



Sterculia quadrifida R.Br: Utilization, Bioactive Compounds, and the Potential as a New Source of Seed Oil - A Comprehensive Review

Mery Rambu B. Djoru¹, Samatcha Krungkaew¹, Malinee Sriariyanun², Yu-Shen Cheng³, Godlief F. Neonufa⁴, and Patchanee Yasurin^{1*}

¹ Theophane Venard School of Biotechnology, Assumption University, Bangkok, 10240, Thailand

² The Sirindhorn International Thai-German Graduate School of Engineering, King Mongkut's University of Technology North Bangkok, Bangkok, 10800, Thailand

³ Department of Chemical and Materials Engineering, National Yunlin University of Science and Technology, Douliu, Yunlin, Taiwan

⁴ Agricultural Technology Faculty, Artha Wacana Christian University, Kupang, Indonesia

* Correspondence: patchaneeYsr@au.edu

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Abstract: *Sterculia quadrifida* R.Br., a plant native to East Nusa Tenggara, Indonesia, and northern Australia, has gained increasing attention due to the diverse traditional uses of bark, roots, leaves, and seeds. Recent studies have shown that this plant is rich in bioactive compounds, including antioxidants, anticancer, antimicrobial, and antifungal agents present in all parts of the plant. This review aims to discuss the utilization of this plant by local communities and summarize various research findings on its bioactive compounds and their health benefits. Additionally, the review focuses on the potential of the seeds as a valuable new source of plant oil, as studies on *Sterculia quadrifida* R.Br. seeds have revealed high lipid content, diverse fatty acids including linoleic and palmitic acids, sterculic acid, triterpenoid, and β -sitosterol, which contribute to their antioxidant, anticancer, antimicrobial, and antifungal properties. This review provides opportunities for further research on the extraction of *Sterculia quadrifida* R.Br. seed oil and its applications in the food, pharmaceutical, and industrial sectors.

Keywords: Faloak tree; bioactivity; seed oil; extraction method; vegetable oil.

1. Introduction

Plants that traditional communities have long utilized may possess bioactive compounds that can be harnessed for modern applications [1]. Indonesia possesses abundant biodiversity in the world, with thousands of plant species widely distributed across tropical rainforests [2], with approximately 7,500 of its 30,000 species recognized for their medicinal potential [3]. Timor Island, Indonesia, has a dry soil structure, low rainfall intensity, and limited water supply, which has led to biodiversity that differs from other regions of Indonesia. One of the endemic plants on Timor Island is *Sterculia quadrifida* R.Br. This plant is categorized as a tropical tree and belongs to the family *Sterculiaceae* [4]. *Sterculia quadrifida* R.Br. exhibits various pharmacological properties and has long been utilized in traditional medicine. The bark is the most frequently used part by the local communities in East Nusa Tenggara for medicinal purposes, such as treating hepatitis or liver disorders, fatigue, gastroenteritis, and

rheumatoid arthritis [5]. Several products derived from the bark of *Sterculia quadrifida* R.Br have already been marketed in local markets and national marketplaces, such as tea and instant health beverages. It has also become one of the most sought-after plants for treating liver diseases.

Several studies have explored the roots, leaves, and seeds of *Sterculia quadrifida* R.Br, revealing a wealth of distinctive compounds [6-9]. Among the plant parts, the fruits of *Sterculia quadrifida* R.Br are particularly abundant each year, especially considering the dense distribution of trees on Timor Island [10]. However, these fruits are underutilized and are discarded seasonally. Research indicates that the seeds of *Sterculia quadrifida* R.Br are rich in fatty acids, including palmitic acid, heptadecenoic acid, stearic acid, and linoleic acid, which are vital components of many plant oils [11]. Additionally, bioactive compounds such as flavonoids, alkaloids, tannins, and phenolic acid found in the seeds demonstrate strong biological activities [7, 12]. The unique combination of fatty acids and bioactive compounds suggests that *Sterculia quadrifida* R.Br seeds have a significant potential as a new and valuable source of plant-based oils.

This review aims to provide a comprehensive review of the potential of *Sterculia quadrifida* R.Br, particularly in terms of its utilization, bioactive compounds, and the prospects of its seed oil benefits. This review summarizes and analyzes various studies related to this plant, given the growing interest in natural and bioactive sources. A thorough review of *Sterculia quadrifida* R.Br can help identify new benefits and utilization opportunities across various sectors, such as health, food, and industry. Additionally, this article provides information about this plant in raising global awareness and understanding of this plant, encouraging further research that could unlock new economic and scientific opportunities.

2. Distribution and Morphology of *Sterculia quadrifida* R.Br

Sterculia quadrifida R.Br. is a tropical tree found in various regions across Australia and Asia [13]. Originally, this plant spread from northern New South Wales to Queensland and extended to Western Australia and parts of Indonesia (Figure 1). In Australia, this plant is known as the Peanut tree or Red Kurrajong [5], in China known as Wu wai zi [6], while in Timor Island, Indonesia, it is known by the local name Faloak [13, 14].

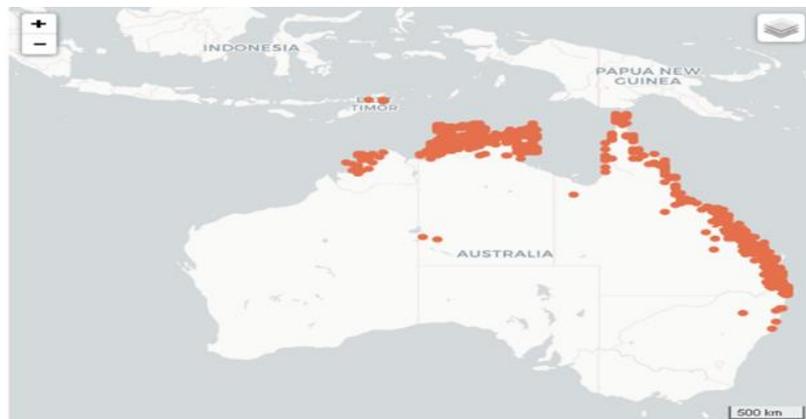


Figure 1. Map of the distribution of *Sterculia quadrifida* R.Br in Australia and Indonesia [15].

