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REVIEW ARTICLE

Nutraceutical and Functional Food Potentials of African Black Elimi (Canarium schweinfurthii): A Review

Abubakar Ibrahim Garba[1], Jude Kelech Agomuo[1], Fatima Abdullahi Sulaiman[1], Idris Kaida Zubairu[1], Abubakar Adam Kabir[1], Ahmad Muhammad Indee[2], Maimuna Garba[3] and Muhammad Salisu Muhammad[1]

[1]Federal University Dutsin-Ma, Katsina, Nigeria
[2]Binyaminu Usman Polytechnic Hadejia, Jigawa, Nigeria
[3]Aliko Dangote University of Science and Technology, Wudil, Kano, Nigeria

ABSTRACT

Medicinal plants have been central to African traditional medicine for centuries, preceding the development of synthetic drugs. Africa is blessed with large medicinal plants that are either under-explored or yet to be studied. This study aimed to find relevant research works on *Canarium schweinfurthii* with the purpose of identifying a new research niche. One hundred eighteen (118) research journals were collected, and 80 publications were synthesized and used to identify non-repeated experiments on the functional and nutraceutical potentials of *Canarium schweinfurthii*. The results of the review revealed that different parts of the plant including leaves, stem bark, roots, fruits, seeds, flowers, gum, and resin were traditionally employed in treating a range of ailments, including diabetes, stomach ulcers, malaria, typhoid, leprosy, reproductive disorders, and fever which are attributed to plant's richness for nutraceutical and functional properties, driven by the presence of bioactive compounds such as antioxidants, alkaloids, saponins, flavonoids, tannins, glycosides, and phenolic compounds. Nutraceutical and functional investigations of the plant have corroborated the antimalarial, anti-cancer, anti-diabetic, analgesic, antioxidant, antimicrobial, anti-bacterial, growth-promoting, nephroprotective, food preservative, anthelmintic, and termiticidal properties of the fruit pulp, fruit bark, stem bark, fruit oil, seed oil of *Canarium schweinfurthii*. This review recommends the plant for proper establishment of a foundation for the plant's pharmaceutical application and underscores the need for further research.

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INTRODUCTION

Natural plant-based products have been utilized for millennia as a primary source of preventive medicines for the treatment and prevention of human and animal diseases (Atanasov *et al.,* 2015; Bagchi, 2006). The words "Let food be your medicine and medicine be your food" were spoken by Hippocrates (460–370 BC). These days, there is a growing correlation between drugs and diet. In an effort to create products that enhance health and wellness, researchers are currently concentrating on foods that combine pharmaceutics with nutrition (Haller, 2010). According to Kyewalabye (2023), research on functional food ingredients indicated that there was potential for using these ingredients in food items to improve consumer health and provide value for producers. Around the world, numerous foods with medicinal value are currently being investigated for the treatment of crippling conditions like diabetes (Kyewalabye *et al.*, 2023; Ssenku *et al.*, 2022). Details on these plants and their therapeutic role are retained for the development of therapeutic food products (Mona *et al.*, 2017; Kakudidi *et al.*, 2016). *Canarium schweinfurthii* plant is a large forest tree characterized by a straight and cylindrical bole, thick bark on young tree fairly smooth, reddish to light brown slash with turpentine-like odor, exuding a heavy, sticky oleoresin yellowish in color; pinnate leaves, mostly opposite, oblong, cordite at the base, and Its creamy white flowers are unisexual about, and the fruit is a small drupe, bluish-purple, glabrous, long and thick containing a hard spindle-shaped that had been used traditionally in treating many ailments (Singab *et al.*, 2014). Ethno-botanical record of *Canarium schweinfurth*ii indicates its effectiveness as anti-diabetic. Part of the plant has been reported to have anti-diabetic effects; stem bark extract of the plant can reverse hyperglycemia caused by streptozotocin (Kamtchouing *et al.,* 2007; Kouambou *et al.,* 2007). Idu *et al.*, (2016) reported *Canarium* oil to have anti-diabetic

Correspondence: Idris Zubairu Kaida. Federal University Dutsin-Ma, Katsina, Nigeria. ✉ idriszubairu09@gmail.com.
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activity and can be considered as a remedy for diabetes. Despite its potential as anti-diabetic, the fruit pulp, which covers about 60 % of the total fruit volume, has not yet been exploited for the anti-diabetic effect.

Canarium schweinfurthii has been used traditionally for a long time to treat various ailments of the human body in many countries in Africa (Shaba *et al.*, 2013). The root, bark, fruit, seed, leaf, flower, gum, and resin are extensively used in traditional medicine by people of rural areas to manage health problems or as the source of their food. Its decoction is used to cure anemia, eye diseases, helminths infections, diarrhea, goiter hypertension, gastrointestinal disorders, toothache, cardiovascular conditions, yellow fever, or to ward off evil spirits (Ngbebe *et al.*, 2008; Okullo *et al.*, 2014). *Canarium schweinfurthii Engl.* is traditionally used in African Traditional Medicine as Insecticide or against dysentery, gonorrhea, coughs, chest pains, pulmonary affections/Mycobacterium tuberculosis, stomach complaints, food poisoning, purgative and emetic, roundworm infections and other intestinal parasites, emollient, stimulant, diuretic, skin affections, eczema, leprosy, ulcers; diabetes mellitus; colic, stomach pains, pains after childbirth, gale; fever, constipation, malaria, sexually transmitted infection and rheumatism (Kuete *et al.*, 2015). The resin of *Canarium shweinfurthii is* used against roundworm infections and other intestinal parasites. It is an emollient, stimulant, diuretic and affects skin affections and eczema. The pounded bark is used against leprosy and ulcers, and the root stem bark and leaves are used for treating fever, constipation, malaria, diarrhea, sexual infection, and rheumatism (Koudou, 2005). The leaves are used as stimulants against fever, malaria, constipation, diarrhea, postpartum pain, rheumatism, and sexually transmitted diseases (Koudou *et al.*, 2005). Whole plant decoction is a treatment against insects, dysentery, gonorrhea, coughs, chest pains, pulmonary affections, stomach complaints, food poisoning, purgative and emetic, roundworm infections and other intestinal parasites, emollient, stimulant, diuretic, skin-affections, eczema, leprosy, ulcers (Orwa *et al.*, 2009); diabetes mellitus (Kouambou *et al.*, 2007); colic, stomach pains, pains after childbirth, gale (Berhaut, 2010); fever, constipation, malaria, sexually transmitted infection and rheumatism (Koudou *et al.*, 2005). The stem bark decoction of *Canarium schweinfurthii* is used as a remedy for roundworms, colic, stomach pains, pain after childbirth, gale, dysentery, and gonorrhea (Berhaut, 2010). The plant's resin is burned, and its smoke is supposed to ward off evil spirits (Shaba *et al.*, 2013). The seed is burned (3 or 4 seeds), and the live coal is soaked in a cup of drinkable water. After approximately 5 min, the filtrate is drunk to treat sore throat. A decoction prepared with a mixture of leaf and stem bark of *Canarium schweinfurthii* is taken as a treatment against anemia, diarrhea, helminths, toothache, rheumatism, roundworms, fever, malaria, pulmonary diseases, gastrointestinal disorder, and sexually transmitted diseases. The same decoction is given to women against postpartum pains. The use of medicinal plants in African traditional medicine has a long history, predating the advent of synthetic drugs. *Canarium schweinfurthii*, known for its diverse phytochemical profile, has shown significant potential in treating various ailments. This review aims to consolidate current research on the nutraceutical and functional properties of this plant, providing a foundation for future studies and applications.

