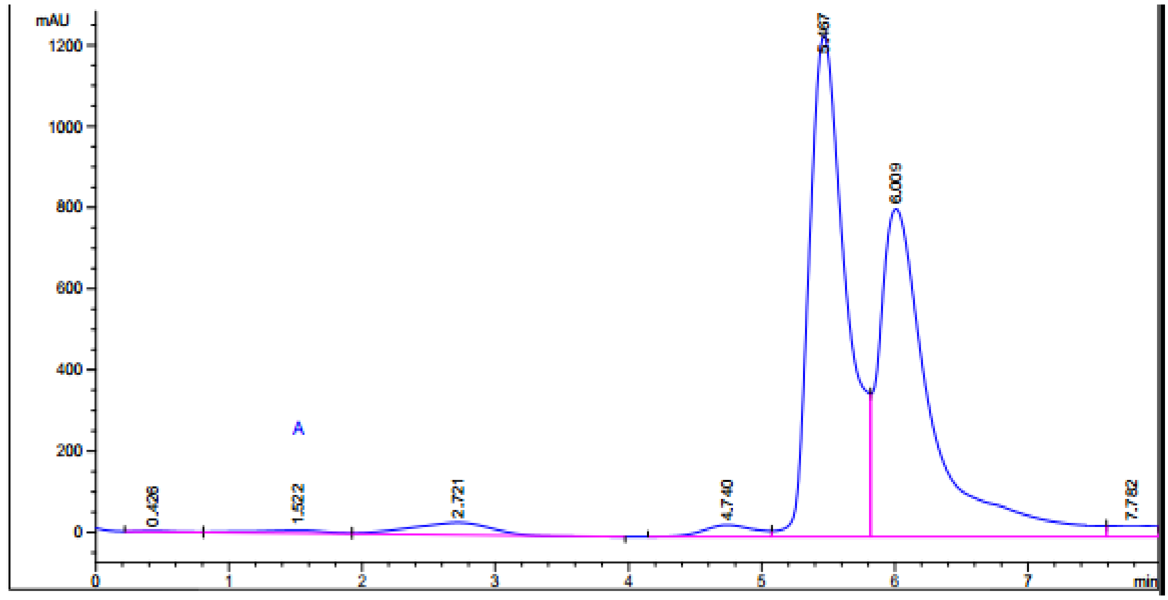

Figure 7.7 HPLC Chromatogram of *Garcinia livingstonei*

A = Retinol

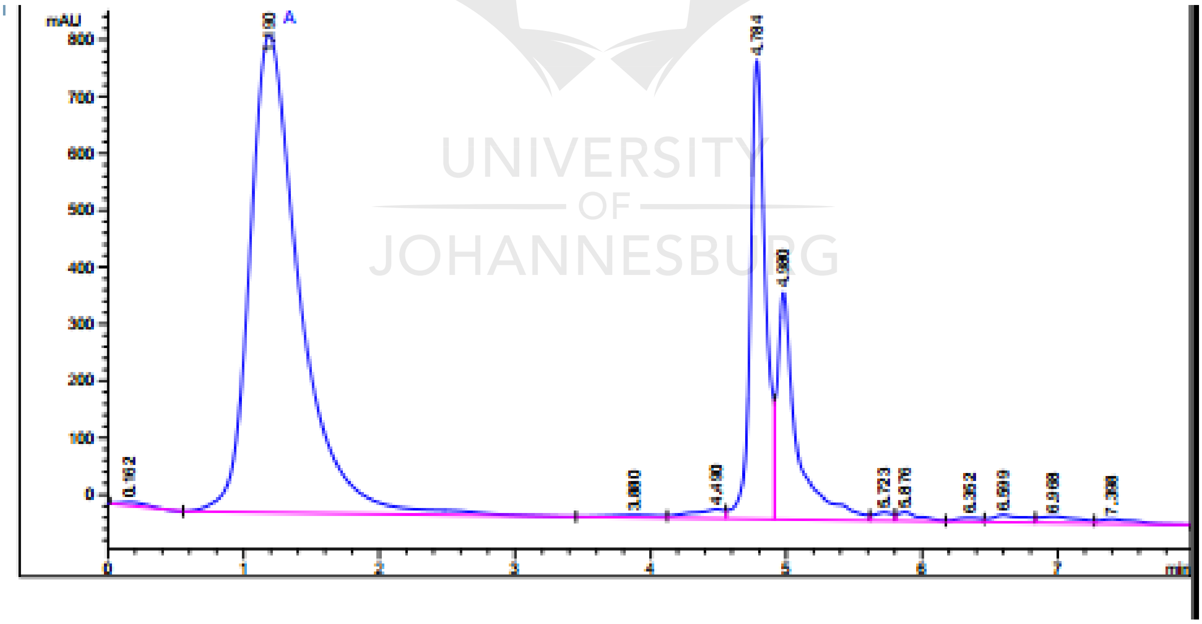