The ecology of *Sterculia quadrifida* R.Br. is characterized by its adaptability to a range of tropical and subtropical environments. This tree often grows in association with other native species and typically grows wild in forest areas and can grow on rocky and drained soils [16]. Moreover, *Sterculia quadrifida* R.Br can grow up to a height of 20 meters, with a sturdy trunk featuring rough bark and thick fibers (Figure 2a). The fruiting season occurs annually between June to October. During this period, when the fruit is ripening, the seeds are protected by the green skin, and after the period ends at the age of 3 to 4 months, the skin of the fruit will turn orange, and the fruits split open, revealing black seeds that are elliptical in shape, typically containing 4-8 seeds per fruit. After 1-3 weeks, the skin of the fruits will turn brown, which indicates the seeds are old (Figure 2b). The seeds of *Sterculia quadrifida* R.Br are approximately 10 mm in size and are edible, with a taste resembling that of raw nuts [10].

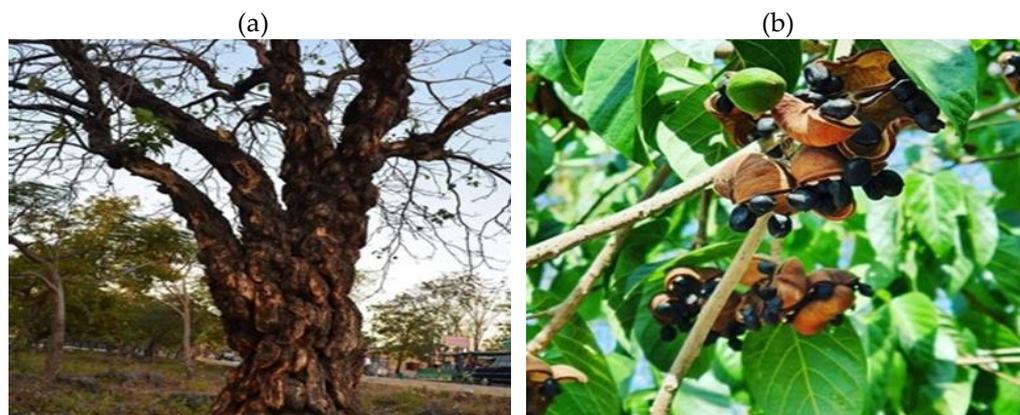


Figure 2. (a) Plant, and (b) Fruit and Seeds of *Sterculia quadrifida* R.Br.

Specific quantitative data regarding the annual fruit yield per tree is not available due to the limited research focusing on the seeds of this tree. However, research indicates that on Timor Island, Indonesia, the density of this plant is relatively high and widespread across various regions with differing densities [17]. Exploratory studies conducted in five districts on Timor Island revealed the distribution data of *Sterculia quadrifida* R.Br. as follows: the highest density was found in the Timor Tengah Selatan District area (14.16 trees/ha), followed by the Kupang District area (7.94 trees/ha), the Belu District area (6.25 trees/ha), Kupang City (4.84 trees/ha), and the Timor Tengah Utara District area (1.4 trees/ha) (Figure 3). Given the high distribution density of this tree, it is expected and estimated to produce a substantial quantity of fruit and seeds from the *Sterculia quadrifida* R.Br. plant each year.

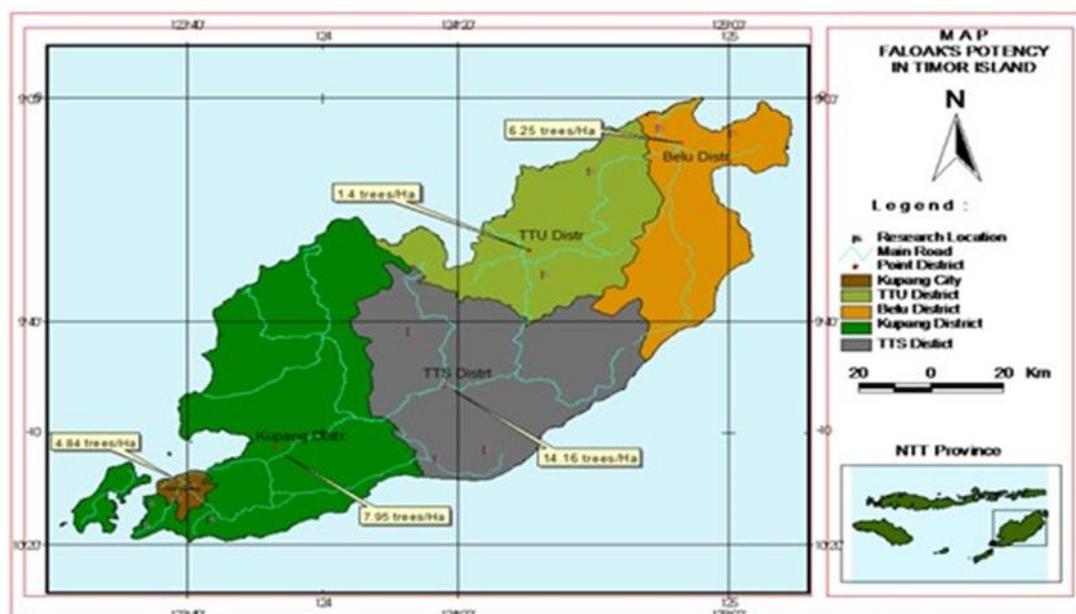


Figure 3. Map of Distribution of *Sterculia quadrifida* R.Br. Trees on Timor Island, Indonesia [17].