DESCRIPTION OF *ATILI* PLANT

According to Molana and Wiart (2011), the term "Canarium" has its roots in the colloquial phrase of the Molucca Island "Kenari" *Canarium schweinfurthiis* belongs to the Burseraceae family and is commonly referred to as Torchwood, frankincense, or incense tree family. Depending on the location, *Canarium schweinfurthii* is known by many names. In English, it is known as African black elimi, incense tree, gum resin tree, or bush candle tree. In Swahili, it is formally known as mpafu/mbani. In Uganda, it is known as muwafu. In French, it is referred to as elemier d'Afrique/elimi de Moahun (Orwa *et al.*, 2009). In Nigeria, it has different names depending on the locality dialect, including *Atili* in Hausa, *Pwat* in Berom, *Agbabubu* or Elimi in Yoruba, and *Ube-agba* in Igbo (Burkill, 1985; Gbile 1984).

1. **The plant:** *Canarium schweinfurthii* is a forest-dwelling, large, and tall tree with crown-wide branches that reaches the forest top canopy with long, clean, straight, and cylindrical bole that is up to 50 meters long or more (Figure 1). *Canarium schweinfurthii* tree trunk has about 4.5 meters average diameter. Thick bark has a smooth appearance when the tree is young, but as it becomes older, it becomes scalier and more cracked. The slash produces a dense, sticky oleoresin that changes to a sulfur-yellow color and solidifies into whitish resin. It has a reddish or light brown tint and smells like turpentine (Ngbebe et al., 2008).
2. **The flowers:** Mature fruit has a firm texture and resembles a dark brown/purplish plum. It has a triangular stone inside. The blooms are unisexual and have a creamy white color (Ngbebe et al., 2008). Clusters up to 28 cm long can be formed by the creamy white, unisexual flowers that grow in inflorescences within the leaf axils. The flowers are around 1 centimeter long. With three creamy petals making up the corolla, the calyx is popular. There is a whorl of six stamens in the androecium, and there are six lobes on the disc that lie between the stamens. Three carpels together to form an ovary

with three lobes make up the gynoecium. According to Ngbebe et al. (2008), the drupes are set atop a woody stone that is encased in a persistent enhanced calyx.

3. **The leaves:** The leaves are arranged pinnately and are clustered at the end of branches. They range in length from 15 to 65 cm. They are made up of eight to twelve leaflet pairs that are usually placed across from one another (Figure 1). The leaflets are 3-6 cm wide, rectangular, and cordate at the base, with lengths varying from 5 to 20 cm. On either side of the midrib, each leaflet has 12–24 major lateral nerves that are noticeable and pubescent on the underside. Interestingly, the bottom leaflets of *Canarium schweinfurthii l*eaves are larger than the upper ones. Wings are present on the upper side of the lower segment of the petiole. Five to twenty-one folios are supported by a terete, flattened rachis with a bulging base. The folios in question exhibit an oblique base, complete, dentate, or serrate borders that are frequently thick, and an acuminate tip at the apex. Near the margin, the secondary nerves arch and merge, while the tertiary nerves display a reticulate pattern. An axillary or terminal panicle is how the inflorescence appears.
4. **The fruit:** the black fruit of *Canarium schweinfurthii* is a small, hairless drupe that is about 1-2 cm thick and 3-4 cm long with a bluish-purple color (Figure 1). The calyx is tenacious. Inside the fruit is a hard, triangular, spindle-shaped stone that eventually breaks to release three seeds.

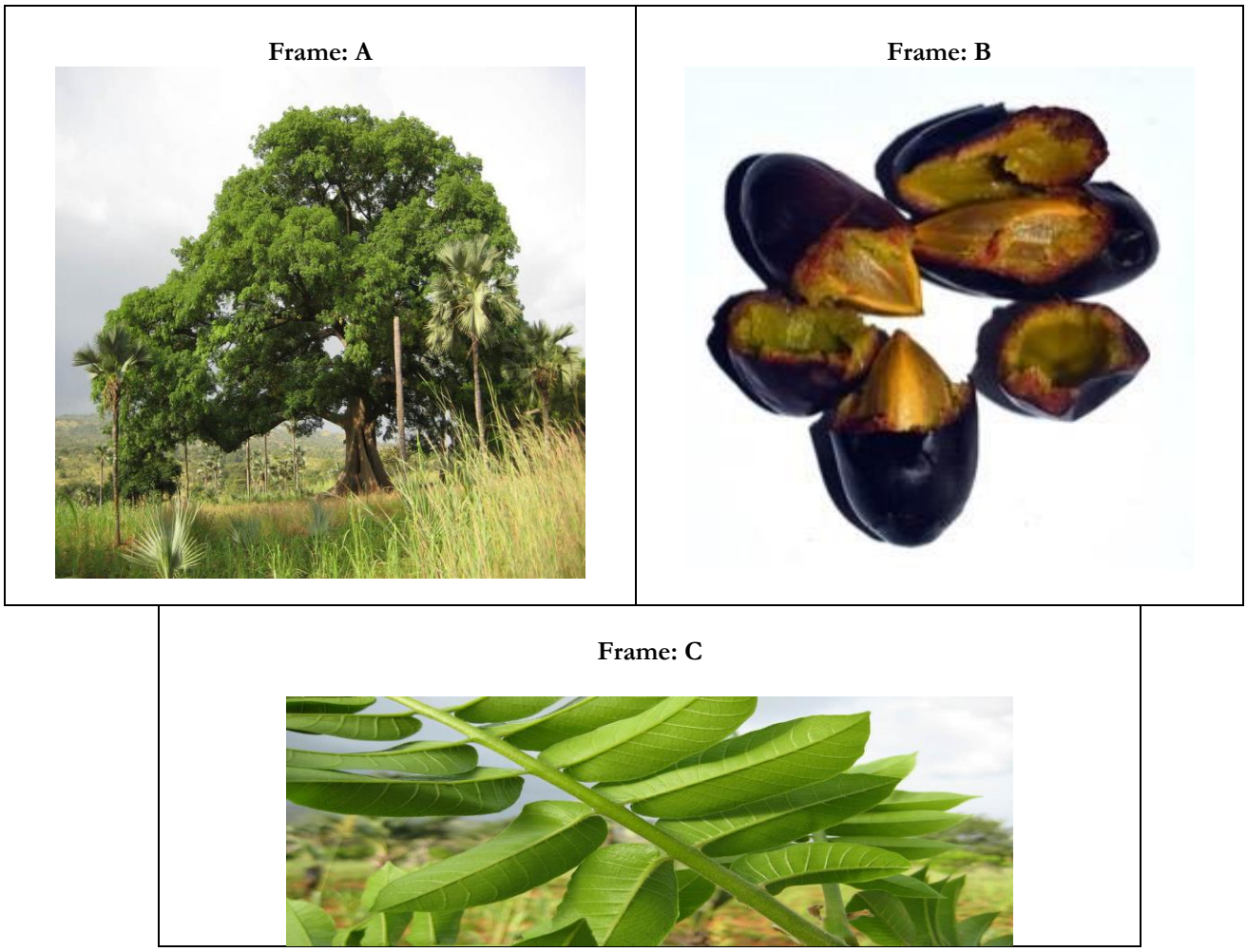

Figure 1: *Canarium schweinfurthii* plant and parts. Frame A shows the structure of the *Atili* plant. Frame B shows the internal and external view of the *Atili* fruit, while Frame C shows a photo of the leaves of the *Atili* plant.

