

**FLAVONOIDS AND ALKALOIDS IN PALM KERNEL (ELAEIS GUINEENSIS)**

**BY**

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**CERTIFICATION**

We the undersigned hereby certify that OKOYO GOD'STIME EROMONSELE (BMS2001126) carried out this research in the Department of Medical Biochemistry, University of Benin, Benin city and thereby approve same as adequate in scope and quality for the award of Bachelor of Science Degree (B.Sc) in Medical Biochemistry.

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## **DEDICATION**

### To the Pillars of My Success

With heartfelt gratitude and love, I dedicate this project to those who have profoundly influenced my life and academic pursuits. To my beloved parents, Mr. Anthony and Mrs. Rosemary OKOYO, your unwavering support, guidance, and encouragement have been my rock, empowering me to reach new heights.

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## ABSTRACT

Elaeis Guineensis(Palm Kernel) oil, an ubiquitous ingredient in global cuisines, has long been recognized for its culinary and industrial applications. However, its nutritional profile remains understudied. This study investigates the chemical composition of Elaeis Guineensis oil, with a specific focus on its flavonoid and alkaloid content. Our rigorous qualitative and quantitative analysis revealed a rich flavonoid profile, with concentrations ranging from 15.20 to 17.10 mg/100g. Conversely, alkaloids were found to be absent in the oil. These findings have significant implications for the potential health benefits of Elaeis Guineensis oil, suggesting its antioxidant, anti-inflammatory, and overall health-promoting properties. Our research contributes meaningfully to the existing body of knowledge on Elaeis Guineensis oil, underscoring its value as a nutritious and versatile ingredient in a healthy diet. The outcomes of this study have far-reaching implications for the food industry, nutritionists, and consumers seeking to make informed choices about their dietary intake.

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## CHAPTER ONE

### 1.1 INTRODUCTION

#### 1.1 BACKGROUND OF STUDY

The oil palm tree (*Elaeis guineensis*) has a rich history, originating from West Africa and later introduced to Java by the Dutch in 1848 and to Malaysia by Scotsman William Sime and English banker Henry Darby in 1910. The oil palm has been highly valued for its therapeutic properties, including its use as a laxative, diuretic, and treatment for various ailments such as gonorrhoea, menorrhagia, bronchitis, headaches, and rheumatism (Wang *et al* 2014).

Phytochemicals, bioactive compounds produced by plants, are present in the *Elaeis Guineensis*. These compounds, including carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and specific polysaccharides, exhibit robust antioxidant activities and have been shown to possess antimicrobial, antidiarrheal, anthelmintic, antiallergic, antispasmodic, and antiviral properties (Sharma *et al* ,2018;Jaeger *et al* 2016). Furthermore, phytochemicals play a crucial role in regulating gene transcription, enhancing gap junction communication, boosting immunity, and providing protection against certain cancers, including lung and prostate cancer (Rowles *et al* 2020;Jiang et al 2018;Cooperstone *et al* 2016;Vallverdú-Coll *et al* 2015;Yuan *et al* 2015).

The oil palm tree, with its rich history and diverse uses, serves as a valuable source of phytochemicals. This study aims to explore the phytochemical profile of *Elaeis Guineensis*, with a specific focus on flavonoids and other bioactive compounds like Alkaloids. By investigating the presence, distribution, and potential health benefits of these phytochemicals, this research seeks to contribute to the growing body of knowledge on the nutritional and medicinal value of oil palm.

## **1.2 JUSTIFICATION OF STUDY**

The justification for this study lies in the growing recognition of phytochemicals as potential therapeutic agents, and the need to explore new sources of these compounds. Oil palm, being a widely cultivated and versatile crop, presents an attractive opportunity for phytochemical discovery. By identifying and characterizing the phenols and alkaloids present in oil palm, this study seeks to contribute to the development of novel nutraceuticals and pharmaceuticals, and to provide new insights into the potential health benefits of oil palm consumption.

## **1.3 AIMS**

The overall aim of this study is to explore the phytochemical potential of oil palm and to contribute to the development of new natural products with potential health benefits.

## **1.4 OBJECTIVES**

The specific objectives of this study are:

1. To identify and quantify the phenolic compounds present in oil palm.
2. To isolate and characterize the alkaloids present in oil palm.
3. To evaluate the antioxidant and antimicrobial activities of the extracted phytochemicals.
4. To investigate the potential health benefits of oil palm phytochemicals.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 ELAEIS GUINEENSIS (OIL PALM) TREE**

##### **2.1.2 HISTORY OF THE OIL PALM EXPLORATION**

The introduction of oil palms to Java by the Dutch in 1848 and to Malaysia by Scotsman William Sime and English banker Henry Darby in 1910 marked the beginning of their cultivation in these regions. Notably, the species *Elaeis guineensis* was brought to Malaysia from Eastern Nigeria in 1961. Originally native to West Africa, the oil palm tree was highly valued by European traders, who referred to the southern coast of Nigeria as the "Palm oil coast" before it was later renamed the Bight of Biafra. In traditional African medicine, various parts of the oil palm plant are utilized for their therapeutic properties, including as a laxative and diuretic, poison antidote, and treatment for various ailments such as gonorrhoea, menorrhagia, bronchitis, headaches, and rheumatism(Wang *et al* 2014). Furthermore, the oil palm plays a significant role in Yoruba religion, featuring prominently in its creation myth and serving as a symbol of connection between heaven and earth. In this context, oil palm fronds are often used to mark sacred areas, while its kernels are prepared for use as a tool in receiving divine guidance(Ogunnaike *et al* 2019). In Cambodia, the oil palm was introduced as a decorative plant in public gardens, where it is known by its Khmer name, dô:ng préing(Pauline,2000).

##### **2.1.3 TAXONOMY**

The Arecaceae family, comprising palms, is a significant group of stem-less, tree-like monocot plants that play a vital role in human livelihoods and biodiversity, particularly in tropical regions (Cosiaux *et al* ., 2018). Among these, the African oil palm (*Elaeis guineensis*) is native to West Africa and holds immense agricultural importance.



Figures 2.1a & 2.1b above: Showing the Oil Palm Tree and Oil Palm Fruit respectively

For over 7,000 years, *Elaeis guineensis*(oil palm) fruits have been a semi-wild food resource in traditional societies, available throughout the year. In its native regions, the *Elaeis guineensis*(oil palm) plant holds great cultural and ecological significance (Cosiaux *et al.* , 2018; Reddy *et al.* , 2019; Okolo *et al.*, 2019).

