

# **Therapeutic Potential of *Carica papaya* Linn.: A Comprehensive Review of its Pharmacological Properties and Health Benefits, with Emphasis on Dengue Fever Healing**

## **ABSTRACT**

For thousands of years, people have used various plant products, foods, spices, and herbs to treat and prevent illnesses. Sri Lankans have used traditional and folk medicine to satisfy their basic health needs from the earliest days. *Carica papaya* Linn. (Caricaceae) is a commercially grown exotic plant in Sri Lanka. The entire plant, including the fruits both ripened and green, leaves, roots, peel, seed, and pulp, was used as medicine in traditional medicinal systems. Plant parts of *Carica papaya* Linn. were frequently used by ancient Sri Lankans to treat diabetes mellitus, hypertension, cancer, dengue fever, skin infections, renal disorders, and infections caused by bacteria, fungi, parasites, and viruses. Dengue fever is the most prevalent and significant arthropod-borne viral disease in humans, and it is extensively spread throughout Sri Lanka. *Carica papaya* Linn. extracts have been used to treat dengue patients to recover from its complications, which include thrombocytopenia, haemolysis, and leukopenia. Studies reveal that the papaya leaf extract can neutralize plasma with the dengue virus, reduce platelet aggregation, and increase the production of the enzyme ALOX12, which promotes platelet production. Moreover, the extract also upregulates the platelet-activating factor receptor (PTAFR) gene and inhibits serine proteases NS2B and NS3 involved in dengue virus replication. In this review, we have discussed extensively the ethnomedicinal and pharmacological properties of *Carica papaya* while highlighting its remarkable potency in healing dengue.

*Keywords: Carica papaya, Dengue, thrombocytopenia, Dengue haemorrhagic fever, ethnomedicine, phytochemical screening, Sri Lanka.*

## **1. INTRODUCTION**

Plants and their products have been used for centuries in complementary medicine to treat various human diseases (1,2,3,4). According to studies, approximately 80% of the world's population relies on plant products for primary medical care (5,6,7,8,9). These plant-based products possess multiple benefits over synthetic drugs, including being less expensive, more readily available, and having fewer side effects after either brief or prolonged consumption (8,9,10,11,12).

*Carica papaya* Linn. (Caricaceae) is commonly known as Papaya and Pawpaw, and in Sri Lanka Gas-Labu and Papol. This plant is native to Mexico, USA, Costa Rica and exotic to Sri Lanka. Papaya is a popular fruit in Sri Lanka, where it is grown as a home garden and a commercial crop for local and export markets. In Sri Lanka, papaya is commercially grown on approximately 8,000 hectares, yielding approximately 32,000 tons annually (13). Ripe papaya is a popular dessert fruit in Sri Lanka available throughout the year. Fruit salads, jelly, marmalade, refreshing drinks, candies, jam, and crystallized fruit can all be made with it. The unripe fruit is a key ingredient used to make a traditional food called Sinhala pickle.

*Carica papaya* Linn. is a succulent evergreen plant, a tree-like herb that grows 2-10 m tall, is usually unbranched, but can become branched due to injury, and contains white latex in all parts. Spiral-arranged leaves clustered near the trunk's apex and flowers are small, yellow-colored, funnel-shaped, and can be found alone or in clusters in the leaf axils. The fruits exhibit a cylindrical shape with juicy,

orange-hued pulp, empty berries, and a slender, yellowish skin upon ripening. Female flowers give rise to fruits that are oblong, spherical, or pear-shaped, while hermaphrodite flowers yield fruits that are elongated, obovoid, or pyriform in structure. The seeds are plentiful, tiny, circular, and enveloped in a gelatinous aril. The tree features petite latex vessels distributed extensively, with a higher concentration observed in fully grown fruit that is yet to commence the maturation process (14). *Carica papaya* is extensively employed in therapeutic applications globally. Each part of the plant is recognized for its distinct medicinal properties. People often use the plant as a remedy for various conditions such as diabetes mellitus, hypertension, parasitic infections, cancer, and dengue. In addition to these ethnomedicinal uses, scientific studies have confirmed that *Carica papaya* possesses a spectrum of pharmacological properties, including antibacterial, anti-inflammatory, anti-malarial, antioxidant, anti-cancer, anti-dengue activity, and more (13, 14).

Dengue fever is identified as the most prevalent and significant arthropod-borne viral (arboviral) disease among humans. It is spread by mosquitos of the *Aedes* genus such as *Aedes aegypti* and *Aedes albopictus*, which have a widespread distribution in Sri Lanka (15). Dengue transmission follows a seasonal pattern in Sri Lanka, characterized by two peaks coinciding with the monsoon rains in June-July and October-December. The majority of cases are reported during the summer monsoon season, spanning from June to July(16). Dengue fever gives rise to various hematological manifestations like thrombocytopenia (low blood platelet counts), hemolysis, and leukopenia. Platelet count is also associated with vascular protein leakage and liver damage. Vascular leakage is the primary pathophysiological marker that determines the level of severity of dengue. Thus, thrombocytopenia may be a significant predictor of mortality. *Carica papaya* extracts have been used to treat dengue patients to recover from thrombocytopenia, hemolysis, and leukopenia (16).

This comprehensive review investigates the vast range of medicinal properties and health benefits of *Carica papaya*, with a particular focus on its potential in treating dengue fever. The article examines the rich composition of bioactive compounds found in different parts of the papaya plant and explores its traditional uses in various cultures. The paper highlights the plant's remarkable ability to mitigate dengue symptoms, reduce the severity of the disease, and potentially aid in the recovery process. Through the integration of current knowledge, the review aims to investigate the precise mechanisms through which *Carica papaya* could play a role in the healing process of dengue.

### 1.1 Taxonomic Hierarchy and Other Names

Kingdom	Plantae - Plants
Subkingdom	Tracheobionta - Vascular plants
Super division	Spermatophyta - Seed plants
Division	Magnoliophyta - Flowering plants
Class	Magnoliopsida - Dicotyledons
Subclass	Dilleniidae
Order	Violales
Family	Caricaceae Dumort.
Genus	<i>Carica</i> L.
Species	<i>Carica papaya</i> L.

Figure 1: Taxonomic Classification of *Carica papaya* (17).

<b>1.1.1</b>	<b>Other</b>	<b>names</b>	<b>(17)</b>
Arabic:	Fafay, Babaya	English:	Pawpaw Tree, Melon Tree, Papaya
Bengali:	Pappaiya, Papeya	Filipino:	Papaya, Lapaya, Kapaya
Burmese:	Thimbaw	French:	Papailler, Papaye, Papayer

German: Papaya, Melonenbaum

Hindi: Papaya, Papeeta

Indonesian: Gedang, Papaya

Malay: Papaya, Betek, Ketalah, Kepaya

Sinhala: Pepol

Spanish: Figuera Del Monte, Fruta Bomba, Papaya, Papaíta, Lechosa

Tamil: Pappali, Pappayi

Thai: Ma Kuai Thet, Malakor, Loko

Vietnamese: Du Du

## 1.2 Geographical distribution

*Carica papaya* thrives across a wide geographical range, from the equatorial tropics to temperate latitudes. Warm and sunny locations, ideally below 1500 meters in elevation, are ideal for growth. Strong winds have a significant negative impact, particularly on soils with limited capacity to compensate for significant transpiration loss. Due to the tree's sensitivity to frost, exposure to cold winds usually results in leaf damage and, as a result, the tree's death. The plant's roots are susceptible to waterlogging, making even brief periods of flooding could be fatal (17,18)

The optimal soil type for papaya cultivation is a well-drained, permeable, and well-aerated fertile loamy soil that is free from root-knot nematodes. Ideally, this soil should be rich in organic matter, promoting a neutral pH range of 6 to 7. Such conditions provide an ideal environment for the growth and development of papaya plants (14).