DISTRIBUTION OF *ATILI* PLANT

The plant is a member of the family Burseraceae, which includes over 700 species of tropical trees divided into 18 genera. Canarium L. is a genus that includes medium-sized to big, buttressed trees that can grow to heights of 40–50 meters, as well as occasionally shrubs (Mogana et al., 2011). Widely dispersed throughout tropical Africa, especially in East, Central, and West Africa, *Canarium schweinfurthii* is native to the equatorial forest zone (Keary, 1989). Ethiopia, Tanzania, Angola, Ghana, Sierra Leone, Sudan, Togo, Guinea-Bissau, Zambia, Liberia, Mali, Nigeria, and Uganda are among the African nations where its native species can be found (Orwa et al., 2009). In Nigeria, the tree grows well in both rocky and flat areas (Nyam et al., 2014). According to Nyam et al. (2014), *Canarium schweinfurthii* is found in Nigeria, mostly in Plateau, Kaduna Bausch, Niger, and Oyo states.

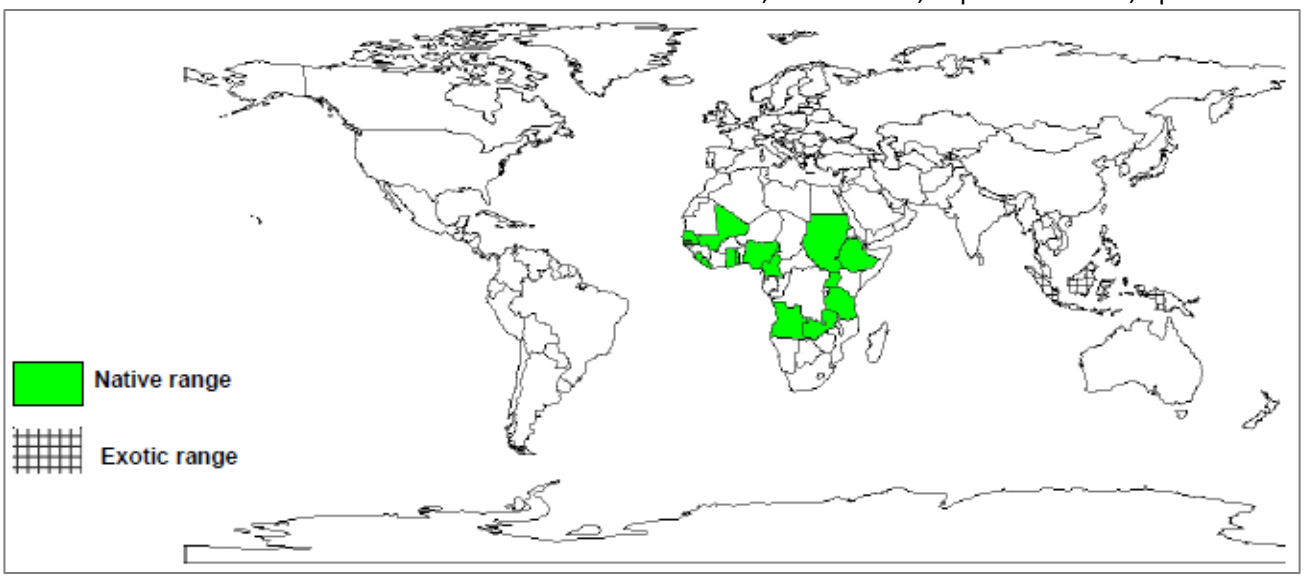

Figure 2: Distribution of *Elimi* Plant. Source: Keary (1989).

RESEARCH METHODOLOGY

Chong and Reinders's (2021) research review was adopted with modification. The relevant literary article was searched through Google Scholars, PubMed, MDPI, Ajol, and Scopus (Elsevier and Science Direct) using different filter phrases including *Canarium schweinfurthii*, *Atili*, Functional and Nutraceutical Plants, Medicinal Plant of Africa, African Black Elimi, Ethnobotany of *Canarium schweinfurthii*, Phytochemical of Atili, Phytochemical of *Canarium schweinfurthii*. One hundred eighteen (118) journal articles and book chapters were obtained, the journals were sorted based on relevance and non-repeated experiment, and 80 different scientific articles were selected and reviewed. About 30 of the journals were from Asia (India and Pakistan), 31 were from Africa (South Africa, Nigeria, Uganda), and 8 were from Europe (Germany and England). 6 were research reviews, while the remaining were research experiments extracted to provide detailed review report used in this study. The sorting procedure involves filter phrasing of the title of the research articles using the search phrase in Microsoft Excel, followed by a filter search of the articles' results and conclusion using the target phrases in Microsoft word. The selection and sorting procedure is described in Figure 3.