Figure 7.8 HPLC Chromatogram of *Dovyalis longispina*

A = Retinol

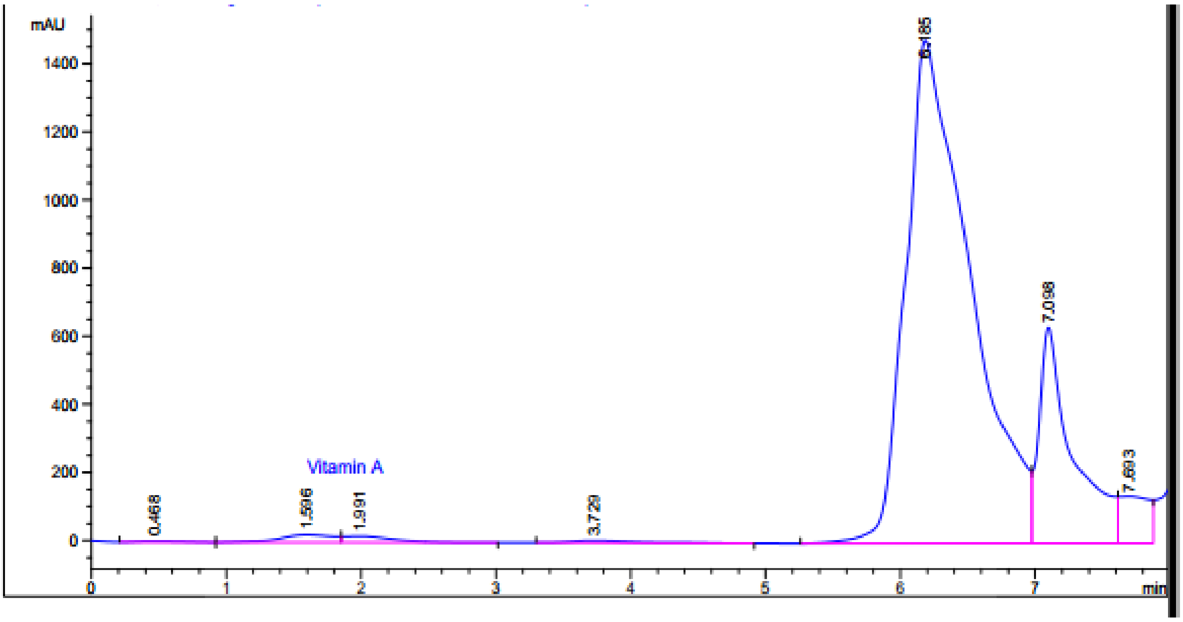

Figure 7.9 HPLC Chromatogram of *Manilkara mochisia*

A = Retinol