#### Scientific Classification Of The *Elaeis Guineensis* Plant

Below is the scientific classification of *Elaeis Guineensis* Plant popularly known as oil Palm

Kingdom	Plantae
Clade	Tracheophytes
Clade	Angiosperms
Clade	Monocots
Clade	Commelinids
Order	Arecales
Family	Arecaceae
Genus	<i>Elaeis</i>
Species	<i>E. guineensis</i>

The African oil palm, *Elaeis guineensis*, is indigenous to western and southwestern Africa, specifically the region between Angola and The Gambia. The species name "guineensis" originates from the historical name for the area known as Guinea, which is distinct from the modern country of Guinea. In addition to its native range, *E. guineensis* has become naturalized in various regions, including Madagascar, Sri Lanka, Malaysia, Indonesia, Central America, Cambodia, the West Indies, and several islands in the Indian and Pacific Oceans. Other palm species, such as *E. oleifera* and *Attalea maripa*, are also utilized for palm oil production. The domestication of *E. guineensis* is believed to have occurred in West Africa, along the south-facing Atlantic coast. However, due to insufficient documentation and research, the exact timing of this event remains uncertain as of 2019 (Okolo *et al* 2019; Brian *et al* 2017). Archaeological evidence suggests that humans may have used oil palms as far back as 5,000 years ago in Egypt, with palm oil discovered in a tomb at Abydos dating back to 3000 BCE (Petra, 2022). As the primary source of palm oil, oil palms exhibit a higher oil yield per land area compared to most other oil-producing plants, surpassing soy and rapeseed by approximately nine and 4.5 times, respectively (Michael, 2018).

Historically, *Elaeis guineensis* (oil palm) cultivation was an informal process, primarily confined to the West/Central African coastal belt. However, with the transportation of oil palm seeds to the Dutch East Indies (present-day Indonesia) and the Malay States (modern Malaysia) during the nineteenth century, the crop's cultivation expanded. Systematic oil palm cultivation on plantations gradually emerged in Malaysia during the twentieth century. On a global scale, large-scale commercial oil palm production is a relatively recent development, gaining prominence in the late twentieth century (Malaysian Palm Oil Production by Year, 2020). Government initiatives in Malaysia during the 1970s and 1980s aimed at improving agriculture and the economy contributed significantly to the industry's growth (Corley and Tinker, 2015; Murphy, 2014).

In Indonesia, the oil palm industry experienced rapid growth in the twenty-first century, with oil production increasing more than fivefold from 8.3 million tons in 2000 to 43.5 million tons in 2020.

The oil palm industry has become a cornerstone of the economies of numerous countries, particularly Indonesia and Malaysia, which are among the largest exporters of oil palm products, including oil, meal, and various derivatives (Murphy, 2019). The cultivation of oil palm has expanded beyond its traditional regions, with large-scale plantations now present in the humid tropical zones of Asia, Africa, and the Americas. These regions serve as significant hubs for the production and export of oil palm products to global markets.

#### **2.1.4 DESCRIPTION AND PLANTING**

*Elaeis guineensis*, the African oil palm, is a monocotyledonous plant (Neale *et al* 2017). Mature palms are characterized by a single stem, reaching heights of up to 20 meters (66 ft). The pinnate leaves can grow up to 3-5 meters (10-16+1/2 ft) in length, with young palms producing approximately 30 leaves annually. Established palms over 10 years old produce around 20 leaves per year. The flowers are arranged in dense clusters, with individual flowers featuring three sepals and three petals. The palm fruit develops from pollination to maturity within 5-6 months, exhibiting a reddish color and a size comparable to a large plum. The fruit grows in large bunches, each consisting of an oily, fleshy outer layer (pericarp) and a single seed (palm kernel) rich in oil.

A mature palm tree can produce between 5-30 kg (11-66 lb) of fruit per bunch, depending on the tree's age. Annually, each hectare of oil palm yields an average of 20 tonnes of fruit, resulting in 4,000 kg of palm oil and 750 kg of seed kernels (Wikipedia, 2025). The seed kernels are processed to produce 500 kg of high-quality palm kernel oil and 600 kg of kernel meal, which is used as livestock feed (Malaysia Palm Oil Board). Commercial oil palm plantations primarily utilize tenera palms or DXP hybrids, obtained by crossing thick-shelled dura with shell-less pisifera. While germinated seed is commonly used, tissue-cultured or "clonal" palms are becoming an alternative, providing exact replicas of high-yielding DXP palms (Wikipedia, 2025).

#### **2.1.5 ELAEIS GUINEENSIS(OIL PALM) PRODUCTION**

Palm oil is extracted from the pulp of the fruit, while *Elaeis guineensis* (oil palm) oil is obtained from the kernel. For every 100 kg of fruit bunches, approximately 22 kg of *Elaeis guineensis* (oil palm) palm oil and 1.6 kg of palm kernel oil can be extracted. The high oil yield of oil palms, reaching up to 7,250 liters per hectare per year, has made it a common cooking ingredient in Southeast Asia and tropical Africa. Its increasing use in the commercial food industry worldwide is driven by factors such as competitive pricing (Yidi *et al.*, 2020), high oxidative stability of the refined product (Ziyang *et al.* 2020; Marini *et al.* 2018), and high levels of natural antioxidants (Jiexin *et al.* 2019). Originating in West Africa, oil palms have been successfully cultivated in tropical regions within 20 degrees of the equator. In some areas, such as the Republic of the Congo, local communities produce palm oil manually by harvesting the fruit, boiling it, and pressing the remaining pulp to extract the reddish-orange-colored oil.



Figure 2.2: Showing the Spikelet; The plant structure housing the palm fruits.

In terms of global production, Malaysia was the largest producer in 1995, accounting for 51% of the world's share. However, since 2007, Indonesia has taken over as the world's largest producer, supplying approximately 50% of the world's palm oil volume. Worldwide palm oil production has continued to grow, reaching 50.3 million metric tons (55.4 million short tons) in 2011/2012, and increasing to 52.3 million metric tons (57.7 million short tons) in 2012/2013 (United States Department Of Agriculture, 2012). In 2010/2011, total palm kernel production was 12.6 million metric tons (13.9 million short tons) (Fao.org, 2012), while in 2019, total production reached 75.7 million metric tons (83.4 million short tons) (Shahbandeh, 2025). Notably, *E. guineensis* is among the few tropical tree crops that exhibit high productivity in actual growing conditions, alongside bananas and citrus (Drenth *et al.* 2016). In Nigeria, the Urhobo people utilize the extract to prepare amiedi soup.

