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AN INVESTIGATION OF THE OIL YIELD AND PHYTOCHEMICAL COMPOSITION OF BAOBAB SEEDS FROM RUSHINGA DISTRICT

BY

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APPROVAL FORM

The undersigned certify that they have supervised, read and recommend to the Bindura University of Science Education for the acceptance of a research dissertation entitled**:**

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DEDICATION

This effort honors God Almighty, my creator, tower of strength, source of inspiration, wisdom, knowledge and insight. He has been my source of strength throughout this program, and I have only been able to fly on His wings. I also dedicate this work to my supervisor, who has been supportive throughout the process. To my parents and friends, I appreciate their support. My love for them has no limits.

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ABSTRACT

Adansonia digitata, seeds are a valuable Zimbabwean indigenous resource that lacks localized scientific data which in turn has limited the understanding of its specific quality attributes and commercial potential. *Adansonia digitata* is commonly known as Muuyu or Umkhomo in local chiShona and isiNdebele languages respectively. This research aimed to determine the oil content, qualitatively identify major phytochemicals and quantify phenolic and flavonoid compounds of seeds collected from Rushinga District. The study embraced a positivist approach and used Soxhlet extraction to obtain the oil from the samples. Phenolics and flavonoids were quantified spectrophotometrically. Qualitative analysis confirmed that tannins, phenolics, flavonoids, terpenoids, saponins and alkaloids were present in the samples. Univariate analysis of variance showed that geographical origin greatly impacted on all the three parameters that were investigated. The results provide compelling evidence that *A. digitata* seeds are rich in oil and phytochemicals. Besides filling a critical gap in scientific literature, the study also provides an insight into the commercial potential of baobabs for nutraceutical or cosmetic industries. The research laid the groundwork for future research into specific genetic and environmental factors driving the high yields observed herein.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

1.1 Introduction

This chapter sets the foundation of the study by providing a comprehensive background on the significance of indigenous plant resources and *Adansonia digitata*.(A.digitata) */muuyu/umkhomo* fruits..It highlights the existing knowledge gap regarding the specific oil yield and phytochemical profile of *A. digitata /muuyu/umkhomo* seeds from less-studied geographical areas especially Rushinga District in Zimbabwe. This chapter will delineate the problem statement, outline the research aim, objectives, and present key hypotheses and discuss its significance, delimitations and limitations. Finally, it will give contextual definitions of key terms and present the overall organisation of this dissertation.

1.2 Background of the study

Across the globe, indigenous plant fruit serve as vital pillars for rural economies, traditional medicine and food security particularly in the developing nations (Kumar et al., 2021; Borelli et al., 2020). Their immense biodiversity offers a reservoir of compounds with significant nutritional, medicinal and industrial potential. In sub-Saharan Africa, a plethora of underutilized plant species holds promise for enhancing food systems and generating income (Ndlovu et al., 2024). Zimbabwe, with its diverse agro-ecological zones, is home to numerous plants that have historically supported local communities through various traditional uses.

Among these invaluable resources, the African baobab often revered as the “Tree of Life”, stands out as a flagship species (Rashford; 2022; Rashford, 2023). Indigenous to the African continent, this majestic tree is celebrated for its longevity, distinctive appearance and remarkable versatility of its various parts which have sustained communities for centuries (Negash, 2021; Stadlmayr et al., 2020).

Traditionally, all parts of the baobab tree are harnessed by local populations. Its leaves are a nutritious vegetable; the fruit is a rich source of vitamins and minerals while the bark and roots are integral to traditional medicine (Assogbadjo et al., 2021; Kabwe et al., 2024). The seed, though often less consumed directly than the pulp, are traditionally used in various forms including roasted snacks, thickeners for soup or as a source of oil (Asogwa et al., 2021; Marappan et al., 2025). Despite the widespread recognition of baobab fruit pulp as a ‘superfood,’ the seeds, which constitute a significant proportion of the fruit’s biomass, often remain underutilized or are discarded as waste (Mwangi, 2023). However, growing scientific

interest points to their considerable potential in terms of nutrition and other industries also. Baobab seeds are known to be rich in essential nutrients including superior-quality oil, protein and dietary fibre (Jasrotia et al., 2021; Mwangi et al., 2023). The oil especially, is gaining traction due to its unique fatty acid profile and the presence of various bioactive compounds making it valuable for both human consumption and cosmetic application (Khoosal, 2021). The nutritional and phytochemical composition of plants, including varies significantly depending on environmental factors such as type of soil, climate, altitude and genetic variation across different geographical regions (Palit & Mandal, 2021). Consequently, generalizable data on baobab seed may not fully capture the specific characteristics of populations from distinct agro-ecological zones (Orina et al., 2021).

While some studies have investigated baobab seed oil yield and phytochemical composition from other parts of Africa (Msalilwa et al., 2020) and even within Zimbabwe, there remains a notable paucity of scientific data specifically pertaining to baobab seeds. This knowledge gap is critical as the place is a region where baobab fruits are prevalent and potentially contribute to local livelihoods. This lack of localised scientific investigation limits the comprehensive understanding of the specific quality attributes and potential commercial value of baobab seed oil. Without this data, opportunities to valorise this local resource for both nutritional enhancement and economic empowerment may be overlooked. Therefore, an in-depth investigation into the oil yield and phytochemical composition of baobab seeds is imperative to provide foundational scientific evidence. Such empirical evidence will not only contribute to the existing body of knowledge on *A. digitata/muuyu/umkhomo* but also inform local communities, policymakers and potential industries regarding the specific value and optimal utilization of this indigenous resource (Masisi, 2022).

1.3 Statement of the problem

Despite the recognized potential of baobab seeds as a source of valuable oil and phytochemicals and the prevalence of baobab fruits, there is a significant lack of specific scientific data regarding oil yield and phytochemical composition of baobab seeds originating from this particular geographical area. Existing literature often presents generalized data or focuses on samples from other areas. This falls short in accurately reflecting the unique characteristics influenced by the area's specific environmental conditions such as altitude, climate and type of soil. Without localised empirical evidence, the specific value and optimal strategies of utilization for the district's baobab seeds remains largely unknown. This potentially results in underutilization of the seeds and also missed economic opportunities.

1.4 Research aim

This study aims to investigate the oil yield and phytochemical composition of *A. digitata* /*muuyu/umkhomo* seeds.

1.5 Research objectives

The objectives of the study are:

- To determine the oil yield from baobab seed samples collected .
- To identify major phytochemicals present in baobab seed extract samples
- To quantify the major phytochemicals (flavonoids and phenolics) present in baobab seed extracts .

1.6 Hypotheses

H_0: No significant difference is there in the oil yield and phytochemical composition of baobab seeds.
H_1: Significant differences exist in the oil yield and phytochemical composition of baobab seeds.

1.7 Significance of the study

This study is of substantial importance for a number of stakeholders. Findings of the study will provide valuable scientific data to the local community on the specific attributes and baobab seeds from that area. The local communities will be better empowered to understand and valorise their indigenous resource resulting in improved harvesting, processing as well as development of local industries hinged on baobab seed oil and extracts. This would significantly improve the livelihoods of the local people. Characterization of potential bioactive compounds in this study will highlight the potential of the seeds as major contributors to dietary diversity and nutritional security. In addition, this research is going to fill a critical knowledge gap by providing localised empirical data on the composition and phytochemical profile of baobab seeds. This will contribute to a broader understanding of *A. digitata* /*muuyu/umkhomo* and the impacts of geographical variations on its biochemical profile thereby enriching the existing scientific literature.

A thorough investigation of oil yield and phytochemical profile is crucial for industries such as food, pharmaceutical and cosmetic who may be interested in sourcing and using baobab seed oil and extracts. This comes as important foundational data for development of products, quality control as well as positioning of the market. Besides, outcomes of this study can inform policies and interventions that are evidence-based aiming to promote full utilization of indigenous plant resource and also fostering local value chains nationally.

1.8 Delimitations

The study focuses on *A. digitata /muuyu/umkhomo* seeds solely and the seeds in this study are sourced from the same district. The district is full of baobab fruits which have better traits since the fruits are produced in large quantities and the fruit trees are more disease resistant than baobab fruits in other districts. This means that fruits produced are of high quality and will be produced in abundance. The dry or semi-arid climatic conditions and soil types of the area which forces or favour the growth of the fruits justifies the reason why baobab seeds from the district may be collected as samples. Due to the cultural beliefs and tradition of people in the area's community on the baobab fruit especially on its medicinal aspect, it is important to promote sustainable use of the indigenous fruit .The geographical climatic conditions of the area favours high growth of high quality baobab fruits and also the type of fertile soils available there favours germination rate of the trees hence available in abundance in the area. Moreover, this research is limited to determination of oil yield and phytochemical profiling using qualitative and quantitative analyses of four major classes of phytochemicals namely flavonoids, phenolics, alkaloids and tannins. Collection of data and laboratory analyses will be done in the 2024/2025 fruiting season hence inability to account for seasonal variations in composition. Specific analytical and laboratory techniques detailed in Chapter 3 will be utilized in this study for oil extraction and phytochemical profiling.

1.9 Organisation of the study

This study is organised into five chapters. Chapter 1 of the study focused on the background of the study, problem statement and objectives. The chapter stated the hypotheses and described the significance of the study while outlining delimitations of the study. The second chapter reviewed literature starting with the phylogeny of A. *digitata /muuyu/umkhomo* Global perspectives on phytochemistry of baobab were discussed together with the effect of geographical origin on oil content and content of phenolic and flavonoid compounds. Chapter

2 also described the impact of extraction techniques on oil yield and quantifiable phytochemicals of *A. digitata/muuyu/umkhomo*. The chapter further described quantitation methods used in natural products chemistry and identified the knowledge gaps that need to be addressed by this study. Chapter 3 of the study described the research design and paradigm. It detailed the methods that were used to attain the set objectives starting with the details of sampling right through to the experimental procedures. Chapter 4 presented findings of the study as well as statistical analyses of the results also, the results were discussed in detail. The final chapter put forward a summary of the study and drew conclusions before outlining the recommendations of the study.

1.10 Chapter summary

The introductory chapter has provided the foundational context for the investigation into the oil yield and phytochemical composition of baobab seed. It has outlined the global and local significance of indigenous plant resources with special reference to the underutilised baobab seeds. This chapter identified a critical knowledge gap regarding the specific characteristics of baobab seeds resulting in formulation of a research problem and clear problem statement with a well-defined aim and measurable objectives. In addition, testable hypotheses were proposed and emphasis was placed on significance of the study. Above all, the scope of the study and its boundaries were outlined as delimitations. An outline of the organization of the study was presented. This has set the stage for subsequent chapters.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter provides a comprehensive review of the existing literature concerning baobab seeds. It elaborates on the multi-faceted significance of the *A. digitata* / *muuyu/umkhomo* fruit and delves into the global perspective on the phytochemicals inherent in *A. digitata /muuyu/umkhomo* seeds and their potential applications. Critical examination of the relationship between geographical origins, methods of processing, oil yield and phytochemical composition follows. The chapter also outlines the analytical techniques that are employed in quantification of the phytochemicals. Keys research gaps are also identified and the rationale and significance of the current study is established. The review aims to consolidate existing knowledge and underscore the imperative need for further targeted research to unravel the full potential of *A. digitata* / *muuyu/umkhomo* seeds.

2.2 The taxonomic classification of *A. digitata*/ *muuyu/umkhomo*

The phylogeny of baobab is as follows;

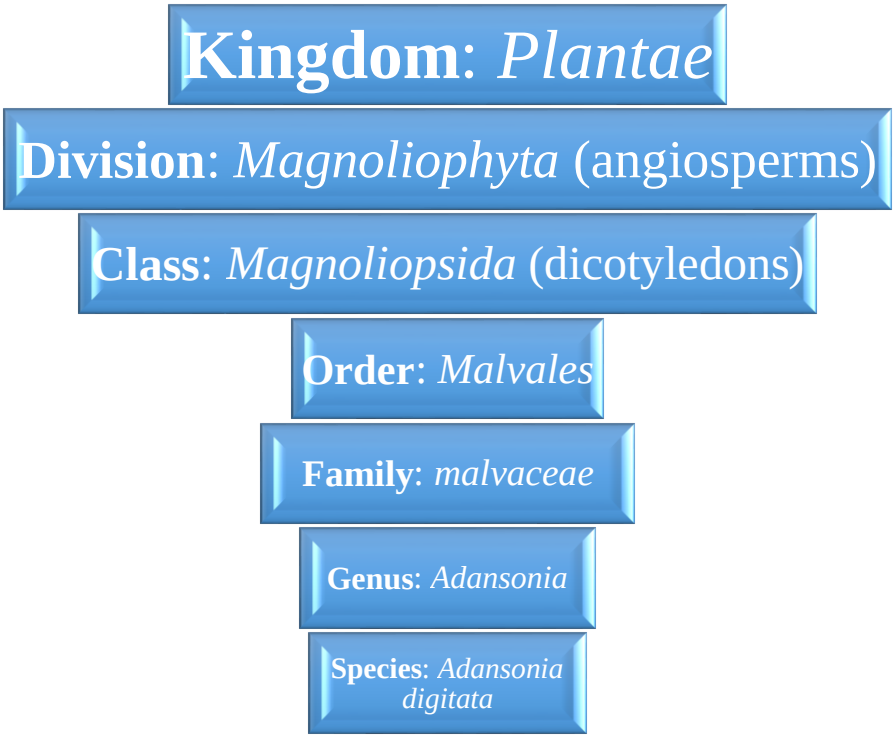


Figure 2. 1: The phylogeny of *A. digitata* (*Sonu et al., (2024))*

Phylogenetic analysis suggests that the genus Adansonia originated from Madagascar with the mainland African species (A. digitata) also occurring on the island but not being native to it (Sonu et al., 2024). *Adansonia digitata* is commonly known as muuyu or umkhomo in local chiShona and isiNdebele languages respectively.*Adansonia digitata* /muuyu/umkhomo/ (baobab) is a large deciduous tree that is native to the African continent and is well known for its distinctive appearance and versatile uses. *Adansonia digitata* is commonly known as muuyu or umkhomo in local and isiNdebele languages respectively.

