RESEARCH PAPER

Phytochemical Profiling, Pharmacological Activity, In Vitro Cytotoxicity, and In Silico Molecular Docking of *Syzygium cumini*

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ABSTRACT
Syzygium cumini Skeels, recognized as Java Plum or Jamun, is single of those plants that have been utilized for treating many diseases in traditional medicine. In this review, the in vitro cytotoxicity of *Syzygium cumini*, in silico molecular docking studies, pharmacological actions of *Syzygium cumini*, and composition of constituents from the plant will be described briefly. Various chemical complexes like flavonoids, phenolic acids, tannins, anthocyanins, alkaloids, glycosides, and terpenoids are existing in different portions of the plant. Phytochemicals play various roles in physiology, such as antioxidative, antidiabetic, antibacterial, anti-inflammatory, anticancer, hepatoprotective, cardioprotective, and neuroprotective activities. The chemical components of S. cumini have been proven in many studies, both in vitro and clinically, to reduce oxidative stress, regulate blood sugar levels, inhibit the growth of microorganisms, and affect inflammatory mechanisms. Many types of cancer cells, such as MCF-7, HeLa, HepG2, and HT-29, exhibited encouraging anti-proliferative and apoptotic effects in toxicity tests. Major phytochemicals such as quercetin, ellagic acid, rutin, and gallic acid also exhibited considerable affinity for interaction with target pharmaceutical proteins involved in inflammation, diabetes, and cancer, molecular docking analysis indicated. This study has provided detailed scientific knowledge on the medicinal uses of *Syzygium cumini* through phytochemistry, pharmacology, cytotoxicity, and computational studies. It is important to undertake further research to determine the safety and effectiveness of this plant for use in medicines.

KEYWORDS: Antioxidant, Molecular docking, Pharmacological activities, Cytotoxicity, Bioactive compound.
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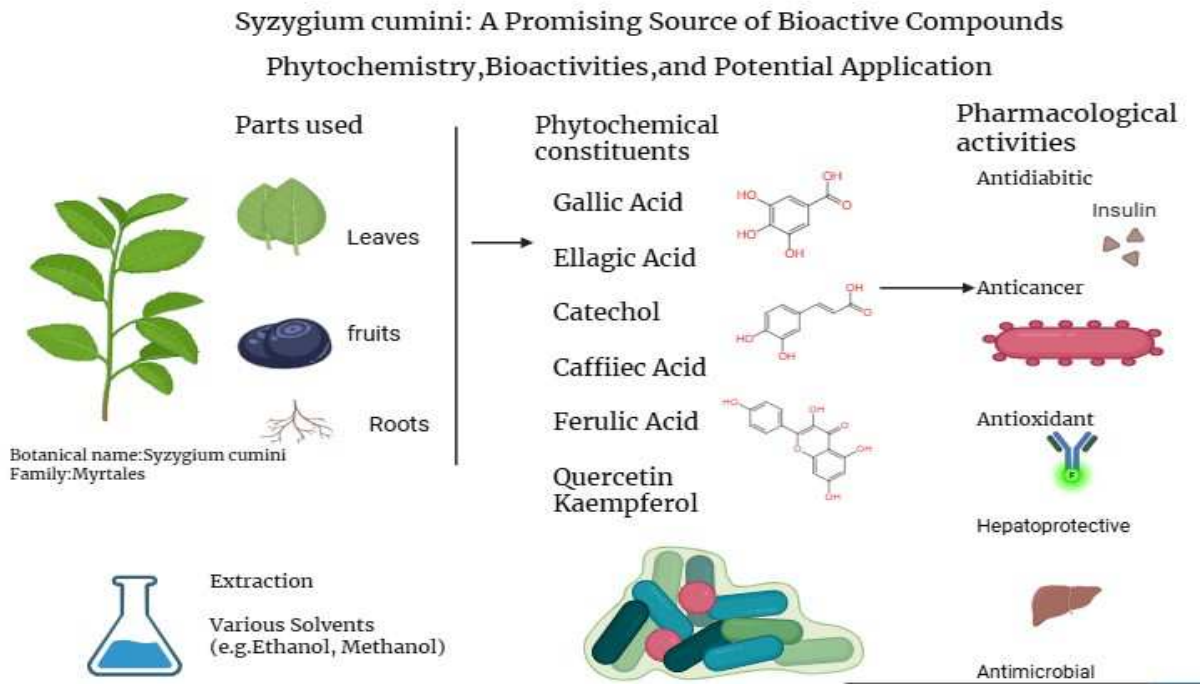


Figure 1: Graphical representation of the *Syzygium cumini*

INTRODUCTION:

Before the advent of development, plants were widely used for both disease prevention and curative purposes.