3. Utilization, Phytochemical Composition, and Bioactivity

3.1 Utilization of *Sterculia quadrifida* R.Br

Studying how indigenous and local communities use plants provides valuable insights into plant species, cultural significance, medicinal properties, and potential economic value [18]. *Sterculia quadrifida* R.Br. has a history of traditional medicinal use in several regions where this species grows. In Australia, Aboriginal communities use the leaves of *Sterculia quadrifida* R.Br. to treat wounds, skin disorders, eye diseases, and mouth

ulcers; the seeds are consumed, and the inner bark is used for weaving baskets and spinning ropes [14]. While in Timor Island, Indonesia utilize the bark of *Sterculia quadrifida* R.Br. is utilized as a medicinal and nutritional herbal drink to treat ailments such as liver disorders, digestive issues, fatigue, gastroenteritis, and rheumatoid [5,19]. In addition, besides the bark, the root extracts of *Sterculia quadrifida* R.Br. have also been traditionally used to treat diabetes and cancer [2]. The harvesting method practiced by the community involves slicing or peeling the tree bark into specific sizes or dimensions before using it or boiling it (Figure 4). Generally, they use clay pots to make a traditional herbal drink.



Figure 4. (a) Bark, and (b) Sliced bark of *Sterculia quadrifida* R.Br Tree

Every local society has its own way of utilizing the bark of *Sterculia quadrifida* R.Br as a herbal drink. While most people use this bark without adding other ingredients, some have developed specific recipes to cure diseases by combining it with additional ingredients such as turmeric, garlic, lemongrass, onion, cinnamon, and sand ginger [19]. Traditionally, there are no specific guidelines for the dosage to boil *Sterculia quadrifida* R.Br bark. Residents who consume it only boil it with water, and the remaining decoction will be used again by adding water as needed, and this activity can be repeated up to 4 times, as long as the color of the boiled water remains red.

3.2 Phytochemical Composition of *Sterculia quadrifida* R.Br Seeds

Phytochemical investigations of *Sterculia quadrifida* R.Br. seeds have revealed the presence of diverse classes of bioactive compounds that contribute to their pharmacological potential. Ethanol extract analyses have identified major groups of secondary metabolites, including flavonoids, alkaloids, tannins, terpenoids, phenolic acids, and phytosterols such as β -sitosterol [11]. These compounds play important roles in various biological activities, including antioxidant, anticancer, antimicrobial, and antifungal effects. In particular, flavonoids and phenolic acids act as strong antioxidants that help protect cells from oxidative stress, while alkaloids and tannins exhibit antimicrobial properties through their ability to disrupt microbial cell membranes and inhibit enzymatic activity. Furthermore, triterpenoids and sterols such as β -sitosterol are reported to have immunomodulatory, anti-inflammatory, and anticancer activities [6,11,20]. The coexistence of these compounds highlights the pharmacological relevance of *Sterculia quadrifida* R.Br. seed extracts and provides a chemical basis for their traditional use in medicine. The presence of such diverse phytochemicals not only confirms the bioactivity of *Sterculia quadrifida* R.Br. seeds but also supports their potential as a novel source of natural compounds for pharmaceutical, nutraceutical, and food industries. These findings suggest that further exploration of seed phytochemistry, alongside biological assays, could open new opportunities for the utilization and development of *Sterculia quadrifida* R.Br. seed oil and its derivatives in modern applications.

3.3 Bioactivity Found in *Sterculia quadrifida* R.Br. Plant

Recent studies and research have increasingly focused on the potential health benefits and bioactive compounds derived from the plant part of *Sterculia quadrifida* R.Br., and the studies show that all parts of this

plant contain various bioactive compounds beneficial to health. Among them, the bark, root, leaf, and the seeds of *Sterculia quadrifida* R.Br have been identified to contain flavonoids, alkaloids, tannins, and unsaturated fatty acids [20]. These compounds exhibit various biological activities, including antioxidant [6,7], antifungal, and anticancer properties [16,21,22]. *Sterculia quadrifida* R.Br, which has been used for centuries as a traditional medicine in various regions, has attracted the attention of numerous researchers who have studied the chemical compounds and pharmacological properties of this species. Several phytochemical studies have led to the extraction and fractionation of various classes of compounds, including flavonoids, propanoids, alkaloids, and terpenoids, from this plant [3]. The potential health benefits of this plant underscore its importance, not only for the local population but also as a candidate for broader scientific exploration. Plants can produce diverse bioactive compounds. The bioactive compounds in plants produce pharmacological or toxicological effects on humans and animals [23]. Studies' results on *Sterculia quadrifida* R.Br seeds have identified varieties of bioactive compounds that will benefit human health, such as antioxidants, antimicrobial, antifungal, antitoxic, and anticancer (Table 1).

As a promising subject for broader scientific research, the potential health benefits of this plant emphasize its importance not only for the local community but also for further research. Although research on this plant is still limited to the local area, preliminary studies indicate that parts of this plant contain beneficial compounds that, if further explored, could contribute not only to the pharmaceutical field but also to the food and cosmetic fields. Reviewing the existing literature on the utilization and discovery of bioactivities of this plant positions *Sterculia quadrifida* R.Br as a promising candidate for a sustainable source of beneficial plants.