2.3 The significance of *A. digitata* / *muuyu/umkhomo* .

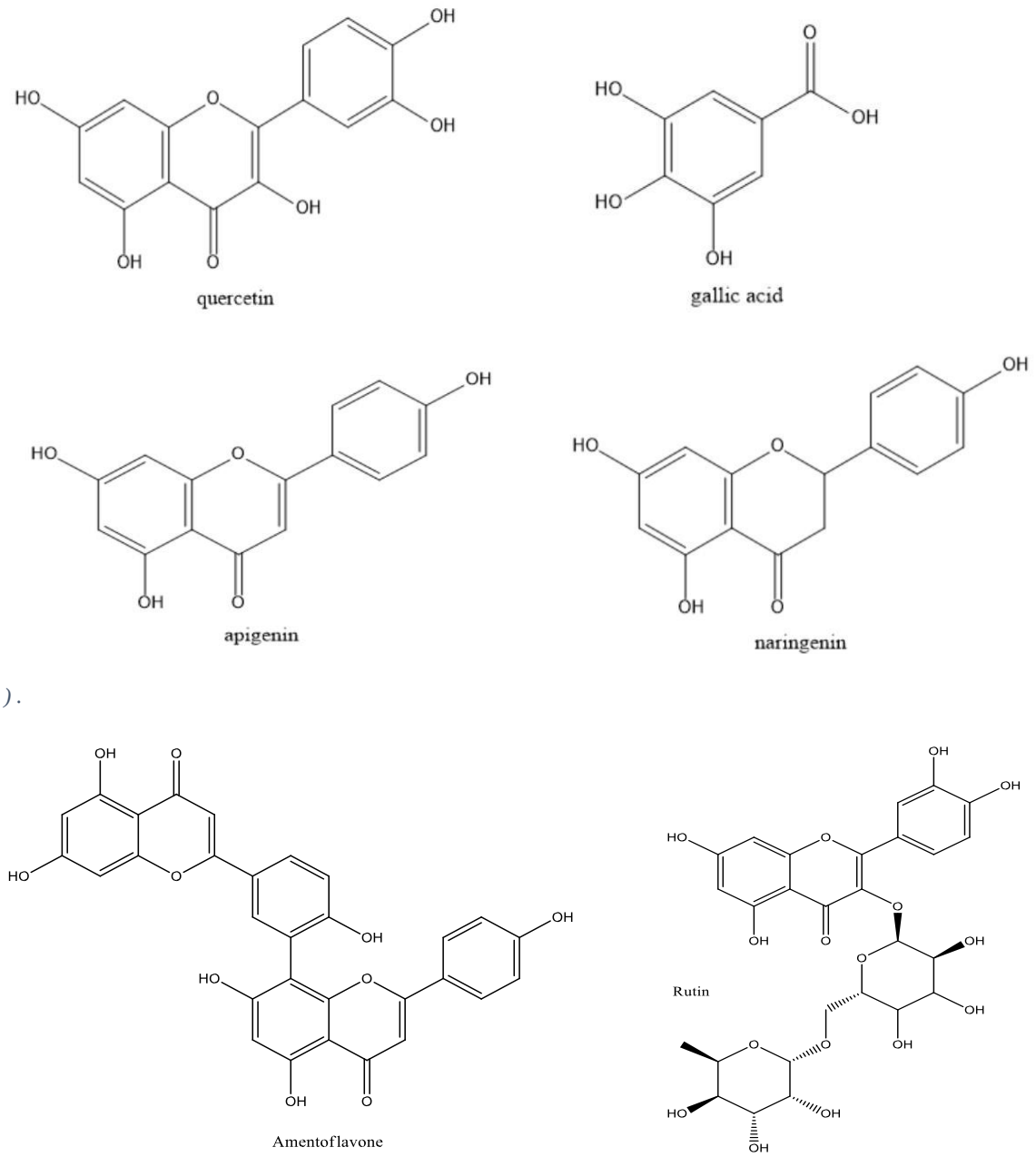
The African baobab fruit is an iconic and important fruit species that is versatile within the ecological and socio-economic settings of semi-arid and sub-humid sub-Saharan Africa (Sonu et al., 2024). The tree is abundant in regions of Africa including Ghana, Botswana, Benin, Mali, Senegal, Malawi, Namibia, Mozambique and Zimbabwe (Sileshi et al., 2023; Chirwa et al., 2024). Its wide distribution underscores its adaptability and resilience across diverse environments. Beyond its ecological presence, *A. digitata* /muuyu/umkhomo fruit is a

cornerstone for rural livelihoods, contributing substantially to food and nutrition security owing to its remarkable nutritional density and minimal input requirements for production (Omotayo & Aremu, 2020; Dagar et al., 2024). Basically, all its components (leaves, roots, fruits, seeds and flowers) are edible and have been used traditionally to sustain lives and for medicinal purposes for generations. The rich profile of the fruit (consisting of vitamins, antioxidants, minerals and essential amino acids) makes it a "superfood" (Marappan et al., 2025).

The seeds of the baobab fruit represent a significant component, approximately 80% of the total mass of the fruit (Chiacchio et al., 2022). The seeds are a valuable source of protein and fat. Baobab seed oil has garnered a lot of interest in the cosmetic and nutraceutical industries in last few decades mainly due to its beneficial fatty acid composition (Sileshi et al., 2023; Varshney et al., 2024). Various studies have reported the presence of substantial amounts of lipids such as linoleic, oleic and palmitic acids in baobab seed oil (Msalilwa et al., 2020; Idris et al., 2020; Sow et al., 2025). Beyond their lipid content, baobab seeds are also rich in diverse secondary metabolites (phytochemicals) including flavonoids, tannins, phenolics, saponins and alkaloids all of which possess potent antioxidant properties. The phytochemicals also have health-promoting properties (Talabi et al., 2023; Thompson et al., 2024). The rich biochemical profile of baobab seeds points towards their significant potential as a functional food ingredient and continuous relevance in ethnomedicine.

2.4 The phytochemical profiles of *A. digitata* / *muuyu/umkhomo* seeds

Baobab seeds are better positioned as valuable ingredients for both nutraceuticals and functional foods due to the diversity of bioactive phytochemicals present in them (Popoola et al., 2023). The pulp and by extension its seeds possess abundant polyphenols which have been reported to have potent antioxidant activity. Some polyphenols present in baobab are gallic acid, catechin and proanthocyanidins (Russo et al., 2020). Research has shown consistent detection of flavonoid compounds in baobab seeds with specific types such as apigenin, naringenin and rutin among others identified (Russo et al., 2020; Chiacchio et al., 2022). Flavonoids are known for their antimicrobial, antioxidant and anti-inflammatory properties (Russo et al., 2020; Chiacchio et al., 2022; Popoola et al., 2023). The structures of some polyphenols and flavonoids are shown in Figure 2.2;



) .

Figure 2.2: The structures of some flavonoid and phenolic compounds in baobab*(Russo et al., 2020; Chiacchio et al., 2022; Popoola et al., 2023)*

Tannins have also been reported present in baobab seeds with unroasted seeds exhibiting lower tannin content than the fruit pulp (Babalola et al., 2020). This class of plant metabolites has been shown to possess a number of biological activities among them antidiarrheal, antifungal, anti-hemorrhoidal and antioxidant effects. Some scholars have reported that higher levels of tannins may hinder nutrient assimilation (Nawab et al., 2020; Huang et al., 2024). Figure 2.3; illustrates the general structure of tannins.

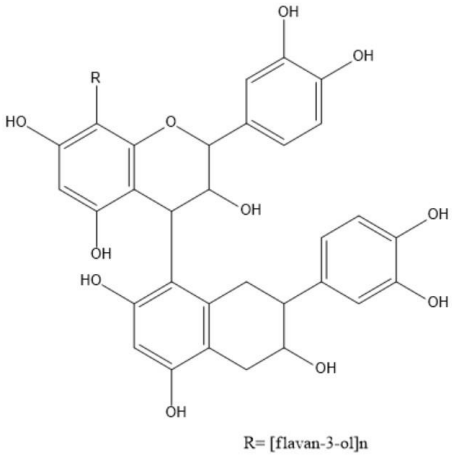


Figure 2.3 A typical tannin *(Nawab et al., 2020; Huang et al., 2024)*

Other classes of bioactive metabolites reported in literature include glycosides, terpenoids, Nacylethanolamines and steroids (Msalilwa et al., 2020; Chiacchio et al., 2022). Nacylethanolamines reportedly influence regulation of apetite, glycemia, inflammation and nutrient metabolism by interacting with receptors in the gastrointestinal tract (Chiacchio et al., 2022). All in all baobab extracts have demonstrated potent antioxidant, antinflammatory and cell-protective activities.

2.5 Effect of origin and processing phytochemical composition of *A. digitata* seeds

Basically, the phytochemical composition of *A. digitata* / *muuyu/umkhomo* seeds has exhibited substantial variation mainly based on the method used during processing and the geographical orign of the seeds. Research has shown that the proximate and mineral content of *A. digitata* /*muuyu/umkhomo* fruit pulp and seeds varies significantly across different African regions (Stadlmayr et al., 2020; Mamman et al., 2021; Zango et al., 2023). For example, baobab seeds in a study done in Malawi exhibited high mean calcium content while that done in Kenya exhibited high mean iron content (Mamman et al., 2021; Zango et al., 2023). In addition, a separate study on Malawian baobab root tubers were shoen to have variations in phytochemicals such as alkaloids, terpenoids, saponins and flavonoids depending on the origin of the tubers in that country (Jansen et al., 2020). These specific findings pertaining to root tubers have broader implications supporting the broader principle of localized diversity in chemical composition in baobab fruit parts obtained across different regions. Baobab fruits from Rushinga are disease resistant unlike those from Checheche which may be weakened by diseases from pests due to poor climatic conditions or soil conditions.Those in Chiredzi might

be vulnerable to different environmental factors or stressors resulting in poor seeds quality being formed unlike seeds from chosen area which are of highest quality and unique genetic makeup due large bio-diversity as compared from others.Baobab fruits favour semi-arid ,dry areas like area under study for growth unlike conditions which are available in Chiredzi and Checheche among others.Gonarezhou National Parks in Masvingo Province ,has baobab fruits but they are fewer than those found in this selected place. For research purposes at the moment, they are very far away and it may be expensive for researcher to go and collect those fruits.Gonarezhou fruits may cause allergies to people since the fruits are under attack by pests and wild animals which view the A.digitata /muuyu/umkhomo fruits as a source of food.Actually, the fruits may be scarce unlike in Kasenzi,Makuni or Nyatsato where they are found in large quantities. Fruits from areas like Chiredzi are not safe since people who live in those areas harvest baobab fruits in very early stages before maturing fully .They (people) do this in a scramble way as they export the fruits to South Africa .This actually shows that there are shortages of baobab fruits while in selected area,fruits have ample time to mature fully in their mother trees and they are in abundance..This makes Rushinga fruits suitabale for research processes. Using baobab seeds from this chosen district enhances sustainable use of the fruit in the community in near future.

Similarly, methods of processing such as roasting have been shown to cause substantial alterations in the phytochemical profile of baobab seeds. Reports in literature suggest that roasted baobab seeds exhibit higher overall phenolic content (Ismail et al., 2022). On the contrary, a more detailed analysis proved a nuanced impact. In as much as roasting increased the content of some flavonoids such as rutin, apigenin and catechin, it led to a simultaneous decrease in the total phenolic content. While gallic acid became higher in roasted seeds, syringic acid became abundant in unroasted seeds and also it is worthy noting that p-coumaric acid was found in roasted seeds(Marcolino et al., 2024). These findings point to the fact that processing can induce bioavailability and concentration transformations for specifc classes of phytochemicals. This subsequently affects the health benefits derived from the seeds. Furthermore, extraction methods employed play a vital role in the recovery of phytochemicals. For instance, analysis of oils extracted from unwashed seeds using high performance luiquid chromatography with an ultra violet detector indicated elevated leaves of tyrosol, caffeic acid and hydroxytyrosol compared to washed seeds (Sow et al., 2025). Processing methods therefore are rather active modulators of phytochemical composition than mere preparation steps. However, this comes with corresponding shift in the balance of some individual metabolites.

Additionally, the documented variability in the composition of *A. digitata muuyu/umkhomo* seeds including fatty acids, oil yield and phytochemicals has a direct impact on suitability of the seeds for particular applications be it nutraceutical, cosmetic or as an ingredient in functional foods (Masqood et al., 2020). This in turn influences their overall economic competence. On the other hand, the inherent variations may be opportunities for targeted selection in breeding and conservation programs (Kalinganire et al., 2023). Therefore, a detailed understanding of the chemical profile from the given selected region is not just a localized observation. It provides vital data to a global knowledge base that informs sustainable harvesting practices, facilitates the development of value chains and anchors the strategic management of genetic resources (Ofori & Addo, 2023). Inarguably, localized studies are indispensable for full realization of the potential of *A. digitata* / *muuyu/umkhomo* while ensuring its long-term viability and ecological integrity.

Moreover, the perpetual inadequacy of comprehensive research into such valuable species is considered a contributing factor to persistent poverty, hunger and malnutrition which are rampant in Africa (Hossain et al., 2021). In this sense, scientific inquiries into the composition of *A. digitata* /*muuyu/umkhomo* such as the current study that is focused on the area are not mere academic pursuits but rather efforts aimed at directly addressing critical global challenges related to food and nutrition security and rural economic advancement. This broader societal relevance underscores the urgency and profound significance of localized research efforts. While variations in phenotypic characteristic of fruits such as seed weight have been observed in different provenances (Kalinanire et al., 2023; Ndong et al., 2024), the direct quantification of how these differences relate to oil yield based on geographical origin is not extensively documented in literature. This is a significant gap which can be explored. As a result, an investigation into oil yield may provide novel and valuable data that directly contributes and fills the identified gap establishing a baseline comparison for other regions in Zimbabwe and beyond.

