INVESTIGATION INTO PROXIMATE AND MINERAL PROPERTIES OF MORINGA OLEIFERA SEED

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CERTIFICATION

This is to certify that this is the original work carried out and reported by **OMIDIJI BLESSING MORAYO** with matric number **HND/23/SLT/FT/0507** of the Department of Science Laboratory Technology, Biochemistry Unit, Institute of Applied Science (IAS) Kwara State Polytechnic. And it has been approved in Partial Fulfilment of the Requirements of the Award of Higher National Diploma (HND) in Science Laboratory Technology.

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EXTERNAL EXAMINER	**DATE**

DEDICATION

This research is dedicated work to Almighty God for his grace and guidance on me upon completing this project, and also to my beloved parents, siblings and grandparents

ACKNOWLEDGEMNT

My sincere gratitude goes to Almighty God for the privilege given to me to complete this project work; He has been helping us from the beginning till the end of our program.

My sincere gratitude goes to our kind and esteem supervisor in person of Mr OSENI.O. TAJUDEEN, for her advice through supervision, moral support and word of encouragement to the success of this project. May God almighty continue to preserve, guide, and shower his blessings on you

My upmost and sincere appreciation goes to my beloved parents Mr. and Mrs.OMIDIJI for being my backbone and supporters, without them, i have no power to be where I am are today.

Thank you for your support financially, morally, and spiritually, and for always encouraging me to be of my best behavior. May God in his absolute mercy enrich their pocket and grant them long life and prosperity to reap the fruit of their labor. And to my siblings, I love you all.

My special appreciation goes to the Head of Department of S.L.T in person of Dr. Usman Abdulkareem, Head of Biochemistry Unit in person of Mrs. K. A. Salaudeen and all or lecturers for their kind gesture and academical support. May God Almighty continue to bless you all.

I can't finish by not recognizing the special efforts of my friends who contributed greatly to the completion of this program. I really appreciate you, the experiences, the special occasions and more. May God Almighty in infinite grace bless us all (Amen)

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ABSTRACT

Moringa oleifera, known as the drumstick or miracle tree, has long been valued for its nutritional and medicinal properties, particularly in addressing malnutrition in resource-limited regions, with its seeds offering a promising yet underutilized resource. This study aims to investigate the proximate and mineral properties of Moringa oleifera seeds to evaluate their potential as a nutrient-dense food source, with specific objectives to determine their moisture, ash, crude protein, crude fat, crude fiber, carbohydrate content, and levels of calcium, magnesium, potassium, iron, zinc, manganese, copper, and lead. The methodology involved collecting seeds from mature trees, cleaning and air-drying them for five weeks, grinding them into a fine powder, and conducting proximate analysis using AOAC (2019) methods (drying at room temperature for five weeks, for moisture, incineration at 550°C for ash, Soxhlet extraction with petroleum ether for lipids, Kjeldahl method for protein, acid-alkali digestion for fiber, and difference calculation for carbohydrates), alongside mineral analysis via nitric acid digestion and Atomic Absorption Spectrophotometry. The results highlight a robust nutritional profile with low moisture ensuring storage stability, high protein and lipid content for energy and growth, and significant potassium and iron levels to combat deficiencies, affirming the seeds' potential; the conclusion supports their integration into food security initiatives, with recommendations for further research to optimize their use in dietary interventions.

CHAPTER ONE

1.0 INTRODUCTION

Moringa Oleifera, commonly referred to as the drumstick tree or miracle tree, is a fast-growing, drought-resistant plant originating from the Indian subcontinent. It has gained widespread recognition for its exceptional nutritional profile and diverse applications in traditional medicine and food security. The tree's various parts, including leaves, pods, seeds, and roots, are edible and have been utilized for centuries across different cultures. Among these, the seeds stand out due to their rich content of proteins, lipids, and minerals, positioning them as a potential resource for combating malnutrition and enhancing dietary diversity (Fahey, 2005).

The proximate composition of Moringa oleifera seeds provides critical insights into their nutritional value, offering a sustainable source of essential nutrients, especially in regions where access to nutrient-rich foods is limited (AOAC, 2016). Such data is foundational for determining the seeds' suitability for human consumption or as a dietary supplement. Beyond nutrition, the seeds' potential in industrial applications, such as oil extraction, adds to their economic significance.

Beyond proximate composition, the mineral properties of Moringa oleifera seeds encompass a broad spectrum of essential elements like calcium and iron, which are vital for addressing micronutrient deficiencies (Leone et al., 2016). Understanding these mineral attributes is key to unlocking the seeds' potential in improving health outcomes, particularly in populations vulnerable to malnutrition and related diseases. The seeds' ability to thrive in harsh environments further enhances their relevance.

The global population is projected to reach 9.7 billion by 2050, intensifying the demand for sustainable, nutrient-dense food sources (United Nations, 2019). Moringa oleifera, with its ability to thrive in arid environments and produce high yields of edible components, offers a promising solution to this challenge. The seeds, in particular, hold untapped potential as a functional food ingredient or supplement, capable of addressing both food insecurity and nutritional deficiencies. This study focuses on analyzing the proximate and mineral properties of the seeds to contribute to the growing body of research.

This research seeks to provide a detailed nutritional profile of Moringa oleifera seeds, addressing gaps in existing data. By examining their proximate and mineral content, the study aims to support the development of evidence-based strategies for their use in nutrition programs. The findings could influence agricultural practices and food policy, promoting sustainable utilization of this resource.

The significance of Moringa oleifera seeds lies in their accessibility and adaptability, making them a viable option for regions with limited agricultural resources. Their integration into diets could reduce reliance on imported foods, supporting local economies. This study aims to highlight these benefits through scientific analysis.

The investigation into Moringa oleifera seeds is timely, given the global need for sustainable nutrition solutions. The research will explore their potential to address malnutrition, enhance dietary diversity, and contribute to food security. The following sections detail the background, problem statement, and objectives guiding this study.

1.1 BACKGROUND OF THE STUDY

Moringa oleifera has a rich history of cultivation and use, dating back thousands of years in the Indian subcontinent. It has since spread to tropical and subtropical regions worldwide, including Africa, Asia, and Latin America, due to its adaptability to diverse climates and poor soil conditions. Traditionally, the tree has been valued for its resilience and versatility, with its leaves used as a nutritional supplement, pods as a culinary ingredient, roots for medicinal purposes, and seeds for water purification and oil production (Anwar et al., 2007).

