**PHYTOCHEMICAL AND ANTIBACTERIAL ACTIVITY OF METHANOL ROOT EXTRACT OF *Carica-papaya* (paw paw)**

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**AUGSUT, 2025**

# TITLE PAGE

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**A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF PHARMACEUTICAL TECHNOLOGY, SCHOOL OF SCIENCE AND TECHNOLOGY, FEDERAL POLYTECHNIC, MUBI, ADAMAWA STATE.**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF NATIONAL DIPLOMA (ND) IN PHARMACEUTICAL TECHNOLOGY.**

**AUGUST, 2025**

# DECLARATION

We hereby declare that this work titled “Phytochemical and Antibacterial Activity of Methanol Root Extract of *Carica-Papaya* (paw paw)”. As a result of research effort and findings and to the best of our knowledge and belief that this work has never been submitted to any institution for the award of any certificate and various sources used has been duly acknowledged by the use of referencing.

…………..…………..... ……..………….....

ADI ROSEMARY UGIONGWUYE Date

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# CERTIFICATION

This project entitled “Phytochemical and Antibacterial Activity of Methanol Root Extract of *Carica-Papaya* (paw paw)” meets the regulation governing the award of National Diploma in Pharmaceutical Technology of the Federal Polytechnic, Mubi and is approved for its contribution to knowledge and literary presentation.

…………..…………..... ……..………….....

**Mr. Richard Elisha**  Date

(Project Supervisor)

…………..…………..... ……..………….....

**Dr. Mahmud Mohammed Tanko** Date

(Head of Department)

…………..…………..... ……..………….....

(External Examiner) Date

# DEDICATION

We dedicated this research work to God almighty for his infinite love and mercy upon us and also for giving us sound knowledge, wisdom and better understanding to successfully write this piece of project and to him be all the glory and honor.

# ACKNOWLEDGEMENTS

We want to acknowledge Almighty God for his infinite mercy and protection throughout our academic activities. And for the understanding in achieving our academic success.

We also recognize our Supervisor Mr. Richard Elisha who took time, despite his busy schedule to direct and guide us throughout this research work.

We also acknowledge the Head of Department Pharmaceutical Technology Dr. Mahmud Mohammed Tanko for his moral encouragement throughout our period of study.

We also acknowledge all Staff of Pharmaceutical Technology Department for their support and encouragement and the knowledge they’ve impacted on us throughout our studies.

We also want to appreciate our parents for their love and care and for giving us the opportunity to be trained and achieve our dreams.

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# ****ABSTRACT****

*Carica papaya (pawpaw) is a medicinal plant widely recognized for its diverse therapeutic properties, including antimicrobial activity. This study investigated the phytochemical composition and antibacterial activity of methanolic and aqueous root extracts of Carica papaya. Roots were collected, air-dried, pulverized, and extracted using methanol and water. Qualitative phytochemical screening revealed the presence of alkaloids, flavonoids, steroids, glycosides, saponins, and terpenoids in both extracts, while phenolics and tannins were absent. Antibacterial activity was evaluated using the agar well diffusion method against Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa. Both extracts demonstrated broad-spectrum antibacterial activity, with inhibition zones ranging from 20 mm to 30 mm. The methanolic extract exhibited higher potency against E. coli (27 mm) and P. aeruginosa (30 mm), whereas the aqueous extract was more effective against S. aureus (30 mm). These variations suggest that solvent polarity influences the extraction and antibacterial efficacy of bioactive compounds. The findings highlight the potential of C. papaya root extracts as natural antimicrobial agents and provide a basis for further studies on their active constituents and possible pharmaceutical applications.*

# CHAPTER ONE

# INTRODUCTION

## 1.1 Background of the study

Plants have been a valuable source of medicine for centuries, and their use in traditional medicine is well-documented across many cultures. Among these, *Carica papaya* (commonly known as pawpaw), a member of the Caricaceae family, has drawn considerable attention due to its diverse pharmacological properties. Originally native to tropical America, *Carica papaya* is now widely cultivated in many parts of the world, including Africa, Asia, and the Caribbean (Akinmoladun *et al.,* 2021).

Papaya (*Carica papaya*) is a major cultivated plant in Nigeria and this plant has a great economical value. According to several previous researches, the papaya seed which is used to be treated as waste, has several great benefits for health. All of parts of papaya tree, from root, leaf, flower, fruit to the seed have great medical values. Traditionally, papaya seed can be used for treatment against roundworm (*Ascaris lumbricoides*), indigestion, diarrhea, skin disease, colds, men contraception and this seed can also be used as oil source containing certain amount of fatty acids**.** Traditionally, different parts of the pawpaw plant—including leaves, seeds, fruits, and roots have been employed in the treatment of various ailments, such as malaria, typhoid, diabetes, and bacterial infections (Onwuka *et al.,* 2023). In particular, the root of *Carica papaya* has been reported to possess antimicrobial, anti-inflammatory, and antioxidant properties, which are largely attributed to its rich phytochemical constituents, including alkaloids, flavonoids, tannins, and saponins (Ismail *et al.,* 2022).

The emergence of multidrug-resistant microorganisms has created an urgent need for the development of new and effective antimicrobial agents. As synthetic antibiotics become less effective due to resistance, natural products—especially those derived from medicinal plants—offer a promising alternative (Ahmed *et al.,* 2020). In this context, the methanolic extract of *Carica papaya* root represents a potential natural therapeutic agent.

Phytochemical analysis helps to identify the bioactive compounds that are responsible for the plant's therapeutic effects, while antibacterial assays determine the efficacy of these compounds against specific pathogenic microorganisms. Previous studies have highlighted that methanol, as a polar solvent, is highly effective in extracting these bioactive phytochemicals (Chinonso & Okezie, 2021). Therefore, investigating the phytochemical and antibacterial activity of the methanol root extract of *Carica papaya* is both timely and essential.

Medicinal plants not only considered as a readily available and affordable source, but they are also able to synthesize diverse active compounds which are effective in controlling and treating many diseases. These active compounds are known as secondary metabolites, such as phenols, tannins, alkaloids, flavonoids, glycosides, saponins and carbohydrates. Medical uses of plants range from extraction and decoction of leaf, bark, root, flower, seeds and stem portion of the plant. *Carica papaya* (CP) is one of the medicinal plants that contributed as a remedy against a variety of diseases. Papaya, papaw or pawpaw belongs to the *Caricaceae* family and is scientifically known as *Carica papaya*. *Carica* *papaya* is a tropical fruit which is one of the major fruit crops cultivated in tropical and sub-tropical zones due to its tasty and juicy flesh, other than that, the increment in demand is because of the high medicinal and nutritive value possessed by papaya fruit ([Subenthiran](https://www.researchgate.net/publication/236676224_Carica_papaya_Leaves_Juice_Significantly_Accelerates_the_Rate_of_Increase_in_Platelet_Count_among_Patients_with_Dengue_Fever_and_Dengue_Haemorrhagic_Fever) *et al.,* 2023).

## 1.2 Statement of the problem

The global increase in bacterial infections and the growing resistance to conventional antibiotics have become a significant public health concern. In Nigeria and many other developing countries, access to affordable and effective antibiotics is limited, prompting a reliance on herbal remedies. Despite the extensive traditional use of Carica papaya, there is limited scientific data validating the antibacterial potency of its root, especially using methanol extracts. This research aims to bridge that gap by identifying and evaluating the phytochemicals and antibacterial efficacy of methanol root extract of Carica papaya.

## 1.3 Aim and Objectives of the study

## 1.3.1 Aim

The aim of this study is to determine the phytochemical and Antibacterial activity of methanol roots extract of *Carica papaya*.