2.6 The effect of extraction methods on oil yield of *A. digitata/ muuyu/umkhomo* seeds

The method chosen during extraction greatly influences the efficiency of extraction of oil from *A. digitata* /*muuyu/umkhomo* seeds. Researchers have employed a variety of techniques each possessing its merits and demerits. Extraction methods include conventional pressing methods (cold pressing, warm pressing and hot pressing), solvent-based methods (Soxhlet extraction) and modernistic, eco-friendly techniques such as supercritical carbon dioxide ($scCO_2$) extraction (Bhadange et al., 2024). Selecting the method of extraction of oil is very important

as it directly affect the oil yield as well as the physicochemical characteristics of the final product. Moreover, pre-treatment processes that are done on the seeds have been shown to play a part in quality and extraction efficiency optimization (Kaseke et al., 2021).

Recent research has put forward important insights into the yield of oil obtained from *A. digitata* / *muuyu/umkhomo* seeds exposed to different conditions of extraction. In a study to optimize $scCO_2$ extraction, 9.3 % oil yield was obtained at 77 ℃ and 0.8 g//ml density of carbon dioxide. The yield, while demonstration the potency of $scCO_2$ extraction, was remarkably lower than that obtained from conventional hot pressing method (37 %) (Gashi et al., 2025). In a separate study, n-hexane Soxhlet extraction exhibited superior extraction efficiency (27.75 %) compared to 5.42 % yield obtained using mechanical extraction (Ofori et al., 2023). These significant differences in yields reported from different methods of extraction further emphasize the fact that method of extraction is a primary determinant of the quality of oil that is produced. Solvent-based and hot-pressing methods produce higher yields but modern alternatives such as $scCO_2$ extraction have distinct advantages especially production highly pure oil that is not solvent-contaminated. This is highly recommended for sensitive applications such as in the cosmetic and nutraceutical industries.

There exists a clear trade-off in the extraction of *A. digitata /muuyu/umkhomo* seed oil between ensuring product quality and maximizing yield (Augusto et al., 2024). This assertion also applies where the oil is required for specific applications. Methods that achieve high yields produce oil that is compromised in terms of quality or potentially toxic solvents such as hexane are used. Authorities such as the European Food Safety Authority have raised concerns with regards to the use of technical hexane (Comandella et al., 2024). Conversely, environmentally friendly methods like supercritical CO_2 extraction, while yielding less oil, produce a highquality, solvent-free product that is highly desirable for sensitive industries such as cosmetics and nutraceuticals (Zorić et al., 2022). The implication is that the most appropriate method of extraction depends on the intended use of the oil.

2.7 Quantification Techniques for Phytochemicals

The quantification of phytochemicals in *A. digitata* /muuyu/umkhomo seeds is achieved through a range of sophisticated analytical techniques. High performance liquid chromatography (HPLC) with advanced detection is one of the methods used. This involves coupling HPLC with Mass Spectrometry (MS) particularly HLPC-MS/MS or

UHPLC/QTOF/MS which is highly sensitive, selective and can elucidate structures (Mannoubi et al., 2025; Hossen et al., 2025). These techniques currently are not available in Zimbabwe. Gas chromatography-Mass Spectrometry (GC-MS) remains an indispensable technique for analysis of volatile and semi-volatile phytochemicals (Nandhini et al., 2025) especially components of essential oils. Advances in sample preparation techniques including microextraction methods have further enhanced the sensitivity and applicability of GC-MS for quantification of trace amounts of volatile compounds in plant samples (Han et al., 2025). Nuclear magnetic resonance (NMR) spectroscopy and quantitative NMR (qNMR) have gained prominence for its ability to provide absolute quantification and structural information simultaneously often with minimal sample preparation. The technique is non-destructive and results are highly reproducible.

Spectrophotometric methods, although they are less specific, they continue to be used for their simplicity, cost-effectiveness and high-throughput capabilities for preliminary screening and quantification of broad classes of phytochemicals such as total phenolic or flavonoid content (Azeem et al., 2025). The principle behind the assays is the Beer-Lambert Law which state that there is direct proportionality between the concentration of the analyte and the path length of light passing through the solution (Wathudura et al., 2025). The Folin-Ciocalteu (FC) assay is widely used for total phenolic content. The assay is based on a redox reaction between phenolic compounds and phosphomolybdic and phosphotungstic acids under alkaline conditions that produces a blue complex whose intensity is directly proportional to the total concentration of phenolics in the sample (Kiketo & Mecha, 2025). Total flavonoid content (TFC) uses aluminum chloride which forms stable, orange/yellow-colored complexes with the flavonoids' hydroxyl groups. Intensity of the color is measured using spectrophotometry (Wathudura et al., 2025). For booth assays, a standard curve is generated using a known phenolic of flavonoid compound such as gallic acid, quercetin, catechin or rutin. Table 2.1 summarizes the merits and cons of spectrophotometric methods.

Table 0.1: Advantages and disadvantages of spectrophotometric method of analysing phytochemicals

Advantages	Disadvantages
Provide a quick quantitative estimation of broad classes of compounds, which is useful for comparing different extracts phytochemical content.	choice of standard 2.(gallic acid for TPC, quercetin for TFC) affects the reported value, as different phenolic or flavonoid compounds react with varying intensities.

Relatively fast, allowing for the analysis of a large number of samples in a short period.	Differences in reagent purity, reaction conditions and calibration can lead to differences in results between laboratories and. Comparison becomes difficult.
The reagents are generally inexpensive, and the equipment is less costly than advanced chromatographic systems like HPLC or GCMS.	Not be suitable for detecting trace amounts of specific phytochemicals compared to more advanced techniques
Involve straightforward chemical reactions and require basic laboratory equipment (a spectrophotometer and common glassware), making them accessible for many research and quality control settings	Components in complex plant matrices can interfere with the reaction, leading to inaccurate results.

All in all, these analytical techniques are indispensable in both quantitative and qualitative analyses of phytochemicals providing comprehensive information into the rich chemical diversity of *A.* digitata /muuyu/umkhomo seed extracts.

2.8 Research gaps

The existing scientific literature reveals a significant knowledge gap regarding comprehensive characterization of *A. digitata /muuyu/umkhomo* seed oil yield and its phytochemical profile from specific less-studied geographical areas across Africa. While general trends indicating variations in composition of *A. digitata /muuyu/umkhomo* seeds due to geographical origin are acknowledged, detailed and localized data from many regions in many countries remain largely undocumented (Kalinganire et al., 2023). Specifically, there is notable paucity of scientific data relating to oil yield and phytochemical composition of *A. digitata /muuyu/umkhomo* seeds . Existing studies have presented generalized data from other regions which fails to accurately reflect the unique characteristics influenced by the region's specific agro-ecological conditions. The absence of localized empirical evidence limits an all-embracing understanding of the specific quality attributes, nutritional benefits as well as commercial viability of *A. digitata/muuyu/umkhomo* seed oil from this particular region. However, this is rather a significant research opportunity that is uniquely positioned. As a result, chances to valorize the local resource for both nutritional enhancement and economic empowerment may be missed. This study therefore, aims to address this critical gap by providing foundational scientific

evidence on *A. digitata* /muuyu/umkhomo seeds thereby contributing novel data to the existing body of knowledge, informing local communities, policy makers and potential industries about the specific value and optimal utilization of this native resource.

2.9 Chapter summary

Chapter 2 provided an in-depth review of the African baobab (*Adansonia digitata /muuyu/umkhomo.*), emphasizing its ecological importance and its vital role in supporting livelihoods and food security across sub-Saharan Africa. The baobab was highlighted as a "superfood" due to the rich nutritional profile of its fruit, particularly its seeds, which constitute a significant portion of the fruit's mass and are valuable sources of protein, fat, and beneficial fatty acids like linoleic, oleic, and palmitic acids.

The chapter further explored the global perspective on the phytochemical richness of *A. digitata/muuyu/umkomo* seeds. It detailed the presence of diverse bioactive compounds, including polyphenols (e.g., gallic acid, catechin, proanthocyanidins), flavonoids (e.g., apigenin, naringenin, rutin), tannins, glycosides, terpenoids, N-acylethanolamines, and steroids. These phytochemicals were noted for their potent antioxidant, antimicrobial, antiinflammatory, and overall health-promoting properties, underscoring the potential of baobab seeds as functional food ingredients and their continuous relevance in ethnomedicine.

A significant discussion point was the substantial variation in phytochemical composition and oil yield of *A. digitata/muuyu/umkhomo* seeds, influenced primarily by geographical origin and processing methods. Examples from Malawi and Kenya illustrated regional differences in mineral content, while studies on roasting revealed nuanced impacts on phenolic and flavonoid concentrations. Different extraction methods, such as conventional pressing, solvent-based techniques (Soxhlet), and supercritical carbon dioxide (scCO2) extraction, were shown to drastically affect oil yield and quality, presenting a clear trade-off between maximizing yield and ensuring product purity suitable for sensitive industries like cosmetics and nutraceuticals. The chapter also outlined the analytical techniques used for phytochemical quantification, ranging from highly sensitive and selective methods like HPLC-MS/MS, UHPLC/QTOF/MS, and GC-MS for detailed structural elucidation and volatile compound analysis, to more accessible spectrophotometric methods (e.g., Folin-Ciocalteu assay for total phenolics and aluminum chloride assay for total flavonoids) for preliminary screening. The advantages and

disadvantages of these methods were discussed, highlighting their respective roles in providing comprehensive chemical profiles.

Finally, the chapter identified a critical research gap: the lack of comprehensive, localized data on *A. digitata/muuyu/umkhomo* seed oil yield and phytochemical profiles from specific, lessstudied geographical areas. This gap limits a complete understanding of the unique characteristics, nutritional benefits, and commercial viability of baobab resources from such regions. The chapter concluded by emphasizing that localized studies are not merely academic pursuits but are indispensable for valorizing local resources, informing sustainable harvesting practices, developing value chains, and directly addressing global challenges related to food and nutrition security and rural economic advancement.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

This chapter outlines the comprehensive methodology employed to achieve the research aim and objectives of investigating the oil yield and phytochemical composition of baobab (*Adansonia digitata* /muuyu/umkhomo) seeds . It details the research design, including the philosophical underpinnings, methodological approach, and specific strategy. Furthermore, it elaborates on the practical research methods, encompassing population and sampling techniques, data collection procedures, and analytical methods. Finally, the chapter ethical considerations inherent in conducting this scientific investigation.

3.2 Research design

This section focuses on the positivist research paradigm providing details on its epistemology and axiology. Positivism looks at empirical evidence and segregation or removal of facts from values .Axiology looks how the values can be separated from facts especially by researcher who try to avoid being biased or have favouratisms. Epistemology(Knowledge)can be obtained through scientific experiment processes.

3.2.1 Research paradigm

The positivist research paradigm was adopted as there is an objective reality (variation in oil yield and phytochemical composition in *A. digitata/muuyu/umkhomo* samples exists independent of the perceptions of the researcher and empirical observation and measurement can help in understanding the mentioned variations. This study assumed that the oil yield and phytochemical compositions of *A. digitata/muuyu/umkhomo* seeds are objective and measurable properties that exist outside the perceptions of the researcher. This is the ontology of this research. Furthermore, the properties are governed by natural laws and can be investigated systematically (Nuswowati, 2022).

The epistemological stance of the current research was that knowledge of oil yield and phytochemical compositions of *A. digitata/muuyu/umkhomo* seeds will be generated through direct experimentation, observation and collection of numerical data. This is directed towards identifying patterns and relationships with regards to chemical composition and oil yield of *A. digitata/muuyu/umkhomo* seeds . This is achievable by use of spectrophotometry to quantify data (Ali, 2024).

In terms of axiology, ethics and values, this study aimed to be objective and free of values. Personal biases and values of the researcher were minimized by ethical research through responsible scientific inquiry.

3.2.2 Research methodology

A quantitative approach was adopted because variables (phytochemical composition and oil yield) are measurable. Also, there are hypotheses to be tested as specified in chapter 1 and numerical data was analysed to establish the statistical relationships between the variables (Li et al., 2024).

3.2.3 Research strategy

An exploratory ad descriptive strategy was used in this study because the researcher sought to investigate and characterise the oil of *A. digitata* /muuyu/umkhomo from the understudied geographical region of the named or chosen area. The study sought to provide a detailed account of oil yield and phytochemical profile. This strategy allowed for novelty in generating foundational data that can inform future, extensive research and practical applications.

3.3 Research methods

In this section, the practical steps in collection and analysis of data are detailed. Population and sampling, sampling method and data collection methods are to be explored thoroughly.

3.3.1 Population and sampling

The population, sampling procedure, data collection methods and statistical analyses are described. *Population*

The target population for this study comprised of mature *A. digitation* /muuyu/umkhomo fruits naturally occurring within the district with special focus of the seeds produced by those fruits. The study exclusively focused on one chosen area as specified in the delimitations section. Sampling method

Stratified random sampling was used. The baobab trees were divided into subgroups (strata) based on wards in the district that have abundant baobabs. Within each ward, the sample size was allocated proportionally based on the number of baobab trees in the area and simple random sampling was used to select the allocated number of baobab trees from each ward for fruit collection. The sample size was determined according to equation 1 based on the statistical power as well as logistical feasibility (Jena et al., 2025).

$$n = \frac{(Z^2 \times p \times (1-p))}{Z^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.1)}$$

Where:

- n = sample size
- Z = Z-score at 95 % confidence interval which is 1.96
- p = proportion of baobab trees with mature fruits in each of the wards
- E = margin of error which is 0.05 at 95 % confidence level

3.3.2 Data collection methods

This stage involved different stages from sample acquisition to laboratory analyses.Experiments were conducted and observations were made and recorded for future use.