The plant is documented to be native to the United States of America, Mexico, and Costa Rica. The plant is now distributed almost all over the world (18).

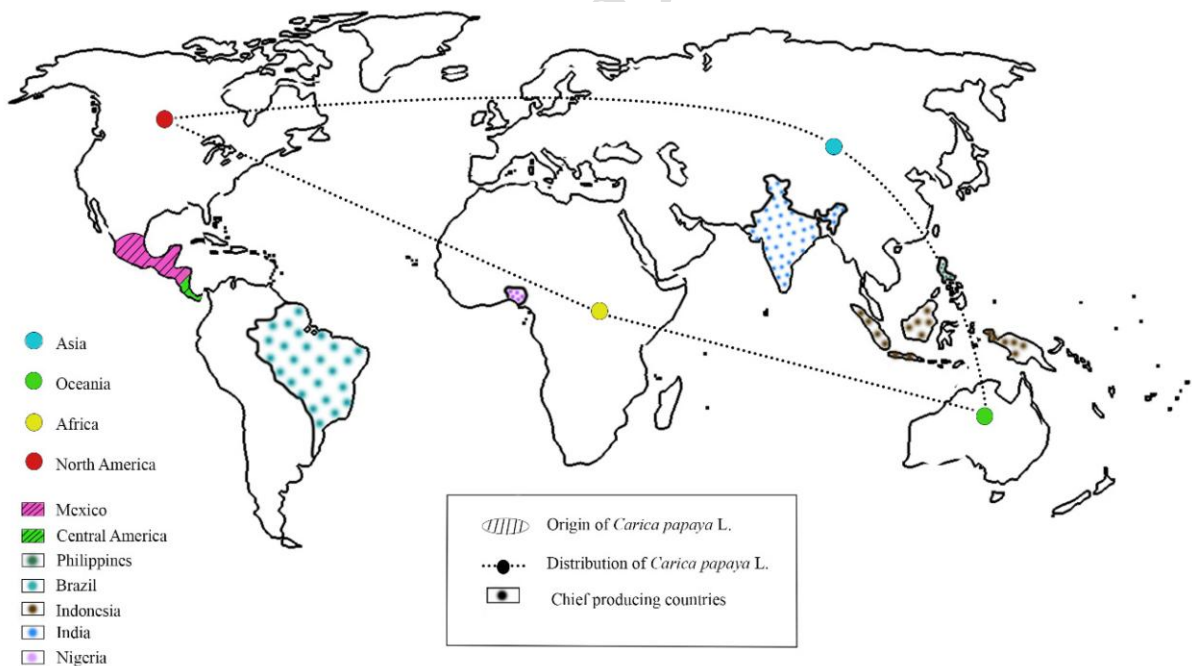


Figure 2: The origin, distribution, and the chief producing countries of *Carica papaya*(18).

## 1.3 Botanical description and cultivation

*Carica papaya*, an evergreen herb with a tree-like appearance, typically reaches 2-10 meters high. While it generally grows as a single unbranched stem, occasional branching may occur as a response to injury. The plant features white latex throughout all its parts. The cylindrical stem measures 10-30 cm in diameter and is characterized by hollowness, prominent leaf scars, and spongy-fibrous tissue. Additionally, *Carica papaya* possesses a comprehensive rooting system (14, 19). The leaves of

*Carica papaya* are spirally arranged and form clusters near the apex of the trunk. The petiole, measuring up to 1 meter in length, is hollow and exhibits a greenish or purplish-green hue. The lamina is orbicular, with a diameter ranging from 25 to 75 cm. It is palmate and deeply divided into seven lobes, presenting a glabrous surface with prominent veins. The lobes themselves are deeply and broadly toothed. The flowers of *Carica papaya* are small, yellow, and funnel-shaped. They can be found either as solitary blooms or in clusters within the leaf axils, categorized into three types (14, 20). Female flowers, ranging from 3 to 5 cm in length, showcase a substantial functional pistil but lack stamens, featuring an ovate-shaped ovary. Male flowers emerge on extended drooping panicles, each adorned with 10 stamens arranged in two rows. These male flowers lack a gynoecium, except for a pistillode. Hermaphrodite flowers, larger than the males, exhibit a 5-carpellate ovary. The occurrence of these flower types is influenced by the tree's season or age (19, 21). The fruits of *Carica papaya* are sizable and cylindrical, featuring fleshy orange pulp within a hollow berry. Upon ripening, the slender skin adopts a yellowish tint. The variety in fruit morphology is apparent, as those derived from female flowers exhibit an oblong, spherical, or pear-shaped form, while those originating from hermaphrodite flowers take on a long, obovoid, or pyriform structure. The seeds are plentiful, small, black, and round, enveloped in a gelatinous aril. Across the tree, petite latex vessels are dispersed, particularly abundant in fruits that have attained full size but are still in the process of ripening (14, 19, 20).

*Carica papaya* typically begins fruiting within 5 months of its growth and has a lifespan of 4-5 years. Typically, male and female flowers are found on separate trees, although some flowers exhibit bisexual characteristics. The pollination process engages a diverse array of insects, encompassing larger bees like *Xylocarpa* and *Trigona*, honeybees, long-tongued sphinx moths (*Sphingidae*), hummingbird moths (*Macroglossa*), and even the wind. Through open (uncontrolled) pollination, a cultivar has the potential to undergo changes and lose its distinctive traits over several generations (14).



Figure 3: A drawing of a papaya plant illustrating the fruit, flowers, leaves, and stem (22).

## 2. NUTRITIONAL VALUE

Papaya is often referred to as the "common man's fruit" due to its affordability and remarkable nutritional value. Phytonutrients can be found in various parts of the papaya plant, including the leaves, unripe, and ripe fruits (23). Renowned for its richness in thiamine, folate, riboflavin, and niacin, as well as vitamins A, B1, B2, and C, along with significant fiber content, papaya holds a special place among fruits. It consistently ranks among the top five fruits, alongside kiwi, watermelon, grapefruit, and guava, when evaluated based on nutritional scores (24, 25).

Table 1: Nutritional content of *Carica papaya*, per 100g (26).

Energy	163KJ
Sodium	3mg
Potassium	257mg
Phosphorus	5mg
Magnesium	10mg
Iron	0.10mg
Calcium	24mg
Vitamin C	61.8mg
Folate	38mg
Vitamin B6	0.1mg
Niacin	0.338mg
Riboflavin	0.05mg
Thiamin	0.04mg
Vitamin A	328IU
Protein	0.61g
Fat	0.14g
Dietary fiber	1.8g
Sugars	5.9g
Carbohydrates	9.81g

Every component of *Carica papaya* proves valuable in some capacity. It is a potent reservoir of three robust antioxidants: C, A, and E. Additionally, this fruit harbors a digestive enzyme called papain, renowned for its efficacy in treating sports injuries, trauma, and allergies (27). Studies reveal that papaya leaves contain numerous active components capable of enhancing overall antioxidant levels in the bloodstream and reducing lipid peroxidation (28). The papaya leaves and fruit complex yield various proteins and alkaloids with significant applications in both pharmaceutical and industrial settings. One noteworthy proteolytic enzyme, papain, is particularly abundant in the milky latex of green, unripe papaya (29).

This fruit stands out as an exceptional source of beta-carotene, shielding against free radical damage and aiding in preventing diabetic heart disease. *Carica papaya* also significantly lowers elevated cholesterol levels (27). Moreover, the *Carica papaya* plant synthesizes natural compounds in its leaf, bark, and twig tissues, demonstrating potent anti-tumor and pesticidal properties (28). With two active components, chymopapain, and papain, *Carica papaya* proves highly advantageous for managing digestive disorders and gastrointestinal disturbances. Importantly, papain retains its efficacy in acidic pH conditions without undergoing denaturation(30).