## 1.3.2 Objectives

1. To investigate and screen the methanolic root extracts of *Carica papaya* for its antibacterial activity.
2. To determine the phytochemical activity of *Carica papaya* against some organisms.

## 1.4 Significance of the study

This study is of considerable importance in both the scientific and public health domains. In recent years, there has been a growing global concern over the rapid emergence and spread of antibiotic-resistant bacterial strains, which have rendered many conventional antibiotics less effective or entirely obsolete. As a result, the search for alternative and complementary therapeutic options has intensified, especially those derived from natural sources. Medicinal plants such as *Carica papaya* offer a promising avenue for the development of novel, plant-based antimicrobial agents.

The root of *Carica papaya*, although widely used in traditional medicine across various cultures, has not been extensively studied using standardized scientific methods—particularly in terms of its phytochemical content and antibacterial potential. By scientifically analyzing the methanol extract of *Carica papaya* root, this research aims to uncover the bioactive compounds responsible for its medicinal properties and determine its efficacy in inhibiting or eliminating pathogenic bacteria.

The findings from this study could contribute significantly to the body of knowledge on herbal medicine and may serve as a foundation for developing affordable, safe, and effective herbal formulations for the treatment of bacterial infections. This is particularly relevant in resource-limited settings such as rural communities in Nigeria and other parts of Africa, where access to modern healthcare and antibiotics is often limited by cost, availability, or infrastructure.

# CHAPTER TWO

# LITERATURE REVIEW

### ****2.1 Botanical Description of**** Carica papaya

Carica papaya L., commonly known as pawpaw or papaya, is a tropical fruit-bearing plant classified under the family **Caricaceae**. It is native to Central America and southern Mexico but has since been widely cultivated in tropical and subtropical regions around the world due to its nutritional, medicinal, and economic value (Obasi et al., 2022).

Morphologically, Carica papaya is a fast-growing, herbaceous tree-like plant that can attain a height of 3 to 10 meters depending on environmental conditions and cultivation practices. The stem is typically soft, greenish, and hollow, containing latex canals which secrete a milky sap when cut. The leaves are large, deeply lobed, and arranged spirally at the top of the trunk. Each leaf is palmately compound, supported by a long petiole that can grow up to 1 meter in length (Afolabi & Olanrewaju, 2021).

The plant is generally dioecious, bearing either male or female flowers on separate plants, although hermaphroditic forms also exist, especially in cultivated varieties. The flowers are tubular, creamy white or yellow, and fragrant, often pollinated by wind and insects (Suleiman et al., 2023).

The fruit of Carica papaya is a large, fleshy berry that varies in size and shape, usually oblong or spherical. When ripe, the skin turns yellow to orange, enclosing a juicy orange to red pulp rich in vitamins A, C, and E, and small black seeds encased in a gelatinous coat. The seeds contain several bioactive compounds, including benzyl isothiocyanate, which have been linked to antimicrobial and antioxidant properties (Nwachukwu et al., 2022).

While the fruit is widely consumed for its nutritional benefits, almost every part of the plant—including the **roots, leaves, seeds, latex, and unripe fruit**—has been employed in traditional medicine. The roots, in particular, are used in decoctions or infusions for treating various ailments such as gastrointestinal infections, fever, and parasitic diseases, due to their reported antibacterial and anti-inflammatory properties (Okonkwo et al., 2023).

## 2.2 Traditional and Medicinal Uses

*Carica papaya*, commonly referred to as pawpaw, has long been recognized in ethnomedicine for its broad spectrum of therapeutic applications. Different parts of the plant—including the leaves, seeds, unripe fruit, latex, and especially the roots—are widely used in various traditional healthcare systems across Africa, Asia, and Latin America (Ajibade *et al.,* 2022). These plant parts are employed either singly or in combination with other herbs to manage and treat several ailments, reflecting the plant’s importance in indigenous pharmacopoeia.

The roots of *Carica papaya*, in particular, have garnered significant attention in traditional medicine. They are commonly boiled into decoctions or pounded into pastes and used for treating gastrointestinal disorders, such as diarrhea, dysentery, and stomach ulcers. In many rural communities, the root extract is also administered for urinary tract infections (UTIs), intestinal worms, and parasitic diseases like schistosomiasis and giardiasis (Okechukwu et al., 2023). These treatments are often supported by anecdotal evidence and generational knowledge passed through oral traditions.

In addition to parasitic and bacterial conditions, *Carica papaya* roots are believed to possess analgesic, anti-inflammatory, and antipyretic properties, and are traditionally used to relieve body pains, fevers, and headaches (Yahaya et al., 2021). For instance, in some West African cultures, root decoctions are consumed to manage symptoms of typhoid fever, malaria, and hypertension, with users reporting reductions in fever and faster recovery times (Enemali et al., 2022).

Furthermore, the antibacterial activity of *Carica papaya* root has been recognized in folk medicine, particularly for skin infections and wound healing. The root is occasionally applied topically in paste form or used in baths to treat infected cuts, abscesses, and rashes. However, despite this extensive traditional use, scientific studies validating the pharmacological efficacy of papaya root—especially under controlled laboratory conditions using standardized antibacterial assays—are still relatively scarce (Ibrahim et al., 2023).

The rising interest in herbal medicine and the global need for alternative antimicrobial agents—especially in the face of rising antibiotic resistance—underscore the importance of systematically investigating the antibacterial potential of *Carica papaya* roots. Documenting and validating these traditional applications through modern pharmacological approaches may lead to the development of novel, affordable, and accessible plant-based therapeutics.

## 2.3 *Carica papaya* (Pawpaw)

Pawpaw is a giant herbaceous plant, resembling a tree but not woody. It belongs to the family Caricaceae, plant division; Tracheobionta, sub division; spermatophyte, class; magnoliopsida, order; brassicales, family; caricaceae, genus; *Carica* and Species; *papaya.* Several species have been used as remedy against a variety of diseases (Alabi *et al*., 2012). It belongs to the fruits and vegetable class; a native to the tropics of America, perhaps from Southern Mexico and neighboring Central America. It was first cultivated in Mexico several centuries before the emergence of Mesoamerican classical civilizations (Alabi *et al*., 2012). Pawpaw grows to a height of 5-10 meters, with spirally arranged leaves confined to the top of the trunk. Lower trunk is conspicuously scarred where leaves and fruits are borne. Leaves are large, 50-70cm in diameter, deeply palmately lobed, with 7 lobes (Sophy, 2017).

Pawpaw plants are generally dioecius, with short stalked female (pistillate) flowers, which are 5- petalled, waxy and white, borne on separate plants from the male (staminate) flowers, which are borne on long panicles (up to 1.8 m). Plants may also bear hermaphrodite or perfect flowers, which have both pistil and stamens, or they may be monoecious, bearing separate male and female flowers on same plant. The fruit that develops varies in shape depending on the flower type. Fruits from female flowers are usually oval to round and smaller than the fruits that develop perfect flower, which are cylindrical or club-shaped, up to 50 cm long and 20cm wide. The fruits, can weigh up to 9kg although common commercial cultivars generally, produce fruits that weigh 0.5 to 2.25 kg, and have a thin but tough waxy skin. Green fruits contain latex, which disappears as the fruit ripens to light or dark yellow. The flesh of the fruit varies from yellow to orange to red and is thick and juicy, with a central cavity filled with many small black seeds.

The plant grows best on deep, well drained soils with high organic matter. Most soil types are suitable but they don’t grow well in heavy clay and water logged soils. Being a tropical plant, it grows best in warm- hot climate and an altitude below 2100m above the sea level with annual rainfall of about 1000mm which is well distributed. They are short live perennial trees whose economic life is about 4 years and they have a lifespan of up to 10 years, (Remberia and Wamoho, 2014).