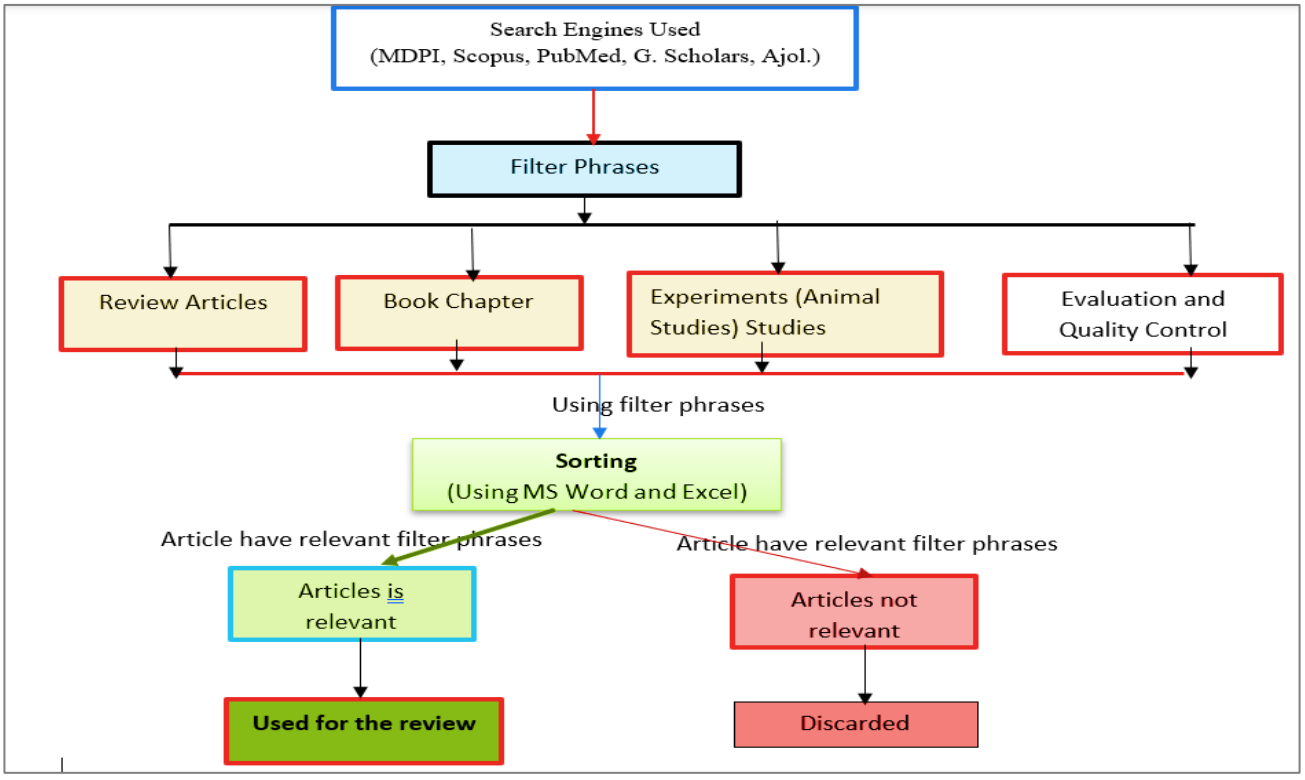

Figure 3: Review and selection procedure

Studies on the phytochemical composition of *Canarium schweinfurthii* have been conducted on nearly every portion of the plant. According to recent research, canarenes, triterpenes, balsams, heart glycoside, steroids, flavonoids, and phenolic compounds were major phytochemicals in *Canarium schweinfurthii* (Ngbebe et al. 2008; Mogana et al. 2011; Atawodi, 2010; Kouambou et al. 2007; Uzama et al. 2012; Tamboue et al. 2016; Yousuf, 2011, Okoli et al. 2015; Kyewalabye *et al.*, 2023; Garba et al. 2024). Major phytochemicals found in different parts of *Canarium schweinfurthii* are displayed in Table 1 below.

Table 1: Major Phytochemicals in different part of *Canarium schweinfurthii*

Phytochemicals	Leaves	Stem Bark	Fruit Pulp	Oil	Resins
Saponins	+	+	+	+	NR
Tannins	+	+	+	+	NR
Cardiac Glycoside	+	+	+	+	NR
Steroids	+	+	+	+	NR
Flavonoids	+	+	+	+	NR
Alkaloids	-	+	+	-	NR
Phenolic	+	+	+	+	NR
Balsams	-	-	+	-	-
Canarenes	-	-	+	-	-
Terpenoids	+	+	+	+	+
Triterpenoic acids	-	-	-	-	+
Anthraquinones	+	+	+	+	NR

Key: + = present, - = Absent, NR = not reported/no data.

Three triterpenoic acids acids, 24-dien-21-oic acid, 3a-hydroxytirucalla-8, and 3α-hydoxytrucalla-7,24-dien-2-oic acid as well as 3β-furotirucalla-7,24-dien-21-oic acid were found in the resin of *Canaium schweinfurthii* by Yousuf et al. (2011). Orwa et al. (2009) reported that fruit mesocarp oil included phenolic chemicals such as dihydroxyphenylacetic acid, catechol, phydroxybenzaldehyde, tyrosol, p-hydroxybenzoic acid, phloretic acid, pinoresinol, dihydroxybenzoic acid, secoisolariciresinol and vanillic acid. While coniferaldehyde, p-hydroxycinnamaldehyde, Schweinfurthinol, p-hydroxybenzaldehyde, amantoflavone and ligballinol were found by Tamboue et al. (2000), phellandrenes and limonene were recovered from the oil. From Canarium schweinfurthii seed, several compounds were also identified, including dihydroxyphenylacetic acid, catechol, tyrosol, dihydroxynezoic acid, phydroxybenzoic acid, vanilic acid, pinoresinol, secoisolariciresinol, and phloretic acid (Atawodi, 2010). According to Modamiro et al. (2016), flavonoids have powerful anti-cancer activity at every stage of carcinogenesis and have a role in avoiding oxidative cell damage. They also exhibit qualities including water solubility, hyper-antioxidant qualities, and the antioxidant ability to scavenge free radicals. According to Salah et al. (1995), digestive tract flavonoids lower the risk of inflammation and heart disease. Due to the anti-bacterial, analgesic, antihypertensive, antimalarial, anti-cancer, and antiarrhythmic properties of alkaloids and their synthetic derivatives (Stray, 1988), these compounds are used in medicine (Wink et al., 1998). Agbo *et al.* (1992) and Shaba *et al.* (2013) reported quantitative phytochemical composition of Canarium schweinfurthii.

Many diseases, including diarrhea, rhinorrhea, and leucorrhoea, are treated with medicinal herbs high in tannin. According to Blytt et al. (1988), tannins have drawn the attention of medical professionals due to their potential to treat lethal conditions like AIDS and different malignancies. In the food industry, Tannins are used in a variety of ways; they are used as clarifying agents in fruit juice, beer, and wine, as well as coagulants in the rubber industry for food packaging. Resistant to bacteria, yeast, viruses, and inflammatory responses are some of the properties of saponins. Serving as antifeedants and shielding the plant from bacteria and fungi are their main roles in plants (Skene et al., 2002). The potential of phenols as disease preventives has been well investigated (Duke, 1992). According to Rice-Evans et al. (1995), steroids are linked to human reproduction and function as antioxidants in vitro. The findings of the phytochemical and micronutrient screening conducted on *Canaium schweinfurthii* validate its pharmacological profile, emphasize its nutritional worth, and support its traditional usage in treating a range of health issues.