*Carica papaya* holds therapeutic potential in ulcer treatment when its unripe fruit is employed. The use of green papaya fruits extends to addressing conditions like amenorrhea, constipation, dyspepsia, expel worms, general debility, high blood pressure, and stimulating reproductive organs (28). *Carica papaya* constituents exhibit an alkaline combination, akin to borax or potassium carbonate, showcasing promising outcomes in treating various skin conditions such as corns, cutaneous tubercles, eczema, skin hardness, and warts. Furthermore, these constituents, when injected into indolent glandular tumors, facilitate their absorption (29). The nutritional content of papaya plays a crucial role in inhibiting cholesterol oxidation. Papaya boasts a significant presence of iron and

calcium. Extracts from unripe papaya are found to encompass terpenoids, alkaloids, flavonoids, carbohydrates, saponins, and steroids (29).

Papaya actively contributes to bolstering the immune system, enhancing resistance against coughs and colds, courtesy of its rich vitamin A and C content. The diverse therapeutic properties of papaya make it a valuable addition to promoting overall health and well-being (27).

### **3. ETHNOMEDICINAL USES OF *Carica papaya***

*Carica papaya* is prominent in traditional and ethnomedicinal practices, extensively utilized for its diverse therapeutic applications across various nations (31). Decoctions derived from different parts of the plant exhibit unique curative potency, forming a key component in traditional medicinal practices (32, 33).

Ethnomedicinal surveys carried out in Nigeria document the use of *Carica papaya* in addressing conditions such as diabetes mellitus, intestinal helminthiasis, and hypertension (32). Additional studies emphasize its application in treating fungal and helminthic infections (34). The Australian Gold Coast reveals that *Carica papaya* leaf juice is utilized in cancer treatment (35).

In India, *Carica papaya* leaf extracts are employed to alleviate asthma, colic disorders, and fever. Additionally, *Carica papaya* is utilized for its contraceptive potential in various Asian countries, including India, Pakistan, and Sri Lanka, while countries in Southeast Asia such as Laos, Cambodia, and Vietnam use it for diverse medicinal purposes. The milky latex juice is employed as a remedy for eczema and psoriasis (32). Moreover, in certain regions, seed extracts are utilized as anthelmintic medicine, thirst quenchers, and pain relief agents. In Cameroon, *Carica papaya* is integrated as an active pharmacological ingredient in antimalarial mixtures (36).

In China, various parts of *Carica papaya*, including leaves, fruits, and seeds, are employed in the treatment of stomach pains, bacterial infections, and inflammations. Lactating mothers in this region consume soup made from nearly ripe fruits with fish to enhance the flow of breast milk (37). This extensive array of traditional and ethnomedicinal uses underscores the cultural and medicinal significance of *Carica papaya* across diverse regions.

### **4. MEDICINAL VALUE OF VARIOUS PARTS OF *Carica papaya***

#### **4.1 Leaves**

The papaya leaf has demonstrated its efficacy as a valuable nutritive agent, characterized by diverse concentrations of essential nutritional components. These include significant amounts of

ascorbic acid (38.6%), carbohydrates (8.3%), iron (0.0064%), minerals such as magnesium (0.035% per 100 g), protein (5.6%), and phosphoric acid (0.225%) within the leaf portion (38).

In the context of Dengue Fever, the juice extracted from *Carica papaya* leaves plays a crucial role in elevating the count of white blood cells (WBCs) and platelets, while also aiding in the normalization of clotting and liver repair (27). Administering the extract of papaya juice to patients with dengue fever has shown remarkable results, with the counts of platelets and WBCs returning to normal levels within 24 hours (16).

The extracts of *Carica papaya* leaves have exhibited the ability to inhibit the growth of cancer cells (27). It enhances the production of crucial signaling molecules known as Th1-type cytokines, which play a pivotal role in regulating the immune system (30).

Papaya leaves are commonly utilized to make tea for the treatment of malaria (39). Some preparations of the plant have been observed to possess antimalarial and anti-plasmodial activity (39), although the underlying mechanism remains unclear and has not been scientifically proven.

Certain compounds are isolated from the leaves including, karpain, a substance known for its ability to eliminate microorganisms that can disrupt digestive function (27).

Other benefits of Papaya Leaves:

- A remedy for acne
- Helps to Increase the appetite
- Easing the menstrual pain
- Acting as a meat tenderizer
- Providing relief from nausea

## 4.2 Fruits

Papaya fruit stands out as a rich source of essential nutrients, including vitamins, minerals, and dietary fiber (27). Within papaya, the presence of Danielone, a phytoalexin, exhibits potent antifungal activity (27). The fruit offers versatile uses, serving as a:

- Laxative
- Cure for indigestion
- Preventive measures against heart attack and stroke

Consuming fresh ripe papaya every morning is recommended to prevent indigestion, constipation, and to enhance appetite (27). Furthermore, the fruit of *Carica papaya* proves beneficial in the treatment of mouth ulcers, gum disease, and toothaches (28).

## 4.3 Seeds

Remarkably, papaya seeds exhibit higher medicinal value compared to other parts of the tree (27). They are noted for their antibacterial properties and prove highly effective against staphylococcus infections. Additionally, the seeds contribute to kidney protection by guarding against toxins and preventing kidney failure. Their beneficial effects extend to aiding in the recovery from piles and typhoid (27).

Dried papaya seeds, in particular, offer enhanced nutritional value. Grinding these seeds and incorporating them into meals can introduce enzymes to the diet, thereby improving digestive problems (27).

## 4.4 Peel

Papaya peel finds versatile applications, not only in cosmetics but also in various home remedies (29). It benefits by functioning as a sunscreen and soothing agent, aiding in the fight against dandruff, and serving as a muscle relaxant (27).

## 4.5 Roots

Papaya roots offer various therapeutic uses in different parts of Asia. The juice extracted from papaya roots is employed to alleviate urinary troubles. Additionally, dried and cured papaya leaves, shaped like cigars, are smoked by individuals dealing with asthma. Fresh papaya leaves, when infused, are utilized to expel or eliminate intestinal worms. Furthermore, fresh young papayas are employed as a remedy for colic, a specific stomach disorder, or cramps.

In the treatment of dyspepsia, a decoction is prepared by boiling the outer part of the papaya tree's roots, highlighting another application for this versatile plant in promoting digestive health (27, 29).

## 4.6 Latex

The milky sap extracted from unripe papaya contains two significant enzymes, chymopapain and papain. Chymopapain, in particular, has received approval for intradiscal injection in individuals with confirmed herniated lumbar intervertebral discs who have not shown improvement with conventional treatment. The latex of the unripe papaya also contains vitamins and traces of an alkaloid called Carpaine. Additionally, the seeds of the fruit contain benzyl senevol, carbohydrate, carpasemine, and


glucoside. Papain, one of the enzymes found in latex, serves various purposes, including acting as a meat tenderizer, degumming natural silk, production of chewing gums, and for the treatment of commercial beer. Cosmetically, it is used in shampoos and certain face-lifting procedures. Interestingly, Carpaine, when consumed by humans, has a slowing effect on the heart, consequently reducing blood pressure (27).





## 5. PHYTOCHEMISTRY AND PHARMACOLOGICAL ACTIVITY OF *Carica papaya*


### 5.1 Phytochemical constituents of *Carica papaya*

*Carica papaya* is found to be rich in various phytochemicals and other compounds. The following table contains the list of phytochemicals in different parts of the papaya plant.