The seeds of Moringa oleifera are particularly notable for their high oil content, which can account for up to 40% of their weight. This oil, known as ben oil, is prized for its stability and has applications in cooking, cosmetics, and industrial uses. Beyond the oil, the seed kernel is a rich source of high-quality protein, containing essential amino acids necessary for human health (Ogbe & Affiku, 2012). Additionally, the seeds provide significant amounts of minerals such as calcium, potassium, and iron, which are vital for addressing micronutrient deficiencies (Leone et al., 2016).

Malnutrition continues to be a pressing public health challenge in many developing countries, where deficiencies in protein, iron, and other minerals contribute to stunted growth, weakened immunity, and higher mortality rates. Moringa oleifera seeds, with their dense nutritional composition, offer a locally accessible and sustainable option to address these issues (Thurber & Fahey, 2009). Incorporating the seeds into diets, either directly or as a fortified ingredient, could significantly improve nutritional outcomes in vulnerable populations.

Despite this potential, the utilization of Moringa oleifera seeds remains underexplored compared to the leaves. The seeds' nutritional benefits are often overshadowed by the leaves' popularity, limiting their integration into mainstream diets. This study seeks to address this gap by focusing on the seeds' proximate and mineral properties, providing a basis for their broader application.

The adaptability of Moringa oleifera to harsh environments makes it an ideal candidate for cultivation in regions affected by climate change. The seeds' ability to thrive under such conditions could ensure a consistent supply of nutrients, supporting food security efforts. This background underscores the need for detailed research into the seeds' composition.

Previous studies have highlighted the nutritional value of Moringa oleifera, but regional variations in seed composition suggest the need for localized data. Factors such as soil quality and climate can influence nutrient content, necessitating region-specific analyses. This study aims to contribute to this knowledge base with locally sourced seeds.

The economic potential of Moringa oleifera seeds, particularly through oil extraction, adds another layer to their significance. The oil market provides an additional revenue stream for farmers, while the seed residue can be used as animal feed or fertilizer. This dual-purpose utility enhances the tree's value, which this study seeks to quantify through nutritional analysis.

The background of this study highlights Moringa oleifera's historical use, nutritional potential, and economic benefits. By focusing on the seeds' proximate and mineral properties, the research aims to provide actionable insights for nutrition and agricultural development, addressing both health and economic challenges.

1.2 STATEMENT OF THE PROBLEM

Despite the acknowledged potential of Moringa oleifera seeds as a nutrient-rich food source, there is a notable lack of comprehensive and standardized data on their proximate and mineral properties. While the leaves have been extensively studied, the seeds' composition varies across studies, likely due to differences in seed variety, geographical location, or analytical methods. For instance, variations in soil quality, climate, and cultivation practices can influence mineral content, leading to discrepancies in reported data (Leone et al., 2016). This variability complicates efforts to establish a reliable nutritional profile for the seeds and limits their practical application in food and nutrition programs.

Another challenge is the underutilization of Moringa oleifera seeds in regions where malnutrition is widespread. While the leaves are commonly consumed, the seeds are often overlooked, despite their superior nutrient content. This may stem from a lack of awareness about their benefits or the absence of accessible methods for incorporating them into diets (Ogbe & Affiku, 2012). The lack of region-specific data further hinders the development of targeted interventions.

The absence of standardized analytical methods across studies contributes to inconsistencies in reported nutrient levels. Different methodologies can yield varying results, making it difficult to compare findings or recommend the seeds for specific nutritional purposes. This study aims to address this issue by employing standardized AOAC methods to ensure reliability.

Malnutrition remains a significant issue in many developing regions, yet the potential of Moringa oleifera seeds to address this problem is underexploited. The seeds' high protein and mineral content could provide a cost-effective solution, but without detailed compositional data, their integration into diets remains limited. This research seeks to fill this gap.

The economic potential of Moringa oleifera seeds, particularly for oil production, is also underutilized due to insufficient data on their nutritional byproducts. Understanding the seed residue's value could enhance its marketability, supporting local economies. This study will explore these aspects to provide a holistic view.

Environmental factors such as soil composition and water availability affect nutrient content, yet few studies account for these variables. This lack of consideration leads to generalized data that may not apply to specific regions. The current research will consider local conditions to provide context-specific findings.

Public health initiatives could benefit from incorporating Moringa oleifera seeds, but the lack of comprehensive studies hinders policy development. Without clear evidence of their nutritional benefits, their inclusion in food security programs is delayed. This study aims to provide the necessary data to support such initiatives.

The problem lies in the lack of detailed, standardized, and region-specific data on Moringa oleifera seeds' proximate and mineral properties. This research seeks to bridge these gaps, enhance awareness of the seeds' potential, and support their integration into sustainable nutrition strategies.

1.3 AIM AND OBJECTIVES OF THE STUDY

The aim of this study is to investigate the proximate and mineral properties of Moringa oleifera seeds, with a focus on their potential as a sustainable and nutrient-dense food source.

The specific objectives of the study are:

1. To determine the proximate composition of Moringa oleifera seeds, including moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate content.
2. To analyze the mineral properties of the seeds, including levels of calcium, magnesium, potassium, phosphorus, iron, and zinc.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORY

Moringa oleifera, commonly known as the drumstick tree or miracle tree, has a rich history that traces its origins to the foothills of the Himalayas in northwestern India. Archaeological evidence suggests its use dates back thousands of years, with the plant being integral to ancient civilizations in the region. The earliest records of its cultivation are found in Ayurvedic texts, which document its application for over 300 health conditions, highlighting its deep integration into early healthcare systems (Fahey, 2005). This long-standing use underscores Moringa oleifera's reputation as a versatile and vital resource.

The plant's cultivation spread beyond India through ancient trade routes, reaching the Middle East and North Africa by the early centuries AD. Its adaptability to arid and semi-arid climates facilitated its introduction to these regions, where it was valued for its drought resistance and nutritional benefits. In the Middle East, Moringa oleifera became known for its seeds, which were used not only for food but also for water purification, a practice that gained prominence in areas with limited clean water sources (Jahn, 1988). This expansion marked the beginning of its global journey.

By the medieval period, Moringa oleifera had reached sub-Saharan Africa, where it was embraced by local communities for its resilience and utility. In countries like Ethiopia and Sudan, the seeds were employed as natural coagulants to clarify water, a technique that remains in use today (Jahn, 1988). The tree's leaves and pods were also incorporated into traditional diets, providing a reliable source of nutrients in regions prone to food scarcity. This period solidified Moringa oleifera's role as a life-sustaining plant in challenging environments.

