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REVIEW ARTICLE

Sapindaceae fruits: A comprehensive overview on phytochemicals, nutraceuticals and health benefits application

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Abstract

The article delves into the intricate realm of the Sapindaceae family, shedding light on the many phytomedicinal advantages that these fruits offer. This family boasts an array of economically significant fruits, including Litchi (*Litchi chinensis*), Rambutan (*Nephelium lappaceum*), Longan (*Dimocarpus longan*), Guarana (*Paullinia cupana*), Ackee (*Blighia sapida*) and Soapberry (*Sapindus saponaria*), each of which has its own set of medicinal characteristics. The Sapindaceae family, also known as the soapberry family, comprises numerous tropical and subtropical plant species known for their phytochemical properties and potential health benefits. Despite the well-known medicinal properties of Sapindaceae fruits, there is a lack of a comprehensive compilation that combines knowledge about their important components, nutritional value, traditional value and medicinal properties. This review aims to address this gap by providing assessments of the medicinal potential of Sapindaceae fruits and their prospects as food products. The study focuses on the chemicals, nutrients and medicinal properties of Sapindaceae fruits, excluding studies lacking therapeutic relevance. Findings show that Sapindaceae fruits contain bioactive compounds such as saponins, flavonoids and phenolic acids, which are antioxidants, anti-inflammatory, anti-cancer, anti-viral, anti-obesity and anti-diabetic. In addition, these fruits are rich in essential nutrients, including vitamins, minerals and dietary fiber, which supports their use as functional foods and vitamins. The review suggests future research on sustainable uptake and development of nutrients from Sapindaceae, which could increase their use in healthcare and potentially lead to the development of cost-effective pharmaceutical products for consumers and the agricultural sector.

Keywords

Sapindaceae; phytomedicine; nutritional profile; Soapberry family; therapeutic properties

Introduction

The Sapindaceae family, popularly known as the soapberry family, has around 140 genera and 1800 species. These fruits are prized for their nutritional worth and therapeutic capabilities, which have been acknowledged in ancient medical systems. This study seeks to better understand the phytomedicinal effects of Sapindaceae fruits. These fruits have been utilized in numerous cultures to cure gastrointestinal illnesses, skin conditions and respiratory problems. The Sapindaceae family is a broad group of flowering plants with a rich history spanning thousands of

years. Sapindaceae species were valued by ancient peoples for their nutritional and medicinal benefits. For example, lychee (*Litchi chinensis*) was cultivated in China more than 2000 years ago and was highly prized by Tang Dynasty emperors for its unique taste and health benefits (1). Similarly, Ackee (*Blighia sapida*) has been a staple food in West Africa for centuries, used to treat fever and as a source of protein. In Columbia, ackee leaves and barks are used to cure stomach aches, epilepsy and yellow fever (2). In the year of discovery, Sapindaceae fruits such as Rambutan (*Nephelium lappaceum*) and Longan (*Dimocarpus longan*) were introduced to new areas, where their medicinal properties extended and were introduced to the traditional medicine. By the 18th century, European botanists began to document the therapeutic properties of these fruits, leading to an increased understanding of their pharmacological potential. Modern research has built upon this traditional knowledge, with scientific studies now validating many of the health claims associated with Sapindaceae fruits. Recent studies have focused on isolating and characterizing bioactive compounds such as saponins, flavonoids, and phenolic acids, which have demonstrated antioxidant, anti-inflammatory and anticancer properties of Soapberry family fruits (3-8). Moreover, advances in analytical techniques have allowed for a detailed exploration of their nutrient profiles, identifying essential vitamins, minerals and dietary fibers. Despite these advancements, there remains a need for comprehensive research on the phytomedicinal properties of the Sapindaceae family, especially considering the potential for developing novel nutraceutical products. This review combines past and recent research on Sapindaceae fruits, highlighting their medicinal properties and providing a foundation for future discoveries.

Sapindaceae fruits

The Sapindaceae family includes a diverse variety of fruit-bearing plants endemic to tropical and subtropical areas. Lychee, a native Southeast asian fruit, is known for its sweet, aromatic flavor and distinctive appearance. It is small, round and has bumpy, red or pink skin. Inside, it contains translucent white flesh, juicy and sweet, surrounded by a large seed. The flesh has a floral aroma and a flavor akin to grape and rose (9).

Rambutan, a fruit native to Southeast Asia, is known for its unique appearance, sweet flavor and numerous health benefits. It is small, round and has a leathery rind covered in soft, hair-like spines. The name comes from the Malay word for "hair." Its translucent white flesh is juicy and sweet, similar to lychee and contains a single seed in the center (10).

Longan, also known as "dragon's eye," is a Southeast Asian fruit tree known for its sweet, juicy and health-promoting fruit. These small, round fruits, ranging from 1 to 2 centimeters in diameter, have a thin, yellowish-brown skin and translucent, aromatic flesh with a single dark seed.

Guarana, a climbing plant native to Brazil, has been used by indigenous tribes for centuries for its stimulating and medicinal properties. Its seeds are highly valued for their caffeine content, often used in energy drinks and supplements. The fruit, resembling a coffee berry, has a distinctive red shell and black seeds covered by a white aril, leading to cultural myths among indigenous peoples (11).

Ackee, a West African fruit, is commonly used in Caribbean cuisine, especially in Jamaica. Ackee trees grow up to 10 m tall, have glossy green leaves and yellow flowers, and have pear shaped fruit that turns green to red or yellow when ripe. When ripe, it contains three black seeds and creamy flesh (12).

Soapberry is a fruit from the genus *Sapindus*, with a high saponin content that gives it soap-like properties. These small, round fruits, typically 0.5 to 1 inch in diameter, have a shiny, leathery exterior and can be orange or brown when ripe. Inside the fruit is a single black seed, which contains high levels of saponins and should not be consumed in large quantities (13).

Traditional applications of sapindaceae fruits

Many of these fruits have long been utilized in traditional medicine and are still well-known for their medicinal properties. Sapindaceae fruits are widely employed in traditional medicine, culinary activities and cultural ceremonies across the world. Their numerous applications underscore their importance as dietary sources as well as key components in traditional healing treatments. A description of many prominent genera and species of the most important sapindaceae fruit crops utilized in this work and an overview of the traditional applications of some notable Sapindaceae fruits are presented in Table 1.