These days, bioactive compounds that are produced from plants play a main part in the creation of novel drugs [1]. Approximately 80% of public universal trust on outdated herbal remedies used for their fundamental medicinal necessities, rendering to assessments from the world health Organization(WHO) Because basils are more widely available, more reasonably priced, and typically have less adverse effect than synthetic medication, herbal remedies are receiving more scientific interest [2] Because they consist of chemical constituents include flavonoids, phenolics, alkaloids, tannins, terpenoids, and glycoside various therapeutic plants have strong medicinal properties [3]. Syzygium cumini, a tropical and subtropical plant in the Myrtaceous family, is frequently referred to as Java plum, Indian blackberry, or jamun [4]. The plant, which is native to the Indian subcontinent, has long been used in Auxetic, Unani, and Siddha Therapy to cure liver issues, diabetes, gastrointestinal issues, inflammation, and pathogenic diseases [5]. Bioactive chemical substances like anthocyanins, Flavonoids, tannins, gallic acid, ellagic acid, quercetin, and terpenoids are abundant in the plant's fruits, seeds, leaves, and bark S. cumini has a comprehensive variety of pharmacologic actions, with antioxidant, antidiabetic drug, antibacterial, anti-inflammatory, anticancer, hepatoprotective, cardioprotective, and neuroprotective, according to recent scientific studies [6]. By determining probable modes of action and target protein interactions, in vitro cytotoxicity studies, and in silico molecular cropping techniques have further bolstered its therapeutic promise. Thus, the goal of this analysis is to offer a thorough summary of the phytochemical components, pharmacological

(a)Botanical discerption:

According to sources, *Syzygium cumini* has its origin in the East Indies and India. This species occurs naturally in Indonesia, but it is also seen growing both in the wild state and as a cultivated crop. This plant is extensively cultivated in such countries as the Philippines, Thailand, Madagascar, East and West Africa, and the West Indies.

Furthermore, it is also seen growing in various subtropical regions such as California, Florida, Israel, and Algeria [8].

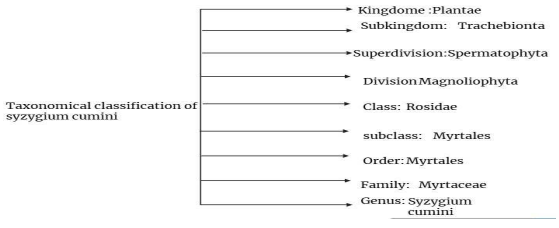


Figure 2. Taxonomical arrangement of *S. cumini* [9]

Morphology/Physiology The distinct physiology and appearance of *Syzygium cumini*, also known as Jamun or Java plum, support its growth, reproduction, and environmental adaptation (Figure 1, Figure 2) [9]. The primary characteristics of its morphology and physiology are as follows: The whole year is the active growing season. Flower colour: green; flageolet: green Texture of foliage: average Fruit/seed colour: black; development of a sole trunk Fast growth; sixty-foot maturity altitude; extended nitrogen fixation; absence of shape and orientation; erect toxicity; absence of developmental needs range: 5.07.0Density of planting:[10] 200400 per Acre Root depth of at least 36 inches The length of the reproductive bloom, the spring fruit/seed period, the rate at which spring summer seeds disperse, the low tolerance to shade, the moderate resilience to salinity, and the intermediate temperature (minimum: 49 °F) [11].

Cultivation and collection Soil.

A wide range of soil kinds can provision the growing of the jamun tree. Deep loams and well-drained soils improve plant growth and yield potential.

- Additionally, these soils retain adequate moisture, which promotes healthy fruiting a d ideal growth [12].