3.3.2.1 Sample collection and preparation

Mature *A. digitata* /muuyu/umkhomo fruits were collected according to the sampling procedure described in the sampling section during the peak fruiting season (2024/2025). The fruits were opened carefully and the seeds separated from the pulp and fibrous material by soaking in distilled water and washing them clean before drying under a shade until a constant

mass is obtained. Dried seeds were pulverised into a powder and stored in separate air tight containers under refrigeration until time of use.

3.3.2.2Extraction of oil

Analytical grade n-hexane Soxhlet extraction was used. 5 g of the powdered seeds samples were placed into a thimble and inserted into the Soxhlet apparatus. Each powder was extracted for 6 hours at 60 ℃ using 50 ml n-hexane. Excess solvent was removed by rotary evaporation. All extraction processes were done in triplicate for each sample. Oil yield was calculated using equation 2:

$$oil\ content = \frac{A-B}{W} \times 100\ \% \quad \text{.....3.2}$$

Where:

- A = mass of the flask and oil after extraction in grams
- B = mass of flask only
- W= mass of sample in grams

All samples were given exactly the same treatment. The extracted oil samples were stored in amber bottles in a refrigerator until needed for further analysis. The method used was obtained from Zhou et al. (2023) and modified.

3.3.2.3Phytochemical Composition Analysis

Both quantitative and qualitative tests were done as described in the sections that follow.

Qualitative Phytochemical Tests

The methods used were obtained from Zhou et al. (2023) with slight modifications.The methods are: Mayer's, froth forming, lead acetate, alkaline and ferric chloride tests

Alkaloids: Mayer's test

I ml of the extract was added to 1ml of potassium mercuric iodide solution (Mayer's reagent) in a test tube. The contents were shaken gently. Presence of the alkaloids is proved by formation of a white precipitate.

Saponins: Froth forming test

5ml of plant extract was shaken with 5mls distilled water in a test tube for 15 minutes. A positive response shows stable foam in the test tube.

Phenolic compounds: Lead acetate test

1mI of seed extract was mixed with 1ml of 10% lead acetate solution. A white precipitate shows positive results.

Tannins: Ferric chloride test

1ml of the extract was diluted with distilled water. 2 drops of ferric chloride were added. A transient green or black colour indicates the presence of tannins.

Flavonoids: Alkaline test

Drops of sodium hydroxide are added to the seed extract followed by drops of sulphuric acid. If flavonoids are present, the solution turns colourless after adding sulphuric acid.

Terpenoids

Add 1ml of chloroform to 1ml seed extract, swirl to mix and add 3ml of sulphuric acid. A reddish-brown colouration at the interface shows the presence of terpenoids.

3.3.2.4Quantitative phytochemical analysis

Determination of total phenolic content

Modified Folin Ciocalteu method was used to determine phenolic content of the extract. 100 µl of plant extract were added to 400 µl of Folin Ciocalteu reagent mixture followed by 1 ml of 7.5 % sodium carbonate. Resulting solution was diluted by a factor of 5 with distilled water and incubated for 1 hour in the dark. Absorbance was measured at 765 nm. Gallic acid was used as a standard. The results were expressed in terms of gallic acid in mg/100g (Zhou et al., 2023).

Determination of total flavonoid content

Total flavonoid content of samples was determined using the aluminium chloride colorimetric assay. The standard used was quercetin. 0.2 ml of 5% sodium nitrate solution were diluted with 3 ml of distilled water and mixed with 1 ml of extract. After 5 minutes, 0.4 ml of 10% aluminium chloride were added. The mixtures were allowed to stand for 5 minutes, and 1.5 ml of 1 mM sodium hydroxide were added followed by 1 ml distilled water. The mixtures were centrifuged at 3500 rpm for 5 minutes. The supernatants were collected and their absorbances measured at 415 nm against a hexane blank containing everything else except the plant extract. The total flavonoid content was expressed as milligrams of quercetin equivalents per 100 grams (mg QE/100g extract).

3.4 Data analysis methods and instruments

All quantitative data obtained from oil yield and phytochemical analyses were analysed using IBM SPSS version 26.0. Each parameter was replicated three times so results were reported as mean ± standard deviation. One-way analysis of variance (ANOVA) was used to determine the statistically significant differences in oil yield and phytochemical composition among the samples of *A. digitata* /*muuyu/umkhomo* seeds . ANOVA indicated significant differences, the Tukey's Honestly Significant Difference (HSD) post hoc test was used to identify which specific means are significantly different from each other at $p<0.05$.

3.5 Ethical issues

All research activities were conducted in strict adherence to ethical guidelines and national regulations governing scientific research in Zimbabwe. Before interaction with local communities or individuals required for sample collection (access to private land), informed consent was obtained from the landowners or headsmen since most of the baobab fruits were obtained from abundant forests. The researcher ensured sustainable and non-destructive harvesting of *A. digitata* /muuyu/umkhomo fruits with no damage being inflicted on the fruits or the surrounding environment. Findings of the study were reported accurately and transparently with no manipulation or misrepresentation.

3.6 Chapter summary

This chapter has provided a detailed exposition of the research methodology that was used for this investigation into the oil yield and phytochemical profile of *A. digitata/muuyu/umkhomo* seeds. It has outlined the research paradigm, quantitative methodology and exploratory strategy opted to guide the study. The chapter meticulously described the practical methods for collecting samples, extracting and characterising the extracted oil. Finally, the chapter emphasized the commitment to ensure the reliability and validity of the findings through rigorous experimental design, statistical analysis and ethical principles. The robust methodological framework was designed to generate high-quality localized scientific data that will contribute significantly to the understanding and valorisation of *A. digitata* /muuyu/umkhomo seeds .

CHAPTER 4: DATA PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter presents the findings of the study on phytochemical composition and quantitative phytochemical analysis of *A. A.digitata/muuyu/umkhomo* seeds from five wards in chosen region. The chapter also presents results of descriptive and inferential statistics.

4.2 Qualitative phytochemical profiling of *A. A.digitata/muuyu/umkhomo* seed oil

Extracts of the five samples of baobab were screened for their phytochemical composition Table 4.1 summarises the results that were obtained. All of the samples tested positive in all the tests that were conducted. Phytochemical screening of the samples revealed the presence of alkaloids, saponins, terpenoids, flavonoids, phenolics, tannins and phytosterols. From human physiology point of view, phenolic compounds are paramount in anchoring the body's defence systems because they have anti-proliferative, antioxidant and anti-inflammatory properties (Msalilwa et al., 2020). In addition, the other phytochemicals are known to equally important to humankind in the same sense as phenolics (Russo et al., 2020). Various scholars have obtained similar results in qualitative. Phytochemical analysis of baobab seed oil (Msalilwa et al., 2020, Masisi, 2022; Russo et al., 2020; Chiacchio et al., 2022; Popoola et al., 2023).

Phytochemicals	Test used	Result				
		Katoni	Nyatsato	Marymount	Kasenzi	Makuni
Alkaloids	Mayer's test	+	+	+	+	+
Flavonoids	Alkaline test	+	+	+	+	+
Phenolic compounds	Lead acetate test	+	+	+	+	+
Tannins	Ferric chloride	+	+	+	+	+
Terpenoids	Salkowski test	+	+	+	+	+
Saponins	Foam test	+	+	+	+	+

Table 4.1: Preliminary phytochemical analysis of samples of A.digitata/muuyu/umkhomo

In the table above positive results are indicated by(+) sign (meaning present) while the negative result is indicated by a (-) sign or it represents absence of phytochemicals like alkaloids,phenolic compounds,tannins ,saponins and terpenoids.Various standard qualitative tests were used.From the evidence above,all samples from Kasenzi,Katoni,Makuni,Marymount and Nyatsato gave positive results .

4.3 Quantitative phytochemical analysis and oil content

This section presents results of oil content, phenolic and flavonoids content of *A. A.digitata/muuyu/umkhomo* seeds collected from five wards in the area.

4.3.1 Overview of the mean parameters of composition

Table 4.2 represents the mean values and standard deviations for oil content, TFC and TPC for baobab seeds collected from five wards as well as the overall total mean. This provides a foundational summary of the central tendency and variability of each measured component across the different geographical origins prior to inferential statistics. Table 4.2:Mean values and standard deviations for oil content, TFC and TPC

Identity of sample	Mean oil content, %	Mean TFC, mg QE/100g	Mean TPC, mg GAE/100g
Kasenzi	42.19 ±0.77	143.67±0.31	195.11±0.95
Katoni	38.24±0.39	145.63± 0.42	197.44±0.68
Makuni	40.60±1.01	145.11±0.19	196.51±0.35
Marymount	38.60±0.62	145.99±0.14 0	198.77±0.21
Nyatsato	39.90±0.39	146.70±0.36	200.15±1.00
Overall total	39.91±1.12	145.42± 1.56	197.59±1.78

From the bove table,Kasenzi recorded the highest oil content and Marymount has the least or lowest amount of oil content.Makuni and Nyatsato obtained higher values of TFC as compared to other wards like Kasenzi among others.TPC was highest in Nyatsato and lowest in Katoni .Mean and standard variations for oil content,TFC and TPC were analysed.It assessed variation in nutritional value and phytochemical profiles due to geographical origin.

The graph in figure 4.1 presents a calibration curve that is used to show quantity of phenolic compounds in baobab seeds extracts. The graph was attained by plotting absorbance against known concentrations of stanadardised solutions

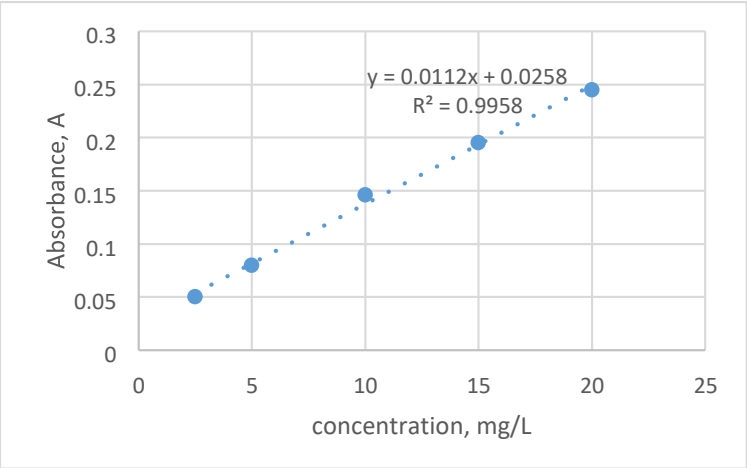


Figure 4. 1: Calibration curve for quantification of phenolic compounds

Absorbance and concentration gave a straight line graph as shown in the graph above .The two seem to directly proportional to each other. Calibration shows a strong linear relationship (R^2 =0.9961) showing increased levels of accuracy and reliability of spectrophotometric method used to find phenolic content. Equation of line helps in making calculations of unknown solutions or concentrations supported by absorbance

The calibration curves for quantitative analyses are presented in figures 4.2 while figure 4.3 compares the TPC and TFC of the five chosen wards. Figure 4.2 shows calibration curve for Quantification of Flavonoids. This graph was used to measure content or amount of flavonoid in baobab seeds samples .The graph was plotted by absorbance of known flavonoid concentrations.

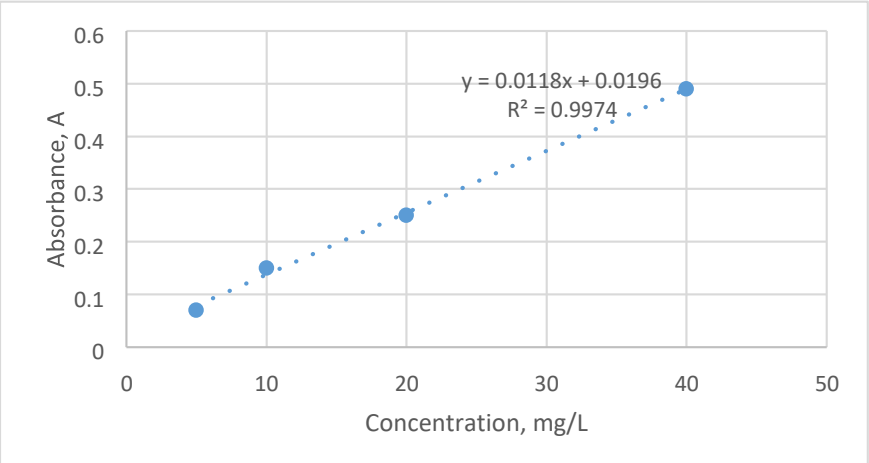


Figure 4.2: Calibration curve for quantification of flavonoids

Positive linear pattern is shown by graph, (R2=0.9974), showing increased or very high correlation between absorbance and the concentration. This may prove that spectrophotometric method is valid as it accurately analyses flavonoid content if baobab seeds samples.

The Figure 4.3 below shows a comparison of TPC and TFC.The bar chart compares Total Phenolic Content(TPC) and Total Flavonoid Content(TFC) obtained from A.digitata/muuyu/umkhomo seeds from all the five selected wards.