Phytochemical composition of Sapindaceae fruits

Sapindaceae fruits are known for their high phytochemical content, which contributes to their medicinal potential. These fruits contain a range of beneficial chemicals, including polyphenols, flavanoids, vitamins and minerals, tannins and saponins. Polyphenols are potent antioxidants that protect against oxidative damage and inflammation. Phenolics are naturally found in plants, including fruits, vegetables, leaves, nuts, seeds and flowers. They are not only consumed by humans but also employed in therapeutic treatments. Flavonoids are the Compounds having anti-inflammatory, anti-cancer and neuroprotective effects. It was described that tannins and saponins which are known for their antibacterial and anti-inflammatory properties. Saponins are a family of oleanane triterpenoids found in several plants. Each genus of Sapindaceae contains both common and distinctive compounds that contribute to the pharmacological and nutritive characteristics of the individual species.

Saponins and flavonoids dominate the *Sapindus* genus, notably *Sapindus mukorossi*, with the unique phytochemical mukurozioside known for its anticancer characteristics and usage as a natural detergent which is a form of saponin with the structure of sesquiterpene glycosides that functions against breast cancer (14).

Table 1. Sapindaceae fruits, traditional application and use.

Fruit	Genus	Species	Traditional Applications	References
Lychee/ Litchi	*Litchi*	*Litchi chinensis*	Blood sugar regulation. Used to soothe coughs and other respiratory ailments. Treatment of diarrhea and dyspepsia. A remedy to eliminate intestinal parasites.	(68, 77, 93)
Rambutan	*Nephelium*	*Nephelium lappaceum*	Used traditionally to treat ailments such as fever, diarrhea and various digestive problems. The fruit is often consumed fresh for its hydrating properties, while the skin, when dried, serves as a conventional remedy in regions like Malaysia The leaves are sometimes applied as a bandage to alleviate headaches.	(20)
Longan	*Dimocarpus*	*Dimocarpus longan*	Pulp has long been used as a Traditional Chinese Medicine to stimulate blood metabolism, relax nerves, alleviate sleeplessness, prevent forgetfulness, lengthen longevity, heal neural discomfort and swelling, treat palpitation and	(19)
Ackee	*Blighia*	*Blighia sapida*	Ackee holds cultural importance in Jamaica, featuring prominently in songs and folklore. Its preparation and consumption are deeply embedded in Jamaican culinary	(94)
Guarana	*Paullinia*	*Paullinia cupana*	Guarana has been traditionally used as a stimulant to increase wakefulness and combat fatigue. Indigenous peoples often consumed crushed guarana seeds in beverages to enhance energy levels during physical exertion or long journeys.	(95)
Soapberry	*Sapindus*	*Sapindus saponaria*	In Ayurveda, soapberries are recognized for their expectorant properties and are used to relieve coughs and respiratory conditions, various infections and skin ailments. Soapberries are traditionally used by Indigenous Peoples in North America to treat digestive ailments. The juice from the berries can help lower blood pressure and alleviate digestive issues The juice is also applied to soothe skin irritations such as eczema. A decoction made from the stems and leaves can serve as a stomach tonic or for treating constipation	(96, 97)

Moving on to the genus *Litchi*, especially *Litchi chinensis*, flavonoids and polyphenols are numerous, with epicatechin functioning as a unique phytochemical that provides antioxidant advantages. Epicatechin is a lychee-specific flavonoid, may form oligomers of various lengths which contributes to its antioxidant and anticancer properties (15).

The unique polyphenol geraniin present in genus *Nephelium* has antioxidant and antidiabetic characteristics and thus plays major role in inhibition of alfa-glucosidase and alfa-amylase (16). It is made up of hexahydroxydiphenoyl (HHDP) groups attached to a glucose core, resulting in a massive polyphenolic structure.

The genus *Dimocarpus*, represented by *Dimocarpus longan*, comprises flavonoids, tannins and polyphenols, with corilagin being a unique component with neuroprotective properties. Corilagin is a gallotannin with antiviral and anti-HIV effects (17), found in the *Dimocarpus* genus. It is an ester-linked tannin structure with a gallic acid and glucose base, distinguished by its strong antioxidant activity.

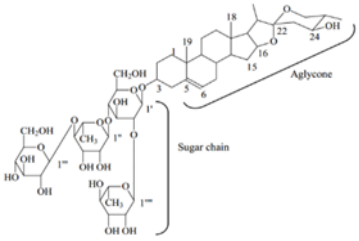
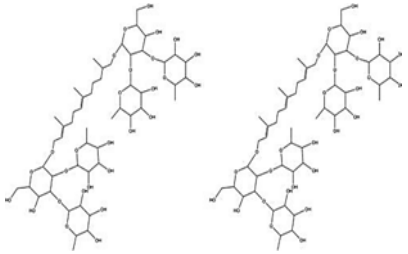
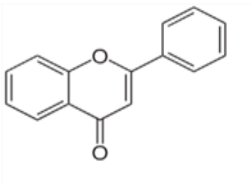
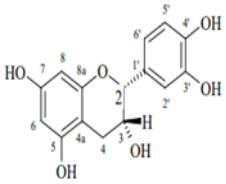
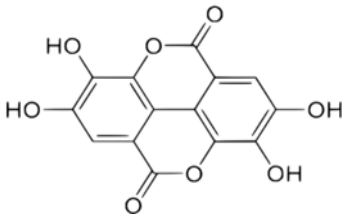
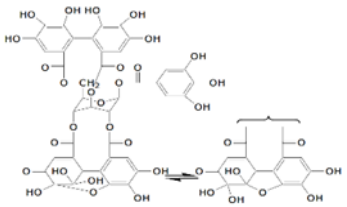
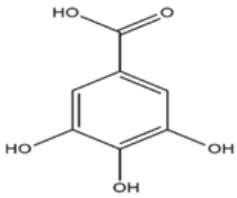
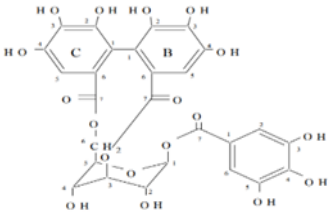
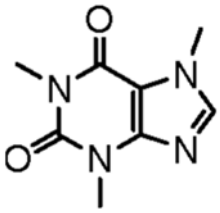
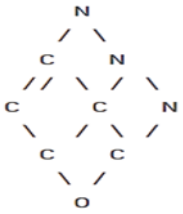
Caffeine and tannins are the primary phytochemicals in *Paullinia*, notably *Paullinia cupana* (guarana), with guaranine standing out for its stimulant and energy-boosting characteristics. The *Paullinia* genus contains Guaranine (11), a kind of caffeine found in guarana seeds, which has a Methylxanthine structure with three methyl groups, comparable to caffeine.