Climate.

- Jamun grows well in steamy and subtropical climates.
- It may also be cultivated in the low Himalayan ranges at a height of 1,300 meters.
- Jamun needs thirsty conditions when the fruit is setting and growing tall [13].



Figure 3. *Syzygium cumini* tree

Syzygium cumini is the scientific name for Java plum, Malabar plum, or black plum. This plant belongs to the Indian subcontinent and adjoining parts of Southeast Asia. Based on observation, the subject tree is quite mature as it has a rich canopy of green leaves, which suggests that it has adapted well to its surroundings. This type of tree is famous because of its fruit, which is a dark-coloured drupe and tastes different from other fruits.

Syzygium cumini is a useful tree not only because of its fruit but also due to its medicinal value.

Propagation: Jamuns can be multiplied by either vegetative or seed methods. Parents can become

realized through seed, thanks to polyembryony, through the application of seeds. Although vegetative approaches have been fairly successful in most situations, proliferation is still preferable. However, it is not advised since seed propagation causes delayed bearing. There is no latency in the seeds. You can plant novel seeds. Seeds normally take ten to fifteen days to grow [14].

Planting Because of its evergreen nature, jamun can be planted in spring or in monsoons. The reason being that owing to opposing climatic situations in May-June, trees implanted in February and March generally tend to die within a few days of their planting [15].

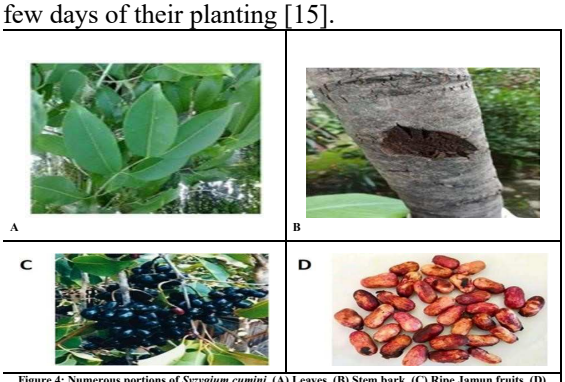


Figure 4: Numerous portions of *Syzygium cumini*. (A) Leaves. (B) Stem bark. (C) Ripe Jamun fruits. (D) Jamun seeds

Fertilizer.

Manure is not usually practical for jamun trees. This is because they can survive extreme neglect, not because they do not need manuring or do not care about it. Since jamun is an evergreen plant, one can choose to plant it either in the spring or through the rainy season season. Due to the poor climatic environments knowledgeable in the months of May and June, most trees that have been established in February and March tend to die shortly after implanting. Annual manuring of about 19 kilograms of forage manure should be done before the period of fruiting, while during the fruiting season, the quantity required is 75 kilograms of forage manure per fruitbearing tree [16].

Blossoming and bearing fruit

- Flowers blossom in the leaf axils of branches.
- In northern India, flowering begins from the first week of March and lasts until April. The fertility of pollen is high in the early days.[17].

Yield and harvesting

A jamun plant requires about 8 to 10 years before producing fruit, while those grafted require only 6 to 7 years to produce fruit. But the economic production of fruits starts after 8-10 years of planting and ends after 50-60 years of its age. June and July are when fruit ripens. A seedling tree yields 80100 kg per year, while a grafted tree yields 6070 kg [18–20].

Marketing and storage

The fruits immediately go bad. Under typical storage circumstances, they can only be stored for three or four days. However, if fruits are first refrigerated and kept in an environment with a low temperature of 8–10 °C and a comparative moisture of 85–90%, the fruits may be stored in polythene bags up to three weeks [21].

(b)Pharmacognostic justification:

This is a tall evergreen tree with thick, leathery, brownish-grey leaves

The leaves

The leaves have many nerves fusing within the edge, are smooth, glossy, and have a rectangular oval to elliptical or obovate elliptical outline. They are also slightly leathery. They are between 6 and 12 cm long. The tip is wider and less acuminate [22].

Flowers

They are round or rectangular-shaped flowers that have a cross-sectional area of about 1 cm2 and branch out in clusters on the stem nodes. These are flowers formed through dichotomous paniculate cymes. The flowers are scented and have a greenish-white to white-pink collar [23].