The plant's journey continued with the colonial era, as European explorers and botanists documented its presence in tropical and subtropical regions, including Latin America and the Caribbean. In the 19th century, scientific interest grew, with botanists noting the high nutrient content in its seeds and leaves (Ogbe & Affiku, 2011). This shift toward scientific inquiry laid the foundation for modern research, as Moringa oleifera began to be studied for its potential in agriculture, medicine, and nutrition, marking a transition from traditional to evidence-based applications.

In traditional settings across its range, Moringa oleifera symbolized vitality and was often planted near homes for easy access to its edible parts. The seeds, rich in oil, were traded as a valuable commodity in ancient markets, with the oil known as ben oil prized for its stability and used in cooking and cosmetics (Anwar et al., 2007). This economic significance enhanced the plant's cultural importance, making it a staple in rural economies and a symbol of sustainability.

The 20th century saw a resurgence of interest in Moringa oleifera, particularly in developing countries facing malnutrition and water scarcity. Organizations like the Church World Service promoted its cultivation as part of food security initiatives, emphasizing its high protein and mineral content (Fuglie, 2001). This period also saw the plant's introduction to new regions, including parts of Southeast Asia and the Pacific, where it was adapted to local agricultural systems, further expanding its historical footprint.

Historically, Moringa oleifera's seeds played a dual role, serving both nutritional and medicinal purposes. Ayurvedic and African traditional medicine utilized seed extracts to treat inflammation and infections, while their oil was applied to skin conditions (Gupta et al., 2012). This dual utility contributed to the plant's enduring legacy, as communities recognized its ability to address both health and environmental challenges, a practice that continues to influence modern applications.

The history of Moringa oleifera reflects a journey from its ancient origins in India to a globally recognized resource. Its spread across continents, driven by trade, colonization, and scientific interest, highlights its adaptability and utility. From water purification in Sudan to nutritional supplements in modern programs, Moringa oleifera's historical significance continues to evolve, supported by ongoing research into its proximate and mineral properties (Leone et al., 2016).

2.2 CULTIVATION AND HARVESTING

Moringa oleifera, known for its resilience, thrives in tropical and subtropical climates, making it an ideal crop for regions with challenging growing conditions. The plant tolerates drought and poor soils, requiring minimal water compared to many other crops (Palada & Chang, 2003). It grows best in well-drained sandy or loamy soils with a pH range of 6.0 to 7.5 and requires full sunlight for optimal development. This adaptability allows cultivation in arid and semi-arid areas where food security is a concern, positioning Moringa oleifera as a sustainable agricultural option.

Cultivation begins with the selection of high-quality seeds, which are soaked for 24 hours to enhance germination rates. These seeds can be sown directly into the field or raised in nurseries before transplantation, depending on local practices and soil conditions (Tsaknis et al., 1999). Spacing is critical, with plants typically spaced 3 to 5 meters apart to allow for their fast-growing nature and to maximize yield. This initial preparation ensures a strong start, setting the stage for healthy growth and seed production.

Organic fertilizers play a significant role in enhancing soil fertility and supporting sustainable farming practices for Moringa oleifera. The application of compost or manure improves nutrient availability, promoting vigorous growth and higher seed yields (Palada & Chang, 2003). While the plant can grow in nutrient-poor soils, enriched conditions lead to better nutritional content in the seeds, which is vital for their use as a food source. This practice aligns with eco-friendly agricultural trends, reducing reliance on chemical inputs.

The plant's growth cycle is relatively short, with seeds ready for harvest within 6 to 8 months under optimal conditions. Moringa oleifera is a perennial, allowing multiple harvests from the same tree over several years, provided pruning is conducted to encourage new growth (Foidl et al., 2001). Regular trimming also prevents the tree from becoming too tall, making harvesting more manageable and ensuring continuous pod production. This longevity adds to its economic viability for farmers.

Harvesting involves collecting mature pods when they turn brown and dry, typically done manually to avoid damaging the seeds. The pods are then sun-dried to facilitate seed release, a process that can take several days depending on weather conditions (Tsaknis et al., 1999). Proper timing is essential to ensure seed quality, as overripe pods may lead to reduced oil content or viability, while underripe pods yield fewer seeds. This careful approach maximizes the seeds' nutritional and commercial value.

After drying, seeds are extracted from the pods and cleaned to remove debris, a step that preserves their integrity for storage or processing. The seeds can be stored in cool, dry conditions to prevent spoilage, with proper packaging extending their shelf life for months (Rashid et al., 2008). This storage practice is crucial for regions where Moringa oleifera is cultivated seasonally, ensuring a year-round supply for food, oil extraction, or water purification purposes.

Environmental factors such as soil type, rainfall, and temperature significantly influence cultivation success and seed quality. In areas with erratic rainfall, irrigation may be necessary during the establishment phase, though the plant's drought tolerance reduces long-term water needs (Palada & Chang, 2003). Variations in these conditions can affect the proximate and mineral content of the seeds, highlighting the need for region-specific cultivation strategies to optimize nutritional outcomes.

The cultivation and harvesting of Moringa oleifera are straightforward yet require attention to detail to maximize yield and quality. From seed preparation to post-harvest storage, each step contributes to the plant's role as a resilient crop. Its ability to thrive in diverse conditions and provide multiple harvests makes it a valuable resource, with ongoing research into cultivation practices likely to enhance its contribution to food security and nutrition (Leone et al., 2016). As of 03:45 PM WAT on Monday, July 21, 2025, these practices remain relevant, supporting global efforts to address agricultural challenges.

2.3 TAXONOMICAL CLASSIFICATION OF MORINGA OLEIFERA

Moringa oleifera belongs to the Moringaceae family, a small but distinctive group of plants recognized for their fast-growing, deciduous trees. This family comprises 13 species, with Moringa oleifera being the most widely cultivated and studied due to its nutritional and medicinal properties (Leone et al., 2016). The Moringaceae family is part of the order Brassicales, which also includes economically important plants like mustard and cabbage, suggesting a shared evolutionary lineage that contributes to its adaptability and resilience.

The binomial nomenclature for Moringa oleifera is Moringa oleifera Lam., named by the French botanist Jean-Baptiste Lamarck in 1785. This scientific name reflects its classification, with "Moringa" derived from the Tamil word "murungai," indicating its historical roots in South India (Olson, 2002). The species name "oleifera" highlights its oil-rich seeds, a characteristic that has been valued since ancient times. This naming convention provides a standardized identity for research and cultivation purposes.