NUTRITIONAL CONTENTS

The fruit pulp of *Canaium schweinfurthii* from Cote d'Ivoire was found to have 30-50 % fat, 5.6 % protein, 11.8 % cellulose, 8.3 % ash, and 8.2 % starch; calcium and potassium contents were maximum at 0.4 % and 1.2 %, respectively (Agbo et al., 1992). However, in the case of the African black elimi from Nigeria, Ehirim *et al.* (2015) and Nyam *et al.* (2014) reported a moderate content of phosphorus (1.74 mg/100g) and sodium (1.53 mg/100g) in the fruit pulp. Additionally, the presence of Vitamin C (13.78 mg/100g) was identified by Ehirim *et al.* (2015). The presence of these minerals indicates the pulp's functional capacity in the development of bones and teeth. Phosphorus and Sodium are crucial components in nerve impulses and systemic homeostasis. The same study found that the fruit pup had low levels of potassium, iron,

and magnesium are crucial to blood coagulation and development. Tannins, phytic acids, and oxalate are examples of anti-nutrients that Nyam et al. (2014) documented as being present. The presence of oxalate at high levels in foods was determined to reduce the metabolic absorption of calcium, while the presence of phytate indicates the potential of the pulp to cause gastroenteritis if consumed at higher doses (Williams, 1999) as well as the potential to decrease iron, zinc, calcium and magnesium absorption, Akalloids are basic compound usually in the form of salt presence in about 10-20% of all higher plants (Eherim *et al.,* 2015). Tannins are a non-toxic but important element in wound healing (Nyam, 2011; Muller, 1988). The presence of these non-mineral elements in the fruit pulp may cause antagonistic physiological reactions which can be reduced by prewarming the fruit or fermenting the fruit pulp before oil extraction (Akwaowo et al., 2000). According to Odunfa (1985), cooking fresh Atili fruit and the fermentation processes increase the nutritional value and remove anti-nutritional elements from meals. The high tannin content in fruit is reported to be purging following large-scale consumption.

Table 2: Nutrient and Proximate Composition of *Atili*.

Composition	Pulp (%) (Agbo *et al.* 1992; Shaba *et al.* 2013; Nyam *et al.* 2014; Eherim *et al.* 2015)	Whole Seed (%) (Maduelosi & Angaye 2015)
Moisture	5.77 - 27.77	7.8 - 16.09
Protein	5.6 – 19.31	19.28
Carbohydrate	8.2 – 20.05	2.85 - 20.03
Fiber	11.8- 16.37	0.78
Ash	3.14 - 8.3	3.14
Fat	30-50	30.56

Key: Data from 1992 to 2015. Limited data is available from 2015 to date.

Table 3: Minerals and Anti-nutrient Content of *African black elimi*

Element	Concentration (mg/100g) (Eherim *et al.* 2015; Nyam *et al.* 2014)
Sodium	1.1359
Phosphorous	1.74
Potassium	0.0508-1.20
Magnesium	0.2188- 0.2861
Alkaloid	0.78
Iron	0.0859 - 0.2062
Calcium	0.4
Phytic acid	162
Tannins	240
Oxalate	26
Vitamin C	13.78

Key: Data from 1992 to 2015. Limited data is available from 2015 to date.

ATILI ESSENTIAL OILS

The hydro-distilled resin oil of *Canarium schweinfurthii* was found to have analgesic properties at doses of 3, 2, and 1 ml/kg, as evidenced using hot plate techniques and acetic acid-induced writhing (Koudou et al., 2005). However, in the cotton pellet-induced granuloma approach, there was no discernible decrease in the inflammatory process (Koudou et al., 2005). Furthermore, anti-lipoxygenase efficacy in essential oils obtained from *Canarium schweinfurthii* resins was observed by Dongmo (2010). Dongmo (2010) conducted a carotene bleaching test and radical scavenging assay using 2,2- diphenylpicrylhydrazyl to evaluate the antioxidant properties of *Canarium schweinfurthii* resin oil and reported excellent antioxidation, high phenol content of the methanol extract of the fruit mesocarp oil was linked using hypoxanthine/xanthine and 2-deoxyguanosine assay mode. This implies a possible function in chemoprevention against malignancies and other illnesses brought on by oxidative damage (Atawodi, 2010). Also, the essential oil of *Canarium schweinfurthii* was reported to have anti-fungal and anti-bacterial properties using micro dilution in the agar diffusion method. According to Dongmo (2010), the essential oil showed anti-bacterial activity against a variety of strains, suggesting its potential use as a natural antimicrobial agent.

Properties of Pulp Essential Oil

The outer pulp of the fruit, which exhibits a slightly greenish hue, possesses an oily and edible nature.

Consumption can occur in its raw state or following cooking through softening in warm water at a temperature below 35 ^{0}C. The oil content of the fruit pulp was determined to be 49.92 (on a dry basis) (Olawole, 2012). Physicochemical properties, as presented in Table 4, closely align with the typical values observed in high-quality oils (Burkill, 1994; Hafchinson and Dalziel, 1954). The iodine value and acid value of the pulp oil also were to be stable at different temperatures within the range of 30℃ to 55℃ (Olawole, 2012). The high oil content of the fruit pulp suggests an economical advantage for oil production at a commercial scale. According to research by Kiin-Kabari et al. (2020), African Elimi Pulp oil contains 50% unsaturated fats, such as stearic acid, and 50% saturated fats, such as oleic acid, with a lesser amount of palmitic acid suggesting excellent quality. The oil also has a competitive edge over other oil types in predicting its structural behavior during the formulation and production of margarine due to its unique properties, such as its fatty acid profile, melting point, and iodine value (Kiin-Kabari et al., 2020).

Table 4: *Atili* pulp oil characteristics (Olawole, 2012; Kiin-Kabari *et al.*, 2020)

Oil Quality Factor	Quantity
Saponification Value	155.47 - 191.44
Unsaponifiable Matter	1.154 – 1.32
Specific Gravity	0.9291
Acid Value (meq KOH/g)	0.94 - 4.0159
Iodine Value	76.79 - 87.381
Free Fatty Acid (%)	2.020
Melting Point (^{o}C)	44.5
Solidification (^{o}C)	34.5
Density (g/ml)	0.907
Refractive Index	1.4
Viscosity (pa.S)	0.368
Flash Point (^{o}C)	291.67
Smoke Point (^{o}C)	197.0
Fire Point (^{o}C)	197.0
Peroxide Value (meq/kg)	1.06
Fatty Acid Constituents Kiin-Kabari *et al.*, (2020)	
Palmitic Acid (%)	2.63
Oleic (%)	30.24
Stearic (%)	32.24
Myristic (%)	9.44
Gadoleic (%)	1.3
Behenic (%)	12.8

Key: Latest data from 2012 to 2020. Limited data is available from 2020 to date.

Properties of Seed Karnel Essential Oil

Atili-extracted fat has a greater acid content than any other vegetable oil, and its melting and solidification values are higher than those recorded in major commercial oils (Maduelosi *et al.*, 2012). Elimi oil exhibits a low level of free fatty acids, indicating reduced susceptibility to rancidity (Maduelosi *et al.*, 2012). Additionally, the oily and edible nature of the seed-kernel makes it a valuable component. Typically obtained by cooking the fruit, it is occasionally processed into vegetable butter in Nigeria, taking the place of shea butter. The kernel's oil content is measured at 51.79% on a dry basis (Olawole, 2012). The characteristics of *Atili* seed kernel oil undergo changes based on processing conditions, such as temperature; acid values experience a substantial increase of approximately

10%, which is significantly higher than the recorded change for pulp oil. A similar pattern is observed in the alteration of iodine values between temperatures of 30 ℃ to 55 ℃ (Olawole, 2012).