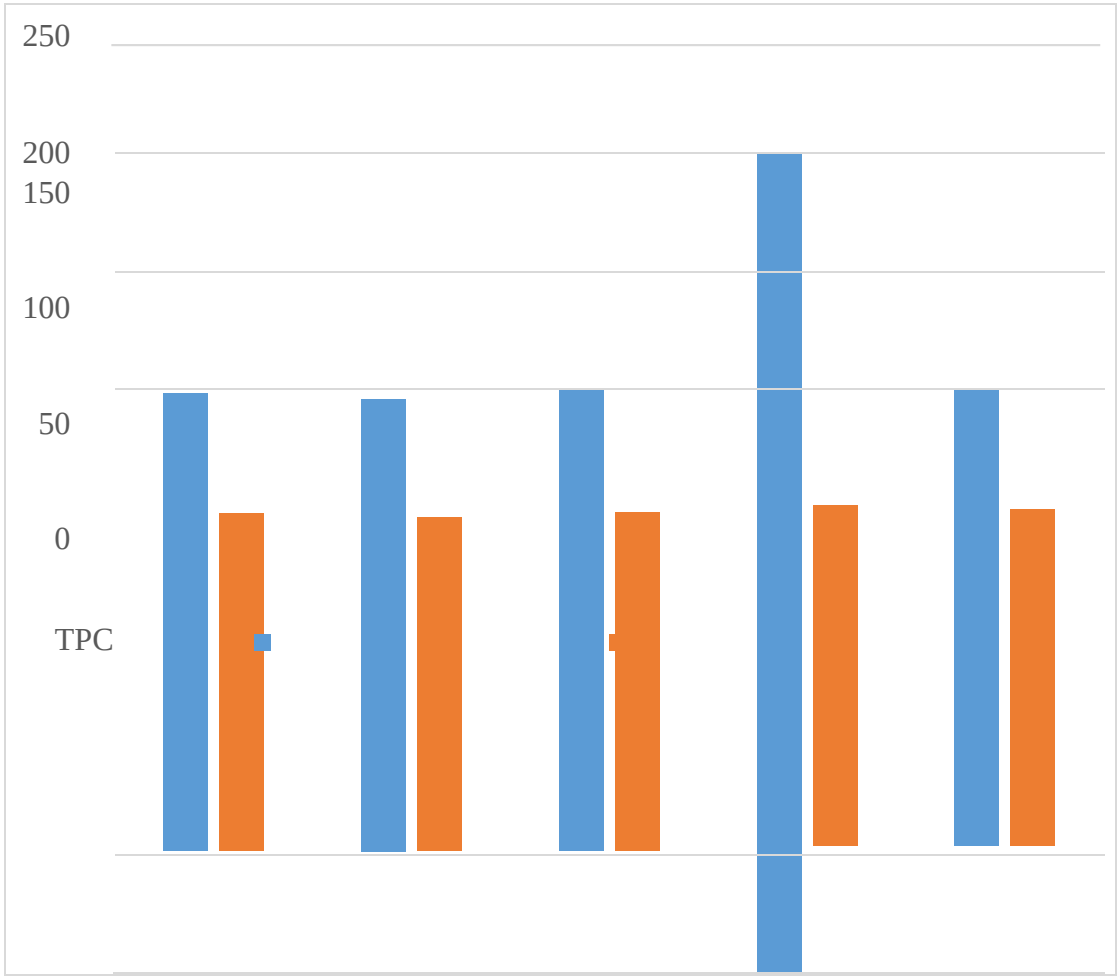


Figure 4. 3: Comparison of TPC and TFC

TPC values are higher in all wards or all places .Nyatsato gave the highest TPC and Kasenzi showed very low or was the lowest in TFC values.The variations shown gave evidence of effects of geographical location on TPC or nutritive value s of A.digitata/muuyu/umkhomo seeds.

The graph below in Figure4.4 shows different amounts of oil yields produced from five different samples. .Oil values were given as percentages and it was a comparison.

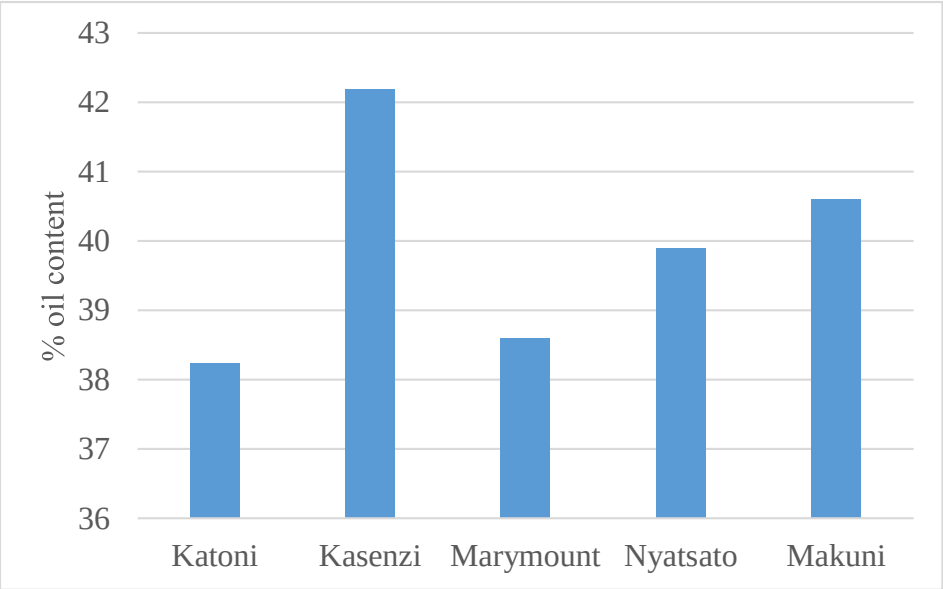


Figure 4.4: Comparison of oil content

From the graph above,it can be deduced that Kasenzi produced the highest oil content by producing above 42% oil yield.The lowest is Katoni with 38% oil content .The rest of the wards like Nyatsato and Marymount produced 39.9% and 38.3% respectively except Makuni which yielded a percentage which was above 40%.Oil yields showed variations depending on geographical location.

4.3.2 Statistical analyses of the results

Highly significant differences (p=0.001) were consistently demonstrated for all the three test parameters under investigation across the five wards. This means that the ward of origin has a statistically significant effect on the levels of these parameters in baobab seeds. Table 4.3 summarizes the ANOVA results.

Table 4.3: Summary of ANOVA results for TPC, TFC and oil content

Dependent variable	F-statistic	Sig.	R_2
Oil content, %	20.798	0.000	0.893
TPC, mg GAE/g	22.576	0.000	0.900
TFC, mg QE/g	21.110	0.000	0.894

The F-statistics were 20.798, 22.576 and 21.110 for oil content, TPC and TFC in that respective order. Additionally, the R^2 values were markedly high (0.894, 0.900 and 0.893 for TFC, TPC and oil content respectively) suggesting that approximately 89-90 % of the observed variability in the three parameters can be explained by the differences between the five wards. Such a

strong statistical relationship shows the influence of geographical location on the chemical composition of baobab seeds in the region of this chosen geographical area.

4.3.2 Post-Hoc analysis

For oil content, the Tukey HSD post-hoc test revealed pairwise differences among the wards (table 4.4). Kasenzi seeds exhibited the highest mean oil content (42.19±0.77 %) which was significantly higher than Nyatsato (39.90±0.39%, p=0.006), Marymount (38.60±0.62%. p=0.000) and Katoni (38.24±0.39%, p=0.000).

Table 4.4: Multiple comparisons for oil content by the Tukey HSD test

I	J	I-J (Mean difference)	Standard error	Sig.	95 % confidence interval	
					Lower bound	Upper bound
Kasenzi	Katoni	3.9500*	0.49470	0.000	2.3219	5.5781
	Makuni	1.5900	0.49470	0.056	-0.0381	3.2181
	Marymount	3.5900*	0.49470	0.000	1.9619	5.2181
	Nyatsato	2.2933*	0.49470	0.006	0.6652	3.9214
Katoni	Makuni	-2.3600*	0.49470	0.005	-3.9881	-0.7319
	Marymount	-0.3600	0.49470	0.945	-1.9881	1.2681
	Nyatsato	-1.6567*	0.49470	0.046	-3.2848	-0.0286
Makuni	Marymount	2.0000*	0.49470	0.016	0.3719	3.6281
	Nyatsato	0.7033	0.49470	0.629	-0.9248	2.3314
Marymount	Nyatsato	-1.2967	0.49470	0.139	-2.9248	0.3314

*The mean difference is significant at 0.05 level.

From the table above it can be deduced that Katoni exhibited significantly lower oil content compared to Makuni and Nyatsato. The homogenous subsets for oil content presented in table 4.4 further illustrate the distinctions by grouping wards with no significant variation from each other. The analysis indicates a clear separation with Kasenzi forming a distinct subset (at the upper end of a subset) indicative of superior oil content.

Statistical analysis inarguably demonstrates substantial variations in oil content of *A.*

A.digitata/muuyu/umkhomo seeds collected from five wards in the district. The results of ANOVA ($F=20.798$, $p<0.001$; $R^2=0.893$) further confirm that geographical origin of the seeds within Rushinga has notable influence on oil accumulation Table 4.5: Homogenous subsets for oil content (Tukey HSD)

sampleID	N	Subset 1 Mean	Subset 2 Mean	Subset 3 Mean	Subset 4 Mean
Katoni	3	38.2433			
Marymount	3	38.6033	38.6033		
Nyatsato	3		39.9000	39.9000	
Makuni	3			40.6033	40.6033
Kasenzi	3				42.1933
Sig.		0.945	0.139	0.629	0.056

Furthermore, Tukey HSD post-hoc analysis indicates that Kasenzi possesses significantly higher mean oil content (42.19%) than the other wards. The observed differences in the oil content suggest that the wards are likely to benefit differently from a combination of factors that are conducive for lipid biosynthesis and storage. Such factors include specific microclimatic conditions (Msalilwa et al., 2020), nutrient profiles of the soils or prevalence of inherent *A. A.digitata/muuyu/umkhomo* genetic predisposition for high accumulation of lipids (Tshabalala & Ndung'u, 2022). Some scholars have reported lower ranges of lipid content (11.6 to 33.3 g/100 g of dry weight) (Nkafamiya et al., 2023) while others have reported ranges falling between 12.25 and 33.00 % (Omotayo & Aremu, 2020). Consistently high oil content observed in Rushinga samples point towards a significant finding. While variation in analytical methodologies such as extraction solvents and extraction conditions can influence reported yields (Niaye et al., 2025), such remarkable and consistence observed in this study imply more than just methodological variance. It suggests that *A. A.digitata/muuyu/umkhomo* populations in the area particularly Kasenzi may have unique genetic characteristics that allow superior lipid biosynthesis or flourish under given environmental conditions (climatic and edaphic) suitable for oil build up. This result is of significance in terms of commercial viability and economic potential of cultivating baobab fruits. Given that the high oil yields obtained in the area are consistently reproducible, the region may emerge as a premier for baobab oil production. This warrants in-depth investigation into factors underpinning this superior yield as well as fatty acid profile and other characteristics of the oil.

Table4 .6 shows the pairwise differences in TPC among the wards according to Tukey HSD multiple comparisons test. Kasenzi exhibited significantly lowest TPC as compared to Katoni, Marymount and Nyatsato.

Table 4.6: Tukey HSD multiple comparisons for TPC

(I) sampleID	(J) sampleID	Mean Difference (I-J)	Std. Error	Sig.	95% ConfidLower Interval Bound	Upper Bound
Kasenzi	Katoni	-2.3367*	0.58179	0.016	-4.2514	-0.4220
	Makuni	-1.4000	0.58179	0.191	-3.3147	0.5147
	Marymount	-3.6600*	0.58179	0.001	-5.5747	-1.7453
	Nyatsato	-5.0400*	0.58179	0.000	-6.9547	-3.1253
Katoni	Makuni	0.9367	0.58179	0.523	-0.9780	2.8514
	Marymount	-1.3233	0.58179	0.230	-3.2380	0.5914
	Nyatsato	-2.7033*	0.58179	0.006	-4.6180	-0.7886
Makuni	Marymount	-2.2600*	0.58179	0.020	-4.1747	-0.3453
	Nyatsato	-3.6400*	0.58179	0.001	-5.5547	-1.7253
Marymount	Nyatsato	-1.3800	0.58179	0.200	-3.2947	0.5347

*The mean difference is significant at 0.05.

The values were 195.11±0.95, 197.44±0.68, 198.77±0.21 and 200.15±1.00 mg GAE/100g in that respective order. The p values were 0.016, 0.001and 0.000 for the wards in that same order. Nyatsato, with the highest TPC was also markedly higher than Katoni (p=0.006) and Makuni (p=0.001).

The homogenous subsets for TPC in table 4.7 show a clear gradient of increasing TPC from the lowest (Kasenzi) to the highest (Nyatsato) with intermediate wards forming overlapping groups The pattern is suggesting a progressive increase in TPC across the five wards.

Table 4.7: Homogenous subsets for TPC (Tukey HSD)

sampleID	N	Subset 1 Mean	Subset 2 Mean	Subset 3 Mean	Subset 4 Mean
Kasenzi	3	195.1067			
Makuni	3	196.5067	196.5067		

Katoni	3		197.4433	197.4433	
Marymount	3			198.7667	198.7667
Nyatsato	3				200.1467
Sig.		0.191	0.523	0.230	0.200

Findings of the study also revealed a significantly high overall variation in TPC among five wards (F=22.576, p=0.001) with ward of origin explaining 90% of the variance (R^2=0.900). Geographical origin strongly influences the TPC of *A. A.digitata/muuyu/umkhomo* basing on statistical analysis. There is a progressive increase in TPC in the order Kasenzi < Makuni/Katoni < Katoni/Marymount < Marymount/Nyatsato suggesting that environmental conditions may vary systematically across the five wards resulting in differential induction of biosynthesis of phenolic compounds. These secondary metabolites are often produced by plants as a response mechanism to environmental stressors or as natural defense mechanisms (Msalilwa et al., 2020). Conversely, the findings could be a reflection of genetic adaptation of the baobabs to their particular ward conditions resulting in varied baseline levels of TPC ((Nkafamiya et al, 2023). A deeper understanding of the underlying factors enables identification of optimal growing conditions for baobab seeds with elevated antioxidant properties that are applicable for nutraceuticals and functional foods. Examination of numerical values of TPC gives rise to a critical point of comparison. The observed values are much higher than some reported literature values. TPC ranges of 4.1 to 5.5 mg GAE/g have been reported for pulp and seeds. In yet another study on soaked seed, values were between 251 and 326 mg GAE/100g (Ndung'u & Mbugua, 2025). This highlights a critical issue of unit consistency and more importantly, methodological differences (Siddeeg et al., 2025). Pretreatments like washing the seeds may impact on composition also (Ndiaye et al., 2025). Therefore, there is need for standardized reporting of analytical methods in phytochemical research to ensure comparability cross studies and geographical regions.