Table 2: Isolated compounds from the papaya plant

Plant part	Isolated compound/ phytochemicals
Leaves  (40)	<ol style="list-style-type: none"> <li>1. Alkaloids</li> <li>2. Anthraquinone</li> <li>3. Tannins</li> <li>4. Saponins</li> <li>5. Steroids</li> <li>6. Resins</li> <li>7. Flavonoids               <ul style="list-style-type: none"> <li>• Kaempferol</li> <li>• Kaempferol 3-(2G-Rhamnosylrutinoside)</li> <li>• Kaempferol 3-Rutinoside</li> <li>• Myricetin 3-Rhamnoside</li> <li>• Quercetin</li> <li>• Quercetin 3-Rutinoside</li> <li>• Quercetin3-(2G-Rham Nosylrutinoside)</li> </ul> </li> <li>8. Phenolic Compounds               <ul style="list-style-type: none"> <li>• Kaempferol</li> <li>• Protocatechuic Acid</li> <li>• Quercetin</li> <li>• 5,7-Dimethoxy Coumarin</li> <li>• Caffeic Acid</li> <li>• P-Coumaric Acid</li> <li>• Chlorogenic Acid</li> </ul> </li> <li>9. Minerals               <ul style="list-style-type: none"> <li>• Calcium</li> <li>• Ferrous</li> <li>• Magnesium</li> <li>• Potassium</li> <li>• Zinc</li> <li>• Manganese (41, 42, 43, 44).</li> </ul> </li> </ol>
Fruit	<ol style="list-style-type: none"> <li>1. Enzymes               <ul style="list-style-type: none"> <li>• Papain</li> <li>• Chymopapain</li> </ul> </li> <li>2. Other phytoconstituents               <ul style="list-style-type: none"> <li>• Carotenoids</li> <li>• Carotenoids – lycopene</li> <li>• Cryptoxanthin</li> <li>• Flavonoids-kaempferol</li> <li>• Myricetin</li> <li>• Quercetin</li> <li>• Violaxanthin</li> <li>• Zeaxanthin</li> <li>• <math>\beta</math> carotene (41, 45)</li> </ul> </li> </ol> <p>The identification of phytochemicals in the unripe fruit</p>

 <p>(40)</p>	<p>aqueous extract was conducted using the GC–MS technique, revealing the presence of fifteen components. Among the major phytochemical compounds identified were,</p> <ul style="list-style-type: none"> <li>• Hexadecenoic acid</li> <li>• Z-11</li> <li>• Methyl ester</li> <li>• Octadecanoic acid.</li> </ul> <p>Minor phytochemical compounds in the unripe fruit aqueous extract were detected within the concentration range of 0.78–5.38% (46).</p>
<p>Seeds</p>  <p>(40)</p>	<ul style="list-style-type: none"> <li>• Papaya oil, derived from the seeds, is known to contain various compounds, including flavonoids, kaempferol, and myricetin (41).</li> <li>• Benzyl glucosinolate and benzyl isothiocyanate have been identified in the seeds, pulp, and pericarp of the papaya (47, 48).</li> </ul> <p>Other phytochemicals</p> <ul style="list-style-type: none"> <li>• Oleic acid (49)</li> <li>• 1,2,3,4-tetrahydropyridin-3-yl-octanoate – An antifertility compound (50).</li> <li>• Fatty acid, amide, nitriles, sterol, fatty aldehydes, and organic acids (51).</li> </ul>
<p>Roots</p>  <p>(40)</p>	<ul style="list-style-type: none"> <li>• Benzyl isothiocyanate</li> <li>• Glucosinolatescarposide (41).</li> </ul>
<p>Latex</p>  <p>(40)</p>	<p>Enzymes</p> <ul style="list-style-type: none"> <li>• Caricain</li> <li>• Chitinase</li> <li>• Chymopapain</li> <li>• Cysteine endopeptidases</li> <li>• Glutaminy cyclase</li> <li>• Papain</li> <li>• Protease omega (52, 53)</li> </ul>

<p>Flowers</p>  <p>(40)</p>	<ul style="list-style-type: none"> <li>• 3-O-(6-O-tetradecanoyl-β-D-glucopyranosyl)-β-sitosterol</li> <li>• Benzyl β-D-glucopyranoside</li> <li>• Caffeic acid</li> <li>• Kaempferol 3-O-β-D-glucopyranoside</li> <li>• Kaempferol 3-O-α-L-arabinopyranoside</li> <li>• Kaempferol 3-O-α-L-rhamnopyranoside</li> <li>• Myricetin</li> <li>• Palmitic acid</li> <li>• Quercetin 3-O-β-D-galactopyranoside</li> <li>• Stigmast-4-ene-3-one</li> <li>• Trans-ferulic acid</li> <li>• Uracil</li> <li>• β-sitosterol 3-O-β-D-glucopyranoside (54, 55)</li> </ul>
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## 5.2 Pharmacological properties of *Carica papaya*

*Carica papaya* demonstrates remarkable efficacy in treating various ailments, attributed to the abundance of diverse phytoconstituents found in nearly all parts of the plant. Literature review that the plant shows the following pharmacological activities (56),

- Antibacterial activity
- Anticancer activity
- Anti-dengue activity
- Antidiarrheal responses
- Anti-inflammatory and immunomodulatory responses
- Anti-malarial activity
- Antioxidant activity
- Insecticidal and repellent responses
- Wound-healing activity

This review aims to investigate the traditional claim that *Carica papaya* leaf juice enhances platelet count with dengue fever and dengue haemorrhagic fever while highlighting the plant's remarkable ability to reduce dengue symptoms, and the severity of the disease, and potentially aid in the recovery process

## 6. *Carica papaya* AND DENGUE

### 6.1 Dengue fever

Dengue stands out as a prominent viral disease, emerging as a significant global public health threat in recent decades. It is commonly found in tropical and subtropical regions of the world, primarily within urban and suburban areas (57). The virus that causes dengue fever is a small structure that can only replicate within a host cell. Dengue viruses are members of the Flavivirus genus and the Flaviviridae family. Dengue infections occur by four closely related viruses (serotypes): (Dengue Virus-1, Dengue Virus-2, Dengue Virus-3, Dengue Virus-4), and are transmitted to people through the bite of an infected mosquito of the *Aedes* species (*Aedes aegypti* or *Aedes albopictus*). These four viruses are classified as serotypes because they interact differently with antibodies found in human blood. Every year, a maximum of 400 million individuals worldwide get infected with the dengue virus. and approximately 500,000 cases of dengue haemorrhagic fever require hospitalization (58), while 40,000 die from severe dengue. An individual can become infected with dengue on multiple occasions in their lifetime (59, 60). An infected individual can manifest symptoms in a healthy host within 5 to 7 days. The different serotypes allow for multiple infections in an individual. While each infection provides life-long immunity for the specific serotype, subsequent infections with a different serotype can facilitate the risk of developing the potentially fatal dengue haemorrhagic fever possibly due to antibody-dependent enhancement (61). It is currently unknown what specific mechanism the dengue

virus uses to cause low platelet counts. However, thrombocytopenia is thought to be caused by various processes that this virus mediates in the host system, as summarised below.