Table 5: Properties of *Atili* seed kernel oil.

S/N	Properties	Quantity
1	Saponification Value	193.545
2	Unsaponifiable Matter	1.745
3	Specific Gravity	0.9143
4	Iodine Value	94.16
5	Acid Value	0.9818
6	Free Fatty Acid	0.4984
	Fatty Acid Constituents	
1	Oleic %	36
2	Linoleic %	28
3	Palmitic %	26
4	Stearic %	10

Source: Latest from Maduelosi *et al.,* (2012).

NUTRACEUTICAL AND FUNCTIONAL PROFILES

Studies on *Canarium schweinfurthii* have demonstrated its exceptional nutritional and pharmacological properties, which are consistent with its many historical uses in treating medical conditions. The main importance is found in:

Antimalarial activity

Using the parasite lactate dehydrogenase technique, Ramadhani et al. (2015) discovered that the Canarium scheinfurthii extract demonstrates antiplasmodial action against the chloroquine-resistant Plasmodium falciparum (Dd2) strain. The investigation additionally revealed that a concentration of 100µg/ml of 80% ethanol extract of *Canarium scweinfurthii* led to a 61.94% suppression of In vitro anti-plasmodial activity on the Plasmodium falciparum Dd2 strain. This led to the original conclusion published by Ramadani et al. (2015) that the plant extract from *Canarium schweinfurthii* is particularly effective against *Pasmodium falciparum*.

Anti-cancer activity

Researchers sought to assess the cytotoxic effects of *Canarium scheinfurthii* on leukemia cells in a study published by Kuete *et al.* (2015). The leaves and stem bark extract of *Canarium schweinfurthii* has up to 50% growth suppression in leukemia CCRF-CEM cells in Kuete *et al.* (2015), according to preliminary tests conducted on these cells at a dose of 40 µg/mL, *Canarium schweinfurthii* extracts can kill drug-resistant leukemia cells through cytotoxicity. The potential application of elimi fruit mesocarp oil for chemoprevention of cancer and other oxidatively-induced disorders was highlighted by Atawodi (2010), whereas Uzama et al. (2012) focused on the chemo-preventive qualities of seed kernel oil. Furthermore, the MTT biological experiment revealed chemo-protective concentration values of 23.44 µg/mL and 34.40 µg/mL for chloroform and ethanol extract of *Canarium schweinfurthii* bark, respectively, showed anti-cancer activity. These extracts were more positively effective against breast cancer cell line MD 468 (Mogana *et al.* 2011).

Antioxidant activity

Free radicals, such as reactive oxygen species (ROS), another name for free radicals, are extremely reactive chemicals that can attack and harm sensitive cells in the body system, depriving them of their functionality and structure. Examples of free radicals include Hydroxyl radicals (OH^+), Hydrogen peroxide (H_2O_2), Oxygen ion (O_2^{-2}), Hypochlorous acid (HOCl), Superoxide anion radicals (O^{2-}), and Hydroperoxyl radical (HO_2). They are typically generated from internal factors such as Phagocytes, Mitochondria stress, Xanthine oxidase, and excessive exercise, as well as external factors like exposure to radiation, UV light, air pollution, and smoking (Ouakil *et al.,* 2022). The body produces free radicals continuously, which results in oxidative stress (Kiranmai *et al.* 2011). A chain reaction that produces more molecules of the original free radicals until the reaction is neutralized is started when free radicals attack bodily cells. According to Alzohairy (2016) and Ouakil *et al.* (2022), there are more than 50 pathogenic processes linked to the actions of free radicals in the body, which also lead to major illnesses, including neurological disorders, inflammatory cases, and cancer, heart disease.

Consequently, it is essential to control free radicals inside the human system (Jose *et al.* 2020), and antioxidants are one way to do this. Free radicals receive electrons from antioxidants, which transform them into safe compounds. They can come from naturally occurring food plants like *Canarium schweinfurthii*, intentionally synthesized substances like sodium benzoate, or naturally occurring substances like vitamin C that are found in the body.

Although there is not much research on the antioxidant capacity of the *Canarium schweinfurthii*, it has been

extensively used in both conventional and alternative medicine. Obame *et al.* (2007) examined the antioxidant potentials of *Canarium schweinfurthii* fruit pulp oil using a radical scavenging assay and carotene bleaching test in inhibiting lipid peroxidation. The essential oil demonstrated strong antioxidant properties and radical scavenging. *Canarium schweinfurthii* oil, obtained from Cameroon, was discovered to have an IC_{50} value of 62.6 ppm, which inhibits the enzymatic activity of lipoxygenase (Dongmo, 2010). However, in a different investigation using samples from central Africa, no activity was seen in the experiment involving the formation of granulomas produced by cotton pellets (Koudou *et al.* 2005). It was the same species. The results of these two investigations point to possible evidence of regional differences in secondary metabolites.

Antimicrobial and anti-bacterial activity

Dzotam et al. (2015) observed the anti-bacterial activity of *Canarium schweinfurthii* against multidrug-resistant gram-negative bacteria using microdilution, the result shows a minimal inhibitory concentration from 64 to 1024 µg/mL against 89.5 % of the bacteria strain. Obame *et al.* (2007) also reported *Canarium schweinfurthii* oil to have effective anti-bacterial and antifungal properties. African black Elimi leaves were found to possess antimicrobial activities (Nyam, 2011). Moshi *et al.* (2009) reported that dichloromethane, ethyl acetate, and ethanol leaf extract of *Canarium schweinfurthii* have antimicrobial effects against gastrointestinal pathogenic bacteria. Ngbede *et al.* (2008) noted that leaves and oils of *Canarium schweinfurthii* Engl. exhibit antimicrobial, antifungal, and insecticidal properties. The dichloromethane extract of *Canarium schweinfurthii* was reported to have a minimum inhibitory concentration of 0.62 mg/ml against gram-negative *Staphylococcus aureus,* while the ethyl acetate extract has a minimum inhibitory concentration of 5 to 10 mg/ml ethanol extract of *Canarium schweinfurthii* shows anti-bacterial effect against *Proteus vulgaris and Vibrio cholera* with minimal inhibitory concentration of 10 and 0.62 mg/ml respectively (Moshit *et al.* 2009). According to Shaba's (2013) summary, *Canarium schweinfurthii* methanol extract is effective against *Bacillus subtilis, Salmonella typhii, Pseudomonas aeruginosa, Klebsiella pneumonia* of 37 mm, and E. coli. Chloroform and n-hexane extracts, however, had no effect against any of the tested microorganisms. When tested against *E. coli* at 27 mm, *Salmonella typhii* at 22 mm, *Pseudomonas aeruginosa* at 21 mm, *Bacillus subtilis* at 12 mm, and Klebsiella pneumonia at 28 mm, the ethyl acetate extract showed action. The anti-bacterial activity exhibited heterogeneity based on the extraction process and solvent utilized, as seen by the minimum inhibitory and minimum bactericidal concentrations that varied from 10 to 0.1 µg/ml.