Similar to oil content and TPC, analysis of variance indicated substantial overall variation in TFC (F=21.110, p<0.001) among the five wards with sample origin accounting for 89.4 % of the variance (R^2=0.894). This means that the levels of TFC are strongly influenced by the area of origin in district. The TFC values in this study highlight significant difference when compared to literature reports whose range for pulp and seeds are 10.1 to 16.5 mg QE/g (Ndung'u & Mbugua, 2025). According to Saka & Nkafamiya, (2025), the TFC of baobab pulp is 2.05 mg/g. Once again, these discrepancies mirror consistent methodological differences

between the cited literature and this study. This further reinforces the critical impact of extraction protocol, choice of solvent as well as specific assay variations on reported phytochemical concentrations (Siddeeg et al., 2020). The observed pattern suggests that baobab seed is truly exceptional in its phytochemical richness and this could be a major biological finding. However, systemic challenges related to absolute comparison of values across different research reports cannot be ignored and the need for robust validation of reporting of methods can never be overemphasized.

4.4 Summary

The chapter characterized baobab seed oil through quantification of oil, TPC and TFC. Qualitative phytochemical analysis confirmed the presence of tannins, phenolics, flavonoids, terpenoids, saponins and alkaloids in all samples. ANOVA suggested substantial effect of geographical origin of seeds on all the three parameters that were under study. Highest mean oil content was obtained in the Kasenzi sample while the highest TPC was observed in Nyatsato.

CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This concluding chapter synthesized major findings of the study and provides a concise summary of the full journey undertaken to determine oil content, TPC and TFC in samples of baobab seeds. The chapter draws main conclusions based on the objectives of the study and the findings. Finally, the chapter provides a series of recommendations for commercial applications and future research direction.

5.2 Summary of the study

This study addresses a significant gap in scientific literature by providing localized empirical data on the characteristics of *A. A.digitata/muuyu/umkhomo* seeds in Zimbabwe. It sought to determine oil content, perform phytochemical analysis and quantify phenolic and flavonoid compounds of the said seeds with a methodology that is rooted in positivism. The study employed systematic sampling and standard laboratory techniques in extraction of oil and analysis of phytochemicals. Qualitative analysis confirmed the presence of alkaloids, terpenoids, saponins, phenolics, flavonoids and tannins in all the samples. Quantitative phytochemistry of the samples revealed high oil content, TPC and TFC. Statistical analysis of results using ANOVA suggested substantial effect of geographical origin of seeds on all the three parameters that were under study ($p<0.001$). High values of R-squared values (approx. 90%) suggested that place of origin strongly determined the observed variability. Post-hoc tests showed that Kasenzi ward had seeds with the highest mean oil content and Nyatsato ward had the highest TPC. Conclusively, this study has provided robust localized evidence for the significant role of geographical origin on oil content, TPC and TPC of baobab seeds in the district. These findings reinforce broader scientific understanding of the impact of edaphic, climatic and genetic factors on metabolism and accumulation of baobab seed metabolites.

5.3 Conclusions

This study demonstrated that *A. A.digitata/muuyu/umkhomo* seeds from five wards in the geographical region exhibit substantial variations in their oil content, total phenolic content and total flavonoid content. The place of origin is a strong determinant of variation in composition with Kasenzi standing out for its superior oil content and a clear gradient in TPC observed across the wards. The findings of this study underscore the critical importance of origin in determining nutritional and commercial value of baobab seeds. They position Rushinga's potential for future methodological standardization and in-depth environmental and genetic investigations to fully harness this valuable resource.

5.4 Recommendations

This study has provided robust localized evidence for the significant role of geographical origin on oil content, TPC and TPC of baobab seed at ward level . These findings reinforce broader scientific understanding of the impact of edaphic, climatic and genetic factors on metabolism and accumulation of baobab seed metabolites. Wards with high oil content such as Kasenzi may be prioritized for sustainable initiatives in oil extraction. As such, wards with high TPC

and TFC can be targeted as sources for nutraceuticals and functional food ingredients owing to their antioxidant potential. To build upon the findings of this study, several future research directions are recommended. There is need for in-depth studies to identify the edaphic factors and microclimatic parameters in the area that correlate with the observed differences in composition of the investigated baobab seeds. Additionally, the specific genotypes associated with high accumulation of oil, flavonoids and phenolics can be determined by genetic profiling of the baobabs seeds. Such information is very important for future breeding plans that aim to develop improved varieties of *A. A.digitata/muuyu/umkhomo*.

Given the observed unit and numerical differences, the critical need for standardized methods of extraction and quantification cannot be ignored so as to establish accurate and reliable comparisons across different studies and regions. Future research can focus on how final composition and stability of baobab seeds are influenced by post-harvest handling and processing. Given the potentially high concentrations of oil and phytochemicals in baobab seeds, future research can explore the bioavailability of these, their *in vitro and in vivo* functional properties.

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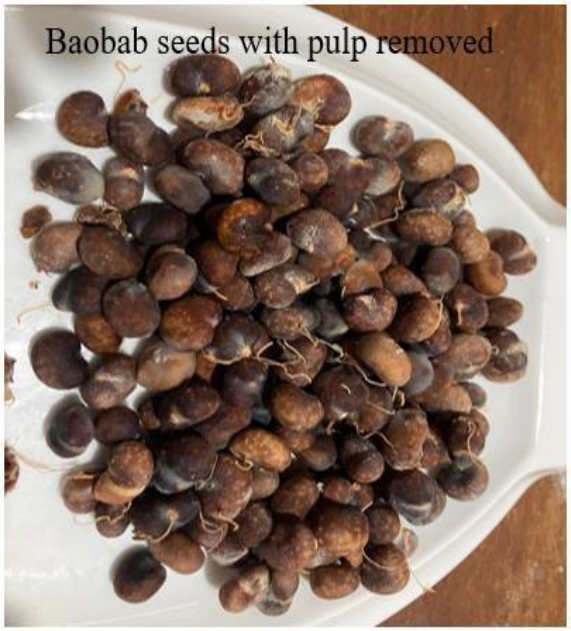
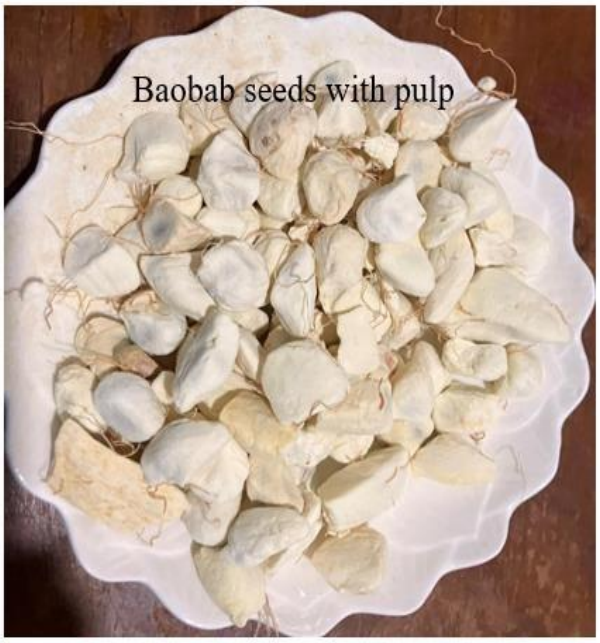
APPENDICES

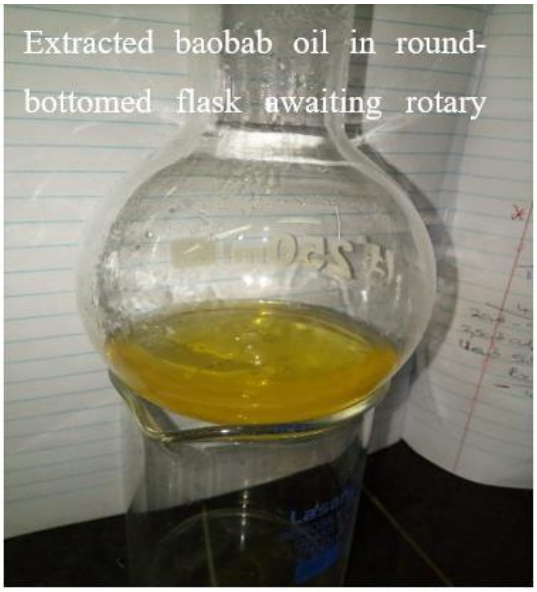
Appendix 1*:* Pictures of some of the processes done during the study

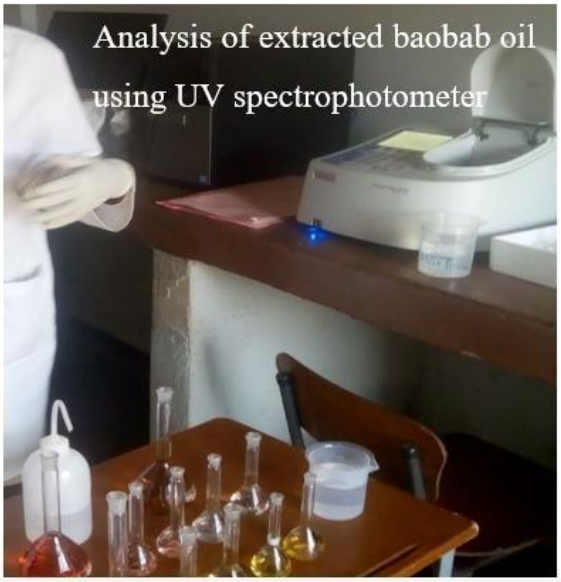

Baobab fruits


Baobab seeds with pulp removed


Baobab seeds with pulp


Crushed baobab seeds





Appendix 2*:* Statistical analysis of results

MEANS TABLES=Oilcontent TFCmgQEper100gram TPCmgGAEper100gram BY sampleID

/CELLS MEAN COUNT STDDEV.

Means

Notes

Output Created		30-JUL-2025 11:44:12
Comments		
Input	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	15
Missing Value Handling	Definition of Missing	For each dependent variable in a table, user-defined missing values for the dependent and all grouping variables are treated as missing.
	Cases Used	Cases used for each table have no missing values in any independent variable, and not all dependent variables have missing values.
Syntax		MEANS TABLES=Oilcontent TFCmgQEper100gram TPCmgGAEper100gram BY sampleID /CELLS MEAN COUNT STDDEV.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

[DataSet3]

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Oilcontent * sampleID	15	100.0%	0	0.0%	15	100.0%
TFCmgQEper100gram * sampleID	15	100.0%	0	0.0%	15	100.0%
TPCmgGAEper100gram * sampleID	15	100.0%	0	0.0%	15	100.0%

Report

sampleID		Oilcontent	TFCmgQEper100gram	TPCmgGAEper100gram
Kasenzi	Mean	42.1933	143.6667	195.1067
	N	3	3	3
	Std. Deviation	.30860	.76501	.95448
Katoni	Mean	38.2433	145.6300	197.4433
	N	3	3	3
	Std. Deviation	.42454	.39154	.67575
Makuni	Mean	40.60333	145.10673	196.50673
	N			
	Std. Deviation	1.01278	.19348	.35019
Marymount	Mean	38.60333	145.99673	198.76673
	N			

	Std. Deviation	.62011	.12897	.21032
	Mean	39.9000	146.7033	200.1467
	N	3	3	3
Nyatsato	Std. Deviation	.38691	.36116	1.00201
	Mean	39.9087	145.4207	197.5940
	N	15	15	15
	Std. Deviation	1.56318	1.11592	1.90725
Total				

UNIANOVA Oilcontent BY sampleID

/METHOD=SSTYPE(3)

/INTERCEPT=INCLUDE

/CRITERIA=ALPHA(0.05)

/DESIGN=sampleID. **Univariate**

Analysis of Variance

Notes

Output Created		30-JUL-2025 11:54:17
Comments		
Input	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	15

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA Oilcontent BY sampleID /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /CRITERIA=ALPHA(0.05) /DESIGN=sampleID.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.03

[DataSet3]

Between-Subjects Factors

		Value Label	N
sampleID	Kasenzi	Kasenzi	3
	Katoni	Katoni	3
	Makuni	Makuni	3
	Marymount	Marymount	3
	Nyatsato	Nyatsato	3

Tests of Between-Subjects Effects

Dependent Variable: Oilcontent

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	30.539[a]	4	7.635	20.798	.000
Intercept	23890.525	1	23890.525	65081.430	.000

sampleID	30.539	4	7.635	20.798	.000
Error	3.671	10	.367		
Total	23924.735	15			
Corrected Total	34.210	14			

a. R Squared = .893 (Adjusted R Squared = .850)

```
UNIANOVA Oilcontent BY sampleID
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /POSTHOC=sampleID(TUKEY)
  /CRITERIA=ALPHA(0.05)
  /DESIGN=sampleID.
```

Univariate

Analysis of Variance

Notes

Output Created		30-JUL-2025 11:58:53
Comments		
Input	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	15

Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA Oilcontent BY sampleID /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /POSTHOC=sampleID(TUKEY) /CRITERIA=ALPHA(0.05) /DESIGN=sampleID.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.05