The genus *Blighia*, specifically *Blighia sapida*, includes flavonoids and tannins (18), that are antioxidants and promote digestive health. This diverse range of phytochemicals highlights the medicinal and nutritional potential of Sapindaceae family as well as its importance in both traditional and modern uses. The most common and unique structures of sapindaceae fruits, as stated above, are included in Table 2.

Nutraceutical composition of Sapindaceae fruits

The Sapindaceae family fruits comprise a diverse range of rich in nutrients. These fruits are valued for their unique flavors and dense nutritional profiles, providing a range of health benefits. The fruits of the Sapindaceae family, including litchi, longan, rambutan, guarana and ackee, present a diverse and nutritionally rich profile that offers numerous health benefits. Litchi is particularly high in vitamin C and provides essential antioxidants, contributing to immune support and skin health. Longan is valued for its calming effects on the nervous system and is rich in carbohydrates (19), offering a quick energy boost . Rambutan is low in calories but high in water content and dietary fiber, making it beneficial for digestion and weight management (20). Guarana stands out due to its high caffeine content, which enhances energy levels and mental focus (21). Ackee, while nutritious with healthy fats and protein, must be consumed only when ripe to avoid toxicity (22). *Sapindus* is notable for its unique nutritional profile and health benefits, primarily due to its high saponin content (23). Collectively, these fruits not only enrich diets with vitamins and minerals but also play

Table 2. Common and unique compound structures.

Common Chemical/ Molecular Structure	Unique Chemical/ Molecular Structures of sapindaceae fruits
 Saponin	 Mukurozioside IIa and Mukurozioside IIb (Soapberry)
 Flavonoids	 Epicatechin (Litchi)
 Polyphenols	 Geranin (Rambutan)
 Tannin	 Corilagin (Longan)
 Caffeine	 Guaranine (Guarana)

significant roles in traditional medicine across various cultures, underscoring their importance in both culinary and health contexts. These fruits are prized for their sweet flavor, juicy texture and nutritional content. The chemical composition of sapindaceae fruits are illustrated in Table 3.

Vitamins and minerals are essential components that promote general health and immunological aspects. Though they are required in small amounts, they play a crucial role in maintaining health, supporting growth and preventing diseases. These nutrients are not produced by the body in sufficient quantities, so they must be obtained through diet or supplements. Fruits from the Sapindaceae family are high in vitamins and minerals, which add to their nutritional value. The nutraceutical composition, which describes quality with nutritional value and that may also be utilized as medicine, is listed with vitamins and bioactive chemicals in Table 4.

Table 3. Chemical composition of Sapindaceae fruits.

Fruit	Component	Amount (per 100 g)/ %
Litchi	Carbohydrates	16.10 g
	Sugars	15.70 g
	Fiber	2.00 g
	Protein	1.13 g
	Fat	< 0.50 g
	Vitamin C	72 mg
	Calcium	3.60 mg
	Iron	0.26 mg
	Potassium	Approx. 250 mg
	Copper	0.20 mg
Rambutan	Carbohydrates	20.87 g
	Lipids	0.21 g
	Moisture	78.3 g
	Ash	1.19 g
	Saturated Fatty Acids	Arachidic (34 %), Oleic (42 %)
Longan	Carbohydrates	Approx. 15-20 g
	Protein	Approx. 1-2 g
	Fat	Approx. 0.2-0.5 g
	Vitamin C	Up to 84 mg
Ackee	Carbohydrates	9.55 g
	Dietary Fiber	3.45 g
	Fat	18.78 g
	Protein	8.75 g
Guarana	Caffeine	9100 – 76000 mg
	Protein	< 98600 mg
	Fat	< 30000 mg
	Starch	50000 – 60000 mg
	Tannin	50000 – 120000 mg
	Theobromine	200 – 400 mg
Soapberry	Sugars	5-10 %
	Fatty acids	1-5 %
	Proteins	1-2 %
	Minerals	Trace (K, Ca, Mg)
	Sugars	5-10 %

Pharmacological and health benefits of Sapindaceae fruits

Anti-inflammatory property

Litchi fruits are renowned for their anti-inflammatory properties, which can reduce the likelihood of chronic diseases and enhance overall health (24). It was suggested that litchi extracts may impact various inflammation-related disease processes, whether acute or chronic. Oligonol, a low molecular weight polyphenol from dried litchi, has been shown to suppress COX-2, NF-κB p65 and iNOS levels in C6 glial cells, suggesting anti-inflammatory benefits, including type II diabetes. This was reported in the study of "Protective role of oligonol from oxidative stress-induced inflammation in C6 glial cell" (25). High polyphenol content in litchi extracts has been found to reduce inflammatory markers in hepatic models (26). Litchi's anti-inflammatory activities are likely derived from (+)-catechin, procyanidin A2 and methyl jasmonates, which are found in litchi seeds (27).

Rambutan peel extracts significantly reduce nitric oxide production in inflammatory models like LPS-induced RAW 264.7 cells, regulated by inducible Nitric Oxide Synthase (iNOS), which increases during inflammatory responses (28). The extract has shown promise in reducing symptoms of rheumatoid arthritis in animal models, such as paw edema and C-reactive protein levels, indicating its potential for managing chronic inflammatory diseases. In monocyte-like cells, the pulp extract of rambutan inhibited the generation of reactive oxygen species (ROS) and decreased the release of pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) (29).

Black Longan extracts significantly reduce the release of pro-inflammatory cytokines like IL-6 and TNF-α, which are crucial in the inflammatory response and linked to age-related diseases (30). Longan extracts have been shown in animal models to diminish carrageenan-induced paw edema, indicating its potential efficacy in controlling inflammatory diseases (31).