Calyx

The calyx has four teeth, is about 4 mm long, and has a funnel-like form. Corolla (flowers). The petals adhere to one another and descend like a little disk.

Stamens

The *Syzygium cumini* flower is identified by its multiple stamens, all of which are about as long as the calyx.

This contributes to the flower's unique brush-like appearance, which is characteristic of the plant [24].

Fruits

The fruit has lavender to white flesh, is ovoid,1.5-3.5cm long, glossy, tasty, and dark purple or almost black in colour. One enormous, two-centimetre-long seed is current trendy the fruit. The fruit is mentioned as per the

'Fruit of Gods' in Hindu mythology [6].

The pharmacogenetic description

Depending on the size of the fruit, *S. cumini* occurs in two varieties: small and gigantic. The lesser variant has a spherical form, flavourful meat, and a huge seed that is rich in acids, tannins, and anthocyanins. The larger variation has an oval shape, sour flesh, and a small seed with less acid, anthocyanin, and tannin. The "Ram Jamun" or "Raja Jamun," which yields rectangular fruit through tiny, shady purple seeds, is the greatest wellliked S. cumini variety in north India. "Paras," another S. cumini variety from central India, has no seeds. The pharmacogenetic description of Syzygium cumini is shown in Figure 3 [25].

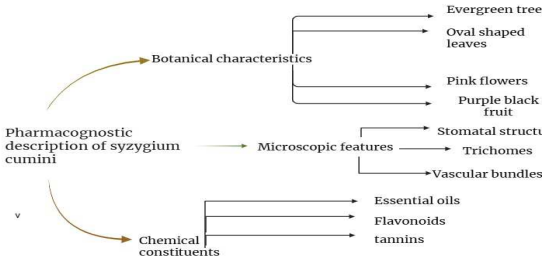


Figure 5. Pharmacogenetic description of *Syzygium cumini*

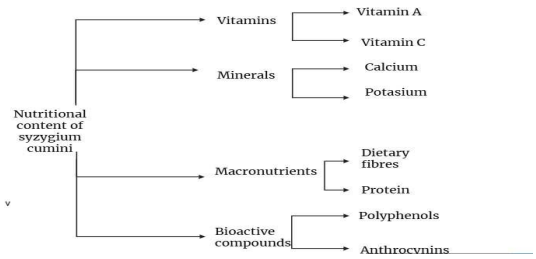


Figure 6. Nutritional content of Syzygium cumini

Nutritional content of *Syzygium cumini*

Vitamins, carbohydrates, minerals, antioxidants, and anthocyanins are some of the essential elements of S. cumini. Fruit colour and flavour are influenced by gallic acid, tannins, and polyphenol concentration Figure 5 [26].

***Syzygium cumini's* nutritional fruit value**

Fruits of *Syzygium cumini* have been regarded as nutritious in nature, with a single 100-gram portion of the fruits containing 14 grams of carbohydrates, 0.12 to 0.28 grams of fat, 0.35 to 0.85 grams of Fiber, 0.15 to 0.72 grams of protein, and around 60 kilocalories of energy. These fruits contain important minerals and vitamins, with 100 grams of fruit containing 14.5 to 26.18 milligrams of sodium, 50 to 75 milligrams of potassium, 12 to 30 milligrams of magnesium, 15 to 17 milligrams of phosphorus, and 8.5 to 18.5 milligrams of calcium. Additionally, these fruits contain trace minerals like copper, chlorine, zinc, and iron, in addition to some important vitamins, including folate, cyanocobalamin, riboflavin, thiamine, and niacin. Most notably, these fruits are known for their high content of anthocyanins [27].