3.3.1 Antioxidant

Antioxidants are compounds that can protect body cells from damage caused by free radicals [35]. Free radicals are unstable molecules that can damage body cells, leading to various diseases and aging [36]. Antioxidants work by scavenging free radicals, thus preventing the damage they cause. The benefits of antioxidants for human health are diverse. Some key benefits include protecting cells from oxidative damage, reducing the risk of heart disease, combating the aging process, boosting the immune system, and even reducing the risk of some types of cancer [37]. Antioxidants can be found in various foods, especially in fruits, vegetables, grains, nuts, and spices [38]. Several bioactive compounds, including flavonoids, alkaloids, steroids, terpenoids, tannins, and fatty acids, are where these bioactive compounds can contribute to the ability of antioxidant activity [39]. Several research results have shown the presence of various secondary metabolites that act as antioxidant agents in *Sterculia quadrifida* R.Br bark, root, leaf, and seeds, such as flavonoids, phenols, and tannin content (Table 1). Flavonoids, phenols, and tannins also gain anti-inflammatory properties and can support cognitive function and brain health, including protection against cardiovascular diseases and some types of cancer [40]. Moreover, the extraction of *Sterculia quadrifida* R.Br has demonstrated strong antioxidant properties based on IC₅₀ values. The bark showed very strong antioxidant activity with an IC₅₀ value of 14.17±0.55 µg/mL, while the roots had an IC₅₀ value of 20.55±0.42 µg/mL [7]. The leaves and seeds exhibited moderate antioxidant activity with IC₅₀ values of 52.59±0.75 µg/mL and 76.62±0.32 µg/mL, respectively [7]. Some studies showed that the extract of new regrown stem bark and old regrown stem bark exhibited potent antioxidant activity with IC₅₀ values of 2.51±0.03 and 3.43±0.12 µg/ml, respectively [41]. They are classified as strong antioxidants. In the context of IC₅₀ values, the lower the IC₅₀ value, the stronger the antioxidant ability of the substance. This indicates that the extract of *Sterculia quadrifida* R.Br. seeds can inhibit the activity of free radicals. It can also prevent oxidative damage to cells with high effectiveness.

Table 1. List of Bioactivity Found in Bark, Root, Leaf, and Seed of *Sterculia quadrifida* R.Br.

Bioactivity	Part of Plant	Research Result	Ref
Antioxidant	Bark	<ul style="list-style-type: none"> The extract of <i>S. quadrifida</i> stem bark using ethanol solvent showed antioxidant activity classified as very strong (IC₅₀ value was 14.17 ± 0.55 µg/ml). 	[7,8]
		<ul style="list-style-type: none"> Total content of flavonoid was found (62.76 ± 4.84 mg/g), phenols (45.37 ± 3.82 mg/g), and tannins (59.64 ± 9.64 mg/g). 	[7]
		<ul style="list-style-type: none"> The extract of the new regrown stem bark exhibited potent antioxidant activity with inhibitory concentration (IC₅₀) values of 2.51 ± 0.03 µg/ml, and the old regrown stem bark with 3.43 ± 0.12 µg/ml, is classified as a strong antioxidant. 	[24]
	Root	<ul style="list-style-type: none"> Based on IC₅₀ values, the antioxidant activity of root extract was classified as very strong (20.55 ± 0.42 µg/ml), and the highest total tannins from all parts of the <i>S. quadrifida</i> plant are in the roots (71.26 ± 10.21 mg/g). 	[7]
	Leaf	<ul style="list-style-type: none"> The antioxidant activity based on IC₅₀ values was 52.59 ± 0.75 µg/ml on a leaf of <i>S. quadrifida</i> (IC₅₀ values of 51-100 µg/ml were classified as strong). The total flavonoid content in the ethanol extract of <i>S. quadrifida</i> leaves was 5.31 ± 0.29% w/w, and the total polyphenol content was 1.79 ± 0.03% w/w. 	[7] [12]
	Seed	<ul style="list-style-type: none"> The antioxidant activity was classified as strong based on IC₅₀ values of 76.62 ± 0.32 µg/ml on the seeds of <i>S. quadrifida</i> R.Br. Flavonoid content was found in the seeds of <i>S. quadrifida</i> extract (1.55 ± 1.44 mg/g). The flavonoid allegedly in the seeds of <i>S. quadrifida</i> causes a high ability to inhibit DPPH free radicals. Phenol content was found in seeds (2.89 mg/g). Phenols are one of the bioactive compounds that can enhance antioxidant activity, alongside flavonoids and tannins. β-sitosterol, also known as stigmast-5-en-3-ol, is a specific phytosterol. It is found in <i>S. quadrifida</i> seeds, which have been demonstrated to have antioxidant activities. 	[7] [3,7,25] [7,26,27] [6,28,29]

Table 1. List of Bioactivity Found in Bark, Root, Leaf, and Seed of *Sterculia quadrifida* R.Br. (Continue)