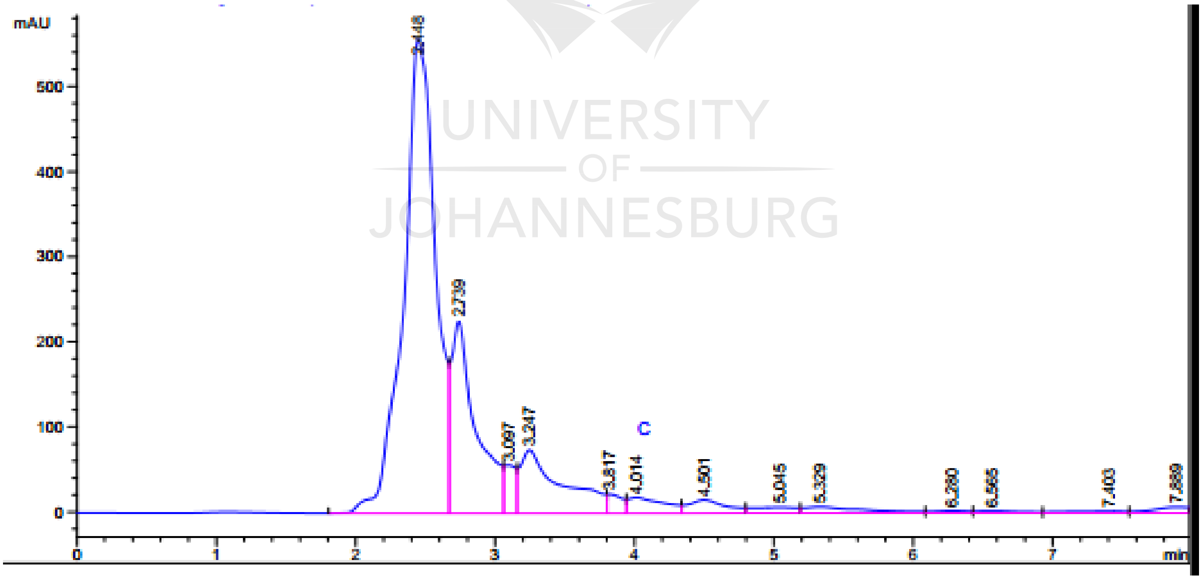

Figure 7.10 HPLC Chromatogram of *Carpobrotus edulis*

C = Ascorbic acid

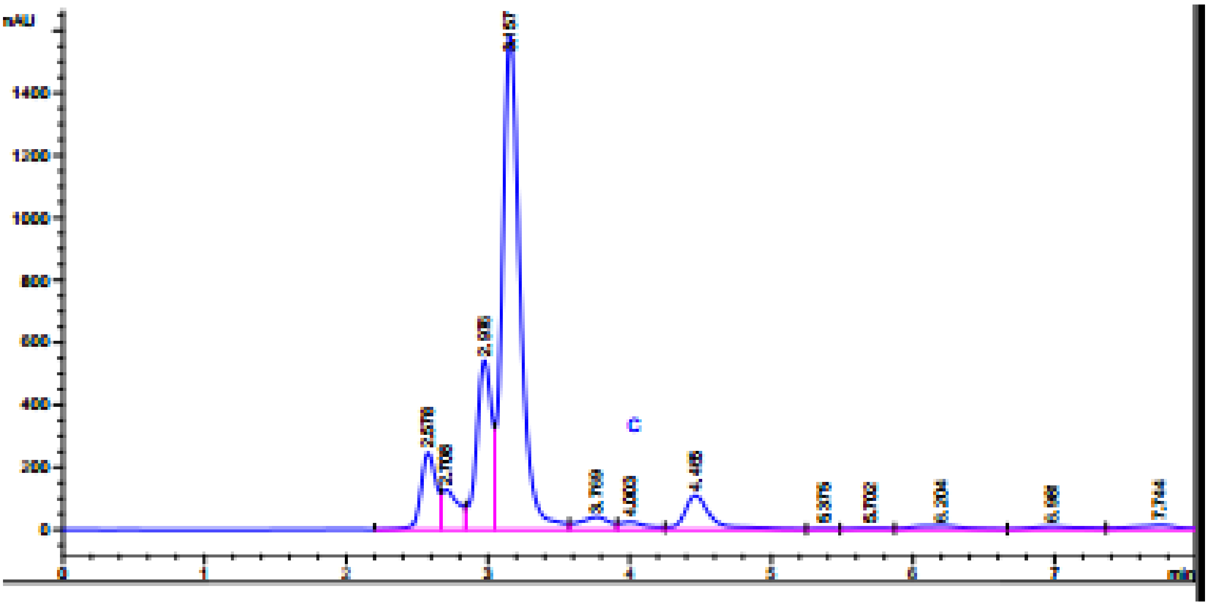