The fruit is valued for its proteolytic enzymes including papain, is used like bromelain, a similar enzyme found in pineapple to treat sport injuries, other cases of trauma and allergies (Annie *et al*., 2004). Papain also aid in digestion and is used as a meat tenderizer. Papain has been used in medicine to treat ulcers and reduce skin adhesions following surgery and studies have also shown that it has antimicrobial properties (Aravind *et al*., 2013). Papain is also used to clarify beer, prepare wool and silk for dyeing and to remove hair from hides’ before tanning (Orchue *et al.,* 2013).

### ****2.4 Antibacterial Activity of**** Carica papaya

The antibacterial properties of Carica papaya have been the subject of increasing scientific interest, particularly due to the growing global challenge of antibiotic resistance and the need for effective alternative therapies. While earlier studies primarily focused on the **leaves, seeds**, and **latex** of the plant, recent research has begun to uncover the **antimicrobial potential of the root,** especially when extracted using organic solvents such as methanol (Oboh *et al.,* 2022).

The **methanol root extract** of Carica papaya has shown promising **broad-spectrum antibacterial activity** against both Gram-positive and Gram-negative bacterial strains. For instance, **Ahmed et al. (2020)** reported that methanol extracts of the roots exhibited significant inhibitory effects against clinically relevant bacterial species, including Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa. These bacteria are commonly implicated in infections of the urinary tract, respiratory system, and wounds, making the findings clinically relevant.

Similarly, **Ismail *et al.* (2022)** found that the extract displayed **dose-dependent antibacterial activity**, with inhibition zones comparable to those produced by conventional antibiotics. The study suggested that this efficacy could be attributed to the **presence of diverse bioactive compounds,** such as flavonoids, tannins, alkaloids, saponins, and phenolics, which may act synergistically to disrupt bacterial cell walls, inhibit protein synthesis, and impair microbial metabolism.

Moreover, **Onwuka *et al.* (2023)** conducted a comparative study evaluating the antibacterial potency of methanolic extracts of Carica papaya roots against standard antibiotics like **ciprofloxacin** and **amoxicillin.** The results demonstrated that, in certain concentrations, the plant extract showed inhibition zones that were statistically comparable to these widely used antibiotics, especially against E. coli and S. aureus. These findings reinforce the idea that Carica papaya root extract could serve as a **natural alternative or adjunct therapy** in the treatment of bacterial infections.

In addition to in vitro results, some **in vivo models** have also reported therapeutic effects of papaya root preparations in animal studies, suggesting potential systemic activity and low toxicity profiles (Adebayo et al., 2021). However, further pharmacokinetic and clinical studies are necessary to validate these outcomes and to isolate specific active compounds responsible for the antibacterial effect.

## 2.5 Classes of Phytochemicals

## 2.5.1 Alkaloids

Alkaloids in clinical use include the analgesics morphine and codeine. Amino acids act as precursors for biosynthesis of alkaloids with ornithine and lysine commonly used as starting materials. The solutions of alkaloids are intensely bitter. They are nitrogenous compounds function in the defense of plants against herbivores and pathogens, and are widely exploited as pharmaceuticals, stimulants, narcotics, and poisons due to their potent biological activities. In nature, the alkaloids exist in large proportions in the seeds and roots of plants and often in combination with vegetable acids. Alkaloids have pharmacological applications as anesthetics and CNS stimulants (Madziga *et al*., 2020). More than 12,000-alkaloids are known to exist in about 20% of plant species and only few have been exploited for medicinal purposes.

## 2.5.2 Saponins

The term saponin is derived from Saponaria vaccaria (*Quillaja* *saponaria*), a plant, which abounds in saponins and was once used as soap. Saponins therefore possess soaplike‟ behaviour in water, i.e. they produce foam. Saponins are also important therapeutically as they are shown to have hypolipidemic and anticancer activity. Saponins are also necessary for activity of cardiac glycosides. The two major types of steroidal sapogenin are diosgenin and hecogenin. Steroidal saponins are used in the commercial production of sex hormones for clinical use. For example, progesterone is derived from diosgenin. The most abundant starting material for the synthesis of progesterone is diosgenin isolated from Dioscorea species, formerly supplied from Mexico, and now from China (Sarker & Nahar, 2017). Other steroidal hormones, e.g. cortisone and hydrocortisone, can be prepared from the starting material hecogenin, which can be isolated from Sisal leaves found extensively in East Africa (Oleszek & Oleszek, 2020).

## 2.5.3 Steroids

Plant steroids (or steroid glycosides) also referred to as „cardiac glycosides‟ are one of the most naturally occurring plant phytoconstituents that have found therapeutic applications as arrow poisons or cardiac drugs (Firn, 2020). The cardiac glycosides are basically steroids with an inherent ability to afford a very specific and powerful action mainly on the cardiac muscle when administered through injection into man or animal. Steroids (anabolic steroids) have been observed to promote nitrogen retention in osteoporosis and in animals with wasting illness (Maurya *et al.,* 2018; Madziga *et al.,* 2020). Caution should be taken when using steroidal glycosides as small amounts would exhibit the much needed stimulation on a diseased heart, whereas excessive dose may cause even death. Diosgenin and cevadine (from Veratrum veride) are examples of plant steroids.

## 2.5.4 Flavonoids

Flavonoids are a group of plant secondary metabolites known for their antioxidant and anti-inflammatory properties. Aiyegoro *et al*., (2020) identified the presence of flavonoids in *Eucalyptus globulus*. Flavonoids have been extensively studied for their potential anti-inflammatory effects through the inhibition of inflammatory mediators (Anyanwu *et al*., 2019). The flavonoid content in *Eucalyptus globulus* contributes to its overall phytochemical profile and may play a role in its anti-inflammatory activities.

## 2.5.5 Phenolic Compounds

Phenolic compounds are widely distributed in plants and have been recognized for their antioxidant and anti-inflammatory properties. Olusola *et al*., (2018) identified the presence of phenolic compounds in *Eucalyptus globulus*. These compounds are known to exert anti-inflammatory effects by modulating key signaling pathways involved in the inflammatory response (Olusola *et al.,* 2018). The phenolic compounds present in *Eucalyptus globulus* contribute to its phytochemical composition and may contribute to its anti-inflammatory activities.

## 2.5.6 Terpenoids

Terpenoids, also known as isoprenoids, are a diverse class of secondary metabolites found in various plants. Although limited studies have specifically investigated the terpenoid content of *Eucalyptus globulus*, it is suggested that the plant may contain terpenoids based on its phylogenetic classification within the family Amaranthaceae. Further research is needed to identify and characterize the specific terpenoids present in *Eucalyptus globulus* and explore their potential anti-inflammatory activities.

## 2.5.7 Tannins

Tannins are polyphenolic compounds widely distributed in plants and known for their antioxidant and anti-inflammatory properties. Aiyegoro *et al.,* (2020) identified the presence of tannins in *Eucalyptus globulus*. Tannins have been reported to exhibit anti-inflammatory effects by modulating inflammatory mediators and reducing inflammatory responses (Aiyegoro *et al.,* 2020). The presence of tannins in *Eucalyptus globulus* contributes to its phytochemical composition and may contribute to its anti-inflammatory activities.