Bioactivity	Part of Plant	Research Result	Ref
Anticancer	Bark	• The <i>S. quadrifida</i> bark ethanol extract can inhibit the development of the breast cancer T47D cell line with an IC ₅₀ of 32.45 µg/ml.	[30]
		• The derivative compound Naptokuinon (2,3-dihydro-6-hydroxy-2-methylenenaphtho [1,2-b] furan-4,5-dione) has cytotoxic activity on breast cancer cell T47D with active category (IC ₅₀ = 9.88 µg/ml)	[31]
		• The <i>S. quadrifida</i> bark with ethyl acetate fraction can inhibit the development of T47D breast cancer by increasing the cytotoxic effect.	[9]
	Leaf	• The ethyl acetate fraction of the <i>S. quadrifida</i> leaf extract exhibited considerable cytotoxic activity in T47D and 4T1 breast cancer cells, with IC ₅₀ values of 19.86±3.48 and 16.70±3.33 µg/ml.	[32]
	Seed	• Methanol extract of <i>S. quadrifida</i> seeds is found to contain a cytotoxic compound, namely Tetramethoxyhydroxybiphenyl (3,3',5,5'-tetramethoxybiphenyl-2,2'-diol), which can exhibit cytotoxic activity against various cancer cell lines, including human colon adenocarcinoma (HT-29), human breast adenocarcinoma (MCF-7), and human lung adenocarcinoma (A549) cells.	[6]
Antimicrobial	Bark	• The ethanol extract of <i>S. quadrifida</i> tree bark, at concentrations of 22.5% w/v, 45% w/v, 75% w/v, and 100% w/v, demonstrates antibacterial activity against the growth of <i>Staphylococcus aureus</i> bacteria.	[13]
		• Fractionation with 96% ethanol extract using the preparative thin-layer chromatography method on the bark of <i>S. quadrifida</i> exhibited strong antibacterial activity, with effective concentrations of 90.51 µg/ml against <i>Bacillus subtilis</i> , 80.12 µg/ml against <i>Escherichia coli</i> , and 77.87 µg/ml against <i>Staphylococcus aureus</i> .	[33]
Antifungal	Seeds	• Extraction with the diethyl ether fraction of <i>S. quadrifida</i> seeds has anti-fungal properties against the parasite <i>Candida albicans</i> , namely the compound 3-hydroxy octadecanoic acid (C ₁₈ H ₃₆ O ₃), which showed an inhibition of 44.33 mm and a minimum inhibitory concentration (MIC) of 30.34 µg/ml.	[16,34]

3.3.2 Anticancer

Anticancer compounds can inhibit the growth of cancer cells, stimulate programmed cell death in cancer cells, or disrupt critical processes in the cancer cell cycle. Cancer treatments, such as chemotherapy and radiation, often lead to cytotoxic effects, which can harm healthy cells in addition to cancerous ones. Anticytotoxic agents may help mitigate these adverse effects by neutralizing or reducing the damage inflicted on normal tissues, thereby improving the overall efficacy and tolerability of cancer treatments. Moreover, some compounds with anticytotoxic properties might have direct anti-cancer effects, as they can also help in reducing oxidative stress and inflammation, which are commonly associated with cancer progression. Several studies have shown extracts and fractions of *Sterculia quadrifida* R.Br to have cytotoxic activity [6][9][31][32]. Ethanol extracts from the stem bark of *Sterculia quadrifida* R.Br demonstrated the ability to inhibit the growth of the T47D breast cancer cell line, with an IC₅₀ value of 32.45 µg/ml [3,30]. Additionally, another study found that the ethyl acetate fraction from the bark of *Sterculia quadrifida* R.Br effectively inhibited the T47D breast cancer cell line, with an IC₅₀ of 24.88 µg/ml and a selectivity index of 15.58. This ethyl acetate fraction was also capable of inducing cell cycle arrest in the S phase, with a percentage of 27.43%, and promoting apoptosis at a rate of 11.88% [9]. Some compounds that show various bioactivities found in *Sterculia quadrifida* R.Br. seeds are sterculic acid, triterpenoid, and β-sitosterol. These compounds are also known for antioxidant, anti-inflammatory, anticancer, antidiabetic, and cytotoxic activities [13]. This activity is often studied in the context of the development of anticancer drugs or other therapies. Furthermore, Dibenzalacetone (2E, 4E)-1, 5-diphenylpenta-2, 4-dien-1-one), a compound isolated from *Sterculia quadrifida* R.Br seeds, belongs to the group of phenylpropanoid compounds, which have anticancer activity through apoptosis induction [10]. In another study, isolation from the roots of *Piper sarmentosum* with cytotoxic activity against MDA-MB-231 breast cancer cells identified two phenylpropanoid compounds, asaricin and isoasarone [42]. Moreover, flavonoids found in the bark, root, leaf, and seeds of *Sterculia quadrifida* R.Br play a crucial role in inhibiting procarcinogen activation, inhibiting cancer cell proliferation, selective cancer cell death through apoptosis, inhibiting metastasis and angiogenesis, and activating immune responses to cancer cells [14]. Therefore, with the discovery of anticancer compounds from *Sterculia quadrifida* R.Br. seeds, they have the potential for use in cancer therapy. These compounds can serve as the basis for drug development or additional therapies. They can also be consumed as preventive measures and included in a healthy diet to help protect the body from cancer risks. Additionally, the utilization of antioxidant, anticancer, and antifungal activity from *Sterculia quadrifida* R.Br plant part in food products can enhance the nutritional value and health of these products. Anticancer-enriched food products can help strengthen the immune system and prevent diseases.

3.3.3 Antimicrobial

Sterculia quadrifida R.Br has been recognized for its antimicrobial properties, primarily attributed to compounds extracted from the bark of this plant. Previous research has shown that the ethanol extract of *Sterculia quadrifida* R.Br. bark has antimicrobial activity in gram-negative and gram-positive bacteria [43]. This antimicrobial activity is generally linked to the presence of bioactive compounds such as flavonoids, tannins, saponins, and alkaloids [44]. These phytochemicals are known to interfere with microbial cell membranes, inhibit enzyme activity essential for microbial growth, and disrupt cellular processes, thus exerting their antimicrobial effects. The analysis showed that the extract from *Sterculia quadrifida* R.Br bark demonstrated the effective inhibition of *Staphylococcus aureus* growth [13]. Another study reported that fractionation with 96% ethanol extract using the preparative thin-layer chromatography method on bark of *Sterculia quadrifida* R.Br exhibited strong antibacterial activity, with effective concentrations of 90.51 µg/ml against *Bacillus subtilis*, 80.12 µg/ml against *Escherichia coli*, and 77.87 µg/ml against *Staphylococcus aureus* [33]. The benefits of these antimicrobial properties are significant in both the food industry and pharmacology. In the food sector, *Sterculia quadrifida* R.Br extracts can be utilized as natural preservatives to extend shelf life and prevent microbial contamination, thus enhancing food safety. In pharmacology, the antimicrobial compounds from *Sterculia quadrifida* R.Br have potential applications in developing new antibiotics or antimicrobial agents,

which is crucial given the rising concerns of antibiotic resistance. The ability to harness these natural compounds can lead to more sustainable and effective treatments, reducing reliance on synthetic drugs and mitigating the impact of resistant pathogens.