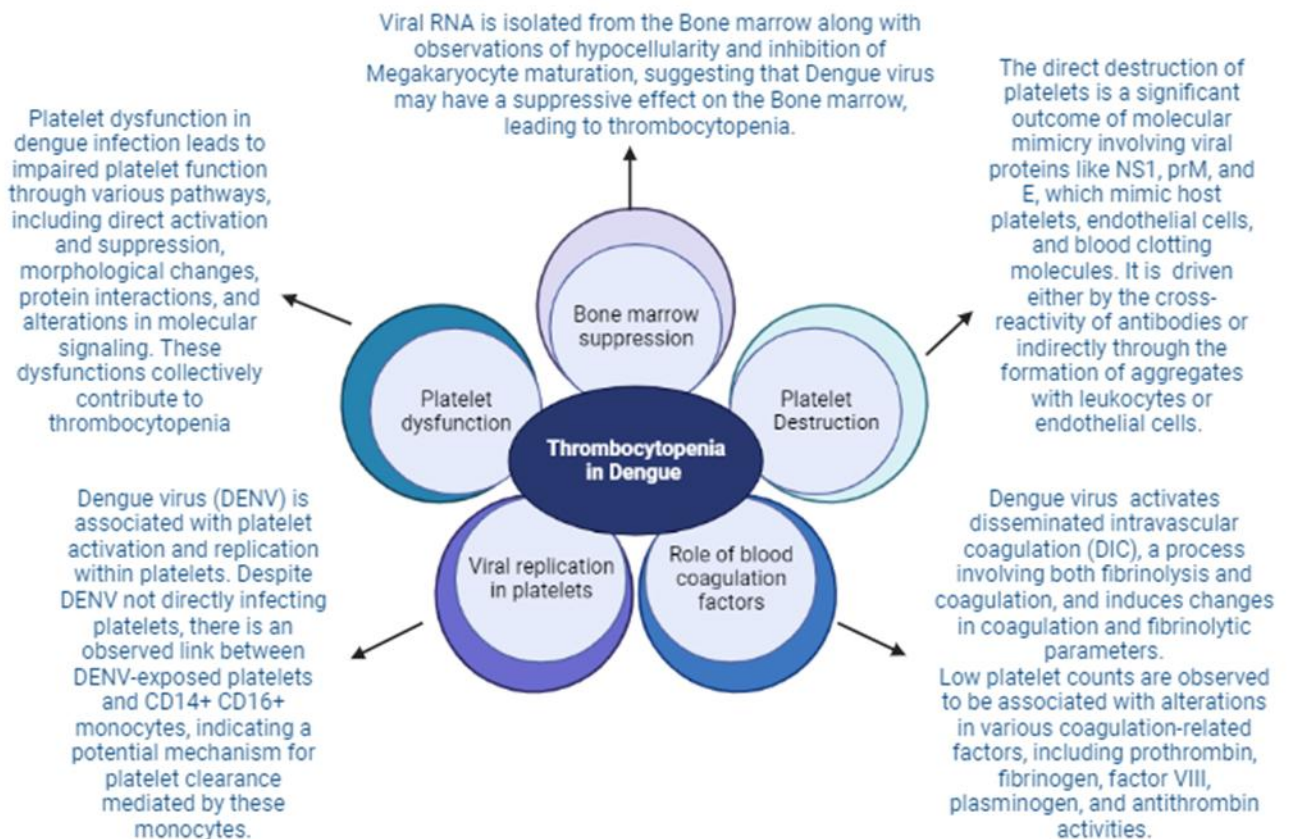


Figure 4: A summary of the development of thrombocytopenia in dengue due to the suppression of bone marrow, destruction and dysfunction of platelets, development of DIC, and viral replication in platelets: Adapted from, *Dengue Fever: Therapeutic Potential of Carica Papaya L. Leaves*. Sarker, Md.M.R., Khan, F. and Mohamed, I.N. (2021). *Frontiers in Pharmacology*, doi:[https://doi.org/10.3389/fphar.2021.610912\(62\)](https://doi.org/10.3389/fphar.2021.610912(62)).

A patient experiencing dengue fever typically presents with the classic dengue triad- fever, headache, and rash. Alongside these, various non-specific signs and symptoms associated with dengue fever (eye pain, nausea, severe joint and muscle pain, and vomiting), and the conditions can progress into dengue haemorrhagic fever, marked by abdominal pain, bleeding, and potential circulatory collapse. The clinical trajectory of dengue unfolds in three distinct phases: the febrile phase, the critical phase, and the recovery phase. The critical phase is characterized by detectable thrombocytopenia, where the platelet count drops below  $100,000/\text{mm}^3$  from the baseline, and haemoconcentration, identified with a 20% or more elevation in the haematocrit. These clinical manifestations occur before the resolution of fever and the onset of a potential shock (63).

Although the disease itself rarely results in death, dengue fever can cause severe pain and weakness and has the potential to spread throughout a population if a new serotype is introduced. Generally, it's self-healing, and only supportive care is needed. Symptomatic fever in patients may be addressed with acetaminophen, while caution is advised against the use of aspirin, brufen, (non-steroidal anti-inflammatory drugs) NSAIDs, antibiotics, and corticosteroids as they not only proven ineffective but may also lead to gastritis and/or bleeding. For those with confirmed or suspected dengue fever, it is crucial to monitor their platelet count a hematocrit daily from the 3<sup>rd</sup> day of illness till 1-2 days after the fever subsides. Even though there are promising tetravalent vaccines in clinical trials, unfortunately,

they are not readily available throughout the world. Therefore, the primary method to prevent getting the disease is to avoid vector bites (57, 58, 64, 65).

## 6.2 Local Prevalence of Dengue Fever.

Dengue fever and most severe Dengue Hemorrhagic fever (DHF) became nationwide reported illnesses in Sri Lanka in 1996, and information before that was based on outbreak reporting. During the early 2000s, the magnitude of Dengue fever and Dengue Hemorrhagic fever (DHF) epidemics in Sri Lanka increased, with two of the largest epidemics occurring in 2002 and 2004, with 8931 cases (incidence of 47 per 100,000 population) and 15463 cases (incidence of 77 per 100,000 population) reported to the national Epidemiological Unit, respectively. Currently, nearly all districts in the country have reported cases. The western province's Colombo, Gampaha, and Kalutara districts had the highest case rate, particularly during the epidemic year (66, 67).

## 6.3 MECHANISM OF ACTION BEHIND THE ANTI-DENGUE ACTIVITY OF *Carica papaya*.

Safety studies, conducted following Organisation for Economic Co-operation and Development (OECD) guidelines for acute, subacute, and chronic toxicity, have demonstrated that the extracts from *Carica papaya* are safe for human consumption (68).

Specific genes play a role in influencing both the production and aggregation of platelets. Notably, the Arachidonic Acid 12-lipoxygenase (ALOX 12), also recognized as the Platelet-type Lipoxygenase, and the Platelet-Activating Factor Receptor (PTAFR) are implicated in these processes. Increased activity in these genes is essential for both the production and activation of platelets. The ALOX 12 gene is prominently expressed in megakaryocytes (haematological progenitor cells of platelets) and is responsible for the production of 12-Hydroxyeicosatetraenoic acid (12-HETE) in platelets. On the other hand, the PTAFR gene, expressed in megakaryocytes, serves a dual role as a precursor for platelet production and in the well-established function of platelet aggregation (69, 70).

A study was conducted in Malaysia, in 2013 aiming to assess the potential of *Carica papaya* leaf juice in elevating platelet levels among patients diagnosed with dengue fever. An open-label randomized controlled trial was conducted, involving 228 participants diagnosed with dengue fever and dengue haemorrhagic fever. The participants were divided into two groups, with approximately half receiving *Carica papaya* leaf juice for three consecutive days, while the control group underwent standard management. Full blood count monitoring occurred every 8 hours over 48 hours. Gene expression studies focused on ALOX 12 and PTAFR genes. Using repeated measure ANCOVA, the study found a significant increase in mean platelet count in the intervention group ( $P < 0.001$ ), particularly 40 hours after the first dose of *Carica papaya* leaf juice, compared to the control group. Further analysis revealed a significantly higher mean platelet count in the intervention group compared to the control group after 40 and 48 hours of admission ( $P < 0.01$ ). The expression of ALOX 12 and PTAFR genes was notably higher in individuals receiving *Carica papaya* leaf juice. This study concludes that *Carica papaya* leaf juice significantly increases platelet counts in patients with dengue fever and dengue haemorrhagic fever. The observed rise in platelet levels, coupled with the increased expression of ALOX 12 and PTAFR genes, suggests a potential therapeutic benefit of *Carica papaya* leaf juice in managing dengue-related thrombocytopenia (71).