Guarana has been proven to enhance anti-inflammatory cytokines, such as interleukin-10 (IL-10), while reducing pro-inflammatory cytokines like IL-6 and TNF-α. This adjustment in cytokine balance indicates that guarana can help moderate the inflammatory response in the body (32). The Anti-inflammatory properties of guarana are attributed to its high bioactive components, including caffeine, tannins, saponins and catechins, which possess antioxidant properties, neutralizing free radicals and reducing oxidative stress (33). In experiments using hyperlipidemic rats, guarana powder was found to reduce inflammation associated with lipotoxicity. It reduced IFN-γ and increased IL-4 levels, creating an anti-inflammatory environment (34). Guarana may help prevent chronic inflammation-related illnesses such as cardiovascular disease and metabolic disorders by lowering inflammation and oxidative stress levels. Its capacity to improve lipid profiles improves its usefulness in managing inflammatory disorders (35).

Table 4. Nutraceutical composition of Sapindaceae fruits.

Fruit	Vitamins	Minerals	Bioactive Compounds	Health Benefits
Lychee	Vitamin C, Vitamin B6, Niacin (B3)	Potassium, Copper, Magnesium	Flavonoids (epicatechin, quercetin), Polyphenols	Antioxidant, immune support, heart health
Rambutan	Vitamin C, Riboflavin (B2)	Calcium, Iron, Phosphorus	Flavonoids, Phenolic compounds (geraniin)	Hydration, antimicrobial, skin health
Longan	Vitamin C, Niacin (B3)	Potassium, Iron	Tannins (corilagin), Flavonoids (proanthocyanidins)	Cognitive function, mood enhancement, antioxidant
Ackee	Vitamin A, B	Iron, Potassium, Zinc	Fatty acids, Alkaloids (hypoglycin)	Nutrient-rich, caution for toxicity
Guarana	Small amounts of B Vitamins	Potassium, Magnesium	Caffeine, Tannins	Energy boost, weight management, cognitive function
Soapberry	Vitamin C	Limited data on minerals	Saponins, Flavonoids	Natural cleanser, antimicrobial, eco-friendly

Ackee is a plant that has shown promising anti-inflammatory abilities in various studies. Ackee seed extract silver nanoparticles exhibit synergistic antibacterial and anti-inflammatory action against a variety of ailments (36). The ethanol extract and fractions of ackee stem bark have anti-inflammatory activities, most likely due to the presence of secondary metabolites such as flavonoids (37). The capacity of Ackee to suppress protein denaturation and maintain cell membranes may account for its anti-inflammatory benefits.

Soapberries are high in saponins, which are natural chemicals with both surfactant and therapeutic qualities. These saponins contribute to the anti-inflammatory benefits by potentially inhibiting bacterial development and lowering skin irritation, hence soapberry is effective in skincare compositions (38). Soapberry contains flavonoids, which have been related to anti-inflammatory activity. These chemicals can control inflammatory pathways, contributing to soapberry's overall health advantages (39). Soapberry extracts can maintain red blood cell membranes, probably preventing the release of inflammatory mediators during inflammatory processes. This stability is critical for maintaining the cellular integrity during inflammation (7).

Anti-Oxidant property

Litchi, rich in antioxidants, offers numerous health benefits, making it crucial in a balanced diet to neutralize free radicals and reduce oxidative stress. Litchi anthocyanins extracted from litchi pericarp exhibited significant antioxidant activity, inhibiting linoleic acid peroxidation and acting as potent electron donors (40). Litchi pericarp extracts showed high antioxidant activity in DPPH and ABTS tests, with ascorbic acid and luteolin being vital antioxidants (41). Litchi peel and seed flour showed antioxidant activity in many assays, including ABTS+, DPPH, β-Carotene/Linoleic Acid and Phosphomolybdenum Complex (42). Antioxidant activity varies by litchi cultivar and found that the "Late Large Red" litchi cultivar had the highest total phenolic content and antioxidant activity among the tested varieties (43).

Rambutan extracts have a high phenolic content, with studies revealing up to 762 mg GAE/g in ethanolic peel extracts. This high phenolic content is associated to antioxidant activity, particularly in tests like DPPH and ABTS. It also possesses metal-chelating properties, effectively trapping metal ions that may accelerate harmful processes, such as Fe^{2}+ and Cu^{2}+ (28). Additionally, they stated that rambutan extracts have been found to protect cells from oxidative damage by lowering reactive oxygen species levels and enhancing antioxidant enzyme activity in HepG2 cells. The Anti-oxidant found in rambutan fruit pulp suppressed TNF- but had little impact on IL-8 (20).

Longan fruits are rich in polyphenols, providing antioxidant and anti-hyperglycemic benefits (53). The total phenolic content of dried longan pulp extracts strongly correlates with DPPH and ABTS radical scavenging studies. Longan seed extract was the most effective antioxidant with the highest free radical scavenging activity when compared to pericarp and aril extracts (51). Black longan, which underwent a thermal aging procedure has a stronger antioxidant-reducing capability than ordinary dry longan (54). Longan pericarp extract boosted the activity of antioxidant enzymes such as catalase, superoxide dismutase and glutathione peroxidase. Longan pericarp extract boosted the activity of antioxidant enzymes such as catalase, superoxide dismutase and glutathione peroxidase (52).

Guarana seeds, rich in antioxidants like caffeine, theobromine, tannins, saponins, catechins and proanthocyanidins, have an antioxidant profile resembling that of green tea. Guarana extracts have been found to protect against oxidative stress in animal models, with a water extract of roasted guarana seeds significantly reducing DNA damage and cell death in eye cells (35). Guarana seed extracts show modest antioxidant activity *in vitro* compared to typical dietary antioxidants like vitamin C and epigallocatechin gallate (EGCG). Their study discovered that a roasted guarana seed extract improved the nematode *C. elegans'* oxidative stress resistance, increased longevity, reduced age-related muscular function deterioration and decreased polyQ40 plaque production, indicating aging (6). Extracts prepared with 60 % ethanol revealed a phenolic concentration of 166 to 172 mg GA/g extract and they exhibited antioxidant property (44).