3.3.4 Antifungal

Compounds with antifungal activity are compounds that can inhibit the growth or kill fungi. They can work through various mechanisms, including disrupting fungal cell membranes, inhibiting enzymes in fungal metabolic processes, and disrupting fungal reproduction processes [45]. *Sterculia quadrifida* R.Br. seeds have been found to contain various compounds with potential antifungal activity [16]. According to phytochemical studies, flavonoid derivatives, phenolic acids, and triterpenoids are a group of main compounds identified in plant parts such as leaves, seeds, and roots, which have biological activity and act as antifungal, antimicrobial, antiparasitic, anti-inflammatory, or antioxidant and cytotoxic [46-48]. The compound 3-hydroxyoctadecanoic acid ($C_{18}H_{36}O_3$) or *stearic acid* is the main antifungal compound found in *Sterculia quadrifida* R.Br. seeds. Analysis result of *Sterculia quadrifida* R.Br. Seeds extraction with diethyl ether fractions against the parasitic fungus *Candida albicans* showed inhibition of 44.33 mm and minimum inhibitory concentration (MIC) of 30.34 $\mu\text{g/ml}$ [12]. This indicates that the diethyl ether fraction from *Sterculia quadrifida* R.Br. seeds extract is capable of inhibiting the growth of *Candida albicans* fungus quite strongly, as evidenced by the significant inhibition zone size. The larger the diameter of the zone, the stronger the inhibitory activity of the tested compound against fungal growth. This suggests that at relatively low concentrations, the compound can effectively inhibit the growth of the parasitic fungus. This testing provides indications that *Sterculia quadrifida* R.Br. seeds contain compounds with significant antifungal activity, which may have applications in the development of drugs or antimicrobial products. The other research found that 3-hydroxyoctadecanoic acid ($C_{18}H_{36}O_3$) has been previously isolated from the extractive substance of *Hypericum lysimachioides* var. *lysimachioides* flower. This species is one of the flora that grows in Turkey, which is widely used as a medicine to heal wounds, antigastritis, antiseptic effect, and has anti-depressant, anti-cancer, and antimicrobial activities [34].

4. Potential Oil in *Sterculia quadrifida* R.Br seed

4.1 Fatty Acids in the Seeds

Research has been conducted to evaluate the chemical composition of *Sterculia quadrifida* R.Br. seeds using GC-MS analysis [11]. The results of the active compounds determination in *Sterculia quadrifida* R.Br. seeds using ethanol extract chromatograms showed that there are several fatty acids identified in these seeds (Figure 5).

Oils rich in saturated and unsaturated fatty acids, including monounsaturated and polyunsaturated fatty acids [49], have broad applications in the food, pharmaceutical, and cosmetic industries. Based on the analysis of the identified fatty acids, the seeds of *Sterculia quadrifida* R.Br. have the potential to offer various health benefits for humans. The fatty acid identified in *Sterculia quadrifida* R.Br. seeds using the GC-MS method with ethanol extract shows that the most dominant compound found in its seeds is hexadecanoic acid. Hexadecanoic acid is a saturated fatty acid commonly known as palmitic acid. Some other plants that contain relatively high levels of palmitic acid include coconut (*Cocos nucifera* L), palm (*Elaeis guineensis*) [37], candlenut (*Aleurites moluccana*) [50], peanut (*Arachis hypogaea*) [51], macadamia nut (*Macadamia Integrifolia*) [52], and almond seed (*Prunus dulcis*) [53]. Palmitic acid has several biological activities, such as hypocholesterolemic, nematicide, antioxidant, and pesticide [54]. Palmitic acid is also important and is often approached with caution due to its association with increased levels of bad cholesterol or Low-Density Lipoprotein (LDL) when consumed in excess. However, in balanced amounts, palmitic acid plays a vital role in the body, including as an energy source and as a structural component of various lipids within cell membranes. The high and dominant content of palmitic acid in *Sterculia quadrifida* R.Br. seeds indicates that these seeds contain a significant amount of plant oil that can be extracted. This oil has potential for use in various industrial and culinary applications. Additionally, the presence of palmitic acid provides stability and resistance to oxidation, which is important for the long-term storage of the oil. The significant amount of palmitic acid also suggests that this oil has good oxidative stability.