A study was conducted on a 45-year-old patient with dengue to observe the potency of *Carica papaya* leaf juice in curing the disease. The patient was administered with 25ml of leaf juice twice a day, for five days. A blood sample was analyzed and compared both before and after administering the leaf juice. The study reveals that the Platelet count (PLT), WBC count, and neutrophil count increased (PLT from  $55 \times 10^3/\mu\text{L}$  to  $168 \times 10^3/\mu\text{L}$ , WBC from  $3.7 \times 10^3/\mu\text{L}$  to  $7.7 \times 10^3/\mu\text{L}$ , and neutrophils from 46.0% to 78.3%) after the administration of *Carica papaya* leaf juice. Concerning the study results, the study concludes that *Carica papaya* leaf juice exhibits significant potency in curing dengue (16).

## 7. CONCLUSION

The literature suggests that *Carica papaya* Linn. leaf extract has high potency in treating dengue patients by increasing platelet counts and neutrophil counts thereby reducing mortality. Further

research is needed to isolate useful phytochemicals and evaluate other medicinal and pharmacological properties of this valuable species.

## REFERENCES

1. Ratnasooriya R, Ranaweera WD, Abeysekara CB, Pathirana WPKM. In vitro, antioxidant activity of methanolic extracts of leaves of *Indigofera indica* and stem bark of *Stereospermumsuaveolens* grown in Sri Lanka. *International Journal of Institutional Pharmacy and Life Sciences*. 2015;5:128–138.
2. Ranaweera C, Abeysekara W, Pathirana R, Ratnasooriya W. Lack of in vitro anti hyaluronidase activity of methanolic leaf extract of *Indigofera tinctoria* L and methanolic stem bark extract of *Stereospermumsuaveolens* DC. *Journal of Pharmaceutical Negative Results*. 2015;6: 40.
3. Silva ARN, Ranaweera CB, Karunathilaka RDN, Pathirana R, Ratnasooriya WD. Antibacterial activity of water extracts of different parts of *Morindacitrifolia* grown in Sri Lanka. *International Journal of Scientific and Research Publication*. 2016; 6:124–27.
4. Ranaweera CB, Chandana AK. *Clitoriaternatea* - Shifting paradigms: From laboratory to industry. *South Asian Journal of Research in Microbiology*. 2021;11:18– 26.
5. Ranaweera CB, Vidanagamage AS, Abeysekara WPK, Silva ARN, Chandana AK, Premakumara S, et al. In vitro effects of aqueous extracts of five Sri Lankan medicinal plants on human erythrocyte membrane stabilization activity. *International Journal of Recent Advances in Multidisciplinary Research*. 2015;2: 486- 89.
6. Samaraweera TU, Samaraweera TU, Senadeera SPNN, Ranaweera CB. Rich diversity & potential medicinal value of endemic Sri Lankan plant: *Jeffreyciazeylanica*. *Asian Plant Research Journal*. 2022;10:21–34. DOI: [https://doi.org/10.9734/aprj/2022/v10i4\\_197](https://doi.org/10.9734/aprj/2022/v10i4_197)
7. Samaraweera T, Samaraweera T, Senadeera N, Ranaweera CB. Evaluation of Antibacterial Activity of Endemic *Jeffreyciazeylanica* Plant Found in Sri Lanka. *South Asian Journal of Research in Microbiology*. 2023;16(1):1–9.
8. Peiris DSHS, Fernando DTK, Senadeera SPNN, Chandana AK, Ranaweera CB. *Mirabilis jalapa* Linn: A folklore ayurvedic medicinal plant in Sri Lanka. *Asian Plant Research Journal*. 2022;10:21–41. DOI: 10.9734/aprj/2022/v10i2187.
9. Peiris DSHS, Fernando DTK, Senadeera SPNN, Ranaweera C.B. Phytochemical screening for medicinal plants: Guide for extraction methods. *Asian Plant Research Journal*. 2023;11:13–34. Available:<https://doi.org/10.9734/aprj/2023/v11i4216>.
10. Fernando DTK, Peiris DSHS, Senadeera SPNN, Chandana AK, Ranaweera CB. Evaluation of in Vitro Anti-Inflammatory and Antibacterial Properties of Tuberous Roots of *Mirabilis jalapa* L. Found in Sri Lanka. *Asian Journal of Research in Botany*. 2023;6(2):192–214.
11. Peiris, D., Fernando, D., Senadeera, S.P.N.N. and Ranaweera, C.B. (2023). A Comprehensive Review of *Salacia reticulata*: Botanical, Ethnomedicinal, Phytochemical, and Pharmacological Insights. *Asian Plant Research Journal*, 11(6), pp.27–43. doi:<https://doi.org/10.9734/aprj/2023/v11i6228>.
12. Samaraweera, T., Samaraweera, T., Senadeera, N. and Ranaweera, C.B. (2023). In Vitro Anti-Inflammatory Activity of Leaves of *Jeffreyciazeylanica* Using the Egg Albumin Denaturation Method and Human Red Blood Cell Stabilization Method. *Asian Plant Research Journal*, 11(6), pp.56–64. doi:<https://doi.org/10.9734/aprj/2023/v11i6230>.
13. Abeysinghe, S., Kumari, W.G.S.M., Arachchi, I.M.M. and Dickinson, M. (2014). First report of the molecular identification of a phytoplasma associated with dieback disease of papaya in Sri Lanka. *New Disease Reports*, 29, p.13. doi:<https://doi.org/10.5197/j.2044-0588.2014.029.013>.
14. Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009). *Carica papaya*: World Agroforestry Centre, Kenya | Feedipedia. [online] Feedipedia.org. Available at: <https://www.feedipedia.org/node/1650>.
15. Dengue: Practice Essentials, Background, Pathophysiology. (2023). eMedicine. [online] Available at: <https://emedicine.medscape.com/article/215840-overview?form=fpf>.