Ackee arils have a high concentration of antioxidants such as polyphenols (5, 175-5, 235 mg GAE/100 g), tannins, saponins, glycosides and squalene contributing to the radical scavenging and lowering ability of the fruit. Ackee arils had modest DPPH radical scavenging action, with 66.0 % and 29.4 % inhibition in oven- and freeze-dried samples respectively (45). Ackee arils, with high vitamin C content and increased antioxidant capacity, may be a valuable natural antioxidant source as they ripen, as demonstrated by ABTS and DPPH tests (18). It was discovered that, Ackee leaf and aril extracts contain antioxidants that reduce heavy metal oxidative damage, enhancing their medicinal potential, including antihypertensive and hepatoprotective properties (46).

S. mukorossi contains phytochemicals with potent antimicrobial properties against certain pathogens as well as strong antioxidant activity (47). Soapberry pericarp contains many antioxidants, including triterpenoid saponins, sesquiterpenoid glycosides, phenylpropanoids, steroids and saccharides which provide soapberry remarkable free radical scavenging and lowering abilities. A metabolomics research employing UHPLC-HRMS examined the changes in soapberry pericarp metabolites across 8 phases of fruit development and ripening. The key results are early fruit development stages (S1-S2) had large quantities of fatty acids, nucleotides, organic acids and phosphorylated intermediates. Fruit ripening phases (S6-S8) exhibit high levels of bioactive chemicals such as troxipide, vorinostat, furamizole, α-tocopherol quinone, luteolin and sucrose. The completely mature stage (S8) was determined as the best time to harvest soapberry pericarp for its antioxidant characteristics (39).

Anti–Cancer property

Litchi, a subtropical fruit, has been linked to potential anticancer effects due to its bioactive chemicals found in its seeds and pericarp. Tests have shown that litchi extracts can inhibit the formation of cancer cells, including breast, lung, cervical and colorectal cancers. Litchi fruit pericarp extract has been found to significantly inhibit breast cancer cell development, reducing tumor mass volume and increasing apoptotic markers like caspase-3. It also causes programmed cell death in cancer cells by modulating multiple signaling pathways controlling the cell cycle and apoptosis. Litchi extracts inhibit both estrogen receptor-positive and negative breast cancer cells, indicating a broad range of activity (48). Litchi seed extracts have been shown to reduce metastasis in cancer models, specifically via modifying cell adhesion and invasion pathways (49, 50). Litchi seed extracts were efficient in reducing the growth of colorectal cancer cells, showing promise for chemoprevention (51).

Rambutan, a fruit rich in phytochemicals like Geraniin, Ellagic Acid and Corilagin, has anticancer properties and is found in its peel, pulp and seeds, contributing to its medicinal properties. The methanol extract significantly reduced cell viability and promoted apoptosis via DNA fragmentation and morphological abnormalities in the cells (52). Various rambutan extracts were tested for phytochemical composition, which indicated high levels of bioactive components that contribute to anticancer activity (53).

Longan seed extract (LSE) has been found to suppress the development of colorectal (SW480, HT-29), liver (HepG2), lung (A-549) and breast cancer cells (MDA-MB-231). Longan extracts have shown potential as chemotherapeutics, as they can significantly reduce cell viability and clonogenic growth. They induce apoptosis in cancer cells by altering critical proteins in the apoptotic cascade. LSE therapy has been linked to increased levels of pro-apoptotic proteins (Bax) and lower levels of anti-apoptotic proteins (Bcl-2), leading to accelerated cell death. Longan extracts show potential against various cancers, with seed and flower extracts being particularly effective in inhibiting colorectal cancer cell development. They also suppress liver and lung cancer cell growth, suggesting potential for cancer treatment. Longan phytocompounds have been shown to interact with breast cancer biomarkers, indicating their potential for targeted therapy (54, 55). Longan antioxidant properties contribute to its anticancer advantages by reducing oxidative stress, which plays a significant role in cancer formation, as its phenolic components scavenge free radicals, shielding cells from oxidative harm (56, 57).

One of the study on “Effect of *Paullinia cupana* on MCF-7 breast cancer cell response to chemotherapeutic drugs” found that, Guarana extracts have an antiproliferative impact on MCF-7 breast cancer cells, resulting in a >40 % reduction in cell growth after 72 h of treatment and enhanced the antiproliferative action of chemotherapeutic drugs such as gemcitabine, vinorelbine, methotrexate, 5-fluorouracil, paclitaxel, doxorubicin and cyclophosphamide on MCF-7 cells (58). The high caffeine level may interfere with chemotherapy medicines, necessitating more evaluation. The assessment of guarana inhibited the growth of colorectal (SW480, HT-29), liver (HepG2), lung (A-549) and breast (MDA-MB-231) cancer cells. It enhanced apoptosis in cancer cells by modifying key apoptotic pathway proteins, such as increasing pro-apoptotic Bax and decreasing anti-apoptotic Bcl-2. The fruit also inhibited the AKT/mTOR/S6K and MAPK pathways, which are frequently activated in cancer cells. It inhibited both mTORC1 (p-S6K) and mTORC2 (p-AKT) in MCF-7 breast cancer cells, but only mTORC1 in HT-29 colorectal carcinoma cells (59).

The Ackee plant extracts include ellagic acid, which has shown good results against a variety of cancer cells, including osteocarcinoma, glioblastoma, oral cancer, ovarian cancer and hepatocarcinoma (46). Ackee's high monounsaturated fatty acid (MUFA) content, particularly oleic acid, has been linked to potential cancer prevention, particularly against prostate cancer, although further research is needed to establish a causal relationship (60). Ackee pods contain saponins, which have been recognized for their anticancer qualities. These substances can cause apoptosis, or programmed cell death, in a variety of cancer types and prevent the growth of cancer cells (61).

Saponins, found in soapberry pericarp, have been studied for potential cancer treatments. These substances can inhibit cell division, trigger apoptosis and prevent cancer cell spread. Saponins can damage cancer cell membranes, potentially reversing multidrug resistance in cancer therapies (62). Soapberries, rich in flavonoids, phenolic compounds and terpenoids, protect cells from DNA damage and oxidative stress, which are crucial for cancer development. Saponins and phytochemicals in soapberry slowed tumor growth by inducing apoptosis in cancer cells, which interferes with signaling pathways that promote cell division, thus effectively stifling tumor progression which was reported in the study on Metabolomics analysis of the soapberry (*Sapindus mukorossi* Gaertn.) pericarp during fruit development and ripening based on UHPLC-HRMS (39).