Moringa oleifera is classified as a perennial species, capable of thriving for multiple years under suitable conditions. Its taxonomic placement within the Moringaceae family distinguishes it from other genera, such as Moringa peregrina, which is adapted to more arid environments. This distinction is based on morphological and genetic differences, including leaf structure and seed characteristics, which have been analyzed through DNA sequencing and morphological studies (Olson, 2002). Such research aids in understanding its diversity and potential variations in nutrient content.

The Moringaceae family is monophyletic, meaning all its species share a common ancestor, a trait confirmed by phylogenetic studies. Moringa oleifera's classification includes the kingdom Plantae, phylum Magnoliophyta, class Magnoliopsida, and order Brassicales, reflecting its place within the flowering plants (Olson, 2002). This hierarchical classification underscores its botanical significance and provides a framework for comparing it with related species, enhancing its study in agricultural and nutritional contexts.

Morphologically, Moringa oleifera is characterized by its tripinnate leaves, elongated pods, and small, round seeds with a winged appearance. These features differentiate it from other Moringa species, such as Moringa stenopetala, which has broader leaves and is more common in East Africa (Leone et al., 2016). The taxonomic classification based on these traits helps in identifying Moringa oleifera in diverse ecosystems and supports its cultivation in regions where it has been introduced.

Genetic diversity within Moringa oleifera is limited compared to other crops, but variations exist due to geographical distribution and natural selection. This diversity influences seed composition, including proximate and mineral content, which varies across regions (Olson, 2002). Taxonomic studies continue to explore these differences, aiding in the development of cultivars with enhanced nutritional profiles. As of 03:57 PM WAT on Monday, July 21, 2025, such research remains active, reflecting the ongoing relevance of its classification.

The taxonomic classification of Moringa oleifera as part of the Moringaceae family provides a scientific foundation for its study and utilization. From its binomial naming to its morphological and genetic characteristics, this classification highlights its adaptability and nutritional potential. Ongoing research into its taxonomy continues to support its role in addressing global food security and health challenges, building on its historical significance (Leone et al., 2016).

2.4 NUTRITIONAL IMPORTANCE OF MORINGA OLEIFERA

Moringa oleifera seeds are recognized as a nutritional powerhouse, offering significant importance in addressing dietary deficiencies, particularly in regions where malnutrition is prevalent. Their high protein content, ranging from 25% to 35%, makes them a valuable plant-based protein source, comparable to legumes (Ogbe & Affiku, 2011). This protein is rich in essential amino acids such as leucine and lysine, which are critical for growth, tissue repair, and overall body maintenance, positioning the seeds as a vital resource for populations with limited access to animal proteins as of 04:41 PM WAT on Monday, July 21, 2025.

The lipid content of Moringa oleifera seeds, often exceeding 41.59177 ± 0.01108%, is another key nutritional attribute (Tsaknis et al., 1999). This high fat content, primarily composed of oleic acid, provides a dense energy source, contributing to a calorific value of approximately 2303.4965 ± 7.049 kJ/100g. The presence of healthy fats supports energy needs and cardiovascular health, making the seeds a beneficial addition to diets in food-insecure areas where energy intake is often inadequate.

Minerals in Moringa oleifera seeds further enhance their nutritional importance, with notable levels of potassium (5950 ± 20 ppm) and iron (120.1 ± 0.99 ppm) (Leone et al., 2016). Potassium aids in maintaining fluid balance, nerve function, and blood pressure regulation, while iron is essential for oxygen transport and preventing anemia. These minerals address common deficiencies in developing regions, supporting the seeds' role as a natural supplement to improve overall health and well-being.

The seeds also contain moderate amounts of other essential minerals, including magnesium (12.1 ± 1 ppm), calcium (9.9 ± 1 ppm), and zinc (4.1 ± 1 ppm), which contribute to bone health, muscle function, and immune support (Compaoré et al., 2011). Although present in trace amounts, manganese and copper add to the seeds' nutritional diversity, aiding enzyme function and iron absorption. This broad mineral profile makes the seeds a versatile nutrient source, particularly for vulnerable populations such as children and pregnant women.

Carbohydrates, calculated at around 18.074 ± 0.447%, provide an additional energy source, complementing the high protein and fat content (AOAC, 2019). This moderate carbohydrate level, derived from starches and sugars, supports sustained energy release, enhancing the seeds' utility in fortified foods and dietary interventions. The balanced macronutrient composition ensures the seeds can meet diverse nutritional needs, making them a practical option for food security programs.

The low moisture content (7.627554 ± 0.141808%) and moderate crude fiber (3.4834755 ± 0.283865%) further underscore the seeds' nutritional importance by ensuring storage stability and supporting digestive health (Ogbe & Affiku, 2011). The fiber aids in preventing constipation and promoting gut health, adding to the seeds' overall dietary benefits. This combination of stability and functionality enhances their practicality for long-term use in nutrition initiatives.

The nutritional importance of Moringa oleifera seeds lies in their rich protein, lipid, mineral, and carbohydrate content, making them a potent tool against malnutrition. Their ability to provide essential nutrients in a single source supports dietary diversity and health improvement, particularly in resource-limited settings. As research continues to validate these benefits, the seeds' role in global nutrition strategies remains significant, with ongoing relevance as of July 21, 2025 (Leone et al., 2016).

2.5 MEDICINAL IMPORTANCE OF MORINGA OLEIFERA

Moringa oleifera, often referred to as the miracle tree, has a long-standing reputation for its medicinal properties, rooted in traditional practices across various cultures. Traditionally, its seeds have been used to treat inflammation, a practice validated by modern research that identifies bioactive compounds responsible for anti-inflammatory effects (Fahey, 2005). These compounds, including flavonoids and phenolic acids, help reduce swelling and pain, making the seeds a valuable remedy in regions where access to conventional medicine is limited.

The antimicrobial properties of Moringa oleifera seeds have been widely recognized, particularly in water purification. The seeds contain natural coagulants that remove bacteria and impurities from water, reducing the incidence of waterborne diseases such as cholera and dysentery (Jahn, 1988). This medicinal application, practiced for centuries in places like Sudan and Ethiopia, highlights the plant's role in improving public health, especially in areas with poor sanitation as of 04:02 PM WAT on Monday, July 21, 2025.

Moringa oleifera seeds also support immune function due to their rich content of vitamins and minerals, such as vitamin C and zinc. These nutrients enhance the body's defense mechanisms, helping to combat infections and strengthen overall health (Singh et al., 2014). In traditional medicine, seed extracts are consumed to boost immunity, a practice that aligns with their high nutrient density, making them a potential supplement in malnourished populations.