[DataSet3]

Between-Subjects Factors

		Value Label	N
sampleID	Kasenzi	Kasenzi	3
	Katoni	Katoni	3
	Makuni	Makuni	3
	Marymount	Marymount	3
	Nyatsato	Nyatsato	3

Tests of Between-Subjects Effects

Dependent Variable: Oilcontent

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	30.539[a]	4	7.635	20.798	.000
Intercept	23890.525	1	23890.525	65081.430	.000
sampleID	30.539	4	7.635	20.798	.000
Error	3.671	10	.367		
Total	23924.735	15			
Corrected Total	34.210	14			

a. R Squared = .893 (Adjusted R Squared = .850)

Post Hoc Tests sampleID

Multiple Comparisons

Dependent Variable: Oilcontent

Tukey HSD

(I) sampleID	(J) sampleID	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Kasenzi	Katoni	3.9500*	.49470	.000	2.3219	5.5781
	Makuni	1.5900	.49470	.056	-.0381	3.2181
	Marymoun	3.5900*	.49470	.000	1.9619	5.2181
	Nyatsato	2.2933*	.49470	.006	.6652	3.9214
Katoni	Kasenzi	-3.9500*	.49470	.000	-5.5781	-2.3219
	Makuni	-2.3600*	.49470	.005	-3.9881	-.7319
	Marymount	-.3600	.49470	.945	-1.9881	1.2681

	Nyatsato	-1.6567*	.49470	.046	-3.2848	-.0286
	Kasenzi	-1.5900	.49470	.056	-3.2181	.0381
	Katoni	2.3600*	.49470	.005	.7319	3.9881
Makuni	Marymount	2.0000*	.49470	.016	.3719	3.6281
	Nyatsato	.7033	.49470	.629	-.9248	2.3314
Marymount	Kasenzi	-3.5900*	.49470	.000	-5.2181	-1.9619
	Katoni	.3600	.49470	.945	-1.2681	1.9881
	Makuni	-2.0000*	.49470	.016	-3.6281	-.3719
Nyatsato		-1.2967	.49470	.139	-2.9248	.3314
	Kasenzi	-2.2933*	.49470	.006	-3.9214	-.6652
	Katoni	1.6567*	.49470	.046	.0286	3.2848
Nyatsato	Makuni	-.7033	.49470	.629	-2.3314	.9248
	Marymount	1.2967	.49470	.139	-.3314	2.9248

Based on observed means.

The error term is Mean Square(Error) = .367.

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Oilcontent

Tukey HSD[a,b]

sampleID	N	Subset			
		1	2	3	4
Katoni	3	38.2433			
	3	38.6033	38.6033		

Marymount	3		39.9000		
Nyatsato				39.9000	
Makuni	3			40.6033	40.6033
Kasenzi	3				42.1933
Sig.		.945	.139	.629	.056

Means for groups in homogeneous subsets are displayed.

Based on observed means. The error term

is Mean Square(Error) = .367.

a. Uses Harmonic Mean Sample Size = 3.000.

b. Alpha = 0.05.

UNIANOVA TPCmgGAEpergram BY sampleID

/METHOD=SSTYPE(3)

/INTERCEPT=INCLUDE

/POSTHOC=sampleID(TUKEY)

/CRITERIA=ALPHA(0.05)

/DESIGN=sampleID. **Univariate**

Analysis of Variance

Notes

Output Created		30-JUL-2025 12:02:31
Comments	Active Dataset	

Input	Filter	DataSet3
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	15
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA TPCmgGAEpergram BY sampleID /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /POSTHOC=sampleID(TUKEY) /CRITERIA=ALPHA(0.05) /DESIGN=sampleID.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.02

[DataSet3]

Between-Subjects Factors

		Value Label	N
sampleID	Kasenzi	Kasenzi	3
	Katoni	Katoni	3
	Makuni	Makuni	3
	Marymount	Marymount	3
	Nyatsato	Nyatsato	3

Tests of Between-Subjects Effects

Dependent Variable: TPCmgGAEper100gram

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	45.849[a]	4	11.462	22.576	.000
Intercept	585650.833	1	585650.833	1153506.899	.000
sampleID	45.849	4	11.462	22.576	.000
Error	5.077	10	.508		
Total	585701.759	15			
Corrected Total	50.926	14			

a. R Squared = .900 (Adjusted R Squared = .860)

Post Hoc Test sampleID

Multiple Comparisons

Dependent Variable: TPCmgGAEper100gram

Tukey HSD

(I) sampleID	(J) sampleID	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Kasenzi	Katoni	-2.3367*	.58179	.016	-4.2514	-.4220
	Makuni	-1.4000	.58179	.191	-3.3147	.5147
	Marymount	-3.6600*	.58179	.001	-5.5747	-1.7453
	Nyatsato	-5.0400*	.58179	.000	-6.9547	-3.1253
Katoni	Kasenzi	2.3367*	.58179	.016	.4220	4.2514

	Makuni	.9367	.58179	.523	-.9780	2.8514
	Marymount	-1.3233	.58179	.230	-3.2380	.5914
	Nyatsato	-2.7033*	.58179	.006	-4.6180	-.7886
	Kasenzi	1.4000	.58179	.191	-.5147	3.3147
	Katoni	-.9367	.58179	.523	-2.8514	.9780
Makuni	Marymount	-2.2600*	.58179	.020	-4.1747	-.3453
	Nyatsato	-3.6400*	.58179	.001	-5.5547	-1.7253
	Kasen	3.6600*	.58179	.001	1.7453	5.5747
	Ketone	1.3233	.58179	.230	-.5914	3.2380
Marymount	Makena	2.2600*	.58179	.020	.3453	4.1747
	Nyatsato	-1.3800	.58179	.200	-3.2947	.5347
	Kasenzi	5.0400*	.58179	.000	3.1253	6.9547
	Katoni	2.7033*	.58179	.006	.7886	4.6180
Nyatsato	Makuni	3.6400*	.58179	.001	1.7253	5.5547
	Marymount	1.3800	.58179	.200	-.5347	3.2947

Based on observed means.

The error term is Mean Square(Error) = .508.

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

TPCmgGAEper100gram

Tukey HSD[a,b]

sampleID	N	Subset			
		1	2	3	4
Kasenzi	3	195.1067			

Makuni	3	196.5067	196.5067		
Katoni	3		197.4433		
				197.4433	
					198.7667
Marymount	3			198.7667	
					200.1467
					.200
Nyatsato	3				
		.191	.523		
				.230	
Sig.					

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .508.

a. Uses Harmonic Mean Sample Size = 3.000.

b. Alpha = 0.05.

UNIANOVA TFCmgQEper100gram BY sampleID

/METHOD=SSTYPE(3)

/INTERCEPT=INCLUDE

/POSTHOC=sampleID(TUKEY)

/CRITERIA=ALPHA(0.05)

/DESIGN=sampleID. **Univariate**

Analysis of Variance

Notes

Output Created		30-JUL-2025 12:58:25
Comments		
Input	Active Dataset	DataSet3
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	15
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA TFCmgQEpergram BY sampleID /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /POSTHOC=sampleID(TUKEY) /CRITERIA=ALPHA(0.05) /DESIGN=sampleID.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

[DataSet3]

Between-Subjects Factors

		Value Label	N
sampleID	Kasenzi	Kasenzi	3
	Katoni	Katoni	3
	Makuni	Makuni	3

	Marymount	Marymount	3
	Nyatsato	Nyatsato	3

Tests of Between-Subjects Effects

Dependent Variable: TFCmgQEper100gram

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	15.588[a]	4	3.897	21.110	.000
Intercept	317207.554	1	317207.554	1718288.728	.000
sampleID	15.588	4	3.897	21.110	.000
Error	1.846	10	.185		
Total	317224.988	15			
Corrected Total	17.434	14			

a. R Squared = .894 (Adjusted R Squared = .852)

Post Hoc Tests sampleID

Multiple Comparisons

Dependent Variable: TFCmgQEper100gram

Tukey HSD

(I) sampleID	(J) sampleID	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Kasenzi	Katoni	-1.9633*	.35081	.002	-3.1179	-.8088
	Makuni	-1.4400*	.35081	.014	-2.5946	-.2854

Katoni	Marymount	-2.3300*	.35081	.000	-3.4846	-1.1754
	Nyatsato	-3.0367*	.35081	.000	-4.1912	-1.8821
	Kasenzi	1.9633*	.35081	.002	.8088	3.1179
	Makuni	.5233	.35081	.589	-.6312	1.6779
Makuni	Marymount	-.3667	.35081	.829	-1.5212	.7879
	Nyatsato	-1.0733	.35081	.072	-2.2279	.0812
	Kasenzi	1.4400*	.35081	.014	.2854	2.5946
	Katoni	-.5233	.35081	.589	-1.6779	.6312
	Marymount	-.8900	.35081	.158	-2.0446	.2646
	Nyatsato	-1.5967*	.35081	.007	-2.7512	-.4421
	Kasenzi	2.3300*	.35081	.000	1.1754	3.4846
Marymount	Katoni	.3667	.35081	.829	-.7879	1.5212
	Makuni	.8900	.35081	.158	-.2646	2.0446
	Nyatsato	-.7067	.35081	.326	-1.8612	.4479
	Kasenzi	3.0367*	.35081	.000	1.8821	4.1912
	Katoni	1.0733	.35081	.072	-.0812	2.2279
Nyatsato	Makuni	1.5967*	.35081	.007	.4421	2.7512
	Marymount	.7067	.35081	.326	-.4479	1.8612

Based on observed means.

The error term is Mean Square(Error) = .185.

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

TFCmgQEper100gram

Tukey HSD[a,b]

sampleID	N	Subset		
		1	2	3
Kasenzi	3	143.6667		
Makuni	3		145.1067	
Katoni	3		145.6300	
				145.6300
Marymount	3		145.9967	145.9967
Nyatsato	3			146.7033
		1.000		
			.158	
Sig.				.072

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = .185.

a. Uses Harmonic Mean Sample Size = 3.000.

b. Alpha = 0.05.

[DataSet1] C:\Users\HomePC\Documents\Untitled4.sav

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	Oilcontent[b]	.	Enter

a. Dependent Variable: TPCmgGAEper100gram

b. All requested variables entered.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.549[a]	.301	.248	1.65433

a. Predictors: (Constant), Oilcontent

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.348	1	15.348	5.608	.034[b]
	Residual	35.578	13	2.737		
	Total	50.926	14			

a. Dependent Variable: TPCmgGAEper100gram

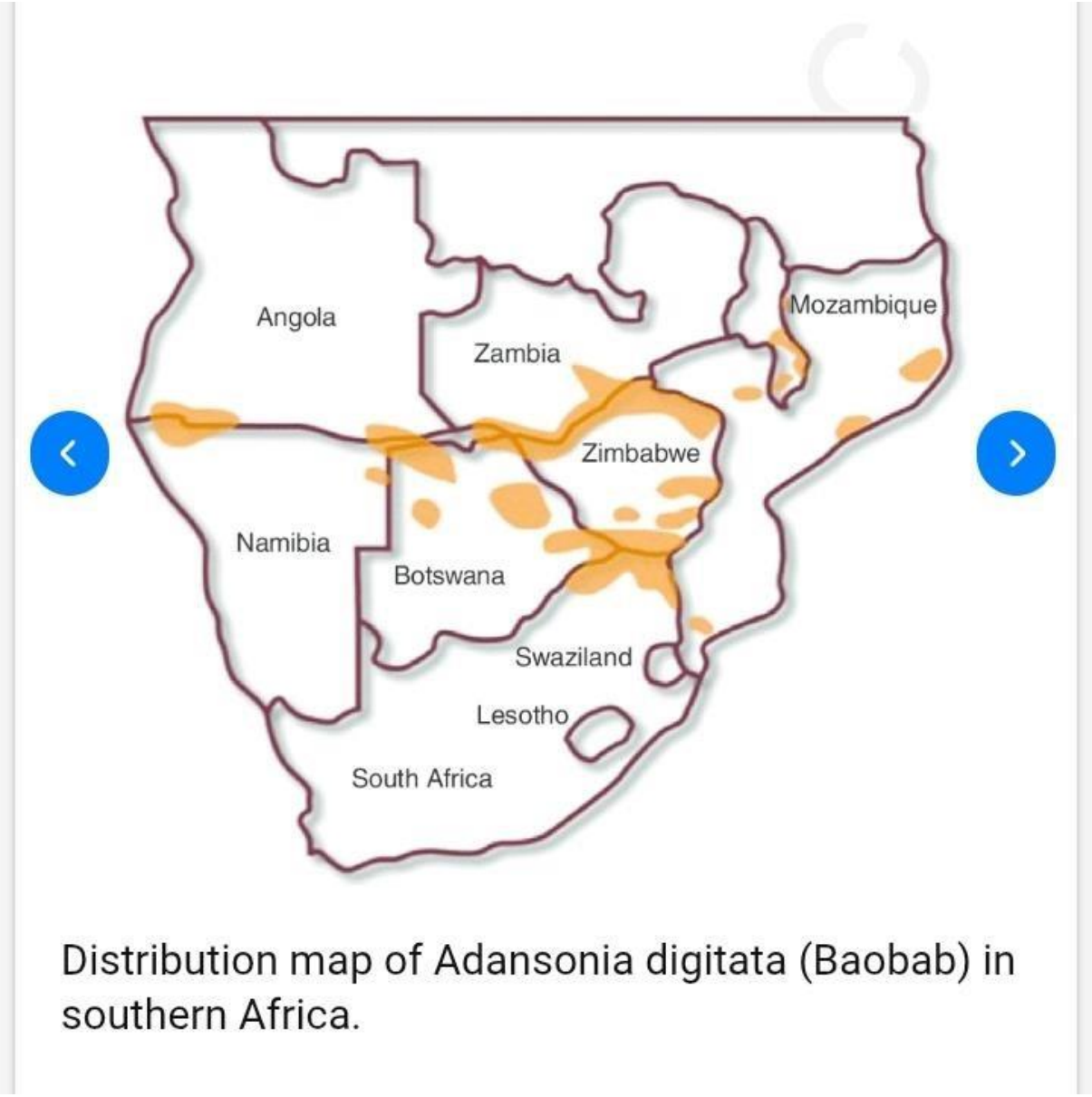
b. Predictors: (Constant), Oilcontent

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	224.325	11.296		19.859	.000