Anti-Viral Property

Litchi has shown significant antiviral activity, particularly against Herpes Himplex Virus (HSV) and influenza virus. It was reported that litchi fruit seeds have been used in traditional medicine in Brazil as an antiviral agent to treat various disorders (63). Litchi flower extract effectively inhibits HSV-1 growth and multiplication in infected corneal epithelial cells, decreasing viral titers and protein expression in a dose-dependent manner (64). Litchi compounds, including proanthocyanidins, have been found to exhibit antiviral properties against HSV-1 and HSV -2 *in vitro* and their flavonoids and triterpenoids have been proven to suppress influenza virus multiplication in cell culture research (65).

Geraniin extracted from rambutan rind has been proven to suppress the reproduction of several viruses, including dengue virus type 2. Geraniin binds to the

envelope protein of virus, effectively inhibiting early viral replication and entrance into host cells (10, 66). Rambutan contains ellagic Acid and Corilagin molecules, which contribute to its antiviral properties. They exhibit a variety of biological actions, including the capacity to suppress viral replication and modulate immunological responses (53).

Longan leaf extracts exhibit strong antiviral activity against HCV, with an EC_{50} of 19.4 µg/mL and no cytotoxicity. They suppress HCV during entry and post-entry phases, suggesting potential use as an adjuvant therapy (67). Longan leaf extract demonstrated antiviral properties against the influenza virus due to its chemical components, which are believed to disrupt viral reproduction (57). Longan bioactive compounds enhance its antioxidant and antiviral properties by reducing oxidative stress and inflammation, conceivably improving the immune response and preventing viral infections (19).

Guarana has various antiviral activities, owing to its high concentration of bioactive components such as caffeine, theobromine, tannins and saponins. Guarana extracts have been found to decrease the replication of HCV and have been shown in trials to have considerable antiviral activity, indicating that they might be used as an adjuvant therapy for HCV treatment. The particular processes entail inhibiting viral entrance and replication in host cells (35).

Sapindus mukorossi, particularly its pericarp, has been found to possess significant antiviral properties against various viruses. Its extract has been shown to inhibit HCV replication in a dose-dependent manner, making it a potential adjunctive therapy for HCV treatment. The soap pericarp contains bioactive compounds like triterpenoid saponins and sesquiterpenoid glycosides, which exhibit antiviral activity against influenza viruses. These compounds disrupt viral membranes, preventing viral entry and replication. The soapberry pericarp also contains terpenoids, phenolic compounds and flavonoids, contributing to its antiviral and antioxidant properties. These compounds interfere with various stages of the viral life cycle, including attachment, entry and replication in host cells (39).

Anti-diabetic property

Litchi, with a low glycemic index of around 50, is an effective fruit for treating diabetes due to its slow digestion and absorption. It contains antioxidants like vitamin C, flavonoids and polyphenols, which can help lower oxidative stress and inflammation, which are common in diabetes. Additionally, litchi seeds contain bioactive chemicals like proanthocyanidins, procyanidins and pavetannins, which inhibit α-glucosidase activity, reducing postprandial blood sugar rises. These antioxidants can help prevent or delay the onset of diabetes problems (68). In a summary, it was described that, litchi with 1.3 g of dietary fiber per 100 g of fruit, slows sugar absorption, minimizes blood sugar swings and maintains long-lasting satisfaction (69). A medical pill containing litchi seed extract was developed in China to treat gestational diabetes (70).

Rambutan peel phenolic extracts have been found to effectively lower fasting blood glucose levels in diabetic mice, enhance body weight and reduce cholesterol, triglycerides and glycated serum proteins. This extract improves liver glycogen content and antioxidant enzyme activity, reducing the oxidative stress associated with diabetes (47). Rambutan, which contains phytochemicals such as flavonoids, tannins and phenolic acids, is thought to help regulate blood sugar levels and avoid diabetic complications. Its historical usage in traditional medicine lends credibility to scientific evidence of its usefulness in treating diabetes and its consequences (48). Rambutan seed extract has potent glucosidase inhibitory properties, possibly aiding in reducing postprandial blood sugar levels and potentially treating diabetes by delaying glucose absorption (43).

Longan is high in antioxidants, dietary fiber, vitamins and minerals, which increase its potential as a functional meal for diabetes treatment. Longan extracts have been shown to improve glucose metabolism and appetite regulation, both of which are important aspects of diabetes management. In a conducted research, it is concluded that, longan extract (LE) treatment in diabetic rats lowered fasting blood glucose levels while improving glucose tolerance and insulin sensitivity. This impact was linked to changes in hypothalamic neuronal activity, notably an increase in pro-opiomelanocortin (POMC) and a decrease in agouti-related peptide (AgRP) neuronal activities, which are important for appetite regulation and energy balance. Longan extract has been shown to lower hypothalamic endoplasmic reticulum (ER) stress, which can contribute to insulin resistance and impaired appetite regulation, presumably helping to normalize eating behavior and improve glucose levels (71).

An *in vitro* study found that Guarana extract increases the survival and proliferation of human peripheral blood mononuclear cells (PBMC) when exposed to high glucose levels, indicating that it may protect against the detrimental effects of high glucose (72). A Research entitled “Guarana (*Paullinia cupana*) Stimulates Mitochondrial Biogenesis in Mice Fed High-Fat Diet” and this animal study had revealed that Guarana can prevent weight gain and improve metabolic profiles. Supplementing mice on a high-fat diet with guarana led to weight loss and reduced glycemic levels, promoting increased energy expenditure and mitochondrial biogenesis, which can control metabolism and enhance insulin sensitivity (73).

Ripe ackee fruit has been linked to hypoglycemic effects, which may help diabetics manage their blood sugar levels. A study revealed that a patient with uncontrolled type 2 diabetes exhibited better hemoglobin A1C levels after ingesting preserved ackee fruit, indicating a possibility for blood sugar management (74). The fruit includes a variety of bioactive components, including antioxidants and phenols, which may contribute to its anti-diabetic properties and can help to lower oxidative stress and inflammation, two essential elements in the pathogenesis of diabetes. Also noted that, unripe ackee fruit has high quantities of hypoglycin A, which can deplete glycogen reserves in the

liver and cause severe hypoglycemia, sometimes known as "Jamaican vomiting sickness." If not treated quickly, symptoms such as vomiting, seizures, and even death may occur. As a result, it is critical to consume only ripe ackee fruit and be aware of the hazards associated with unripe types (46). In a diabetic rat model, an ethanolic extract of B. sapida stem bark given orally dramatically lowered fasting blood glucose (75).