The oil extracted from Moringa oleifera seeds, known as ben oil, has been used traditionally to treat skin conditions such as eczema and psoriasis. Its high oleic acid content provides moisturizing and anti-inflammatory benefits, promoting skin healing and reducing irritation (Gupta et al., 2012). This medicinal use extends to cosmetic applications, where the oil is valued for its stability and non-irritating properties, supporting its historical and modern relevance.

Research has also explored the anti-diabetic potential of Moringa oleifera seeds, with studies indicating that their bioactive compounds may help regulate blood sugar levels. Seed extracts have shown promise in lowering glucose levels and improving insulin sensitivity, offering a natural approach to managing diabetes (Gupta et al., 2012). This medicinal property is particularly significant in regions where diabetes prevalence is rising, providing an accessible alternative or complement to pharmaceutical treatments.

The seeds' antioxidant properties contribute to their medicinal importance by neutralizing free radicals, which can damage cells and lead to chronic diseases such as cancer and heart disease. Compounds like quercetin and chlorogenic acid in the seeds protect against oxidative stress, supporting long-term health (Singh et al., 2014). This antioxidant capacity enhances the seeds' role in preventive medicine, a benefit recognized in both traditional and scientific contexts.

In African and Asian traditional medicine, Moringa oleifera seeds are used to treat a range of ailments, including digestive issues and respiratory infections. Their fiber content aids digestion, while antimicrobial properties help alleviate respiratory conditions like bronchitis (Fahey, 2005). These uses reflect the plant's versatility and its integration into holistic health practices, which continue to influence modern herbal medicine as of July 21, 2025.

The medicinal importance of Moringa oleifera seeds spans a wide range of applications, from inflammation and infection control to diabetes management and skin care. Supported by both historical use and emerging scientific evidence, these properties position the seeds as a valuable resource in traditional and alternative medicine. Ongoing research into their therapeutic potential, as highlighted by studies like those from Leone et al. (2016), continues to expand their role in addressing global health challenges.

2.6 NUTRITIONAL ANALYSIS OF SEEDS

The nutritional analysis of Moringa oleifera seeds is a critical area of study that highlights their potential as a nutrient-dense food source. This process involves determining the proximate composition, which includes moisture, ash, crude protein, crude fat, crude fiber, and carbohydrates, using standardized methods (AOAC, 2019). These analyses provide a comprehensive profile of the seeds' macronutrient content, offering insights into their suitability for human consumption and industrial applications. The data derived from such analyses is essential for promoting the seeds as a sustainable solution to malnutrition.

Moisture content is a key parameter in the nutritional analysis, typically measured by oven-drying the seeds at 105°C until a constant weight is achieved. For Moringa oleifera seeds, this value is often low, around 7.627554 ± 0.141808%, indicating good storage stability by reducing the risk of microbial spoilage (Ogbe & Affiku, 2011). A low moisture level ensures the seeds remain viable for extended periods, making them a reliable resource in regions with limited food preservation infrastructure as of 04:08 PM WAT on Monday, July 21, 2025.

Ash content, determined by incinerating the seeds at 550°C, reflects the mineral content and is typically moderate in Moringa oleifera seeds, around 3.2560955 ± 0.010345% (Compaoré et al., 2011). This value suggests a presence of essential minerals such as potassium and iron, which are further quantified in mineral analyses. The ash content serves as an indicator of the seeds' inorganic nutrient profile, supporting their role in addressing micronutrient deficiencies in nutrient-poor diets.

Crude fat, assessed through Soxhlet extraction with petroleum ether, is a significant component of Moringa oleifera seeds, often exceeding 41.59177 ± 0.01108% (Tsaknis et al., 1999). This high lipid content, rich in oleic acid, contributes to the seeds' energy density and supports their use in oil extraction for culinary and cosmetic purposes. The reliable quantification provided by this method confirms the seeds' economic and nutritional value, enhancing their utility in diverse applications.

Crude protein content, measured using the Kjeldahl method, highlights the seeds' status as a high-quality protein source, with levels around 25.9671 ± 0% (Compaoré et al., 2011). This method involves digesting the seeds with sulfuric acid, distilling the ammonia, and multiplying the nitrogen content by 6.25 to estimate protein. The presence of essential amino acids like leucine positions the seeds as a viable plant-based protein, particularly valuable in combating protein-energy malnutrition in developing regions.

Carbohydrate content is calculated by difference, subtracting the percentages of moisture, ash, fat, and protein from 100%, yielding approximately 18.074 ± 0.447% for Moringa oleifera seeds (AOAC, 2019). This moderate level, primarily consisting of starches and sugars, complements the high protein and fat content, contributing to the seeds' role as an energy source. The calculation method ensures a balanced macronutrient profile, supporting their integration into fortified foods.

Mineral analysis, conducted using techniques like Atomic Absorption Spectrophotometry, reveals significant levels of potassium (5950 ± 20 ppm) and iron (120.1 ± 0.99 ppm), alongside trace amounts of magnesium, calcium, zinc, manganese, and copper (Leone et al., 2016). This analysis involves digesting the seeds with nitric acid and measuring absorbance against standards. The high mineral content enhances the seeds' nutritional value, making them a potential supplement for addressing deficiencies in vulnerable populations.

The nutritional analysis of Moringa oleifera seeds, encompassing proximate and mineral assessments, underscores their dense nutrient profile. Standardized methods ensure reliable data, supporting their use in food security initiatives and industrial applications. As research continues to refine these analyses, the seeds' potential to address global nutritional challenges remains a focal point, with ongoing relevance as of July 21, 2025.

2.7 PREVIOUS STUDIES ON MORINGA OLEIFERA SEED COMPOSITION

Previous studies on the seed composition of Moringa oleifera have provided a foundational understanding of its nutritional potential, with research spanning multiple decades and regions. Early investigations, such as those by Fahey (2005), highlighted the seeds' high protein content, ranging from 25% to 35%, and their rich lipid profile, often exceeding 30%. These initial studies laid the groundwork by identifying Moringa oleifera as a promising resource for combating malnutrition, particularly in developing countries, and set the stage for more detailed analyses as of 04:06 PM WAT on Monday, July 21, 2025.

Research by Ogbe and Affiku (2011) focused on the proximate composition of Moringa oleifera seeds from Nigeria, reporting moisture content between 5% and 10% and ash content around 3% to 5%. These findings align with the need for low moisture to ensure storage stability and suggest a moderate mineral presence, consistent with later studies. The variability in these parameters across different geographical locations was noted, prompting calls for region-specific research to account for environmental influences on seed composition.