### 2.1.6 PALM KERNEL

The oil palm tree (*Elaeis guineensis*) is a vital crop in many tropical countries, including Brazil, Indonesia, Malaysia, Thailand, Colombia, and Ecuador, due to its prominent role in vegetable oil production (Vijay *et al* 2016). Palm kernel cake (PKC), a by-product of oil extraction, is a valuable source of nutrients, comprising fat, protein, minerals, and carbohydrates (Xiapeng *et al* 2021). Extensive research has been conducted to evaluate the feeding value of PKC and its effects on broiler chicken diets. As one of the world's largest palm oil producers, Malaysia generates a substantial amount of PKC, creating opportunities for its utilization in the poultry industry as a protein and energy source (Hanafiah *et al* 2017).



Figures 2.3a & 2.3b: Displaying the outer and inner structures of the palm fruits.

The primary objective of the palm oil industry is to produce palm oil, with PKC generated as a by-product from palm fruit nuts (Muhammad *et al* ., 2017). Although PKC is commonly used in ruminant diets, its application in non-ruminant diets, particularly in poultry, is limited due to its high fiber content (Sharmila *et al* 2014). However, PKC has potential as a poultry feedstuff due to its moderate crude protein (16.43%) content and energy value (Alshelmani *et al* 2016). The nutritional quality of PKC can be enhanced through solid-state fermentation (SSF) using cellulolytic bacteria (Alshelmani *et al* 2013; Lee *et al* 2019).

This review aims to provide an in-depth examination of palm kernel's nutritional value by using PKC's composition, nutritional value, and utilization as a poultry feed, as well as the effects of SSF on PKC as a suitable example. PKC has been recognized as a valuable component in animal feeds, offering attractive prices, long-term availability, and nutritional benefits (Xiapeng *et al.* , 2021). The extraction method used to produce palm oil influences the nutritional content of PKC. Expeller or screw press extraction yields PKC, whereas solvent extraction produces palm kernel meal (PKM) with higher crude protein and crude fiber content (Bashirat *et al.* 2018).

The nutritional values of PKC and PKM differ significantly depending on the extraction method (Xiapeng *et al.*, 2021). PKC is primarily composed of cell-wall components, including mannose, xylose, arabinose, galactose, lignin, and ash (Ceveró *et al.* 2010). The main component of palm kernel by-products' non-starch polysaccharides (NSPs) is  $\beta$ -mannan, which is considered a prebiotic and has been shown to enhance birds' immune systems and reduce pathogenic bacteria in the small intestines (Bashirat *et al.* 2018).

## **2.2 PHYTOCHEMICALS**

### **2.2.1 DEFINITION AND IMPORTANCE**

Phytochemicals are bioactive compounds produced by plants as a defense mechanism against environmental stresses and pathogens. These plant-based compounds can be sourced from various foods, including whole grains, fruits, vegetables, nuts, and herbs. To date, over a thousand phytochemicals have been identified, each with unique properties and potential health benefits. Key phytochemicals include carotenoids, polyphenols, isoprenoids, phytosterols, saponins, dietary fibers, and specific polysaccharides. These compounds exhibit robust antioxidant activities and have been shown to possess antimicrobial, antidiarrheal, anthelmintic, antiallergic, antispasmodic, and antiviral properties (Sharma *et al.*,2018;Jaeger *et al.*, 2016). Furthermore, phytochemicals play a crucial role in regulating gene transcription, enhancing gap junction communication, boosting immunity, and providing protection against certain cancers, including lung and prostate cancer (Rowles *et al.* 2020;Jiang *et al.* 2018;Cooperstone *et al.* 2016;Vallverdú-Coll *et al.* 2015;Yuan *et al.* , 2015).

## **2.3 PHYTOCHEMICALS IN PALM KERNEL**

In a study conducted by Shie *et al* 2013, it was found that *Elaeis Guineensis* had the following phytochemicals: Alkaloids, saponins, coumarins, phenolic compounds, tanins, terpenoids and steroids, flavonoids and carbohydrates. However, in this study, we will be analyzing the phytochemicals Flavonoids and Alkaloids.

### **2.3.1 METHODS OF EXTRACTION AND ANALYSIS OF PHYTOCHEMICALS IN PALM KERNEL**

Extraction is defined as a process of removing or obtaining the desired compounds from the source material (Marriam-Webster, 2022). In a study lead by Ashwani *et al* 2023, they identified several extraction methods such as maceration, percolation, decoction, reflux extraction, Soxhlet extraction, pressurized liquid extraction, liquid gas extraction, microwave assisted extraction, ultrasound assisted extraction, pulsed electric field extraction, enzyme assisted extraction, super critical fluid extraction, high hydrostatic pressure processing and natural deep eutectic solvent extraction (Ashwani *et al* 2023).

### **2.3.2 FACTORS INFLUENCING PHYTOCHEMICAL CONTENTS**

The phytochemical composition of plants is heavily influenced by their genetic makeup. Significant variations in the range, type, and levels of individual bioactive compounds can be observed across different crops, species, genera, and even cultivars. Fruits, vegetables, and herbs are particularly rich in terpenoids, carotenoids, polyphenols, and sulfur-containing compounds. In contrast, cereals and pulses are notable sources of plant sterols, while oilseed crops like olive, linseed, sunflower, and canola (rapeseed) are abundant in fatty acids and sterols. Phytoestrogens, including isoflavones and lignans, are predominantly found in leguminous crops such as soybeans, pulses, and certain seed crops (Konar, 2013).

## 2.4 FLAVONOIDS IN PALM KERNEL

Flavonoids are a class of polyphenolic compounds renowned for their profound health benefits, largely attributed to their potent antioxidant properties. Structurally, flavonoids comprise a 15-carbon skeleton, consisting of two aromatic rings (A and B) linked by a three-carbon chain, forming an oxygenated heterocyclic C ring (Kopustinskiene *et al* 2020;Ghorbani *et al* 2019;Al-Ishaq *et al* 2019). The classification of flavonoids is based on the position of ring B's attachment to ring C, as well as the degree of unsaturation and oxidation of ring C. In the context of oil palm leaves (OPL), the primary subclasses of flavonoids are flavan-3-ols and flavones (Figure 2). Flavan-3-ols are characterized by a hydroxyl group at position C3 of ring C, whereas flavones feature an unsaturated bond between positions C2 and C3, accompanied by a carbonyl group at position C4 (Kopustinskiene *et al* 2020; Al-Ishaq *et al* 2019;Visoli *et al* 2020).