16. Ahmad, N., Fazal, H., Ayaz, M., Abbasi, B.H., Mohammad, I. and Fazal, L. (2011). Dengue fever treatment with *Carica papaya* leaf extracts. *Asian Pacific Journal of Tropical Biomedicine*, [online] 1(4), pp.330–333. doi:[https://doi.org/10.1016/s2221-1691\(11\)60055-5](https://doi.org/10.1016/s2221-1691(11)60055-5).
17. USDA, NRCS. 2024. The PLANTS Database (<http://plants.usda.gov>, 01/06/2024). National Plant Data Team, Greensboro, NC USA.
18. Koul, B., Pudhuvai, B., Sharma, C., Kumar, A., Sharma, V., Yadav, D. and Jin, J.-O. (2022). *Carica Papaya* L.: a Tropical Fruit with Benefits beyond the Tropics. *Diversity*, 14(8), p.683. doi:<https://doi.org/10.3390/d14080683>.
19. Silva, J.d.; Rashid, Z.; Nhut, D.T.; Sivakumar, D.; Gera, A.; Souza, M.T.; Tennant, P. *Papaya (Carica papaya L.) Biology and biotechnology*. *Tree For. Sci. Biotechnol.* 2007, 1, 47–73.
20. Chen, L.-F.; Bau, H.-J.; Yeh, S.-D. Identification of Viruses Capable of Breaking Transgenic Resistance of Papaya Conferred by the Coat Protein Gene of Papaya Ringspot Virus. *Acta Hort.* 2002, 575, 465–474. [CrossRef]
21. Morton, J.F.D.C.F. *Fruits of Warm Climates*; Morton, J.F., Ed.; Distributed by Creative Resources Systems: Miami, FL, USA; Winterville, NC, USA, 1987.
22. Indies Gallery (2022). *Papaya Fruit Plant 'Carica Papaya' Antique Prints*, Indies Gallery Collection. | Fruit plants, Papaya tree, Papaya fruits. [online] Pinterest. Available at: <https://in.pinterest.com/pin/933652566472462612/> [Accessed 7 Jan. 2024].
23. Karunamoorthi, K.; Kim, H.-M.; Jegajeevanram, K.; Xavier, J.; Vijayalakshmi, J. *Papaya: A gifted nutraceutical plant—A critical review of recent human health research*. *Cellmed* 2014, 4, 2.1–2.17. [CrossRef]
24. Saeed, F.; Arshad, M.U.; Pasha, I.; Naz, R.; Batool, R.; Khan, A.A.; Nasir, M.A.; Shafique, B. Nutritional and phyto-therapeutic potential of papaya (*Carica papaya* Linn.): An overview. *Int. J. Food Prop.* 2014, 17, 1637–1653. [CrossRef]
25. Alara, O.R.; Abdurahman, N.H.; Alara, J.A. *Carica papaya: Comprehensive overview of the nutritional values, phytochemicals, and pharmacological activities*. *Adv. Tradit. Med.* 2020, 22, 1–31. [CrossRef]
26. USDA National Nutrient Database for standard references, release 18 (2005). Available online: <http://www.nal.usda.gov/fnic/foodcomp/search/>
27. Aravind, G., Debjit, B., Duraivel, S. and Harish, G. (2013). Traditional and Medicinal Uses of *Carica papaya*. *Journal of Medicinal Plants Studies*, [online] 1(1), pp.7–15. Available at: [www.plantsjournal.com](http://www.plantsjournal.com) [Accessed 10 Jan. 2024].
28. Baskaran, C., bai, V.R., Velu, S. and Kumaran, K. (2012). The efficacy of *Carica papaya* leaf extract on some bacterial and a fungal strain by well diffusion method. *Asian Pacific Journal of Tropical Disease*, 2, pp.S658–S662. doi:[https://doi.org/10.1016/s2222-1808\(12\)60239-4](https://doi.org/10.1016/s2222-1808(12)60239-4).
29. *The Biology and Ecology of Papaya (paw paw), Carica papaya L., in Australia*. (2003).
30. Da Silva, J., Rashid, Z., Nhut, D., Sivakumar, D., Gera, A., Souza, M. and Tennant, P. (2007). *Papaya (Carica Papaya L.) Biology and Biotechnology*. *Tree and Forestry Science and Biotechnology*, 1(1), pp.48–66.
31. NS Anuar, SS Zahari, IA Taib, MT Rahman, Effect of green and ripe *Carica papaya* epicarp extracts on wound healing and during pregnancy, *Food Chem. Toxicol.* 46 (2008) 2384–2389, doi:10.1016/j.fct.2008.03.025.
32. Nguyen, T.T., Parat, M.-O., Shaw, P.N., Hewavitharana, A.K. and Hodson, M.P. (2016). Traditional Aboriginal Preparation Alters the Chemical Profile of *Carica papaya* Leaves and Impacts on Cytotoxicity towards Human Squamous Cell Carcinoma. *PLOS ONE*, 11(2), p.e0147956. doi:<https://doi.org/10.1371/journal.pone.0147956>.
33. AB Nafiu, MT Rahman, Anti-inflammatory and antioxidant properties of unripe papaya extract in an excision wound model, *Pharm. Biol.* 53 (5) (2015) 662–671, doi:10.3109/13880209.2014.936470
34. O Okpe, N Habila, J Ikwebe, VA Upev, SI Okoduwa, OT Isaac, Antimalarial potential of *Carica papaya* and *Vernonia amygdalina* in mice infected with plasmodium berghei, *J. Trop. Med.* 2016 (2016) 8738972, doi:10.1155/2016/8738972

35. N Otsuki, NH Dang, E Kumagai, A Kondo, S Iwata, C Morimoto, Aqueous extract of *Carica papaya* leaves exhibits anti-tumor activity and immunomodulatory effects, *J. Ethnopharmacol.* 127 (3) (2010) 760–767, doi:10.1016/j.jep.2009.11.024.
36. Tarkang, P.A., Okalebo, F.A., Siminyu, J.D., Ngugi, W.N., Mwaura, A.M., Mugweru, J., Agbor, G.A. and Guantai, A.N., 2015. Pharmacological evidence for the folk use of Nefang: antipyretic, anti-inflammatory and antinociceptive activities of its constituent plants. *BMC Complementary and Alternative Medicine*, 15(1), pp.1-11.
37. R Zhang, J Lv, J Yu, H Xiong, P Chen, H Cao, JJJ Martin, Antioxidant analysis of different parts of several cultivars of papaya (*Carica papaya* L.), *Int. J. Fruit Sci.* 22 (1) (2022) 438–452, doi:10.1080/15538362.2022.2047138.
38. SP Singh, S Kumar, SV Mathan, MS Tomar, RK Singh, PK Verma, A Kumar, S Kumar, RP Singh, A Acharya, Therapeutic application of *Carica papaya* leaf extract in the management of human diseases, *Daru* 28 (2) (2020) 735–744, doi:10.1007/s40199-020-00348-7.
39. Udoh P, Essien I, Udoh F. Effect of *Carica papaya* (paw paw) seeds extract on the morphology of pituitary-gonadal axis of male Wistar rats. *Phytother Res.* 2005;19:1065–8.
40. www.missouribotanicalgarden.org. (2020). *Carica papaya* - Plant Finder. [online] Available at: <https://www.missouribotanicalgarden.org/PlantFinder/PlantFinderDetails.aspx?kempercode=d374#AllImages> [Accessed 14 Jan. 2024].
41. Adachukwu, I., Ogbonna, A., Faith, E., 2013. Phytochemical analysis of paw-paw (*Carica papaya*) leaves. *Int. J. Life Sci. Biotechnol. Pharma Res.* 2, 347–351.
42. Nugroho, A., Heryani, H., Choi, J.S., Park, H.J., 2017. Identification and quantification of flavonoids in *Carica papaya* leaf and peroxynitrite-scavenging activity. *Asian Pac. J. Trop. Biomed.* 7, 208–213. <https://doi.org/10.1016/j.apjtb.2016.12.009>.
43. Canini, A., Alesiani, D., D'Arcangelo, G., Tagliatesta, P., 2007. Gas chromatography-mass spectrometry analysis of phenolic compounds from *Carica papaya* L. leaf. *J. Food Compos. Anal.* 20, 584–590. <https://doi.org/10.1016/j.jfca.2007.03.009>.
44. Musa, Y.M., 2015. Isolation and purification of flavonoids from the leaves of locally produced *Carica papaya*. *Int. J. Sci. Technol. Res.* 4, 282–284.
45. Chandrika, U.G., Jansz, E.R., Wickramasinghe, S.M.D.N., Warnasuriya, N.D., 2003. Carotenoids in yellow- and red-fleshed papaya (*Carica papaya* L.). *J. Sci. Food Agric.* 83, 1279–1282. <https://doi.org/10.1002/jsfa.1533>.
46. Ezekwe, S.A., Chikezie, P.C., 2017. GC–MS analysis of aqueous extract of unripe fruit of *Carica papaya*. *J. Nutr. Food Sci.* 07, 3–7. <https://doi.org/10.4172/2155-9600.1000602>.
47. Nakamura, Y., Yoshimoto, M., Murata, Y., Shimoishi, Y., Asai, Y., Eun, Y.P., Sato, K., Nakamura, Y., 2007. Papaya seed represents a rich source of biologically active isothiocyanate. *J. Agric. Food Chem.* 55, 4407–4413. <https://doi.org/10.1021/jf070159w>.
48. Rossetto, M.R.M., Oliveria Do Nascimento, J.R., Purgatto, E., Fabi, J.P., Lajolo, F.M, Cordenunsi, B.R., 2008. Benzylglucosinolate, benzylisothiocyanate, and myrosinase activity in papaya fruit during development and ripening. *J. Agric. Food Chem.* 56, 9592–9599.
49. Ghosh, S., Saha, M., Bandyopadhyay, P.K., Jana, M., 2017. Extraction, isolation and characterization of bioactive compounds from chloroform extract of *Carica papaya* seed and its in vivo antibacterial potentiality in *Channa punctatus* against *Klebsiella* PKBSG14. *Microb. Pathog.* 111, 508–518. <https://doi.org/10.1016/j.micpath.2017.08.033>.
50. Julaehe, E., Permatasari, Y., Mayanti, T., Diantini, A., 2015. Antifertility compound from the seeds of *Carica papaya*. *Procedia Chem.* 17, 66–69. <https://doi.org/10.1016/j.proche.2015.12.135>.
51. Sani, M.S.A., Bakar, J., Rahman, R.A., Abas, F., 2020. Effects of coated capillary column, derivatization, and temperature programming on the identification of *Carica papaya* seed extract composition using GC/MS analysis. *J. Anal. Test.* 4, 23–34. <https://doi.org/10.1007/s41664-020-00118-z>.
52. Azarkan, M., El Moussaoui, A., Van Wuytswinkel, D., Dehon, G., Looze, Y., 2003. Fractionation and purification of the enzymes stored in the latex of *Carica papaya*. *J. Chromatogr. B Anal. Technol. Biomed. Life Sci.* 790, 229–238. [https://doi.org/10.1016/S1570-0232\(03\)00084-9](https://doi.org/10.1016/S1570-0232(03)00084-9).
53. Azarkan, M., Garcia-Pino, A., Dibiani, R., Wyns, L., Loris, R., Baeyens-Volant, D., 2006. Crystallization and preliminary x-ray analysis of a protease inhibitor from the latex of *Carica*