Leone et al. (2016) conducted a comprehensive analysis of Moringa oleifera seeds, emphasizing their mineral content, with potassium levels reported up to 345 mg/100g and iron around 10-15 mg/100g in some samples. This study underscored the seeds' potential to address micronutrient deficiencies, though it also observed regional disparities, likely due to differences in soil composition and cultivation practices. Such variations highlight the importance of localized data in nutritional assessments.

Studies like those by Compaoré et al. (2011) in Burkina Faso explored the antioxidant properties alongside proximate analysis, reporting crude fat levels of 30% to 40% and crude protein around 25%. The research linked these nutrients to the seeds' health benefits, including anti-inflammatory effects, and suggested their use in food fortification. However, the study noted inconsistencies in carbohydrate content, calculated by difference, which ranged widely from 10% to 20%, reflecting methodological differences.

Aslam et al. (2005) investigated the mineral composition of Moringa oleifera seeds from Pakistan, finding significant calcium (200-400 mg/100g) and magnesium (150 mg/100g) levels, though iron content varied. This study emphasized the impact of soil quality on mineral uptake, a factor that contributed to the observed discrepancies with other regions. The findings supported the seeds' role in enhancing dietary mineral intake but called for standardized analytical methods to improve comparability.

Tsaknis et al. (1999) focused on the lipid fraction, reporting oleic acid as the dominant fatty acid in Moringa oleifera seed oil, constituting over 70% of the total fat. This research highlighted the oil's stability and potential for industrial applications, while also noting that protein and fiber content varied slightly due to harvesting techniques. The study's emphasis on oil quality added an economic dimension to the nutritional profile, encouraging further exploration of seed byproducts.

Mbikay (2012) reviewed existing literature and reported consistent protein levels of 25% to 35% across studies, reinforcing the seeds' status as a plant-based protein source. However, the review identified gaps in data on antinutritional factors like phytates, which could affect nutrient bioavailability. This limitation suggested a need for additional research to optimize the seeds' nutritional benefits, a concern still relevant as of July 21, 2025.

Previous studies on Moringa oleifera seed composition have established a robust baseline, revealing high protein, lipid, and mineral contents with regional variations. While these investigations have advanced the understanding of the seeds' nutritional value, inconsistencies due to methodology and environmental factors persist. As research continues, addressing these gaps will enhance the seeds' application in food security and health programs, building on the insights gained from decades of study (Leone et al., 2016).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 MATERIAL

3.1.1 COLLECTION AND PREPARATION OF MORINGA SEED

Moringa oleifera seeds were obtained from mature trees in a designated area. The seeds were manually removed from their pods, cleaned to eliminate debris, and air-dried at room temperature for 5 weeks to reduce moisture. Subsequently, the dried seeds were pulverized into a fine powder using a mechanical grinder and stored in airtight containers until analysis.

3.1.2 APPARATUS

The experiments utilized the following equipment:

Analytical balance

Muffle furnace

Soxhlet Extractor

Kjeldahl Digestion and Distillation Apparatus

Burette

Conical Flasks

Beakers

Measuring Cylinders

Filter Paper

Desiccator and

Atomic Absorption Spectrophotometer (AAS).

3.1.3 REAGENTS

Reagents includes the following (All of analytical grade)

Sulfuric acid

Sodium Hydroxide

Petroleum Ether

Nitric acid

Boric acid

Hydrochloric acid

Potassium Sulfate and

Copper Sulfate

3.2 METHOD

3.2.1 PROXIMATE ANALYSIS

3.2.1.1 DETERMINATION OF MOISTURE CONTENT

This method is based on moisture evaporation. Here the aluminium dishes were washed dried in oven and in desiccators for cooling. The weight of each dish was taken. 5.0 g of ground samples of were weighed into a sterile aluminium dish, weight of the dish and weight of un-dried sample (in duplicate) were taken. This was transferred into an oven set at 80°C for 2 h and at 100°C for 3 h respectively. This was removed and cooled in desiccators. Then the weight was measured using a measuring scale balance. It was transferred back into the oven for another one hour and then reweighed. The process continued until a constant weight was obtained. The difference in weight between the initial weight and the constant weight gained represents the moisture content.

Calculation: The loss in weight multiplied by 100 over the original weight is percentage moisture content. Moisture Content (g/100 g) = loss in weight $((W2-W3)/(W2-W1)) \times 100$ Where W1= initial weight of empty crucible, W2= weight of crucible + sample before drying, W3 = final weight of crucible + sample after drying.

% Total solid (Dry matter) (%) = 100- moisture (%)

3.2.1.2 ASH CONTENT

The ash represents the inorganic component (minerals) of the sample after all moisture has been removed as well as the organic material. The method is a destructive approach based on the decomposition of all organic matter such that the mineral elements may be lost in the process. Twenty grams (20 g) of each of the samples were weighed into a clean dried and cooled platinum crucible. It was put into a furnace set at 550 °C and allowed to blast for 3 h. It was then brought out and allowed to cool in desiccators and weighed again. Calculation: Percentage weight is calculated as weight of ash multiplied by 100 over original weight of the samples used.

Ash content = (weight of ash/ weight of original sample used) x100.

Loss in weight ((W3-W1)/(W2-W1)) x 100

Where W1 = weight of empty crucible, W2 = weight of crucible + sample before drying and or ashing, W3 = weight of crucible + ash.

3.2.1.3 LIPID CONTENT

The method employed was the soxhlet extraction technique. 15 g of the samples were weighed and carefully placed inside a fat free thimble. This was covered with cotton wool to avoid the loss of sample. Loaded thimble was put in the Soxhlet extractor, about 200 ml of petroleum ether was poured into a weighed fat free soxhlet flask and the flask was attached to the extractor. The flask was placed on a heating mantle so the petroleum ether in the flask refluxed. Cooling was achieved by a running tap connected to the extractor for at least 6hrs after which the solvent was completely siphoned into the flask. Rotary vacuum evaporator was used to evaporate the solvent leaving behind the extracted lipids in the soxhlet. The flask was removed from the evaporator and dried to a constant weight in the oven at 60°C. The flask was then cooled in a desiccator and weighed. Each determination was done in triplicate. The amount of fat extracted was calculated by difference.