***Syzygium cumini's* nutritional seed value:**

Syzygium cumini seeds are highly nutritious and have high amounts of carbohydrates, which are approximately 41.4 g/100 g of seeds, along with fiber content ranging from 2.3 to 16.9 g per 100 g of seeds. The seeds are a good source of proteins with a content ranging from 6.3 to 8.5 g per 100 g of seeds, while their fats and ash contents range from 0.83 to 1.18 g/100 g and 2.04 g/100 g, respectively. *Syzygium cumini* seeds have various bioactive molecules, among which are polyphenols with 361.30 mg/100 g and tannins with 168.24 mg/100 g of seeds. They are a source of nutrients like calcium and phosphorus [28] ***Syzygium cumini* nutritional leaf value:**

In 100 g, protein content is 9.2 g, fat content is 4.5 g, fiber content is 17 g, phosphorus content is 0.19 mg, and calcium content is 1.3 mg. Essential oils in the leaves make it aromatic [29].

(c) PHYTOCHEMICAL INVESTIGATION OF SYZYGIUM CUMINI

Many physiologically active substances can be found in the entire S. cumini, a traditional medicinal plant. Among the many compounds included in jamun are myricetin, isoquercetin, glucoside, anthocyanins, ellagic acid, also kaempferol. Adding sugar, mineral salts, and vitamin C to java plums increases the health advantages of vitamin C, anthocyanins, and flavonoids [30,31]. Metabolic issues and other illnesses can be avoided or lessened by these bioactive compounds. The plant's functional characteristics and health-protective advantages have been shown by several in vitro and in vivo pharmacological studies. Table 1 and Figure 5 show the main phytoconstituents present in the various sections of S. cumini [32, 33].

Table 1: Phytoconstituents Extracted from Unlike Parts of *Syzygium cumini*

Sr. No.	Plant Parts	Constituents	References
1	Root	Bioactive substances present in *Syzygium cumini* are glycosides, flavonoids, and isorhamnetin-3-O-rutinoside.	[34]
2	Bark	Several biologically active substances have been isolated from Syzygium cumini. They are myricetin, quercetin, β-sitosterol, ellagic acid, gallic acid, kaempferol, bergenins, and various flavonoids and tannins.	[35]

3	Fruit	Syzygium fruits contain high amounts of organic acids and sugars, thereby acting as a natural source of citric acid, malic acid, fructose, glucose, and raffinose. Furthermore, anthocyanin derivatives such as malvidin-3-laminaribioside and delphinidin-3-gentiobioside are present in these fruits.	[36]
4	Flower	Some other phytochemicals that are reported to be present in Syzygium cumini are oleanolic acid, ellagic acid, isoquercetin, quercetin, kaempferol,	[37]
5	Leaves	Acylated flavanol glycosides, esterase, triterpenoids, tannins, myricetin, and quercetin are some of the chemical compounds existing in the plant.	[38]
6	Seed	*Syzygium cumini* includes quercetin, glycosides, minute amounts of essential oils, albumin, fats, chlorophyll, mastic, jambosine, ellagic acid, gallic acid, and β-s	[39]

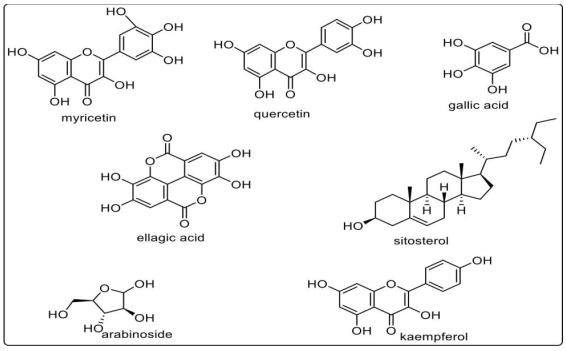


Figure 7:Chemical structure *of Syzygium cumini* phytoconstituents.

(d) Pharmacological activity Antioxidant Activity :

Numerous chronic disorders, among them diabetes mellitus, heart disease, cancer, and neurological conditions, are significantly exacerbated through oxidative stress. Oxidative pressure rises after there is a mismatch among the levels of reactive oxygen species (ROS) generated and the antioxidants present in the body. Among the different free radicals that cause cellular damage, hydrogen peroxide, superoxide anions, and hydroxyl radicals are some of the major ones. They react with important macromolecules like nucleic acids, proteins, and lipids causing cell damage. Based on its elevated concentration of polyphenolic chemicals, flavonoids, tannins, and anthocyanins, *Syzygium cumini* has been shown to have potent antioxidant action. Jamun's strong antioxidant qualities have been validated by several in vitro tests, such as the elimination of the DPPH test, the ABTS radical degradation test, the FRAP (standard) test, and the standard lipid peroxidation limits test. Research has shown that kernel extracts have additional antioxidant activity compared with extracts from leaves and bark.