Figure 7.11 HPLC Chromatogram of *Cordyla africana*

C = Ascorbic acid

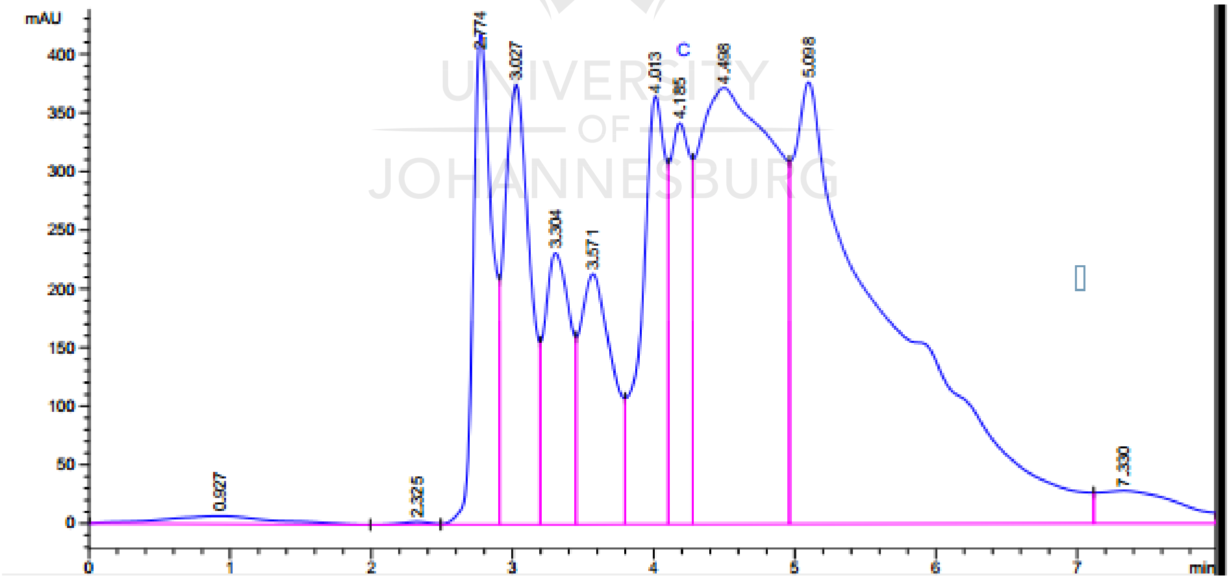

Figure 7.12 HPLC Chromatogram of *Dovyalis caffra* (NEL)