Figure 1. Basic Structures of Flavonoid Subclasses

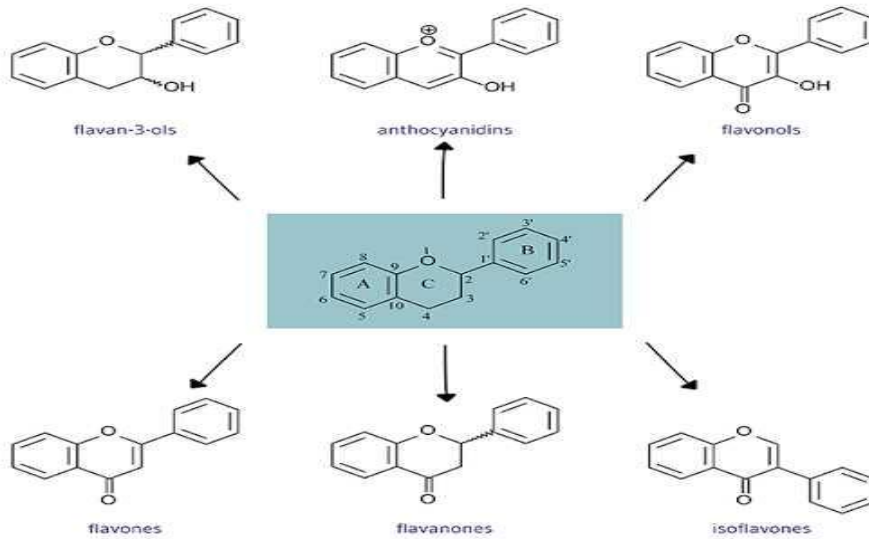


Figure 2.4a: Showing the basic structures of Flavonoids.

Flavonoids can exist in various forms, including aglycones, glycosides, methylated, and prenylated derivatives. In plants, flavonoid glycosides are the predominant form, exhibiting specific glycosylation patterns, such as O-glycosides and C-glycosides. In O-glycosides, a sugar moiety is attached to the aglycone's hydroxyl group, whereas C-glycosides involve a carbon-carbon bond between the sugar moiety and the aglycone (Yang *et al* 2018;Jaffri *et al* 2011).

### 2.4.1 HEALTH BENEFITS OF FLAVONOIDS

Extensive research on flavonoids has unveiled their numerous health benefits, including disease prevention and treatment (Kozłowska *et al* 2014; Rana *et al* 2019). These compounds have exhibited a wide range of biological activities, including antioxidant, anti-inflammatory, antibacterial, and antiviral properties (Ruiz-Cruz *et al* 2017). Additionally, flavonoids have been found to possess anti-allergic, anti-carcinogenic, and anti-oxidant effects (Doha 2022). The protective effects of flavonoids are attributed to their ability to reduce oxidative stress in the body.

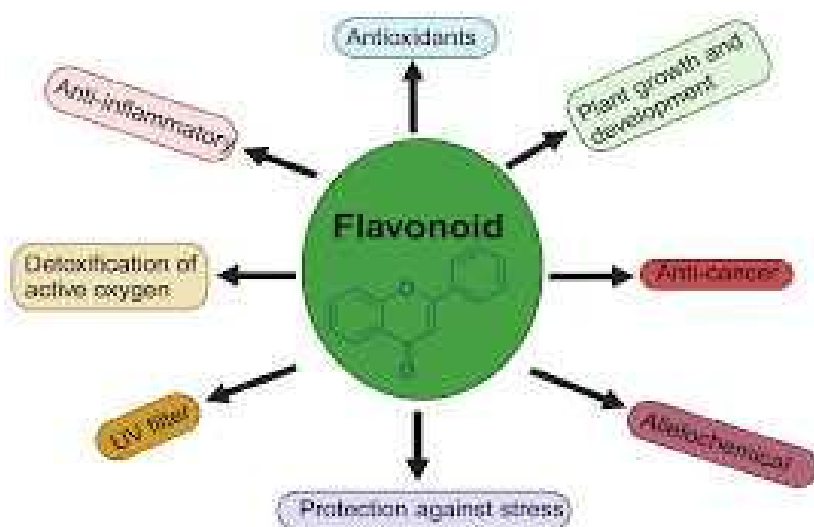


Figure 2.4b; A diagram showing the health benefits of flavonoids

Specifically, certain flavonoids such as myricetin, tricetin, apigenin, luteolin, quercetin, and isorhamnetin have been reported to exhibit cholesterol-lowering, anti-cancer, and antioxidant activities (Singh *et al* 2017). Furthermore, flavonoids have been found to possess anti-viral, anti-bacterial, anti-cancer, cardioprotective, and anti-inflammatory effects (Sundu *et al* 2017). Their ability to act as chelating agents, topoisomerase inhibitors, and exhibit anti-aggregational, anti-atherosclerotic, and detoxification activities has also been reported (Doha *et al.*, 2022). The hydroxyl group present in flavonoids plays a significant role in determining their biological activities (Kumar *et al* 2017).

Quercetin, a specific flavonoid, has been found to reduce the risk of cancer, eye diseases, arthritis, and allergic disorders (Lakhanpal *et al* 2007). Proanthocyanins and flavone-3-ols have also been reported to decrease the risk of cardiovascular disease (Hayat *et al* 2017).

#### 2.4.2 METABOLISM AND BIOAVAILABILITY

The absorption and bioavailability of dietary flavonoids vary significantly depending on their specific type. Isoflavones exhibit the highest absorption rates, followed by flavanols, flavanones, and flavonol glycosides, which display intermediate absorption. In contrast, proanthocyanidins, flavanol gallates, and anthocyanins are poorly absorbed (Abid *et al* 2022). However, the absorption of dietary flavonoids can be influenced by the food matrix in which they are consumed. For instance, studies have shown that flavonoid excretion in urine is enhanced when consumed with foods high in fat content.

The variability in absorption kinetics among different foods can be attributed to the heterogeneity of saccharides and functional groups attached to the flavan nucleus. Additionally, several factors can impact flavonoid absorption, including dosage, administration vehicle, prior diet, sex differences, genetic properties, and the microbial population of the colon (Kaeko *et al* 2018).