- papaya. *Acta Crystallogr. Sect. F Struct. Biol. Cryst. Commun.* 62, 1239–1242.  
<https://doi.org/10.1107/S1744309106046367>.
54. Van, D.T.T., Cuong, D.H., Lien, G.T.K., Yen, P.H., 2020. Phytochemical study of the ethyl acetate extract of male *Carica papaya* flowers from Quang Nam - Da Nang. *Vietnam J. Chem.* 58, 145–150. <https://doi.org/10.1002/vjch.201900029>.
  55. Nga, V.T., Trang, N.T.H., Tuyet, N.T.A., Phung, N.K.P., Duong, N.T.T., Thu, N.T.H., 2020. Ethanol extract of male *Carica papaya* flowers demonstrated non-toxic against MCF-7, HEP-G2, HELA, NCI-H460 cancer cell lines. *Vietnam J. Chem.* 58, 86–91.  
<https://doi.org/10.1002/vjch.2019000142>.
  56. Ugbogu, E.A., Dike, E.D., Uche, M.E., Etumnu, L.R., Okoro, B.C., Ugbogu, O.C., Oluwapelumi, A.E., Chinma, C.E., Ohaeri, E. and Iweala, E.J. (2023). Ethnomedicinal Uses, Nutritional Composition, Phytochemistry and Potential Health Benefits of *Carica papaya*. *Pharmacological Research - Modern Chinese Medicine*, 7, pp.100266–100266.  
doi:<https://doi.org/10.1016/j.prmcm.2023.100266>.
  57. Akram W, Khan HAA, Hafeez F, Bilal H, Kim YK, Lee JJ. The potential of citrus seed extracts against Dengue fever mosquito, *Aedes albopictus* (Skuse) (Culicidae). *Pak J Bot* 2010; 42: 3343-3348.
  58. Maheswaran R, Satish S, Ignacimuthu S. Larvicidal activity of *Leucas asper* (Willd) against the larvae of *Culex quinquefasciatus* Say. and *Aedes aegypti* L. *Inter J Integrative Biol* 2008; 2: 214-217.
  59. Centers for Disease Control and Prevention (2020). Dengue | CDC. [online] [www.cdc.gov](http://www.cdc.gov). Available at:  
<https://www.cdc.gov/dengue/index.html#:~:text=Dengue%20viruses%20are%20spread%20to>.
  60. Nature Education (2011). Dengue Viruses | Learn Science at Scitable. [online] [Nature.com](http://Nature.com). Available at: <https://www.nature.com/scitable/topicpage/dengue-viruses-22400925/>
  61. Morens, Fauci, Brody JE. Mosquito thrives; so does dengue fever. Geneva: WHO; 2008.
  62. Sarker, Md.M.R., Khan, F. and Mohamed, I.N. (2021). Dengue Fever: Therapeutic Potential of *Carica Papaya* L. Leaves. *Frontiers in Pharmacology*, [online] 12. doi:<https://doi.org/10.3389/fphar.2021.610912>.
  63. World Health Organization. Clinical diagnosis, 16, 2011.
  64. Murthy JM, Rani PU. Biological activity of certain botanical extracts as larvicides against the yellow fever mosquito, *Aedes aegypti* L. *J Biopest* 2009; 2: 72-76.
  65. Moreno-Sanchez R, Hayden M, Janes C. A web-based multimedia spatial information system to document *Aedes aegypti* breeding sites and dengue fever risk along the US-Mexico border. *Health & Place* 2006; 12: 715-727.
  66. [www.epid.gov.lk](http://www.epid.gov.lk). (2022). - Epidemiology Unit. [online] Available at: <https://www.epid.gov.lk/dengue-could-be-a-silent-killer>.
  67. [www.dengue.health.gov.lk](http://www.dengue.health.gov.lk). (2022). NDCU - Sri Lanka Situation. [online] Available at: <https://www.dengue.health.gov.lk/web/index.php/en/information/sri-lanka-situation>.
  68. S. Z. Halim, N. R. Abdullah, Z. Afzan, B. A. Abdul Rashid, I. Jantan, and Z. Ismail, "Acute toxicity of *Carica papaya* leaf extract in Sprague Dawley rats," *Journal of Medicinal Plants Research*, vol. 5, no. 10, pp. 1867–1872, 2011.
  69. G. Kaur, G. Jalagadugula, G. Mao, and A. K. Rao, "RUNX1/core binding factor A2 regulates platelet 12-lipoxygenase gene (ALOX12): studies in human RUNX1 haplodeficiency," *Blood*, vol. 115, no. 15, pp. 3128–3135, 2010.
  70. I. C. Macaulay, M. R. Tijssen, D. C. Thijssen-Timmer et al., "Comparative gene expression profiling of in vitro differentiated megakaryocytes and erythroblasts identifies novel activatory and inhibitory platelet membrane proteins," *Blood*, vol. 109, no. 8, pp. 3260–3269, 2007.
  71. Subenthiran, S., Choon, T.C., Cheong, K.C., Thayan, R., Teck, M.B., Muniandy, P.K., Afzan, A., Abdullah, N.R. and Ismail, Z. (2013). *Carica papaya* leaves Juice Significantly Accelerates the Rate of Increase in Platelet Count among Patients with Dengue Fever and Dengue Haemorrhagic Fever. *Evidence-Based Complementary and Alternative Medicine*, 2013, pp.1–7. doi:<https://doi.org/10.1155/2013/616737>.

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