## 2.5.8 Glycosides

Glycosides are compounds that consist of a sugar molecule bound to a non-sugar substance, typically referred to as the aglycone or genin. These compounds are widely distributed in plants and play a significant role in plant defense mechanisms. Glycosides can be classified based on the type of aglycone group, with the most common types being cardiac glycosides, cyanogenic glycosides, and flavonoid glycosides. Cardiac glycosides are especially well-known for their therapeutic use in treating heart conditions, particularly in heart failure and arrhythmias (Mazzanti *et al.,* 2016). These glycosides influence the force of heart muscle contraction and are derived from plants such as *Digitalis purpurea* and *Strophanthus* species. Some well-known examples of cardiac glycosides include digoxin and digitoxin, which have been used in clinical settings to manage heart diseases.

### ****2.6 Classification of**** Carica papaya

#### **Scientific Names**

**Kingdom**: Plantae  
**Subkingdom**: Tracheobionta  
**Super Division**: Spermatophyta  
**Division**: Magnoliophyta  
**Class**: Magnoliopsida (Dicotyledons)  
**Subclass**: Dilleniidae  
**Order**: Brassicales  
**Family**: Caricaceae  
**Genus**: Carica  
**Species**: Carica papaya L.

#### **Vernacular Names**

**Hausa**: Gwanda  
**Yoruba**: Ibepe  
**Igbo**: Okwuru-ezi  
**Hindi**: Papita  
**English**: Pawpaw, Papaya, Melon tree  
**Latin**: Carica papaya  
**Swahili**: Mpapai  
**French**: Papayer  
**Spanish**: Papayo  
**Urhobo**: Ukodo  
**Kanuri**: Ngwando



Figure 2.1: Carica papaya plant

# CHAPTER THREE

# MATERIALS AND METHODS

## 3.1 Sample Collection and preparation

The plant *Carica papya* was collected at Federal Polytechnic, Mubi campus in July, 2025. The roots were cut into smaller pieces and air dried for fourteen days and ground into powdered form with a wooden mortar and pestle.

## 3.2 Materials

The materials used for this research include *Carica papaya* (roots), burette (50 ml), retort stand and clamp, beakers (100 ml and 250 ml), measuring cylinders (5 ml, 100 ml, and 250 ml), volumetric flask (1000 cm³), pipettes (0.5 ml, 1 ml, 2 ml, and 5 ml), porcelain evaporating dishes, funnels, test tubes and test tube racks, watch glasses, mortar and pestle, filter paper (Whatman No.1), oven, desiccator, heating mantle or water bath, analytical balance, and spectrophotometer (for absorbance readings at 720 nm), methanol, ethanol, distilled water, chloroform, petroleum ether, glacial acetic acid, concentrated sulfuric acid (H₂SO₄), acetic anhydride, ferric chloride (FeCl₃), sodium carbonate, Folin-Ciocalteau reagent, Folin-Denis reagent, 10% lead acetate solution, aluminium chloride solution, sodium acetate solution, ammonium hydroxide (NH₄OH), 1% hydrochloric acid (HCl), Mayer’s reagent, Wagner’s reagent, Fehling’s solution A and B, olive oil, gallic acid (used as the standard for phenolic content determination), and 20% potassium hydroxide (KOH) solution.

## 3.3 Methods

The method used for the project are discussed below:

## 3.3.1 Phytochemical Analysis

The qualitative analysis were done using different methods.

## 3.3.1.1 Qualitative methods

**Test for Tannins**

2ml of the methanolic extract was stirred with 2ml of distilled water and few drops of FeCl3 solution was added. The formation of a green precipitate was an indication for the presence of tannins (Singleton *et al.*, 2015).

**Test for saponins**

2ml of extract was shaken vigorously with 5ml of distilled water in a test tube and warmed. The formation of a stable form was taken as an indication of the presence of saponins (Singleton *et al.*, 2015).

**Test for flavonoids**

10ml of extract was added with 1ml of 10% lead acetate solution. The formation of a yellow precipitate was taken as a plosive test for flavonoid (Singleton *et al.*, 2015).

**Test for alkaloids**

2ml of extract was stirred with 3ml of 1% HCL on a steam bath. Mayer’s and Wagner’s reagent was then added to the mixture. Turbidity of the resulting precipitate was taken as evidence for the presence of alkaloids (Singleton *et al.*, 2015).

**Test for phenolics**

0.5g of the extract was stirred with 10ml of distilled water and then filtered. Few drops of 5% FeCl3 reagent was added to the filtrate. Blue black or blue green coloration or precipitate was taken as an indication of the presence phenolics (AOAC, 2020).

## Test for Steroids

10g of the test sample was extracted in the chloroform and filtered. The filtrate was mixed with 2 ml of conc. H2SO4 carefully so that the sulphuric acid formed a lower layer. A reddish-brown colour at the interphase indicated the presence of steroidal ring (Singleton *et al.*, 2015).

## Test for Glycosides

Dilute Sulphuric acid (5 ml) was added to the portion of the extract in a test tube and boiled for 15 minutes in a water bath, then cooled and neutralized with 20% potassium hydroxide solution. 10 ml of a mixture of equal parts of Fehling’s solution A and B was added and boiled for 5 min. A denser brick red precipitate indicated the presence of glycoside (Singleton *et al.*, 2015).

## Test for Terpenoids.

2.0 ml of chloroform was added with the 5 ml aqueous plant extract and evaporated on the water bath and then boiled with 3 ml of H2SO4 concentrated. A grey color formed which showed the entity of terpenoids (Singleton *et al.*, 2015).

### ****3.4 Determination of Antibacterial Activities of Extracts****

The antibacterial activity of Carica papaya root extract was assessed using the agar well diffusion method as described by Cheesbrough (2016), with slight modifications. Fresh bacterial cultures of ***Escherichia coli*, *Staphylococcus aureus*,** and ***Pseudomonas aeruginosa*** were obtained from a microbiology laboratory and used as the test organisms. The bacterial strains were maintained on nutrient agar slants and subcultured 24 hours before use to ensure viability.

Mueller-Hinton agar was prepared, sterilized, and poured into sterile Petri dishes and allowed to solidify. The standardized bacterial inoculum, adjusted to match 0.5 McFarland standard (approximately 1.5 × 10⁸ CFU/ml), was evenly spread over the surface of the agar using a sterile swab. Wells of 6 mm diameter were made on the agar plates using a sterile cork borer. Each well was filled with 100 µl of different concentrations (e.g., 25 mg/ml, 50 mg/ml, 100 mg/ml) of the methanolic extract of Carica papaya roots. Standard antibiotics such as ciprofloxacin (5 µg/ml) and amoxicillin (10 µg/ml) were used as positive controls, while methanol served as the negative control.

The plates were allowed to stand for 30 minutes at room temperature to permit diffusion of the extracts into the medium before being incubated at 37°C for 24 hours. After incubation, the zones of inhibition (clear areas around the wells) were measured in millimeters using a transparent ruler. The antibacterial activity was evaluated by comparing the diameters of inhibition zones of the extracts to those of the standard antibiotics. All experiments were carried out in triplicates to ensure reliability of the results, and the mean values were recorded.

# CHAPTER FOUR

# RESULTS

## 4.1 Results

**Table 4.1: Phytochemical Analysis of *Carica papaya* (Paw paw) in solvent and aqueous extraction**

|  |  |  |
| --- | --- | --- |
| **Test** | **Solvent** | **Aqueous** |
| Alkaloid | **+** | **+** |
| Flavonoid | **+** | **+** |
| Phenolic | **-** | **-** |
| Steroids | **+** | **+** |
| Glycosides | **+** | **+** |
| Tannins | **-** | **-** |
| Saponins | **+** | **+** |
| Terpenoids | **+** | **+** |

**Key:** + = Present, – = Absent

Table 4.1 presents the qualitative phytochemical screening of *Carica papaya* extracts obtained through solvent (methanolic) and aqueous extraction methods. The results indicate the presence of alkaloids, flavonoids, steroids, glycosides, saponins, and terpenoids in both extraction types, as denoted by the positive (+) signs. Phenolic compounds and tannins were not detected in either extract, as indicated by the negative (–) signs.