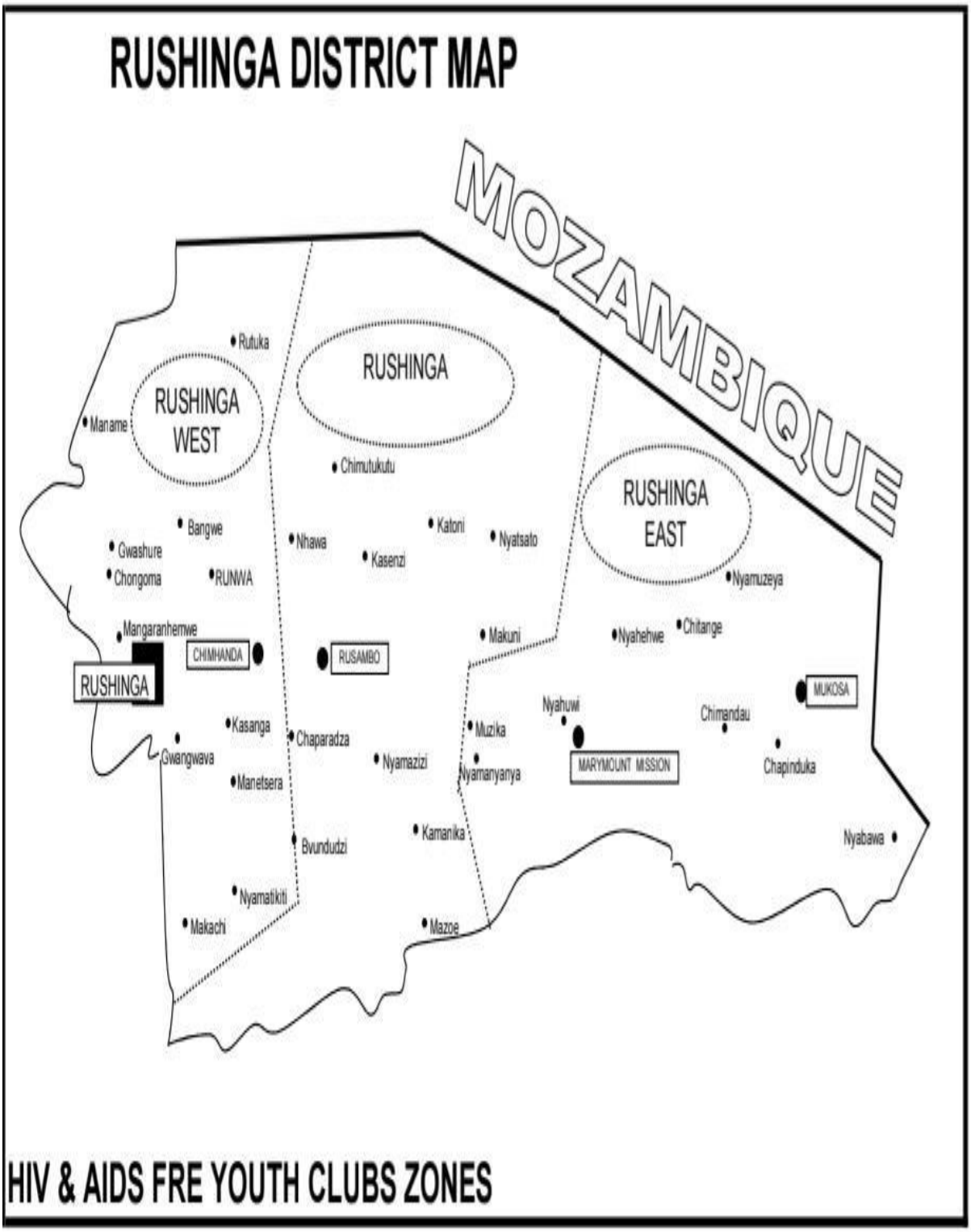
Oilcontent	-.670	.283	-.549	-2.368	.034

a. Dependent Variable: TPCmgGAEper100gram

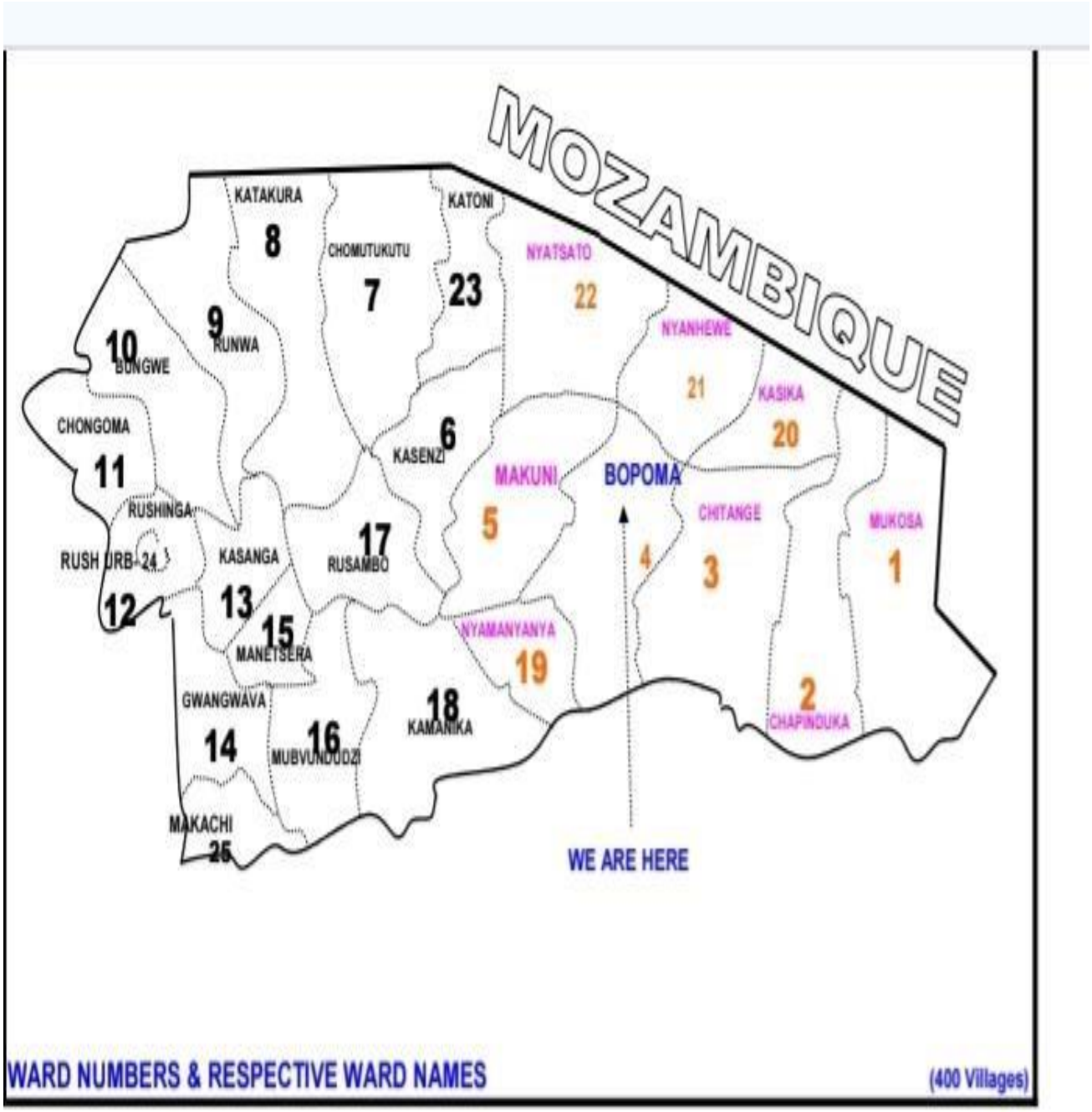


A map showing distribution of baobab fruits in Southern A frica .(Smith & Nkosi ,2021)

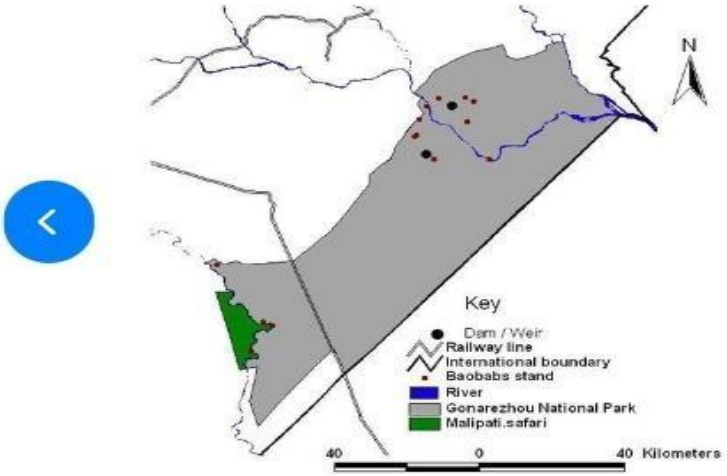
A map showing provinces of Zimbabwe used to locate area under study in Mashonaland Central Province .(World Atlas , 2023)



A map showing areas of study in Rushinga District .(Rushinga District Council, 2023)

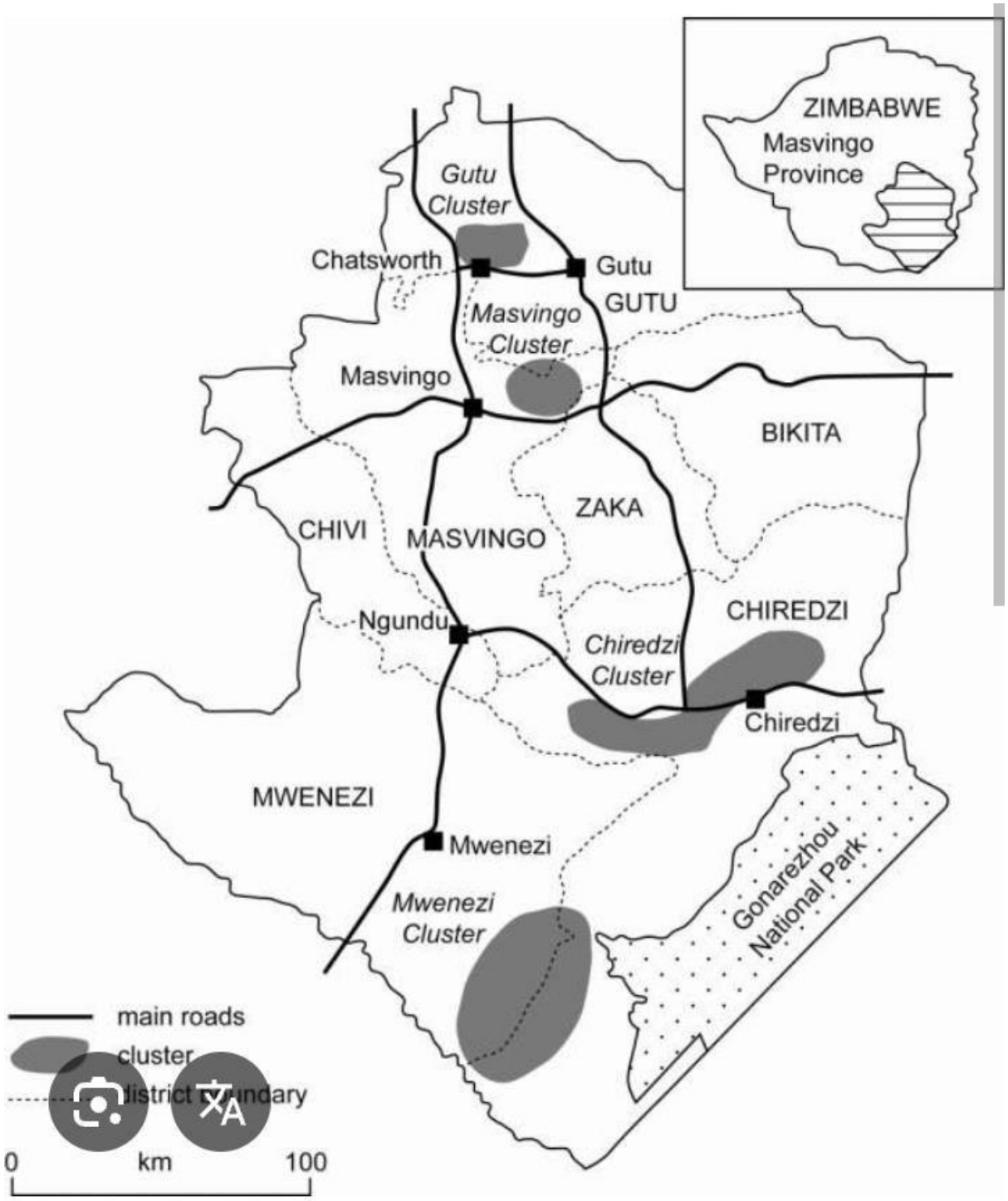


A map showing areas of study in Rushinga District .Marymount Mission is also called Bopoma .(Rushinga District Council, 2023)



1: GNP map showing the distribution and density of baobab study sites.

A map of Gonarezhou National Park showing distribution and density of baobab study sites for comparison .(Moyo& Chirwa, 2023)



A map of Masvingo Province showing areas of comparison during study .(Mhlambo & Dube , 2022)