Flavonoids undergo extensive metabolism before entering systemic circulation. Upon absorption, flavonoids bind to albumin and are transported to the liver via the portal vein (Surangi *et al.*, 2013). The liver plays a crucial role in flavonoid metabolism, with various biotransformations leading to different conjugated forms. However, other tissues, including the intestinal mucosa, kidney, and others, also contribute to flavonoid metabolism. The primary metabolic transformation reactions of flavonoids include oxidation, reduction, hydrolysis, and conjugation with sulfate, glucuronate, or O-methylation (Aida *et al* 2012). These reactions significantly impact the antioxidant activity of flavonoids and their interactions with proteins, as suggested by DAY *et al.* (Day *et al* 2000). Conjugation reactions with glucuronic acid and/or sulfate are the most common metabolic pathways for flavonoids. Glucuronidation, primarily occurring in the small intestine, is facilitated by uridine-5'-diphosphate glucuronosyltransferases (UGTs)

(Masoumeh *et al* 2017). This process is efficient and rapid, even surpassing cytochrome P450-mediated oxidation. The UGT superfamily exhibits remarkable diversity in substrate recognition, catalyzing glucuronidation of various functional groups. Sulfation and methylation occur in the cytosol, mediated by sulphotransferases (SULTs) and catechol-O-methyltransferases, respectively (Oteiza *et al* 2018). Specific SULT enzymes, such as SULT1A1 and SULT1A2, are involved in the sulfation of phenol-type substrates.

After absorption and intestinal metabolism, hepatic metabolism of flavonoids takes place. The primary products found in the hepatic portal vein are glucuronides and possibly methylated glucuronides. These polar conjugates are further modified within hepatocytes, although the mechanism of uptake is unknown. In the liver, flavonoids undergo additional methylation, sulfation, and glucuronidation reactions (Gary *et al.*, 2018). Unabsorbed flavonoids can be degraded by colon microorganisms, which may impact flavonoid bioavailability. The fraction of flavonoids reaching the colon can be extensively metabolized by microflora enzymes. This process depends on the hydroxylation patterns of the flavonoids, with certain patterns enhancing ring opening after hydrolysis. Enzymes responsible for the initial ring fission of flavonoids and for demethylation and dehydroxylation of the resulting phenolic acids are primarily those of intestinal microorganisms. The ring scission depends on the type and extent of oxidation of the carbon atoms of the heterocyclic ring.

Flavonoids with a 3',4'-dihydroxylation pattern in the B ring are metabolized in mammalian species, resulting in the formation of conjugates of their 3'-O-methyl esters. In humans, the major urinary metabolites of these flavonoids are glucuronide and sulfate conjugates of the methyl esters (Zhongjian *et al.*,2014). However, the primary route of elimination for flavonoids is through bile excretion. Research by Masoumeh *et al.*,2017 revealed that the flavanone eriodictyol exhibits the highest biliary excretion, followed by luteolin, kaempferol, quercetin, and (+)-catechin, which shows minimal elimination via this route.

The flavonoids eliminated in bile are present as conjugated metabolites, highlighting the importance of conjugation reactions in the metabolism and elimination of these compounds.

## 2.5 ALKALOIDS IN PALM KERNEL

The use of alkaloid-containing plants dates back to ancient civilizations in Asia, Europe, and Africa, with records showing their utilization as early as 2000 BCE (Kumar *et al.*, 2015). A significant milestone in the history of alkaloid research was the isolation of morphine by Friedrich Serturmer in the 19th century. This breakthrough paved the way for the successful isolation and discovery of various compounds by European scientists, including xanthine (1817), strychnine (1818), atropine (1819), quinine (1820), and caffeine (1820) (Henrich, 2013). Plants produce a diverse range of secondary metabolites, among which alkaloids are a prominent group. Alkaloids are naturally occurring compounds characterized by the presence of basic nitrogen atoms, although some may exhibit neutral or weakly acidic properties (Sweta *et al.* 2021; Erick *et al.* 2020). These compounds are produced by a wide variety of organisms, including bacteria, fungi, plants, and animals. Alkaloids are renowned for their therapeutic significance, diversity, and efficiency, with approximately 5,500 known compounds.

The term "alkaloid" originates from the word "alkaline," describing nitrogen-containing bases. Alkaloids are typically organic bases that form salts with acids and yield alkaline solutions when soluble. Flowering plants, particularly Angiosperm, are the primary source of alkaloids. These compounds play a crucial role in plant defense against herbivores and pathogens, with around 20% of plant species containing alkaloids. Structurally, alkaloids are cyclic compounds containing nitrogen in a negative oxidation state, which is relatively rare in living organisms (Emin *et al.*, 2015). Many alkaloids have been employed in medicine for centuries, and they continue to be a vital component of modern pharmacology. Throughout history, alkaloids from plant extracts have been used as ingredients in medicinal preparations and poisons. Ancient cultures utilized plant extracts containing alkaloids to treat various ailments, including snakebites, fever, and insanity.

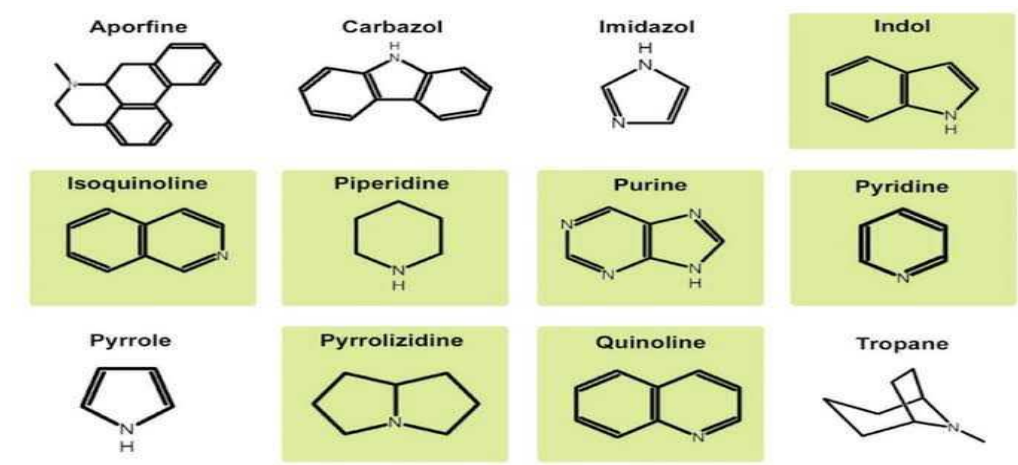


Figure 2.5: The above are basic structures of alkaloids found in Palm kernel oil

Alkaloids are a class of compounds that, despite their toxicity, exhibit significant therapeutic effects at low concentrations. They play a crucial role in plant defense against microorganisms, insects, herbivores, and competing plants through their antibacterial, antifungal, and allelopathic activities (Hélio *et al* 2015). This defensive function has led to their utilization in medicine.