The antifungal effects of Elimi essential oils and resins were evaluated by Agwanande et al. (2014). They discovered that Aspergillus flavus was inhibited at minimum inhibitory concentrations (MIC) of 1800 ppm and 4500 ppm. For essential oils and resins, Aspergillus fumigatus showed MIC values of 3800 and 1300 ppm, respectively, but Aspergillus niger had MIC values of 3500 and 2800 ppm. With values surpassing 250, 1200, and 800 ppm against *Aspergillus niger, Aspergillus flavus,* and *Aspergillus fumigatus*, the specie of *Canarium schweinfurthii* demonstrated stronger antifungal inhibitory activity than the reference preservative sorbic acid. The investigation found that the essential oils of *Canarium schweinfurthii* can be used to preserve food. Ayanbimpe and Yikigwe (2009) use the crude *Atili* oil extract to maintaining fungal culture, their findings suggested that this method was suitable for preserving some fungi, especially yeasts, without affecting their morphological characteristics. However, dermatophyte species were less well-suited for this storage method, which suggests that other preservation techniques should be investigated.

Anti-diabetic activity

Kamtchouing *et al.* (2007) studied the anti-diabetic effect of methanol/methylene chloride extract of the stem bark of Canarium schweinfurthii on diabetes induced by streptozotocin (STZ). Their findings revealed that at 300 mg/kg dose, the *Canarium schweinfurthii* extract has a blood sugar-reducing effect of up to 69.9 %. This result suggests a medicinal activity of the plant in the control of hyperglycemia (diabetes). Moreover, treated rats exhibited a weight gain of 6.6%, in contrast to untreated rats, which experienced a 14.1% loss in body weight. Additionally, there were notable reductions in food and fluid intake by 79.7 and 68.5 %, respectively. These outcomes collectively suggest that the extract has the potential to counteract hyperglycemia, polyphagia, and polydipsia associated with streptozotocin, underscoring its anti-diabetic activity (Kamtchouing *et al.* 2007).

Analgesic activity

Koudou *et al.* (2005) reported an excellent analgesic effect of *Canarium schweinfurthii* resin oil extracted by hydro-distillation on acetic acid-induced writhing and hot plate method at 1-3 ml/kg dose. The same research also reported an ineffectual inflammatory-reducing effect in the cotton pellet-induced granuloma approach.

Nephro-protective activity

Okwuosa et al. (2009) investigated the preventive effects of the aqueous and methanol extract of *Canarium schweinfurthii* stem bark on rats' kidneys after acetaminophen-induced renal damage. The extract was able to preserve the renal architecture opposite to the

acetaminophen and negative control, which shows different levels of necrosis, tubular cast, tubular erosion, and increased urinary pole.

Growth promoting effect

The potential use of charcoal made from *Canarium schweinfurthii* seeds as an antibiotic replacement in broiler diets was evaluated. Kana et al. (2012) used a completely randomized approach to examine the effects of Canarium schweinfurthii seed charcoal and the antibiotic growth activator Doxycycline on the growth performance of day-old broiler chicks. The control group fed grower and starter diets made primarily of corn and soybeans to their broiler chickens. Next, as an antibiotic growth promoter, 0.1% Doxycycline was added to the basal diets in addition to 0.4 or 0.2 % Canarium seed charcoal. The major conclusions showed that throughout the experiment, there was no difference in feed intake and carcass yield ($p>0.05$) across all the dietary regimens. The intestinal density and feed conversion ratio of the antibiotic group, however, were noticeably lower than those of the basal diets that included plant charcoal supplements. When compared to the basal diet and charcoal treatments, the antibiotic significantly boosted the increase in live body weight. Although the effects of charcoal and the control diet were similar, there was a propensity for charcoal to enhance feed conversion ratio and weight gain. Given that the use of antibiotics as growth promoters is prohibited in many nations across the world due to pathogenic microbes in the enterococcus group developing resistance and the accumulation of chemical residues on agricultural products that may harm consumer health, this result is especially noteworthy (Vicente et al., 2007).

Food preservation

Philip *et al.* (2009) revealed the repellent properties and toxic effects on insect heart muscles associated with the *Canarium schweinfurthii* plant. Additionally, Vera *et al.* (2009) observed that this plant species imparts resistance against diamondback moths and flea beetles. Thus, *Canarium schweinfurthii* emerges as a promising botanical insecticidal agent that warrants further exploration across various crops for its efficacy (Philip *et al.*, 2009; Vera *et al.*, 2009). Concurrently, *Canarium schweinfurthii* was identified as having a contact effect on tissues against *Callosobruchus maculatus* in stored legumes (Katunku *et al.* 2014). Katunku *et al.* (2014) opined that all parts of *Canarium schweinfurthii* plant exhibit an impact on the survival of *Callosobruchus maculatus*, with the powder from cotyledon and mesocarp of *Canarium schweinfurthii* tissues resulting in 25-97% mortality. Similarly, a study by Katunku *et al.* (2014) revealed that the mesocarp oil of *Canarium schweinfurthii* exhibited a 55 to 100 percent rate of mortality against *Callosobruchus maculatus*. Moreover, the extract of fruit mesocarp tissues caused an 80 to 100 percent rate when applied at a rate of 1.25 mg/ml/50g to 2.5 mg/ml/50g grain within three days of treatment.

Termiticidal activity

The termiticidal potential of the essential oil obtained from *Canarium schweinfurthii* with 96% monoterpenes was noted by Nagawa *et al.* (2015) to have a significant termiticidal action.

Anthelminthic activity

Anthelminthic refers to the capacity of food/drugs to treat infections caused by parasitic worms in animals (Holden-dye, 2014). The anthelminthic effect of food is a significant public health concern, particularly in tropical regions with limited health investment (Holden-dye, 2014). Therefore, exploring anthelminthic potentials in *Canarium schweinfurthii* is of paramount importance. Okoli *et al.* (2016) conducted a screening of the anthelminthic effect of *Canarium schweinfurthii*. The extract showed 66.7% inhibition against the test pathogens at a dosage of 50 mg/mL in the initial antimicrobial screening. With *Salmonella typhii, Candida albicans, and Candida tropicalis* inhibited at 12.5 µg/mL, the isolated 3β-hydroxylolean-2,8-diene shows inhibitory activity at 6.25 µg/mL against a variety of microorganisms, including *E. coli, S. aureus, Shigella dysenteria, Klebsiella pneumonia, Candida stellatoidea and Bacillus subtilis.* Comparing the 3β-hydroxyl olean-12,18-diene's ovacidal and larvacidal activities against the pre-infective and infective stages of *Ascaris suum,* percentage inhibition ranged from 65% to 62% and 86% to &6%, respectively, the findings of this research show potential for anthelminthic medication.