Jamun fruits contain anthocyanins like delphinidin, cyanidin, petunidin, also malvidin glycosides, which are important for neutralizing reactive oxygen species and shielding cells after oxidative assault. Additionally, phenolic acids, such as ellagic acid and gallic acid, aid in lipid peroxidation prevention and metal chelation. cumini extracts dramatically raise endogenous antioxidant enzymes like glutathione peroxidase (GPx), catalase (CAT), and superoxide dismutase (SOD), according to in vivo research utilising animal-based models. These results suggest that jamun improves the body's antioxidant defence systems in addition to directly scavenging free radicals.[40]

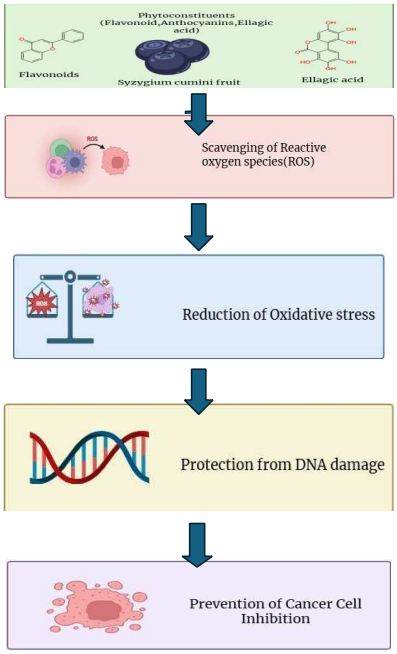


Figure 7: Antioxidant pathway

Antidiabetic Activity

Diabetes mellitus, which is a worldwide physiologic condition, is defined by persistent hyperglycaemia caused by aberrant insulin production, action, or both. Substantial study on medicinal plants with antidiabetic potential has been spurred by the rising worldwide prevalence of hyperglycaemia. Ayurvedic and other conventional medicinal systems have long utilized Syzygium cumini seeds as an antidiabetic drug. These conventional assertions have been confirmed by contemporary scientific investigation employing in vitro, in vivo, and clinical studies.

Antidiabetic Action Mechanisms Gastrointestinal Enzymes Inhibition Associated with Carbohydratedegrading enzymes α- amylase, besides α-glucosidase, are inhibited by S. cumini extracts. Jamun lowers postprandial blood glucose levels by blocking those enzymes.

Increased Secretion of Insulin Studies utilizing pancreatic β-cell models have shown that extracts from jamun seeds increase the production of insulin, which enhances tissue uptake of glucose.

Enhancement of Insulin Sensitivity Jamun's polyphenolic chemicals improve peripheral tissue glucose absorption and insulin receptor sensitivity.

Regulation of Glucose Transporters S. cumini enhances the expression of glucose transporter proteins, specifically GLUT-4. This provides the means for increased glucose acceptance by power rather than adipose tissue

Protection of Pancreatic β-Cells The antioxidants keep pancreatic β-cells from damage by oxidative stress.

Animal Studies The *Syzygium cumini* seeds' extracts have been shown to decrease significantly the fast blood sugar level of streptozotocin-induced diabetic rats. Moreover, there was an improvement in the lipid profile of blood, along with a recovery in the structure of pancreatic tissue.

Clinical Studies Only a limited medical study has indicated that there is a marked decrease in fasting blood glucose and HbA1C levels in subjects with diabetes mellitus following the intake of *Syzygium cumini* seed powder. Nonetheless, more research in the form of randomized controlled trials is needed for its validation [41].