**Table 4.2 Antibacterial Activity of methanolic and Aqueous Root Extract of *Carica papaya* (paw paw)**

|  |  |  |
| --- | --- | --- |
| **Test** | **Methanolic** | **Aqueous** |
| *Escherichia coli* | + | + |
| *Staphylococcus* aureus | + | + |
| *Pseudomonas Aeruginosa* | + | + |

**Key**: **+** = Antibacterial activity observed (growth inhibition present), **–** = No antibacterial activity observed (no growth inhibition)

Table 4.2 summarizes the antibacterial screening results of methanolic and aqueous root extracts against three pathogenic bacteria: *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. The positive (+) signs indicate that both methanolic and aqueous extracts exhibited antibacterial activity against all the tested organisms.

**Table 4.3: Zone Inhibition in Antibacterial test.**

|  |  |  |
| --- | --- | --- |
| **Test** | **Methanolic** | **Aqueous** |
| *Escherichia coli* | 27 mm | 25 mm |
| *Staphylococcus* aureus | 20 mm | 30 mm |
| *Pseudomonas Aeruginosa* | 30 mm | 20 mm |

**Key:** Values in mm = Diameter of the clear zone around the extract sample where bacterial growth was inhibited (measured in millimeters), Methanolic = Extract obtained using methanol as the solvent, Aqueous = Extract obtained using water as the solvent.

Table 4.3 provides the quantitative measurement of antibacterial activity by showing the diameter of inhibition zones (in millimeters) produced by the methanolic and aqueous extracts against the test organisms. For *E. coli*, the methanolic extract recorded a slightly higher inhibition zone (27 mm) compared to the aqueous extract (25 mm), suggesting a marginally greater potency in the solvent-based extraction. In the case of *S. aureus*, the aqueous extract produced a larger inhibition zone (30 mm) than the methanolic extract (20 mm), indicating that certain antibacterial compounds in *Carica papaya* may be more water-soluble and thus more effective against Gram-positive bacteria. For *P. aeruginosa*, the methanolic extract showed a larger inhibition zone (30 mm) compared to the aqueous extract (20 mm). These variations suggest that the solvent used in extraction influences the spectrum and intensity of antibacterial activity, likely due to differences in phytochemical solubility and concentration.

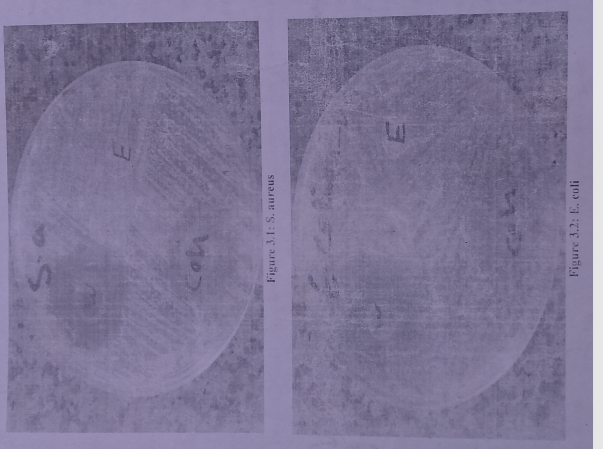


Figure 4.1: *Staphylococcus* aureus

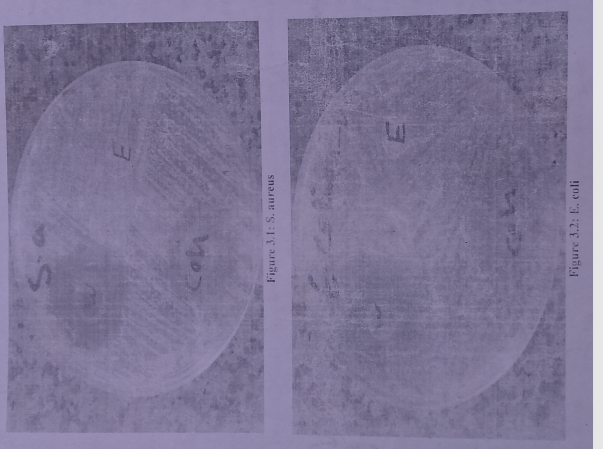


Figure 4.2: *Escherichia coli*

# CHAPTER FIVE

# DISCUSSION, CONCLUSION AND RECOMMENDATIONS

## 5.1 Discussion

The findings of this study reveal that *Carica papaya* root extracts, obtained through both methanolic and aqueous extraction methods, contain a variety of bioactive phytochemicals, including alkaloids, flavonoids, steroids, glycosides, saponins, and terpenoids. These compounds are well-documented for their pharmacological properties. Alkaloids have been associated with antimicrobial, antimalarial, and analgesic activities (Ngulde *et al.,* 2019), while flavonoids are recognized for their antioxidant and anti-inflammatory effects (Panche *et al.,* 2016). The detection of these compounds in both extraction types aligns with previous research by Dawet *et al.* (2020), who reported the presence of similar phytochemicals in *Carica papaya* leaves and roots, suggesting that both water and methanol are effective solvents for extracting these metabolites. The absence of phenolics and tannins in this study may be due to differences in plant part used, maturity stage, or environmental factors influencing phytochemical content (Edeoga *et al.,* 2005).

The antibacterial screening results further demonstrate that both methanolic and aqueous extracts exhibited inhibitory activity against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. This broad-spectrum antibacterial activity supports earlier findings by Oloyede (2011), who observed that *Carica papaya* seed and root extracts inhibited the growth of multiple Gram-positive and Gram-negative bacteria. The observed inhibition against *S. aureus* and *E. coli* corroborates the work of Akinmoladun *et al.* (2020), who attributed such effects to the synergistic action of alkaloids, saponins, and flavonoids. Notably, the stronger inhibitory effect of the aqueous extract against *S. aureus* in this study suggests that certain antibacterial constituents of *Carica papaya* may be more water-soluble, supporting the conclusions of Iloki-Assanga *et al.* (2015) that solvent polarity plays a critical role in antimicrobial activity.

The quantitative zone of inhibition measurements reveal variations in potency between the two extraction methods. The methanolic extract showed greater activity against *E. coli* and *P. aeruginosa*, while the aqueous extract was more effective against *S. aureus*. This differential activity could be attributed to variations in the solubility of active compounds and the structural differences between Gram-positive and Gram-negative bacterial cell walls (Nostro *et al.,* 2000). Gram-negative bacteria possess an outer lipopolysaccharide membrane that can restrict the penetration of certain hydrophilic compounds, which may explain why methanolic (less polar) extracts demonstrated greater activity against them. Conversely, Gram-positive bacteria lack this barrier, potentially allowing hydrophilic compounds in aqueous extracts to be more effective.

Overall, these findings align with a growing body of literature that supports the use of *Carica papaya* as a natural source of antimicrobial agents (Aravind *et al.,* 2013; Rathi *et al.,* 2017). The results of this study not only validate previous reports but also highlight the influence of extraction solvent on the spectrum of antibacterial activity. This reinforces the importance of selecting appropriate solvents to target specific pathogens and optimize the medicinal potential of plant-based extracts.