The principal chemical elements of soapberry pericarp are triterpenoid saponins and sesquiterpenoid glycosides, which may contribute to its anti-diabetic properties.

Vescalagin, a chemical present in the fruit, has been showed to enhance insulin resistance and glucose metabolism (39).

Anti-obese activity

It was found that, Litchi seed extract suppresses adipogenesis, aiding weight management and obesity prevention. It inhibits lipid oxidation, improving food safety and quality and as a result, the consumption of litchi improves lipid profiles, aiding weight control (76). Litchi may help reduce excess fat buildup by increasing lipid metabolism (77) and Litchi's antioxidant activity may enhance metabolic health and potentially aid in weight control (78).

A research was conducted on ethanol extracts of rambutan leaves which were examined for their effects on obesity and insulin resistance on rat models. According to the findings, rambutan leaf extract significantly reduced body weight and food consumption in obese rats, with a dosage of 17.5 mg/kg resulting in a 2.44 % weight loss and decreased appetite. The extract also reduced blood glucose levels, suggesting weight management and glycemic control. At larger dosages, it enhanced fecal excretion and decreased fat accumulation (79).

Longan extract stimulates pro-opiomelanocortin (POMC) neurons while inhibiting agouti-related peptide (AgRP) neuron activity. This modulation helps control appetite and may contribute to lower food consumption, which is important for weight management (71). Polyphenol -rich extracts from longan flowers showed anti-obesity and hypolipidemic benefits in rats fed a high-calorie diet. These extracts helped modulate lipid metabolism, confirming the fruit potential involvement in weight management (57, 80).

Guarana supplementation can help prevent weight gain, even when combined with a high-fat diet. In mouse trials, individuals given guarana gained no weight while eating the same amount of food as the control group. This implies that guarana may improve energy metabolism and thermogenesis, allowing for weight control without lowering food consumption (73). Guarana has been found to promote mitochondrial biogenesis, which is essential for cellular energy generation. This impact can lead to higher energy expenditure and fat oxidation, resulting in weight loss and better metabolic health. Guarana administration boosted the expression of genes related to mitochondrial activity and energy metabolism, including Pgc1α and Ucp1 in brown adipose tissue. Guarana's effects on gut flora, crucial for metabolism and weight management have been associated to improved metabolic health and the prevention of fat gain and it was revealed (81).

Ackee is a low-calorie fruit that aids in weight loss and maintenance due to its low calorie content. It contains beneficial fatty acids like monounsaturated fats, which are essential for bodily functions, cholesterol balance, and heart health, which are crucial in managing obesity (82). Ackee has moderate amounts of protein, which is required for muscle maintenance and repair. Higher protein consumption can also induce satiety, which helps control hunger and lower overall calorie intake (83). The overall pharmacological and health benefits of Sapindaceae fruits is furnished compoundwise in Table 5.

Value Added Products

Value-added products are agricultural goods that have been altered or improved to boost their market value. Processing these items not only prolongs their shelf life but also ensures their availability over time, allowing producers to meet market demand effectively.

Litchi

Litchi-based products present a delightful array of options that emphasize the unique flavor and versatility of this tropical fruit. Litchi pulp serves as a key ingredient in various beverages, including squash, nectar, ready-to-serve (RTS) drinks and cordials, providing a rich and refreshing taste. Canned litchi features arils preserved in sugar syrup and sealed in airtight glass bottles, ensuring both longevity and quality. Other innovative products include dehydrated litchi nuts, which are whole dried fruits that retain their flavor and freshness. Additionally, litchi syrup and litchi jam, made from pure litchi pulp, serve as excellent spreads, while litchi sherbet offers a refreshing beverage option. Litchi honey, derived from honey collected in litchi orchards, contributes to the product range by providing sweetness and character. For those seeking a more indulgent experience, litchi wine, produced through the anaerobic fermentation of litchi pulp, contains 10-12 % alcohol and maintains the fruit's distinctive flavor. Collectively, these products illustrate the diverse ways in which litchi can be enjoyed, catering to a wide array of tastes and preferences (84, 85).

Rambutan

Rambutan is processed into various products that showcase its unique flavor and versatility. Besides being eaten fresh, it can be made into liquor, providing a distinctive beverage. Canned rambutan preserves the fruit in syrup or juice for easy consumption throughout the year. Rambutan syrup is a popular sweetener for desserts and drinks, while rambutan juice offers a refreshing option for smoothies and cocktails. The fruit is also transformed into dried pulp, which can be added to baked goods, granola bars and trail mixes. Jams and jellies made from rambutan are perfect for spreading on toast and fruit concentrates are used in ice creams, sauces and marinades. Additionally, the seeds, known for their bitter taste, can be roasted and ground into powder for chocolate blends and other treats. This variety of products demonstrates rambutan's adaptability in the food

Table 5. Pharmacological and health benefits of Sapindaceae fruits.