C = Ascorbic acid

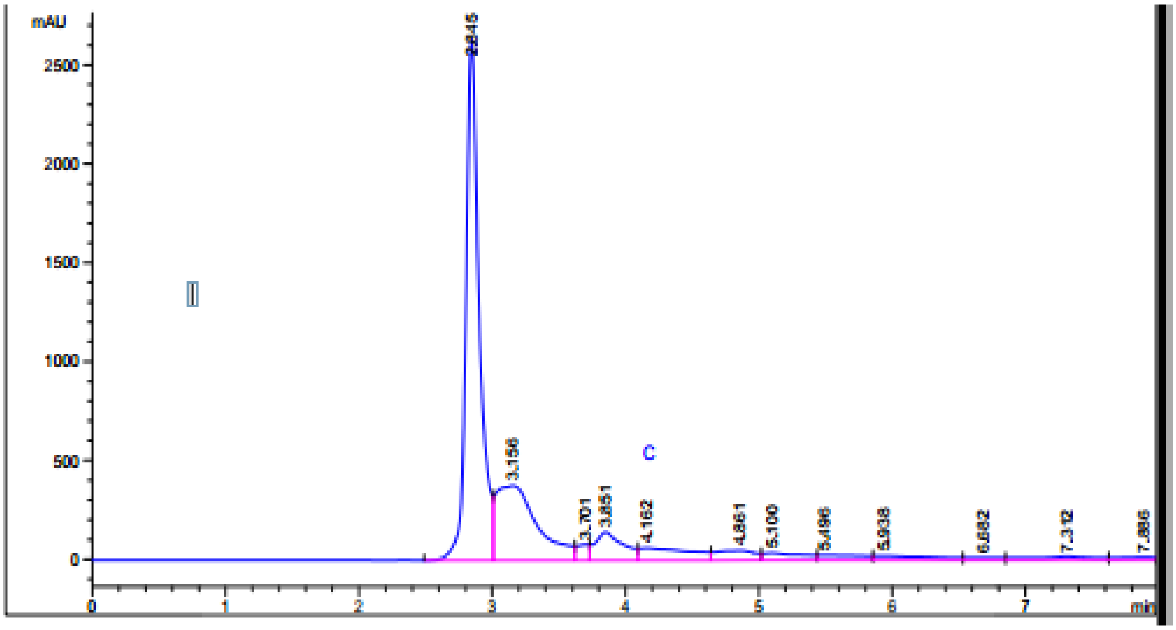

Figure 7.13 HPLC Chromatogram of *Carissa macrocarpa*

C = Ascorbic acid

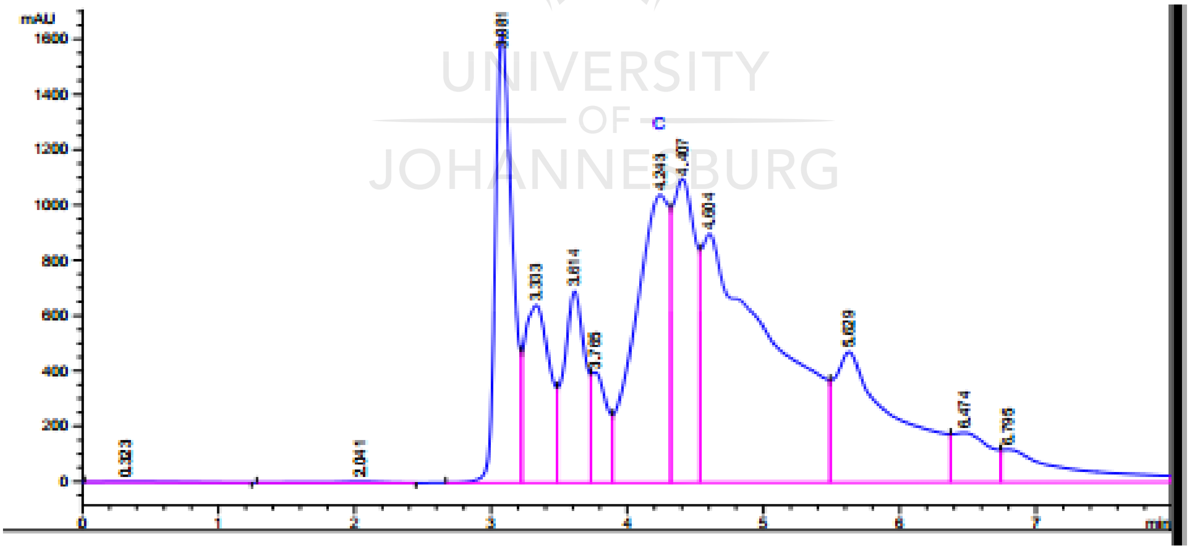

Figure 7.14 HPLC Chromatogram of *Dovyalis caffra* (EC)