Antimicrobial Activity

Microbial infections have consistently caused a burden of morbidity and mortality globally, necessitating a search for new antimicrobial agents, especially owing to the emergence of antibiotic resistance. Antimicrobial activity of *Syzygium cumini* extracts has been described against various pathogenic microorganisms. Various studies have highlighted the antibacterial activities of these extracts against Gram positive germs such as S. aureus, B. subtilis, and S. mutans, and Gram-negative bacteria like E. coli, P. aeruginosa, and S. typhi. Apart from that, various fungi like Candida albicans and various species of Aspergillus have also shown susceptibility to these plants. The attendance of phenolic mixes, flavonoids, besides tannic acid which are able to alter the membrane honesty of the cell, inhibit the activity of enzymes, and interfere with the synthesis of nucleic acids, is responsible for the antimicrobial activity [42].

Anti-inflammatory Activity

Inflammation is a defensive response that the body mounts in reaction to injuries and infections. While inflammation has a significant role in helping wounds heal and in protecting the body against diseases, prolonged and chronic inflammation can principal to other illnesses, among them cancer, heart disease, neurodegenerative diseases, and arthritis. Syzygium cumini extracts have exhibited high anti-inflammatory potential by reducing major inflammatory molecules like COX, LOX, TNF-α, and a variety of interleukins. Carrageenan-induced paw edema and formalin-induced inflammation experiments conducted on animal models have also shown strong dose-related anti-inflammatory activity. Jamun possesses significant anti-inflammatory activities due to bioactive substances like flavonoids, ursolic acid, and oleanolic acid. These compounds inhibit the activation of the NF- κB pathway responsible for inflammation [43].

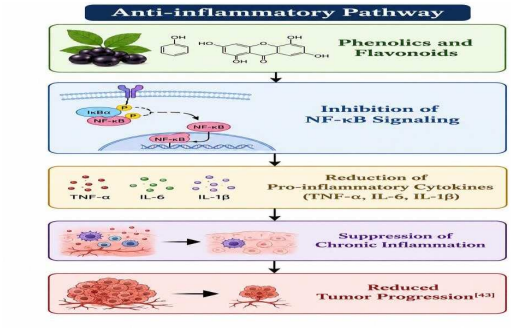


Figure 9: Anti-inflammatory pathway

Anticancer Activity

Cancer is one of the top mortality risk factors globally. Natural substances are essential for developing the pharmacological treatment of cancer. The extracts from *Syzygium cumini* have exhibited the potential for growth inhibition of various types of human cancer cell lines and induction of apoptosis in vitro. This movement of *Syzygium cumini* extract has been studied in various human cancer models, such as MCF-7 human breast carcinoma, HeLa cervix carcinoma, HepG2 human liver carcinoma, and HT-29 human colon carcinoma.

Mechanisms of Anticancer Activity

Induction of apoptosis via mitochondrial pathways. Arrest of the cell cycle at G0/G1 and G2/M stage. Reserve of both angiogenesis and metastasis. Protection of DNA via the antioxidant defence system. Jamun is rich in anthocyanins and polyphenols, which are recognized as potent anticancer agents.[44]

Hepatoprotective Activity

The liver is involved in the detoxification and metabolism of the body. Hepatobiliary injury caused by pharmaceuticals and xenobiotics is a serious health issue. In various in vivo models of hepatotoxicity caused by carbon tetrachloride, S. cumini extracts provided a protective effect to the liver. A decline in liver enzymes, including ALT, AST, and ALP, suggests hepatoprotective effects.[45]

Cardioprotective Activity

Cardiovascular illnesses rank as the greatest common cause of mortality worldwide. Jamun seed extracts display the potential to lower cholesterol, triglycerides, and LDL while elevating HDL due to their cardioprotective and preventive properties.[46]

Neuroprotective Activity

The majority of neuropathological conditions are primarily caused by sensory neuron death due to oxidative stress and inflammation, which Jamun extracts are shown to prevent oxidative stress in neurons and improve spatial learning and memory in a rodent model.[47]

Anti-obesity and Hypolipidemic Activity

S. cumini regulates the enzymes of lipid metabolism and lipid accumulation and subsequently decreases the gain of body weight and lipids.[48]

Antidiarrheal and Gastroprotective Activity

Jamun contains tannins and flavonoids, which have antidiarrheal and gastroprotective effects by diminishing intestinal.