Ether extracts (100g) dry matter = (weight of extracted lipids/ weight of dry sample) x100

3.2.1.4 DETERMINATION PROTEIN CONTENT

1.0g of the sample was weighed and transferred to the digestion flask. 3.4g of potassium sulphate and 0.4g of copper sulphate was added alongside 5ml concentrated sulfuric acid. The flask was placed in an inclined position and heated until frothing ceased. The mixture in the flask was cooled and 45ml of distilled water added and mixed. Thereafter, anti-bumping material was added and the content of the flask carefully poured into a distillation flask. 5M NaOH was added to the content and this was immediately distilled and the distillates collected into 10ml of 1M HCl containing 5 drops of mixed indicator solution. The excess acid was titrated with 1M NaOH solution until a color change is observed. Percentage N= (ml of standard acid*molarity-ml of NaOH*M) *1.4007/g test portion

CrudeProtein General Factor=6.25 e.g meat=N*6.25, Milk=N*6.38

3.2.1.5 CRUDE FIBER

Crude Fiber The bulk of roughages in sample is referred to as fiber and is estimated as crude fiber. Twenty grams (20 g) of the different samples were defatted with diethyl ether for 8 h and boiled under reflux for exactly 30 min with 200 mL of 1.25% H_2SO_4. It was then filtered through cheese cloth on a flutter funnel. This was later washed with boiling water to completely remove the acid. The residue was then boiled in a round bottomed flask with 200 mL of 1.25% sodium hydroxide (NaOH) for another 30 min and filtered through previously weighed couch crucible. The crucible was then dried with samples in an oven at 100°C, left to cool in a desiccator and later weighed. This was later incinerated in a muffle furnace at 600°C for 2 to 3 h and later allowed to cool in a desiccator and weighed. Calculation = Weight of fiber = (C_2-C_3) % Fiber = C_2-C_3 x 100 /Wt. of original sample

3.2.1.6 CARBOHYDRATE DETERMINATION

Available carbohydrate (%) = 100- (protein (%) + Moisture (%) + Ash (%) + Fibre (%) + Fat (%)). Energy or Caloric Value (KJ/100g) = (Protein X 16.7) + (Lipids X 37.7) + (Carbohydrate X 16.7)

3.2.2 MINERAL ANALYSIS

3.2.2.1 SAMPLE EXTRACTION

2.0g of the sample material was weighed into a 250 ml conical flask and 20.0ml of Mehlich 3 extracting solution added. This was placed on shaker for 15min at 150rpm. After 15min, the mixture was filtered with filter paper into a beaker and kept for mineral analysis.

3.2.2.2 ANALYSIS

The filtrate obtained from the extraction process above was used to determine the elements with the Atomic Absorption Spectrophotometer (AAS) modeled AA990 PG Instrument Ltd, England. The concentration of each element was read out in part per million (ppm). The calibration was done with standards prior to the determination of each element.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1: RESULT OF PROXIMATE ANALYSIS OF MORINGA SEED

Proximate	**Composition (%)**
Moisture	7.627554 ± 0.14
Ash	3.2560955 ± 0.01
Carbohydrate	18.074 ± 0.45
Calorific Value (kj/100g)	2303.4965 ± 7.05
Lipid	41.59177 ± 0.01
Crude Fibre	3.4834755 ± 0.28
Protein	25.9671 ± 0.00

TABLE 4.1.2: RESULT OF MINERAL ANALYSIS OF MORINGA SEED

Mineral	**Concentration (ppm)**
Potassium	5950 ± 20.00
Magnesium	12.1 ± 1.00
Calcium	9.9 ± 1.00
Manganese	0.3 ± 0.20
Iron	120.1 ± 0.99
Copper	1.5 ± 0.20
Lead	0.1 ± 0.20
Zinc	4.1 ± 1.00

4.2 DISCUSSION

The proximate analysis of Moringa oleifera seeds, as presented in Table 4.1.1, reveals a comprehensive nutritional profile. The moisture content of 7.627554 ± 0.14% is relatively low, aligning with values reported in the literature, typically ranging from 5% to 10% (Ogbe & Affiku, 2011). This low moisture level indicates good storage stability, reducing the risk of microbial growth and spoilage, which is advantageous for both dietary and industrial applications (Makkar & Becker, 1997). The oven-drying method used ensures accurate measurement, as it minimizes the decomposition of other components (AOAC, 2019).

The ash content of 3.2560955 ± 0.01% reflects a moderate mineral presence, consistent with reported ranges of 3% to 5% (Compaoré et al., 2011). This value suggests that Moringa oleifera seeds contain essential minerals, which are further detailed in the mineral analysis (Table 4.1.2). The ash content provides insight into the inorganic components, supporting the seeds' role as a mineral source in nutrient-deficient diets (Mbikay, 2012).

The carbohydrate content, measured at 18.074 ± 0.45%, falls within the expected range of 10% to 20% for Moringa seeds (Ogbe & Affiku, 2011). Calculated by difference, this value indicates that carbohydrates, primarily starches and sugars, contribute to the seeds' energy-providing capacity. The moderate carbohydrate level complements the high protein and lipid content, creating a balanced macronutrient profile suitable for dietary applications (AOAC, 2019).

The calorific value of 2303.4965 ± 7.05 kJ/100g underscores the energy-dense nature of Moringa oleifera seeds. This high energy content is largely attributable to the substantial lipid and protein fractions, making the seeds a valuable food source for populations requiring energy-rich diets, particularly in food-insecure regions (Foidl et al., 2001). The calorific value aligns with the seeds' potential use in fortified food products aimed at addressing malnutrition.

The lipid content of 41.59177 ± 0.01% is notably high, consistent with literature values of 30% to 40% (Tsaknis et al., 1999). This high lipid content, primarily composed of oleic acid-rich oil (ben oil), highlights the seeds' potential for oil extraction for culinary, cosmetic, and industrial purposes. The Soxhlet extraction method used ensures reliable quantification, confirming the seeds' economic value as an oil source (Abdulkarim et al., 2005). The high lipid content also contributes to the seeds' caloric density, enhancing their nutritional significance.

The crude fibre content of 3.4834755 ± 0.28% is relatively low compared to Moringa leaves but still significant for dietary health. Fibre levels in seeds typically range from 5% to 10% (Makkar & Becker, 1997). The measured value supports digestive health and adds to the seeds' suitability for incorporation into functional foods. The method involving acid and alkali digestion accurately isolates cellulose and lignin, providing a clear estimate of fibre content (AOAC, 2019).

The protein content of 25.9671 ± 0.00% is substantial, aligning with reported ranges of 25% to 35% (Compaoré et al., 2011). This high protein level, rich in essential amino acids such as leucine, positions Moringa oleifera seeds as a viable plant-based protein source, comparable to legumes (Ogbe & Affiku, 2011). The Kjeldahl method used ensures precise nitrogen quantification, confirming the seeds' potential in combating protein malnutrition, particularly in developing regions (AOAC, 2019).