## 5.2 Conclusion

This study demonstrated that *Carica papaya* root extracts, obtained through both methanolic and aqueous extraction methods, contain important bioactive phytochemicals such as alkaloids, flavonoids, steroids, glycosides, saponins, and terpenoids, all of which are known for their medicinal properties. The absence of phenolics and tannins in the extracts may be attributed to plant-specific or environmental factors. The antibacterial assays confirmed that both methanolic and aqueous extracts possess broad-spectrum antibacterial activity against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*, with varying inhibition strengths depending on the solvent used. Methanolic extracts exhibited higher activity against *E. coli* and *P. aeruginosa*, while aqueous extracts were more effective against *S. aureus*. These findings affirm the antimicrobial potential of *Carica papaya* roots and underscore the influence of extraction solvents on the potency and specificity of antibacterial action.

## 5.3 Recommendations

1. The demonstrated antibacterial activity of *Carica papaya* root extracts suggests that they could be explored further as raw materials for the development of plant-based antimicrobial agents, especially for combating antibiotic-resistant strains.
2. Given that methanolic and aqueous extracts showed varying efficacy against different bacterial strains, future applications should consider solvent choice depending on the targeted pathogen type (Gram-positive or Gram-negative).
3. Advanced chromatographic and spectroscopic techniques should be employed to isolate and characterize the specific bioactive compounds responsible for the observed antibacterial effects.
4. Future studies should investigate the activity of *Carica papaya* root extracts against a wider range of bacterial and fungal pathogens to fully establish its antimicrobial spectrum.
5. Based on the results, research into incorporating the extracts into topical, oral, or preservative formulations could enhance their practical application in medicine and industry.

# REFERENCES

Abdullah, M., Chai, P. S., Loh, C. Y., Chong, M. Y., Quay, H. W., Vidyadaran, S., Seman, Z., Kandiah, M., & Seow, H. F. (2011). *Carica papaya* increases regulatory T cells and reduces IFN-γ+CD4+ T cells in healthy human subjects. *Molecular Nutrition & Food Research, 55*(5), 803–806. <https://doi.org/10.1002/mnfr.201100087>

Adachukwu, I., Ogbonna, A., & Faith, E. (2013). Phytochemical analysis of paw-paw (*Carica papaya*) leaves. *International Journal of Life Science, Biotechnology and Pharma Research, 2*(3), 347–351.

Addai, Z. R., Abdullah, A., Mutalib, S. A., Musa, K. H., & Douqan, E. M. A. (2013). Antioxidant activity and physicochemical properties of mature papaya fruit (*Carica papaya* L. cv. Eksotika). *Advance Journal of Food Science and Technology, 5*(7), 859–865. https://doi.org/10.19026/ajfst.5.3173

Adejuwon, A., Agbaje, E., & Idika, N. (2011). Antifungal and antibacterial activities of aqueous and methanolic root extracts of *Carica papaya* Linn. (*Caricaceae*). *International Research Journal of Microbiology, 2*(8), 270–277.

Agada, R., Usman, W. A., Shehu, S., & Thagariki, D. (2020). In vitro and in vivo inhibitory effects of *Carica papaya* seed on α-amylase and α-glucosidase enzymes. *Heliyon, 6*(e03618). <https://doi.org/10.1016/j.heliyon.2020.e03618>

Agarwal, R., Garg, N., & Kashyap, S. R. (2015). Antibacterial finish of textile using papaya peels derived silver nanoparticles. *Indian Journal of Fibre & Textile Research, 40*(2), 105–107.

Agunbiade, F. O., & Adewole, T. A. (2014). Methanolysis of *Carica papaya* seed oil for production of biodiesel. *Journal of Fuels, 2014*, 1–6. <https://doi.org/10.1155/2014/904076>

Ahlawat, J., Kumar, V., & Gopinath, P. (2019). *Carica papaya*-loaded poly(vinyl alcohol)-gelatin nanofibrous scaffold for potential application in wound dressing. *Materials Science & Engineering C, 103*, 109834. <https://doi.org/10.1016/j.msec.2019.109834>

Ahmad, N., Fazal, H., Ayaz, M., Abbasi, B. H., Mohammad, I., & Fazal, L. (2011). Dengue fever treatment with *Carica papaya* leaves extracts. *Asian Pacific Journal of Tropical Biomedicine, 1*(4), 330–333. <https://doi.org/10.1016/S2221-1691(11)60055-5>

Ahmed, A., Saleem, A., Shaikh, A. W., Jehan, F., & Abbasi, B. A. (2017). Incremental response of total thrombocyte count of papaya leaves. *Pakistan Journal of Medical and Health Sciences, 11*(4), 1583–1586.

Airaodion, A. I., Ekenjoku, J. A., Akaninyene, I. U., & Megwas, A. U. (2020). Antibacterial potential of ethanolic and aqueous extracts of *Carica papaya* leaves. *Asian Journal of Biochemistry, Genetics and Molecular Biology, 3*(3), 33–38. https://doi.org/10.9734/ajbgmb/2020/v3i330088

Akindele, A. J., Awodele, O., Alagbaoso, A. A., & Adeyemi, O. O. (2011). Antidiarrhoeal activity of DAS-77 (a herbal preparation). *Nigerian Quarterly Journal of Hospital Medicine, 21*(4), 317–323.

Akinmoladun, F. O., Komolafe, T. R., Komolafe, F. O., Farombi, E. O., & Oyedapo, O. O. (2020). Phytochemical constituents and antimicrobial activity of *Carica papaya* Linn. root extracts. *Scientific African, 9*, e00480. https://doi.org/10.1016/j.sciaf.2020.e00480

Alabi, O. A., Haruna, M. T., Anokwuru, C. P., Jegede, T., Abia, H., Okegbe, V. U., & Esan, B. E. (2012). Comparative studies on antimicrobial properties of extracts of fresh and dried leaves of *Carica papaya* (L.) on clinical bacterial and fungal isolates. *Advances in Applied Science Research, 3*(5), 3107–3114.

Aldhous, M.C., Prescott, R.J., Roberts, S., Samuel, K., Waterfall, M., Satsangi, J., 2008. Does nicotine influence cytokine profile and subsequent cell cycling/apoptotic responses in inflammatory bowel disease?. Inflamm. Bowel Dis. 14, 1469–1482. <https://doi.org/10.1002/ibd.20523>.

Alotaibi, K.S., Li, H., Rafi, R., Siddiqui, R.A., 2017. Papaya black seeds have beneficial anticancer effects on PC-3 prostate cancer cells. J. Cancer Metastasis Treat. 3, 161. [https://doi.org/10.20517/2394-4722.2017.33.](https://doi.org/10.20517/2394-4722.2017.33)

[Anantharaman, A., George, M., 2016. Green synthesis of calcium oxide nanoparticles and its applications. J. Eng. Res. Appl. 6, 27–31. www.ijera.com.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0095)

Aravind, G., Bhowmik, D., Duraivel, S., & Harish, G. (2013). Traditional and medicinal uses of *Carica papaya*. *Journal of Medicinal Plants Studies, 1*(1), 7–15.

Bahnas, W.M., Abbas, K.A., Metry, W.A., Elewa, N.A.H., 2019. A novel bio-fermented beverages from dairy by-products based with papaya pulp and stevia leaves. J. Food Dairy Sci. 10, 467–472. [https://doi.org/10.21608/jfds.2019.71362.](https://doi.org/10.21608/jfds.2019.71362)

Balavijayalakshmi, J., Ramalakshmi, V., 2017. Carica papaya peel mediated synthesis of silver nanoparticles and its antibacterial activity against human pathogens. J. Appl. Res. Technol. 15, 413–422. [https://doi.org/10.1016/j.jart.2017.03.010.](https://doi.org/10.1016/j.jart.2017.03.010)

Banala, R.R., Nagati, V.B., Karnati, P.R., 2015. Green synthesis and characterization of Carica papaya leaf extract coated silver nanoparticles through x-ray diffraction, electron microscopy and evaluation of bactericidal properties. Saudi J. Biol. Sci. 22, 637–644. [https://doi.org/10.1016/j.sjbs.2015.01.007.](https://doi.org/10.1016/j.sjbs.2015.01.007)

Baskaran, C., Bai, V.R., Velu, S., Kumaran, K., 2012. The efficacy of Carica papaya leaf extract on some bacterial and a fungal strain by well diffusion method. Asian Pacific J. Trop. Dis. 2, S658–S662. [https://doi.org/10.1016/S2222-1808(12)60239-4.](https://doi.org/10.1016/S2222-1808(12)60239-4)

[Bertran, D.M., 1997. The Healing Garden (an Exhibit of the NIH Visitor Information Center). Natl. Institutes Heal, Washington, D.C.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0195).