C = Ascorbic acid

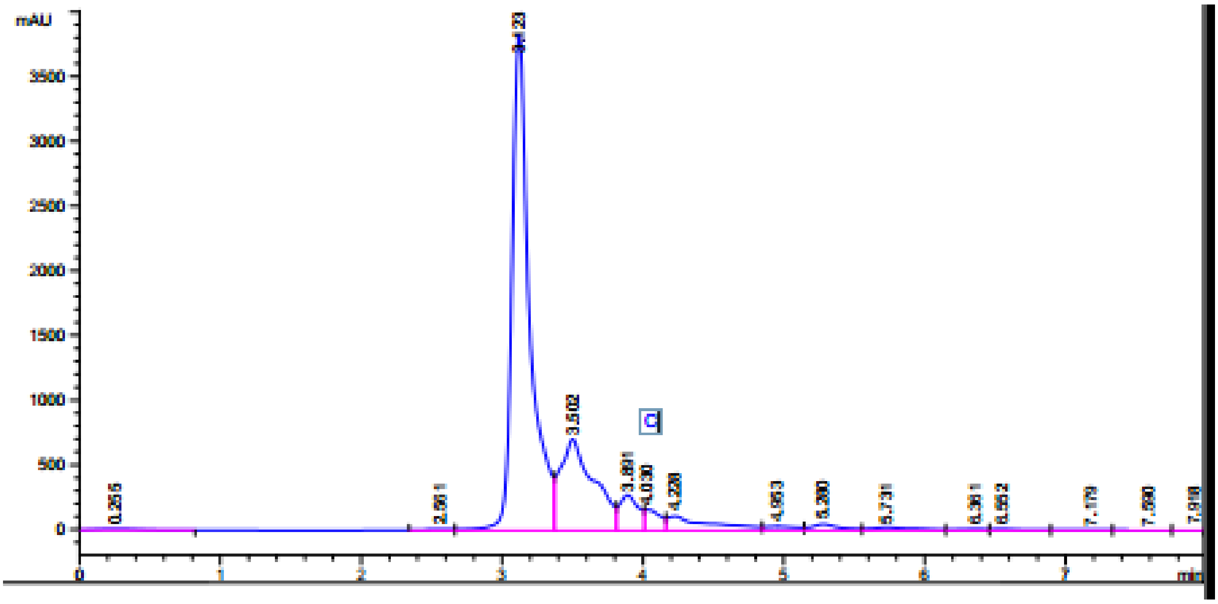

Figure 7.15 HPLC Chromatogram of *Halleria lucida*

C = Ascorbic acid

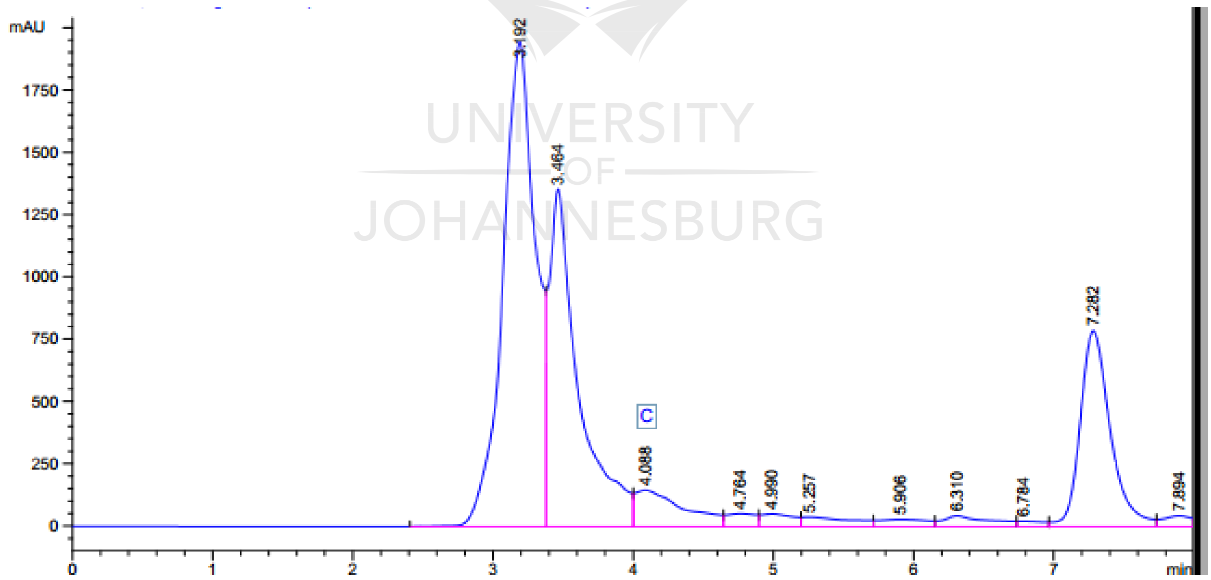

Figure 7.16 HPLC Chromatogram of *Englerophytum magalismontanum*

C = Ascorbic acid