ETHNO-BOTANY OF *Canarium schweinfurthii*

Ethno-botany represents the accumulated knowledge within a specific community that evolves (NAARAP, 2016). This knowledge, grounded in experiential learning and often validated over centuries, adapts to local cultures and environments, demonstrating a dynamic and ever-changing nature (NAARAP 2016). *Canarium schweinfurthii* has long been used traditionally in several African nations to cure a variety of human illnesses (Shaba et al., 2013). Canarium schweinfurthii is a plant that is widely used in rural regions for food or medicinal purposes. Its bark, root, fruit, leaf, seed, flower, resin, and gum are all used extensively (Ngbebe et al. 2008; Okullo et al. 2014). This plant's infusion is used to treat different ailments, including yellow fever, helminth infections, anemia, diarrhea, hypertension, goiter, toothaches, cardiovascular problems, and gastrointestinal disorders (Ngbebe et al., 2008; Okullo et al., 2014). It is used as a decoction to ward off bad spirits.

In African traditional medicine, *Canarium schweinfurthii* is also used as an insecticide and in treating food poisoning, pains, gonorrhea, coughs, diarrhea, pulmonary infection/mycobacterium tuberculosis, stomach aches, roundworm infection, purgative and emetic and intestinal parasites (Ngboula et al. 2014; Kuete et al. 2015). As a stimulant and emollient, the plant's resin is used against

roundworm infection and intestinal parasites. Leprosy and ulcers are treated with the pounded bark; fever, constipation, malaria, diarrhea, genital diseases, and rheumatism are treated with the roots, stem bark, and leaves (Koudou, 2005). According to Koudou et al. (2005), leaves are used as a stimulant for several ailments, including constipation, fever, malaria, diarrhea, rheumatism, STDs, and postpartum discomfort. The whole plant is decocted and used as treatment for rheumatism, malaria, gonorrhea, leprosy, diabetes mellitus, colic, fever, constipation, coughs, skin disorders, ulcers, stomach complaints, food poisoning, chest pains, pulmonary affections, infections caused by roundworms and other intestinal parasites (Orwa et al. 2009; Kouambou et al. 2007; Berhaut 2010; Koudou et al. 2005). Canarium schweinfurthii's stem bark infusion is especially used to treat roundworms, colic, stomachaches, postpartum pain, diarrhea, and gonorrhea (Berhaut, 2010). In addition, burning the plant's resin releases smoke that is thought to fend off evil spirits (Shaba et al., 2013). Sore throats can be treated by soaking the burned seeds in potable water. To treat helminthes, anemia, diarrhea, toothache, roundworms, rheumatism, fever, gastrointestinal disorders, STDs, malaria, and lung diseases, a decoction made from leaf and steam back concoction is taken. Women who experience postpartum pain are given this identical concoction (Shaba et al., 2013).

Table 6: Ethno-botanical use of *elimi*

Plant Part	Medicinal application	Preparation
Leaf, Root and Seed	Treatment of:	The concoction is made by boiling leaves and drinks.
	Stomach ache/pain	Seed and coal is sucked in water, filtered, and drink.
	Leprosy and Chest pain	Leaves are used or burnt as insecticide.
	Constipation and Ulcers	
	Diabetics and Fever	
	Rheumatism and Goiter	
	STDs and Malaria	
Bark	Treatment of:	The bark is boiled and mixed with the bark of *Parkia biglobosa* and taken orally
	Pile (hemorrhoids)	The bark is boiled and child is placed in it to sit.
	Roundworm infection	Grounded bark is mixed with oil and applied to the child's anus and some are given to the child to eat.
	Stomach pain	
	Dysentery and Fever	
	Gonorrhea.	
Gum/Resin	Toothache	Gum is applied on tooth Gum/Resin boiled together with the root for children.
	Pile (hemorrhoids).	Rub gum/resin on the affected area
	Skin infection (eg Eczema).	
	For perfume products.	
Fruit	Ulcer	Fruit is eaten cooked
	Pile (hemorrhoids)	
Oil	Ulcer and Typhoid	Used in food or taken orally
	Pile (hemorrhoids)	Used in food
	Bone fracture and Burns (from hot water and fire)	For fractures apply oil on the bone after bone is locally joined to heal.
	Rheumatism	Oil is applied on the burns

Source: Modified Dawang *et al.,* (2016)

Table 7: Ethno-food use of African black *elimi*

Plant part	Utilizable part	Nutritional usage
Leaf	Fresh leaves are used as fodder for animals, particularly goats.	1. Utilized as feed for animals usually consumed dried or fresh.
Plant root	Utilized solely for medicinal applications.	Not as for food
Fruit Seed	Cracked seed is eaten. A seed akin to a "groundnut/cashew nut" can also be revealed by roasting it before it cracks.	1. Seed kernel builds the body 2. Used as Food and for variety utilization.
Bank	Utilized for medicinal purposes	Not used as food.
Gum/Resins	Utilized in cosmetics for perfume production.	Not as for foods.
Fruit	The pulpy portion of the fruit is consumed after it has been heated or boiled in hot or warm water.	1. Fruit builds the body
Oil	You can use the oil as dressing, to add taste to meals or meat, or to sweeten cooked beans.	1. Builds the body. 2. Oil helps fight diseases. 3. Oil repairs the blood veins. 4. Source of energy and strong bones.

Source: Modified Dawang *et al.,* (2016).

CONCLUSION

Canarium schweinfurthii is used in African traditional medicine to treat a wide range of human diseases. This scientific review delves deeply into this practice. All parts of the *Canarium schweinfurthii* bark, root, tree leaves, fruit, gum, resin, seeds, and flowers are used by traditional healers. Antioxidant, analgesic, antimicrobial, growth-promoting, nephroprotective, anti-bacterial, food preservative, anthelminthic, antimalarial, termiticidal, and anti-cancer research, among other disciplines, has demonstrated the plant's valuable biochemical content. Presence of diversified classes of phytochemicals such as steroids, triterpenes, gl. The multifarious qualities of the plant in traditional medicine are supported by its diversified phytochemical makeup, which includes phenolic compounds, steroids, triterpenes, glycosides, saponins, tannins, alkaloids, and flavonoids. Its high nutrient content further confirms its nutritional worth.

Despite the comprehensive exploration in this review, there remains a need for research to quantify the phytochemical composition of the resins and seed kernel. The research highlights the variety of secondary metabolites and pharmacological profiles found in *Canarium schweinfurthii*, highlighting the possibility of finding new uses for its bioactive ingredients in the food and medicine sectors. The absence of data quantifying waste for this product is noted throughout the review. The secondary metabolites and pharmacological properties of *Canarium schweinfurthii,* as discussed in this paper, underscore the untapped potential within this medicinal plant. Evaluating the biological activity and mechanisms of action of generated organic acid extract from this plant species is crucial, given its therapeutic importance. With an acidity level of less than 0.8%, comparable to olive oil, as reported by Agu *et al.* (2008), Atili oil presents an opportunity for incorporation in food production and cosmetics industries, potentially alleviating the demand for olive oil. While *Canarium schweinfurthii* oil's mycology has been tested on yeast, further research is warranted to explore its mycological impact on bacterial isolates. Despite its proven medicinal properties, additional investigations should ascertain the potential toxicity and any side effects associated with prolonged usage.

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