Alkaloids are typically bitter, optically active substances that are colorless, crystalline, or liquid at room temperature. Quinine, for example, is one of the most bitter substances known, with a significant bitter taste at a molar concentration of  $1 \times 10^{-5}$  (Philip,2020). Plant-derived alkaloids and their synthetic derivatives are widely used as medicinal agents, leveraging their analgesic, antispasmodic, and bactericidal properties (Neha, 2015).

In humans, alkaloids primarily affect the nervous system, influencing the activity of chemical transmitters such as acetylcholine, epinephrine, norepinephrine, gamma-aminobutyric acid, dopamine, and serotonin (Qingqing *et al.*, 2023). Certain alkaloids, like berberine and sanguinarine, are employed as antiseptics due to their antibiotic activity, finding applications in ophthalmics and toothpastes, respectively (Noureddine,2018). Alkaloids can be classified into various categories based on their biosynthetic precursors and heterocyclic ring systems. These categories include indole, piperidine, tropane, purine, pyrrolizidine, imidazole, quinolizidine, isoquinoline, and pyrrolidine alkaloids (Kaur *et al* 2015). Researchers have proposed different classification systems, including one that divides alkaloids into three main categories (Vafa *et al.*,

2014): true alkaloids, proto-alkaloids, and pseudo-alkaloids. True alkaloids are compounds derived from amino acids and feature a heterocyclic ring with nitrogen, as seen in atropine and nicotine. Proto-alkaloids contain a nitrogen atom derived from an amino acid that is not part of the heterocyclic ring, exemplified by adrenaline and ephedrine. Pseudo-alkaloids, on the other hand, do not originate from amino acids, with caffeine and theobromine serving as examples.

### **2.5.1 PHARMACOLOGICAL PROPERTIES OF ALKALOIDS**

Alkaloids have been found to exhibit a wide range of biological activities, including toxicity to herbivores, cytotoxicity, and antimicrobial properties. Many alkaloids are highly toxic to animals, causing death if ingested in large quantities. Some alkaloids, such as nicotine and anabasine, are used as insecticides due to their toxicity. Alkaloids can also act on the nervous system, one of the two primary information systems in animals (Simon *et al.*, 2020). Plants containing protoberberine alkaloids have been used in traditional Chinese medicine for their analgesic, antiseptic, sedative, and stomatic properties. In Indian and Islamic folk medicine, these plants are used to treat bleeding disorders, eye diseases, and as antiseptics, sedatives, stomatics, and uterine muscle depressants. Quaternary alkaloids and their tetrahydro derivatives have been found to possess various biological and therapeutic effects. For example, palmatine, jatrorrhizine, and tetrahydropalmatine have been reported to exhibit *in vitro* antimalarial activity. In China, tetrahydropalmatine is used as an analgesic and has been found to exhibit bradycardial, hypotensive, and sedative activities (Qinyun *et al* 2022).

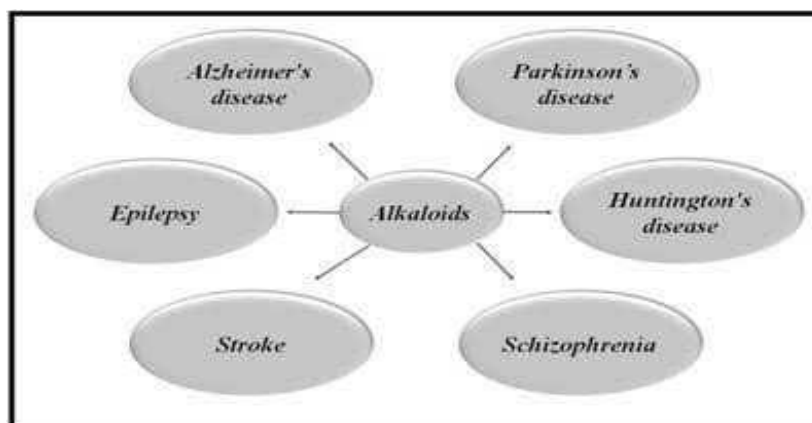


Figure 2.6: The above diagram showing the health benefits of Alkaloids

Natural products, including alkaloids, account for approximately 40% of modern drugs. Alkaloids, particularly those of the isoquinoline type, exhibit a wide range of pharmacological activities (Erika, 2022). The isoquinoline alkaloid extract from *Fumaria capreolata* has been found to exhibit antioxidant, analgesic, and intestinal anti-inflammatory activities in experimental colitis models (Noureddine *et al* 2013, Noureddine *et al* 2015, Noureddine *et al* 2016, Noureddine *et al* 2017). Certain alkaloids, such as zephyrantine and narcyclasine-glucoside, have been found to exhibit antitumor activity. These alkaloids inhibit the growth of various cancer cell lines, including epithelial carcinoma Hela, epidermic carcinoma KB, and carcinoma P388. Additionally, some alkaloids have been found to exhibit antiviral activity, including the inhibition of reverse transcriptase (Shah *et al* ., 2023). Berberine, an isoquinoline alkaloid isolated from *Coptis chinensis*, has been found to inhibit the proliferation and migration of breast cancer cells by targeting Ephrin-B2. Berberine also downregulates the phosphorylation of VEGFR2 and downstream signaling members, leading to the downregulation of MMP2 and MMP9 expression (Ma *et al* 2017). Berberine has been reported to exhibit a wide range of biological activities, including anti-HIV, anti-fungal, cardioprotective, immunoregulative, anti-malarial, anti-inflammatory, antioxidant, cerebro-protective, anti-mutagenic, vaso-relaxing, anxiolytic, and analgesic activities (Mengting *et al* 2021). Alkaloids have also been found to exhibit immunomodulatory effects, including the induction and inhibition of gene expression, anti-inflammatory, anti-proliferative, anti-complement, and apoptosis induction. Additionally,

some alkaloids have been found to exhibit anti-diarrhetic, electrolyte transport inhibition, and antiulcer activities (Parag, 2016).