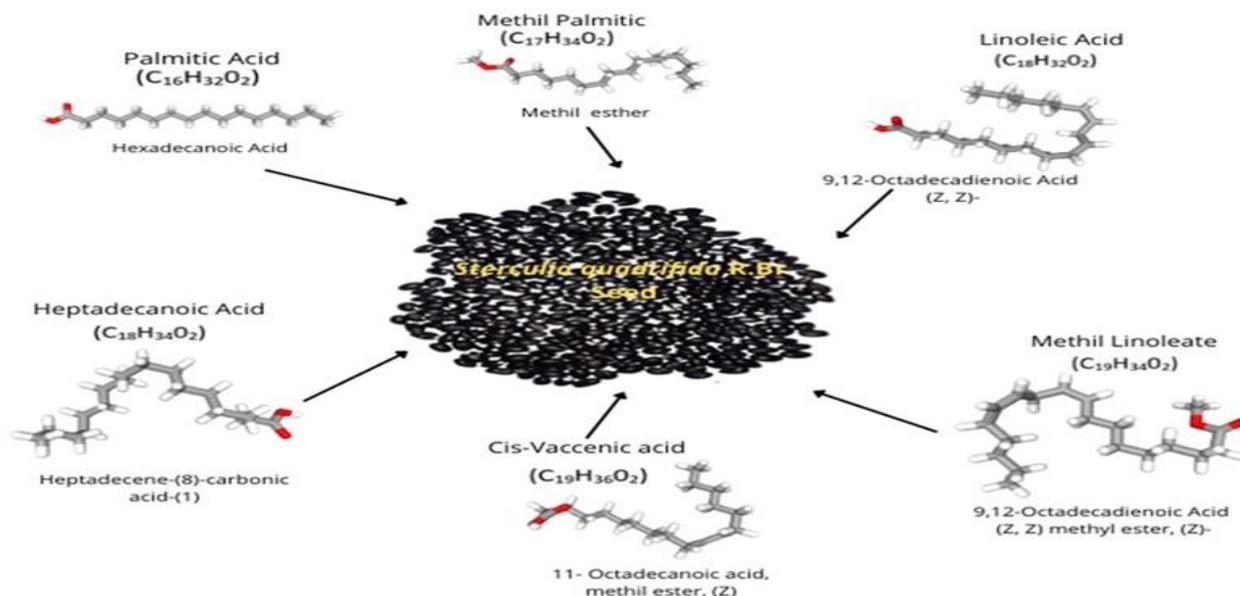


Figure 5. Fatty Acids Identified in *Sterculia quadrifida* R.Br Seed [11].

Heptadecene-8-carbonic acid-(1) or heptadecanoic acid is the following dominant compound found in *Sterculia quadrifida* R.Br. seeds. This compound, also known as margaric acid, is a saturated fatty acid with 17 carbon atoms that is commonly found in small amounts in some food sources, including grains, milk, and meat [55]. This compound is integrated with other compounds to provide antioxidant, antibacterial, and antiproliferative effects [56]. Research also shows that consuming odd-chain saturated fatty acids, such as heptadecanoic acid, may play a role in supporting heart health [57]. Another fatty acid discovery was 9,12-octadecadienoic acid, which is known as linoleic acid. Linoleic acid is an essential omega-6 fatty acid and the most beneficial for health. This fatty acid is essential for the growth and development of children, as it cannot be synthesized by the human body. It is also a major component of cell membranes and is important for nervous system function [58]. Linoleic acid offers several benefits to the human body, including maintaining lipid balance, regulating metabolism, and supporting optimal brain function, such as promoting brain development. Additionally, research indicates that linoleic acid plays a crucial role in protecting pancreatic β -cells [59]. Pancreatic β -cells are the type of cells responsible for producing insulin, a hormone that regulates blood sugar levels in the body. In other words, this acid helps maintain the health and function of pancreatic β -cells, which is important in preventing or reducing the risk of diseases such as diabetes. Moreover, linoleic acid reduces the risk of heart disease and contributes to metabolic health, making it highly valued in a healthy diet [49,60]. Additionally, cis-vaccenic acid and methyl linoleic acid are unsaturated fatty acids, both monounsaturated and polyunsaturated, that also offer health benefits. Cis-vaccenic acid is an omega-7 fatty acid that helps improve heart health by lowering bad cholesterol or LDL and increasing good cholesterol or High-Density Lipoprotein (HDL) [49,60]. Moreover, this omega-7 fatty acid contributes to skin and mucous membrane integrity and has potential anti-inflammatory properties [61]. As a polyunsaturated fatty acid (PUFA), methyl linoleic acid has antioxidant potential that can support immune function and prevent cellular damage [62]. Another beneficial fatty acid found is octadecanoic acid, also known as stearic acid, which is found in the extraction of *Sterculia quadrifida* R.Br seeds (Figure 5). Octadecanoic acid is a compound containing an 18-carbon chain. It is classified as an omega-9 fatty acid [63], and consuming omega-9 fatty acids can help lower LDL cholesterol levels in the blood, thus reducing the risk of heart disease [64]. Overall, the oil produced from these fatty acids has significant potential health benefits, particularly due to its content of polyunsaturated fatty acids like linoleic acid. The applications of this oil may include its use in functional foods, dietary supplements, and cosmetic products that support skin health and overall bodily functions. Thus, extracting oil from a source rich in such fatty acids can provide valuable contributions to enhancing human health.

4.2 Potential of the seed as a New Resource Supplying Oil

Plant oil is a key commodity in various food and non-food industries. Thus, identifying new plant oil sources can reduce dependence on a few types of oils. Extracting oil from the underutilized seeds of *Sterculia quadrifida* R.Br could provide a potential new source, offering health or nutritional benefits and economic advantages to society now and in the future. The discovery of various interesting bioactive and phytochemical compounds in *Sterculia quadrifida* R.Br. seeds by several researchers provides a deeper understanding of the potential of these seeds. A review and summary of the bioactive compounds found in *Sterculia quadrifida* R.Br. seeds is highly necessary, as this will provide valuable and useful information for obtaining high-quality oil in optimal quantities. Thus, this review makes an important contribution to further exploration of the benefits and potential of oil from these seeds, particularly in supporting broader industrial applications. Based on the findings from research on the bioactive compounds in *Sterculia quadrifida* R.Br. seeds, it has been demonstrated that these seeds contain various beneficial fatty acid compounds that are of significant interest [3,7]. A comprehensive analysis of the phytochemical composition indicates a substantial potential for extracting these compounds, thereby unveiling the prospective discovery of a new type of vegetable oil. The fatty acid components are particularly noteworthy, renowned for their promising properties across various industries, ranging from foods to pharmaceuticals. *Sterculia quadrifida* R.Br. seeds have the potential to be extracted into plant oil for several reasons (Figure 6).