Bhattachrjee, S.K., 2001. Carica papaya. In: Hand Book of Medicinal Plant, edition: 3rd Revised, editors: Shashi Jain, Pointer Publisher, Jaipur, India.

[Bhuiyan, M.S.H., Miah, M.Y., Paul, S.C., Aka, T.D., Saha, O., Rahaman, M.M., Sharif, M.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0220) J.I., Habiba, O., Ashaduzzaman, M., 2020. Green synthesis of iron oxid[e](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0220) nanoparticle usin[g](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0220) [Carica papaya](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0220) leaf extract: application for photocatalyti[c degradation of remazol yellow RR dye and antibacterial activity. Heliyon 6, (8)](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0220) e04603.

[Boghani, A.H., Raheem, A., Hashmi, S.I., 2012. Development and storage studies of blended papaya-aloe vera ready-to-serve (RTS) beverage. J. Food Process. Technol.3,](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0205) [1–4](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0205).

Brekke, J.E., Chan, H.T., Cavaletto, C.G., 1972. Papaya puree: a tropica[l](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0210) [flavour ingredient. Food Prod. Dev., 36–37](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0210).

Brocklehurst, K., Salih, E., McKee, R., Smith, H., 1985. Fresh non-fruit latex of Carica papaya contains papain, multiple forms of chymopapain A and papaya proteinase omega. Biochem. J. 228, 525–527. [https://doi.org/10.1042/bj2280525.](https://doi.org/10.1042/bj2280525)

Callixte, C., Baptiste, N.J., Arwati, H., 2020. Phytochemical screening and antimicrobial activities of methanolic and aqueous leaf extracts of Carica papaya grown in Rwanda. Mol. Cell. Biomed. Sci. 4, 39. <https://doi.org/10.21705/mcbs.v4i1.74>.

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.](https://doi.org/10.1016/j.jfca.2007.03.009)

[Chakraborty, M., Karmakar, I., Haldar, S., Nepal, A., Haldar, P.K., 2015. Anticancer and antioxidant activity of methanol extract of](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0235) [Hippophae salicifolia](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0235) [in EAC induced swiss albino mice. Int. J. Pharm. Pharm. Sci. 7, 180–184.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0235)

Chan, H.T., Cavaletto, C.G., 1978. Dehydration and storage stability of papaya leather. J. Food Sci. 43, 1723–1725. <https://doi.org/10.1111/j.1365-2621.1978.tb07398.x>.

Chandrasekaran, R., Gnanasekar, S., Seetharaman, P., Keppanan, R., Arockiaswamy, W., Sivaperumal, S., 2016. Formulation of Carica papaya latex-functionalized silver nanoparticles for its improved antibacterial and anticancer applications. J. Mol. Liq. 219, 232–238. [https://doi.org/10.1016/j.molliq.2016.03.038.](https://doi.org/10.1016/j.molliq.2016.03.038)

Chandrasekaran, R., Seetharaman, P., Krishnan, M., Gnanasekar, S., Sivaperumal, S., 2018. Carica papaya (Papaya) latex: a new paradigm to combat against dengue and filariasis vectors

Dawet, A., Yakubu, J. M., & Aliyu, R. (2020). Phytochemical screening and antimicrobial activity of leaf and root extracts of *Carica papaya*. *Journal of Medicinal Plants Research, 14*(4), 179–185. https://doi.org/10.5897/JMPR2019.6844

Edeoga, H. O., Okwu, D. E., & Mbaebie, B. O. (2005). Phytochemical constituents of some Nigerian medicinal plants. *African Journal of Biotechnology, 4*(7), 685–688. https://doi.org/10.5897/AJB2005.000-3127

El-Mesallamy, A.M.D., Hussein, S.A.M., Abd El Azim, M.H.M., El-Gerby, M., 2015[.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0335) Phenolic composition and biological activities of methanolic extract o[f](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0335) [Caricapapaya. Nat. Prod. Indian J. 10, 91–98.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0335)

Espin, N., Islam, M.N., 1998. Stabilization of papain from papaya peels. Food Sci[. Technol. Int. 4, 179–187](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0340).

Eze, P.M., Abonyi, D.O., Abba, C.C., Proksch, P., Okoye, F.B.C., Esimone, C.O., 2019. Toxic, but beneficial compounds from endophytic fungi of Carica papaya. Euro Biotech J. 3, 105–111. [https://doi.org/10.2478/ebtj-2019-0012.](https://doi.org/10.2478/ebtj-2019-0012)

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/10.4172/21559600.1000602.](https://doi.org/10.4172/2155-9600.1000602)

FAO, 2020. Major tropical fruits – preliminary market results 2019. Rome 3–4.

Farida, Y., Iswahyuni, I., 2018. Isolation, identification, and antioxidant activity of chemical compound in ethanol extract of papaya leaves (Carica papaya L.). Asian J.

Fauziya, S., Krishnamurthy, R., 2013. Papaya [(Carica papaya](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0365)): source material fo[r anticancer. CIBTech J. Pharm. Sci. 2, 2319–389125.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0365)

Firdaus, M., Andriana, S., Elvinawati, Alwi, W., Swistoro, E., Ruyani, A., Sundaryono, A., 2016. Green synthesis of silver nanoparticles using Carica papaya fruit extract under sunlight irradiation and their colorimetric detection of mercury ions. J. Phys. Conf. Ser. 755, 0–6. https://doi.org/10.1088/1742-6596/755/1/011001

García-Sols, P., Yahia, E.M., Morales-Tlalpan, V., Díaz-Muñoz, M., 2009. Screening of antiproliferative effect of aqueous extracts of plant foods consumed in México on the breast cancer cell line MCF-7. Int. J. Food Sci. Nutr. 60, 32–46. [https://doi.org/ 10.1080/09637480802312922.](https://doi.org/10.1080/09637480802312922)

Gbolade, A.A., 2009. Inventory of antidiabetic plants in selected districts of Lagos state,

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 it’s 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.](https://doi.org/10.1016/j.micpath.2017.08.033)

Gohain, M., Laskar, K., Paul, A.K., Daimary, N., Maharana, M., Goswami, I.K., Hazarika, A., Bora, U., Deka, D., 2020. Carica papaya stem: a source of versatile heterogeneous catalyst for biodiesel production and C-C bond formation. Renew. Energy 147, 541–555. [https://doi.org/10.1016/j.renene.2019.09.016.](https://doi.org/10.1016/j.renene.2019.09.016)

Gupta, A., Patil, S.S., Pendharkar, N., 2017. Antimicrobial and anti-i[nflammatory activity of aqueous extract of](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0395) [Carica papaya. J. Herb. Med. Pharmacol. 6, 148–152](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0395).