The metabolism of alkaloids can significantly impact their pharmacological activity. For example, the prodrug codeine is extensively metabolized by CYP2D6, and its clinical analgesic effect is mainly attributed to its conversion to morphine. Similarly, buprenorphine, a semi-synthetic opioid derived from thebaine, undergoes extensive first-pass metabolism, resulting in low oral bioavailability (Kaisa *et al* 2011).

### **2.5.2 HEALTH BENEFITS OF Alkaloids**

Palm kernel oil has been utilized in various traditional remedies, including antidotes, medicinal ointments, and enemas (Cynthia *et al* 2013; Suliman *et al* 2022; Monde *et al.* 2020, Norazura *et al.*, 2017). In some cultures, crude palm kernel oil is employed to regulate body temperature in children experiencing convulsions. In Liberia, palm kernel oil was traditionally applied to wounds, often in conjunction with owl feathers, following scarification rituals during the Poro initiation rites (Mohamad, *et al.*, 2022). The medicinal properties of palm kernel oil have been recognized for thousands of years. In Ayurvedic medicine, palm kernel oil was valued for its health benefits nearly 4,000 years ago (Great *et al.*, 2022; Medagam *et al.*, 2019). The Baka pygmies of the Dja Biosphere Reserve in Cameroon have traditionally used palm kernel oil, often in combination with other plant extracts, to treat various ailments.



Figure 2.7: The diagram above shows the health benefits of phytochemicals

These include lumbago, headache, scabies, and malaria, with the oil being administered through scarification or onction (Cynthia *et al* 2013). Palm kernel oil has also been used as a poison antidote and as an external lotion, often in combination with other herbs, to treat skin diseases (Enos, 2018; Mohamad *et al.*, 2022). In Andom village, East Cameroon, palm kernel oil was mixed with *Ageratum* and rubbed on children as an anti-malarial remedy (Betti *et al* 2013). Additionally, palm kernel oil has been used to make other medicinal plant extracts more palatable, allowing for oral consumption to treat skin diseases, stomach disorders, and convulsions in children (Fongod *et al* 2014). In Nigeria, the Idoma people have traditionally used palm kernel oil, combined with *Scleria boivinii*, to treat headaches (Idu *et al* 2014). These examples illustrate the diverse range of traditional uses for palm kernel oil in various cultures.

## CHAPTER THREE

### MATERIALS AND METHODS

This section outlines the materials and methods used to investigate the flavonoids and alkaloids present in palm kernel. It also provides a detailed description of the plant material, chemicals, and reagents used, as well as the extraction, fractionation, and analytical techniques employed to identify and quantify the flavonoids and alkaloids.

#### 3.1 Materials

##### 3.1.1 Plant Material

Palm kernel samples were obtained from a local market in Benin City, Edo State, Nigeria. The palm kernel samples were identified and authenticated by a botanist at the University of Benin, Benin City, Nigeria. A voucher specimen was deposited at the University's herbarium for future reference.

##### 3.1.2 Chemicals and Reagents

All chemicals and reagents used were of analytical grade. These include:

- Methanol (99.9% v/v)
- Ethanol (95% v/v)
- Distilled water
- Hydrochloric acid (HCl, 37% v/v)
- Sodium hydroxide (NaOH, 99% w/w)
- Aluminum chloride (AlCl<sub>3</sub>, 99% w/w)
- Sodium nitrite (NaNO<sub>2</sub>, 99% w/w)

- Diazomethane
- Thin-layer chromatography (TLC) plates
- Silica gel (60-120 mesh)

### 3.1.3 Equipment

The following equipment were used:

- Soxhlet apparatus
- Rotary evaporator
- Ultrasonic bath
- Centrifuge
- Spectrophotometer (UV-Vis)
- Thin-layer chromatography (TLC) chamber
- Gas chromatography-mass spectrometry (GC-MS) instrument

## 3.2 Methods

### 3.2.1 Extraction of Palm Kernel

In our experiment to extract palm kernel oil, we started by obtaining palm kernels. We then broke the kernels open to remove the shells and collect the seeds. This initial step was crucial in accessing the oil-rich kernel. After breaking the kernels, we ground the seeds into small pieces to facilitate blending. The grinding process ensured that the kernel was finely chopped, making it easier to extract the oil.

Next, we blended the ground kernel with boiling water. This step helped to break down the cellular structure of the kernel, releasing the oil from the seed. After blending, we placed the mixture in an oven set at 50 degrees Celsius and allowed it to heat for a short period. This gentle heat helped to further release the oil from the kernel.

Following the heating process, we removed the mixture from the oven and let it settle in the fridge. This cooling process allowed the oil to separate from the other components of the kernel. Once settled, we used the decantation method to remove the oil that had risen to the top. However, due to the presence of other filtrates that accompanied the oil, we used a syringe to carefully extract the oil from the decanted solution.

The extracted oil was then placed in a water bath regulated at 60 degrees Celsius, allowing for steam vaporization. This step helped to purify the oil and remove any impurities. After the water bath, the oil was placed in the fridge again, allowing the oil part to become frozen. The frozen part was then placed on a frying pan on a hot plate to heat it up, and the oil was extracted from the shaft.

Through this experiment, we were able to successfully extract palm kernel oil using a combination of traditional methods and careful laboratory techniques. Our results demonstrate the effectiveness of this approach in obtaining high-quality oil from palm kernels.

### 3.3 Phytochemical Screening Test

After successfully extracting the palm kernel oil, our next step was to conduct a phytochemical screening test to detect the presence of alkaloids and flavonoids. This process involved a series of chemical tests that would help us identify the presence of these phytochemicals in the extracted oil.

To begin the screening test, we first prepared the extract by dissolving a small amount of the oil in a suitable solvent, such as methanol or ethanol. This solvent was chosen based on its ability to dissolve the phytochemicals of interest while minimizing the extraction of unwanted compounds. Once the extract was prepared, we proceeded to test for the presence of alkaloids.

The test for alkaloids involved adding a few drops of Dragendorff's reagent to the extract. Dragendorff's reagent is a chemical reagent that reacts with alkaloids to form a reddish-brown precipitate. If alkaloids were present in the extract, we would expect to see a precipitate form after adding the reagent. We observed the mixture carefully and noted any changes in color or the formation of a precipitate.