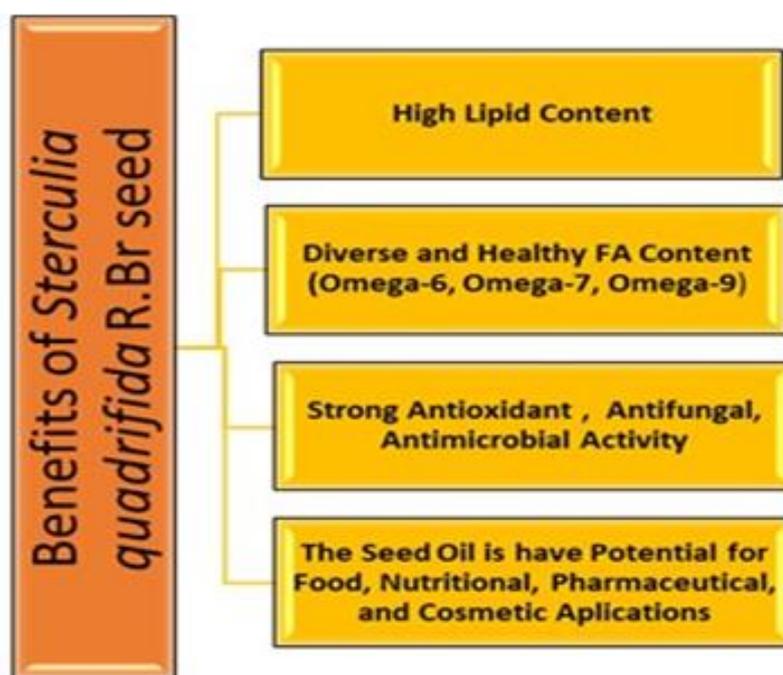


Figure 6. Benefits of *Sterculia quadrifida* R.Br. Seed

Continued research and development efforts are essential to unlock their full potential, paving the way for their integration into the food, pharmaceutical, and cosmetic industries. By leveraging the unique properties of *Sterculia quadrifida* R.Br oil, it is possible to enhance the diversity and sustainability of plant oil sources, contributing to improved health outcomes and economic resilience. Some of the potentials of *Sterculia quadrifida* R.Br. seeds are explained as follows;

- High lipid Content; *Sterculia quadrifida* R.Br. seeds are proven and have a relatively high lipid content [11]. Plant oil is obtained by extracting lipids from seeds, and seeds with high lipid content are a good choice for extraction into plant oil. Oil extracted from *Sterculia quadrifida* R.Br. seeds can become a potential source of new vegetable oil for the food, pharmaceutical, and cosmetic industries.
- Diverse, Healthy, and Beneficial Fatty Acid Content; *Sterculia quadrifida* R. Br seeds contain various types of fatty acids, including saturated, monounsaturated, and polyunsaturated fatty acids [4,11,15].

These fatty acids are the main components of plant oil and impart unique characteristics to the extracted oil. Some fatty acids found in *Sterculia quadrifida* R.Br. seeds, such as linoleic acid (omega-6), cis-vaccenic acid (omega-7), and octadecanoic acid (omega-9), are essential fatty acids required by the human body as the human body cannot synthesize them on its own [64]. The presence of these essential fatty acids makes vegetable oil extracted from *Sterculia quadrifida* R.Br. seeds nutritionally valuable.

- **Potential Health Benefits:** The fatty acids found in vegetable oil from *Sterculia quadrifida* R.Br. seeds, such as monounsaturated and polyunsaturated fatty acids, have been associated with various health benefits, including maintaining heart health, skin health, pancreatic health, nervous system health, and brain health [64][65]. In addition to fatty acids, oil from *Sterculia quadrifida* R.Br. seeds may also contain other bioactive compounds such as tocopherols (vitamin E) and phenolic compounds, which have antioxidant activity and other health benefits [11,20,40].

- **Benefit in food, pharmaceutical, and cosmetic Applications:** Oil extracted from *Sterculia quadrifida* R.Br. seeds has great potential in various applications due to its unique physico-chemical properties. *Sterculia quadrifida* R.Br. oil contains a beneficial profile of fatty acids, vitamins, and antioxidants that are important for health, in addition to its unsaturated fatty acid content, which can support heart health and reduce the risk of cardiovascular disease. For culinary applications, this oil can be used as cooking oil or food additives, and in the cosmetic sector, antioxidant properties can help fight premature aging and protect the skin from damage caused by free radicals.

With the combination of these factors, the fruiting season that occurs every year, and the availability of fruit and seeds that have not been utilized, *Sterculia quadrifida* R.Br. seeds have the potential to be a valuable source of plant oil. Overall, the oil extracted from these seeds has great potential for application in various sectors, offering good health and economic benefits.

5. Conclusions

The bioactive components, including various fatty acids, exhibit antioxidant, anticancer, antimicrobial, and antifungal activities found in every part of *Sterculia quadrifida* R.Br., potentially contributing to more fundamental research on the utilization of this plant. The seeds of *Sterculia quadrifida* R.Br., rich in lipids, fatty acids, and significant bioactive compounds, have the potential to be extracted into plant seed oil that is beneficial for the food, health, and nutrition sectors. Further research is essential to fully characterize its bioactive compounds, optimize extraction methods, and explore new ways to utilize its diverse applications. Thus, *Sterculia quadrifida* R.Br. seed oil stands out as a promising natural resource for enhancing health and well-being, and this plant, from all parts, has the opportunity to be studied and used as a natural antioxidant agent.

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