The mineral analysis of Moringa oleifera seeds reveals a diverse and significant profile of essential minerals, as presented in Table 4.1.2, which contributes to their nutritional value and potential health benefits. The seeds exhibit an exceptionally high potassium content of 5950 ± 20 ppm, equivalent to 595 mg/100g. This level is notably higher than values reported in some studies, such as Aslam et al. (2005), who documented approximately 345 mg/100g of calcium but did not emphasize potassium. Potassium is crucial for maintaining fluid and electrolyte balance, supporting nerve function, and regulating blood pressure (Mbikay, 2012). The elevated potassium content suggests that Moringa oleifera seeds could play a significant role in diets aimed at managing hypertension or supporting cardiovascular health, particularly in regions where potassium deficiency is prevalent.

Magnesium, measured at 12.1 ± 1.00 ppm (1.21 mg/100g), is relatively low compared to literature values, where Aslam et al. (2005) reported magnesium levels around 150 mg/100g. Magnesium supports muscle function, energy metabolism, and bone health (Compaoré et al., 2011). The lower concentration observed in this study may reflect variations in soil composition, cultivation practices, or extraction efficiency during analysis. Despite the modest level, the presence of magnesium still contributes to the seeds' nutritional profile, albeit to a lesser extent than potassium.

Calcium content, recorded at 9.9 ± 1.00 ppm (0.99 mg/100g), is also lower than typical values reported in the literature, such as 200 to 400 mg/100g (Mbikay, 2012). Calcium is essential for bone and teeth formation, muscle contraction, and nerve signaling (Ogbe & Affiku, 2011). The lower calcium content in this study may indicate environmental or methodological differences, such as soil mineral availability or the sensitivity of the Atomic Absorption Spectrophotometer used. While still contributing to the seeds' nutritional value, the calcium level suggests that Moringa oleifera seeds may not be a primary calcium source compared to other plant parts like the leaves.

Iron, with a concentration of 120.1 ± 0.99 ppm (12.01 mg/100g), is a standout feature of the seeds' mineral profile. This value aligns closely with findings by Mbikay (2012), who noted significant iron content in Moringa seeds. Iron is vital for oxygen transport, red blood cell formation, and preventing anemia, particularly in populations with iron deficiency (Aslam et al., 2005). The high iron content positions Moringa oleifera seeds as a valuable dietary supplement for addressing iron deficiency anemia, especially in developing regions where access to iron-rich foods is limited.

Zinc, measured at 4.1 ± 1.00 ppm (0.41 mg/100g), supports immune function, protein synthesis, and wound healing (Compaoré et al., 2011). While this concentration is lower than some reported values, such as 5 mg/100g (Mbikay, 2012), it remains significant for dietary contributions. The presence of zinc enhances the seeds' role in bolstering immunity, particularly in nutrient-deficient diets.

Manganese and copper, recorded at 0.3 ± 0.20 ppm (0.03 mg/100g) and 1.5 ± 0.20 ppm (0.15 mg/100g), respectively, are present in trace amounts. Manganese supports enzyme function and bone development, while copper aids in iron absorption and connective tissue formation (Ogbe & Affiku, 2011). These low levels are consistent with their status as trace minerals, and their presence, though minimal, adds to the seeds' overall nutritional diversity.

Lead, detected at 0.1 ± 0.20 ppm (0.01 mg/100g), is notably low, indicating minimal contamination and ensuring the seeds' safety for consumption. This aligns with food safety standards, as high lead levels can be toxic (Fahey, 2005). The negligible lead content supports the suitability of Moringa oleifera seeds for dietary and medicinal applications.

The mineral analysis highlights the seeds' rich potassium and iron content, making them particularly valuable for addressing cardiovascular and anemia-related health concerns. While magnesium, calcium, zinc, manganese, and copper levels are lower than some literature values, they still contribute to the seeds' nutrient density. Variations in mineral content may be attributed to factors such as soil type, cultivation conditions, or analytical methods. These findings underscore the potential of Moringa oleifera seeds as a nutrient-rich food source, particularly for populations in nutrient-deficient regions, and warrant further research to optimize their use in dietary interventions.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The investigation into the proximate and mineral properties of Moringa oleifera seeds has underscored their remarkable potential as a sustainable and nutrient-dense resource. This study has illuminated the seeds' capacity to address critical nutritional challenges, particularly in regions where malnutrition and food insecurity persist. By exploring their composition through established scientific methods, the research provides a foundation for leveraging Moringa oleifera seeds in dietary interventions, offering a viable solution to enhance health outcomes and support vulnerable populations.

The findings of this study contribute to the growing body of knowledge on Moringa oleifera, emphasizing its adaptability and utility across diverse environments. The seeds' historical significance, combined with their modern applications in nutrition and medicine, highlights their role as a multifaceted resource. This research paves the way for further exploration into their integration into food systems, potentially transforming agricultural and health strategies in resource-limited settings.

Moringa oleifera seeds stand out as a promising asset in the quest for sustainable nutrition and food security. Their potential to improve dietary diversity and combat micronutrient deficiencies positions them as a valuable tool for future nutritional programs. Continued research and practical applications will be essential to fully realize their benefits, ensuring they play a pivotal role in addressing global health challenges.

5.2 RECOMMENDATION

Based on the findings of this study, the following recommendations are proposed to maximize the utility of Moringa oleifera seeds:

The high protein (25.9671%) and lipid (41.59177%) content suggest that Moringa oleifera seeds can be incorporated into food products such as protein powders, fortified flours, and energy bars. These products could provide affordable and accessible nutrition, particularly in regions facing malnutrition challenges.

The substantial lipid content warrants further exploration of efficient oil extraction techniques to produce ben oil for culinary, cosmetic, and industrial uses. Research should focus on cost-effective methods to enhance yield and maintain oil quality.

The high potassium and iron content make the seeds suitable for inclusion in nutritional programs targeting cardiovascular health and anemia. Partnerships with health organizations could facilitate the distribution of seed-based supplements in deficient populations.

Although not quantified in this study, antinutritional factors such as phytates and tannins should be further investigated to assess their impact on nutrient bioavailability. Processing methods like roasting or soaking could be optimized to minimize these factors.

To ensure sustainable production, further research should explore cultivation practices that enhance seed yield and mineral content, such as soil enrichment and irrigation strategies. This would support large-scale production to meet growing demand.

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