Gurudatta, M., Deshmukh, Y., Naikwadi, A.A., 2015. Anticancer effects of Carica papaya in experimental induced mammary tumors in rats. Int. J. Med. Res. Heal. Sci. 4, 667. [https://doi.org/10.5958/2319-5886.2015.00127.7.](https://doi.org/10.5958/2319-5886.2015.00127.7)

Haldar, S., Mohapatra, S., Singh, R., Katiyar, C.K., 2020. Isolation and quantification of bioactive carpaine from Carica papaya L. and its commercial formulation by HPTLC densitometry. J. Liq. Chromatogr. Relat. Technol. 43, 388–393. [https://doi.org/ 10.1080/10826076.2020.1725558.](https://doi.org/10.1080/10826076.2020.1725558)

Hayatie, L., Biworo, A., Suhartono, E., 2015. Aqueous extracts of seed and peel of Carica papaya against Aedes Aegypti. J. Med. Bioeng. 4, 417–421. [https://doi.org/ 10.12720/jomb.4.5.417-421.](https://doi.org/10.12720/jomb.4.5.417-421)

Hirose, M., Yamaguchi, T., Kimoto, N., Ogawa, K., Futakuchi, M., Sano, M., Shirai, T., 1998. Strong promoting activity of phenylethyl isothiocyanate and benzyl isothiocyanate on urinary bladder carcinogenesis in F344 male rats. Int. J. Cancer 77, 773–777. [https://doi.org/10.1002/(SICI)1097-0215(19980831)77:5<773:: AID-IJC17>3.0.CO;2-2.](https://doi.org/10.1002/(SICI)1097-0215(19980831)77:5%26lt;773::AID-IJC17%26gt;3.0.CO;2-2)

Hunaldo, V.K.L., Clímaco, G.N., de Freitas, A.C., dos Santos, L.H., Xavier, T.A.L., Campos, R. de S., Costa, J. de R.M., Lobato, J.S.M., 2020. Papaya jelly with coconut babassu: sensorial processing and evaluation. Brazilian J. Dev. 6, 19837–19845. https://doi.org/10.34117/bjdv6n4-233.

Husen, A., 2020a. Carbon-based nanomaterials and their interactions with agricultural crops. In: Husen A, J.M. (Ed.), Nanomaterials for Agriculture and Forestry Applications. Elsevier Inc., pp. 199–218.

Husen, A., 2020b. Interactions of metal and metal-oxide nanomaterials with agricultural crops: an overview. In: Husen A, J.M. (Ed.), Nanomaterials for Agriculture and Forestry Applications. Elsevier Inc., pp. 167–197. https://doi.org/10.1111/ cjag.12228.

Husen, A., 2020c. Introduction and techniques in nanomaterials formulation. In: Husen A, J.M. (Ed.), Nanomaterials for Agriculture and Forestry Applications. Elsevier Inc., pp. 1–14.

Ibrahim, A.M., Ghareeb, M.A., 2020. Preliminary phytochemical screening, total phenolic content, in vitro antioxidant and molluscicidal activities of the methanolic extract of five medicinal plants on Biomphalaria alexandrina snails. J. Herbs Spices Med. Plants 26, 40–48. [https://doi.org/10.1080/10496475.2019.1666769.](https://doi.org/10.1080/10496475.2019.1666769)

[Igwe, O., 2015. Chemical constituents of the leaf essential oil of](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0445) [Carica papaya](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0445) [from](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0445) south east nigeria and its antimicrobial activity. Int. J. Res. Pharm. Chem. 5[,77–83](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0445).

Iloki-Assanga, S. B., Lewis-Luján, L. M., Lara-Espinoza, C. L., Gil-Salido, A. A., Fernandez-Angulo, D., Rubio-Pino, J. L., & Haines, D. D. (2015). Solvent effects on phytochemical constituent profiles and antioxidant activities, using four different extraction formulations for analysis of *Bersama abyssinica* leaves. *Journal of Medicinal Food, 18*(4), 390–398.

[Islam, M.N., Molinar-Toribio, E.M., 2013. Development of a meat tenderizer based on papaya peel. ID Technol. 9, 2013.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0450)

[j.jep.2008.10.013.](https://doi.org/10.1016/j.jep.2008.10.013)

[Jadhav, B.A., Joshi, A.A., Chilkawar, P.M., 2012. Effect of varying pulp concentration on sensory quality of noni](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0455) [(Morinda citrifolia](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0455) [L.)](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0455) – [toffee blended with papaya and guava pulp. Carpath. J. Food Sci. Technol. 36–39.](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0455)

Jadhav, D.B., Kokate, R.D., 2019. Green synthesis of SnO2 using green papaya leaves for nanoelectronics (LPG sensing) application. Mater. Today Proc. 26, 998–1004. <https://doi.org/10.1016/j.matpr.2020.01.180>.

[Jain, A., Ahmad, F., Gola, D., Malik, A., Chauhan, N., Dey, P., Tyagi, P.K., 2020. Multi](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0470) dye degradation and antibacterial potential of Papaya leaf derived silve[r nanoparticles. Environ. Nanotechnol. Monitor. Manag. 14,](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0470) 100337.

[Jain, D., Daima, H.K., Kachhwaha, S., Kothari, S.L., 2009. Synthesis of plant-mediated silver nanoparticles using papaya fruit extract and evaluation of their anti microbial activities. Dig. J. Nanomater. Biostructures 4, 557–563](http://refhub.elsevier.com/S2590-2628(20)30016-2/h0465).

Jarisarapurin, W., Sanrattana, W., Chularojmontri, L., Kunchana, K., Wattanapitayakul, S.K., 2019. Antioxidant properties of unripe Carica papaya fruit extract and its protective effects against endothelial oxidative stress. Evid. Based Complementary Altern. Med. 2019, 1–15. <https://doi.org/10.1155/2019/4912631>.

Jayakumar, R., Kanthimathi, M.S., 2011. Inhibitory effects of fruit extracts on nitric oxide-induced proliferation in MCF-7 cells. Food Chem. 126, 956–960. [https://doi. org/10.1016/j.foodchem.2010.11.093.](https://doi.org/10.1016/j.foodchem.2010.11.093)

Joshi, A., Sharma, A., Bachheti, R.K., Husen. A., Mishra, V.K., 2019. Plant-mediated synthesis of copper oxide nanoparticles and their biological applications. In: Husen, A., Iqbal, M. (eds.), Nanomaterials and Plant Potential. pp. 221–237.

Ngulde, S. I., Sandabe, U. K., & Hussaini, I. M. (2019). Phytochemical constituents and medicinal properties of *Carica papaya* Linn. *Asian Journal of Plant Science and Research, 9*(4), 8–15.

Nigeria. J. Ethnopharmacol. 121, 135–139. [https://doi.org/10.1016/](https://doi.org/10.1016/j.jep.2008.10.013)

Nostro, A., Germano, M. P., D’Angelo, V., Marino, A., & Cannatelli, M. A. (2000). Extraction methods and bioautography for evaluation of medicinal plant antimicrobial activity. *Letters in Applied Microbiology, 30*(5), 379–384.

Oloyede, O. I. (2011). Chemical profile of unripe pulp of *Carica papaya*. *Pakistan Journal of Nutrition, 4*(6), 379–381.

Panche, A. N., Diwan, A. D., & Chandra, S. R. (2016). Flavonoids: An overview. *Journal of Nutritional Science, 5*, e47. https://doi.org/10.1017/jns.2016.41

Pharm. Clin. Res. 11, 118–121. [https://doi.org/10.22159/ajpcr.2018.v11s1.26583.](https://doi.org/10.22159/ajpcr.2018.v11s1.26583)

Rathi, M. A., Meenakshi, P., & Arumugam, S. (2017). Phytochemical screening, antioxidant and antimicrobial potential of *Carica papaya* leaf extracts against human pathogens. *International Journal of Pharmacy and Pharmaceutical Sciences, 9*(5), 192–197.