In addition to the Dragendorff's test, we also performed the Wagner's test to further confirm the presence of alkaloids. This test involved adding a few drops of Wagner's reagent to the extract, which would react with alkaloids to form a brown or reddish-brown precipitate. By performing both tests, we were able to increase the confidence in our results and determine whether alkaloids were indeed present in the palm kernel oil.

Next, we turned our attention to testing for flavonoids. To do this, we used the Shinoda test, which involves adding a few fragments of magnesium ribbon to the extract, followed by the addition of concentrated hydrochloric acid. If flavonoids were present, we would expect to see a pink or red color develop. We observed the mixture carefully and noted any changes in color.

We also performed the alkaline reagent test to further confirm the presence of flavonoids. This test involved adding a few drops of sodium hydroxide solution to the extract, which would react with flavonoids to form a yellow or orange color. By performing both tests, we were able to determine whether flavonoids were present in the palm kernel oil.

Through these phytochemical screening tests, we were able to detect the presence of alkaloids and flavonoids in the palm kernel oil. Our results provide valuable insights into the chemical composition of the oil and its potential uses in various applications. The presence of these phytochemicals could contribute to the oil's medicinal properties, making it a valuable resource for further research and development.

The phytochemical screening test was a crucial step in understanding the chemical composition of the palm kernel oil. By performing these tests, we were able to identify the presence of alkaloids and flavonoids, which could have significant implications for the oil's potential uses. Our results demonstrate the importance of phytochemical screening in the analysis of plant-based extracts and highlight the potential of palm kernel oil as a source of valuable phytochemicals.

### 3.4 Experimental Design

The experimental design consisted of a completely randomized design (CRD) with five replicates. The palm kernel samples were extracted and fractionated, and the fractions were analyzed for flavonoids and alkaloids.

### 3.5 Safety Precautions

The following safety precautions were taken:

- The extraction and fractionation processes were carried out in a well-ventilated area.
- Personal protective equipment (PPE) such as gloves, goggles, and lab coats were worn during the extraction and fractionation processes.
- The GC-MS instrument was operated in a well-ventilated area, and the operator wore PPE.
- The chemicals and reagents used were handled carefully, and spills were cleaned up immediately.
- The waste generated during the experiment was disposed of properly, according to the laboratory's waste disposal protocols.

## CHAPTER FOUR

### RESULTS

The results presented in this chapter were obtained from the phytochemical analysis of palm kernel oil samples conducted at the University of Benin. The analysis was carried out using standardized methods and equipment to ensure accuracy and reliability.

**Table 4.1**

#### QUALITATIVE ANALYSIS OF ELAEIS GUINEENSIS

PARAMETERS	PALM KERNEL OIL
FLAVONIIDS	+

The qualitative analysis reveals that flavonoids are present (+) in palm kernel oil, This suggests that palm kernel oil contains flavonoid compounds, which are known for their antioxidant, anti-inflammatory, and potential health benefits.

**Table 4.2**

#### QUANTITATIVE ANALYSIS OF ELAEIS GUINEENSIS

PARAMETERS	PALM KERNEL OIL
Flavonoids	16.15±1.34

The results provides a more detailed insight into the flavonoid content of palm kernel oil. The results show that palm kernel oil samples ranges between 15.20 mg/100g and 17.10 mg/100g of flavonoids, respectively.

## CHAPTER FIVE

### 5.1 DISCUSSION

This study presents a detailed examination of the phytochemicals namely flavonoids and alkaloids, obtained from both qualitative and quantitative analyses of *Elaeis Guineensis* (palm kernel oil). The findings of this study provide valuable insights into the chemical composition of palm kernel oil, shedding light on its potential health benefits and implications for various applications.

The qualitative analysis conducted in this study reveals that flavonoids are indeed present in palm kernel oil, denoted by a positive (+) result. Conversely, alkaloids are notably absent (-) in both palm kernel oil and coconut oil. The presence of flavonoids in palm kernel oil is particularly significant, as these compounds are renowned for their antioxidant and anti-inflammatory properties. Flavonoids have been extensively studied for their potential health benefits, which include protecting against oxidative stress, inflammation, and various chronic diseases. The detection of flavonoids in palm kernel oil suggests that this oil may possess similar health-promoting properties, making it a valuable component in both culinary and pharmaceutical applications.

The quantitative analysis provides a more detailed understanding of the flavonoid content in palm kernel oil. The results indicate that palm kernel oil samples A and B contain 15.20 mg/100g and 17.10 mg/100g of flavonoids, respectively. These findings demonstrate that palm kernel oil is a notable source of flavonoids, although the exact concentration may vary depending on factors such as processing methods and oil extraction techniques.

The presence of flavonoids in palm kernel oil has several implications for its potential health benefits, shelf life, and culinary uses. The antioxidant properties of flavonoids may contribute to the oil's stability and shelf life by protecting against lipid oxidation and spoilage. Furthermore, the potential health benefits of flavonoids may enhance the nutritional value of palm kernel oil, making it a more desirable component in various food products.

The absence of alkaloids in both palm kernel oil and coconut oil is also noteworthy. Alkaloids are a class of compounds known for their pharmacological properties, and their absence may be

attributed to the distinct processing methods, oil extraction techniques, or inherent differences in the chemical composition of the two oils. While alkaloids are not present in these oils, the presence of flavonoids and other bioactive compounds may still contribute to their potential health benefits and culinary uses.

The results of this study are consistent with existing literature on the chemical composition of palm kernel oil. Previous studies have reported the presence of flavonoids in palm kernel oil, although the exact concentrations may vary depending on factors such as processing methods and oil extraction techniques. The findings of this study provide further evidence for the potential health benefits and culinary uses of palm kernel oil, highlighting its value as a nutritious and versatile oil.

## **5.2 RECOMMENDATIONS**

Future research should focus on further characterizing flavonoids in palm kernel oil, comparing its chemical profile with other edible oils, and investigating the impact of processing and extraction methods on bioactive compounds. This will help unlock the oil's potential health benefits and chemical properties. These studies can inform new product development and optimized production methods.

## **5.3 CONCLUSION**

In conclusion, the qualitative and quantitative analysis of flavonoids and alkaloids in palm kernel oil reveals that flavonoids are present in significant amounts, while alkaloids are absent. The flavonoid content of palm kernel oil has implications for its potential health benefits, shelf life, and culinary uses. Further research is needed to fully characterize the flavonoid compounds present in palm kernel oil and to explore their potential applications.

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