Sl. No.	Compound	Crop	Plant Part Extracted	Pharmocological and health Properties/ Benefits	Reference
1	5-Hydroxymethyl-2-furfurolaldehyde (5-HMF)	Litchi	Pulp/ fruit	Anti-obese	(77)
2	α-Terpineol	Longan	Fruit	Anti-cancer	(55)
3	α-Tocopherol Quinone	Soapberry	Pericarp	Anti-oxidant	(39)
4	Anthocyanin	Litchi, Ackee	Pericarp (Litchi); Fruits and Leaves (Ackee)	Anti-oxidant	(40, 46)
5	Arabinose	Litchi	Pulp/ fruit	Anti-cancer	(50)
6	Arabinoxylan	Litchi	Pulp/ fruit	Anti-diabetic	(69)
7	Ascorbic Acid	Rambutan, Ackee	Pulp	Anti-oxidant, Anti-inflammatory	(20, 29)
8	Benzyl Alcohol	Litchi	Pulp/ fruit	Anti-obese	(77)
9	Catechin	Litchi, Longan, Guarana, Ackee	Various (e.g., Guarana Powder)	Anti-oxidant, Anti-viral	(41, 67)
10	Citric Acid	Longan	Fruit	Anti-cancer	(55)
11	Corilagin	Longan	Fruit	Anti-diabetic Anti-obese	(57, 71)
12	Epicatechin	Litchi, Longan	Leaves	Anti-oxidant, Anti-viral	(41, 67)
13	Ellagic Acid	Longan, Ackee, Longan	Leaves, Flowers, Trunk, Seeds (Longan), Fruits and leaves (Ackee)	Anti-cancer, Anti-viral, Anti -diabetic	(46, 57, 67, 71)
14	Flavan-3-ol	Litchi	Pulp/Fruit	Anti-inflammatory	(26)
15	Flavonoids	Litchi, Rambutan, Soapberry	Peel and Seed (Litchi); Pulp, Leaves (Rambutan); - (Soapberry)	Anti-oxidant, Anti-diabetic, Anti-obese	(42, 79, 98)
16	Phenolic Compounds	Litchi, Soapberry	Bioactive and Starchy Polysaccharides, Proteins, Oil content, Minerals (Litchi); - (Soapberry)	Anti-viral	(65)
17	Phenolic Acids	Rambutan, Longan	Peel and seed	Anti-diabetic	(98)
18	Phenolics	Litchi, Rambutan, Longan, Guarana, Soapberry	Pericarp, Flower (Litchi, Soapberry), Peel (Rambutan), Seed, Fruit (Longan and Guarana)	Anti-cancer, Anti-inflammatory, Anti-viral	(28, 30, 39, 44, 48, 64, 99, 100)
19	Phlobatannins	Ackee	Stem Bark	Anti-diabetic	(75)
20	Proanthocyanidins	Litchi	Seed and Fruit	Anti-diabetic	(68)
21	Procyanidin A2	Litchi	Seeds	Anti-oxidant	(41)
22	Procyanidin B2				
23	Proteins	Litchi, Ackee, Soapberry	Fruits	Anti-viral, Anti-obese	(18, 63)
24	Quercetin	Longan	Leaves	Anti-viral	(67)
25	Rutin	Litchi	Pericarp	Anti-oxidant	(41)
26	Saccharides	Soapberry	Pericarp	Anti-inflammatory	(39)
27	Saponins	Litchi, Ackee, Soapberry	Seeds (Litchi, Ackee); Pods (Soapberry)	Anti-inflammatory, Anti-viral, Anti-cancer	(36, 39, 61)
28	Squalene	Ackee	Fruits	Anti-oxidant	(45)
29	Tannins	Rambutan	Various	Anti-diabetic	(79, 98)
30	Terpenoids	Ackee, Soapberry	Fruits and pericarp (Soapberry), Seeds, Stem bark, leaves (Ackee)	Anti-diabetic, Anti-cancer, Anti-oxidant, Anti-inflammatory	(36, 39, 46, 75)
31	Theobromine	Guarana	Seeds	Anti-oxidant	(35)
32	Theophylline	Guarana	Guarana Powder	Anti-diabetic	(72)
33	Triterpenes	Ackee	Fruits	Anti-diabetic	(74)

industry, meeting diverse consumer preferences (10, 66, 86).

Longan

Longan fruits can be enjoyed in various forms, including dried longan pulp, longan juice, longan jelly, longan wine and canned longan in syrup. Among these, dried longan fruit, commonly known as "nuts," is particularly popular in Asia. Due to their high total soluble solids (TSS) content, these fruits require minimal sugar additives, making them a versatile ingredient. Longan can even be canned in its own juice, which helps to preserve its distinctive flavor, ensuring that canned longan fruit retains its appealing taste. Additionally, longan fruit can be frozen without adversely affecting the aril, providing further options for preservation, or it can be processed into juice or wine, enhancing its versatility in various culinary applications (87, 88).

Ackee

Ackee can be consumed both cooked and raw, with the edible portion being the arils. These arils can be parboiled, fried or incorporated into various dishes such as stews, curries and ackee preserves. Additionally, canned ackee offers a convenient option for enjoyment. Ackee flour serves as a suitable substitute for wheat flour in many baked goods, canned products and pasta. Furthermore, ackee can be blended with banana, coconut water, lemon juice and other fruits to create a delicious smoothie, showcasing its versatility in both savory and sweet culinary applications. Its rich flavor and nutritional benefits make ackee a popular choice in various cuisines, adding both taste and texture to a wide range of dishes (89, 90).

Guarana

Guarana is associated with a diverse array of value-added products across multiple industries. Primarily recognized for its stimulating properties, guarana powder is a favored ingredient in energy drinks and dietary supplements. Additionally, it serves as a flavoring agent in various foods, including snacks, cakes and bread, enhancing both their taste and nutritional content. Moreover, the byproducts generated during the processing of guarana can be repurposed to produce bioproducts such as alcohols, organic chemicals, polyphenols, alkaloids and polysaccharides. Finally, guarana powder can also be used to prepare tea, offering a flavorful and invigorating beverage option for consumers (11, 91).

Soapberry

Soap nuts are a versatile natural cleaning option that can be used directly in laundry by placing a few berries in a cloth bag and adding them to the wash. They can also be boiled to produce a liquid soap suitable for various cleaning and personal hygiene purposes. The extract from soap nuts is commonly found in shampoos, body washes and facial cleansers, offering a gentle cleansing solution ideal for individuals with allergies or sensitive skin. Additionally, soap nuts possess medicinal properties and are utilized in traditional medicine to treat skin conditions such as eczema and psoriasis. They are also employed as natural pesticides in agriculture, making them an eco-friendly alternative for pest control (92).

Summary and Conclusion

The Sapindaceae family has a variety of nutritionally dense fruits that give considerable health advantages due to their high quantities of vitamins, minerals and bioactive chemicals. Their antioxidant, anti-inflammatory and possible anti-cancer characteristics make them useful supplements to a balanced diet. The creation of value-added goods increases their appeal and accessibility, while continued study reveals their medicinal potential. By increasing the optimum consumption of these fruits, we may contribute to public health programs aiming at illness prevention and general wellbeing, emphasizing their role in contemporary nutrition.

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Authors' contributions

SSS: Writing of original draft and conceptualization. C: Revision of draft, inclusion of tables and figures, proof reading. SKRAC: Revision, formatting and Supervision. All authors read and approved the final manuscript.

Compliance with ethical standards

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