Table 2. Pharmacological properties of dissimilar bioactive compounds/extract of *Syzygium cumini*

Bioactive compounds / Extracts	Pharmacological effects	Mechanism of action	References
Polyphenols (e.g., Ellagic acid)	Antioxidant	Free radical scavenging and oxidative stress reduction	[50]
Anthocyanins	Anti-inflammatory	Suppression of pro-inflammatory molecules like TNF-α, IL-6, and COX enzymes	[51]
Flavonoids (e.g., quercetin)	Antidiabetic	Improves insulin compassion and modulates glucose metabolism	[52]
Tannins	Antimicrobial	Disrupts bacterial cell walls and inhibits biofilm formation	[53]
Ethanolic leaf extracts	Hepatoprotective	Lowers AST and ALT enzyme indicators in the liver and prevents	[54]

		liver damage	
Seed extracts	Antihyperlipidemic	Reduces LDL cholesterol and increases HDL cholesterol concentrations	[55]
Essential oils	Antifungal	Fungal cell membrane disruption	[56]
Saponins	Immunomodulatory	Facilitates immune response through the activation of macrophages and T cells	[57]
Methanolic bark extracts	Anticancer	Mitigation of tumor growth through apoptosis induction	[58]
Aqueous fruit pulp extracts	Cardioprotective	Stimulates the production of antioxidants and prevents lipid peroxidation	[59]

Table:3. Comparative Table: Major Phytochemicals and Therapeutic Activities of *Syzygium cumini*

Plant Part	Major Phytochemical/ Compound	Major Pharmacological Activity	References
Seed	Ellagic acid, jambosine, gallic acid	Antidiabetic, antioxidant	[60]
Leaves	Quercetin, myricetin, flavonoids	Anticancer, anti-inflammatory	[61]
Fruit	Anthocyanins, cyanidin, delphinidin	Antioxidant, cardioprotective	[62]
Bark	Tannins, β-sitosterol, kaempferol	Antimicrobial, hepatoprotective	[63]
Flower	Oleanolic acid, isoquercetin	Anti-inflammatory, antioxidant	[64]
Root	Glycosides, isorhamnetin	Antimicrobial, antioxidant	[65]
Methanolic leaf extract	Polyphenols and flavonoids	Cytotoxic and antiproliferative activity	[66]
Seed extract	Polyphenols and alkaloids	Hypoglycaemic and anticancer activity	[67]
Fruit pulp extract	Anthocyanins and phenolic acids	Cardioprotective and neuroprotective activity	[68]
Bark extract	Triterpenoids and tannins	Anti-inflammatory and antimicrobial activity	[69]

IN VITRO CYTOTOXICITY STUDIES OF SYZYGIUM CUMINI

(a) Introduction to Cytotoxicity and Its Importance

Studying cytotoxicity is important when gauging the highly sought-after anticancer, antiproliferative, and toxicological activities of phytochemicals. Many researchers use cytotoxicity assays as an initial screening test to determine the extract's or the isolated constituent's ability to hamper the proliferation of both neoplastic and healthy tissue cell lines. The results of these types of investigations can be helpful for researchers in formulating and documenting the therapeutic

efficacy of the phototherapeutic agents and the associated safety concerns of the proposed medicinal plant for further in vivo investigations and scientific trials. Natural products are the sources of a number of anticancer drugs, such as paclitaxel, vincristine, and camptothecin. Thus, assessing the cytotoxic potential of Syzygium cumini would offer opportunities for identifying novel anticancer candidates and exploring its mechanism of action [70].

Cell Lines

Used in Cytotoxicity Studies of Syzygium cumini The cytotoxic activities of S. cumini extracts and isolated phytochemicals have been studied using a variety of human and animal cancer cell lines. The selected lines include:

Breast Cancer Cell Lines

- MCF-7 (oestrogen receptor-positive breast cancer cell line) MDA-MB-231 (triple negative breast cancer cell line) [71]

Cervical Cancer Cell Lines

- HeLa (human cervical carcinoma cell line) [72]

Liver Cancer Cell Lines

- HepG2 (human liver cancer cell line)
- Huh-7 cell line [73]

Colon Cancer Cell Lines

- HT-29
- HCT-116 [74]

Lung Cancer Cell Lines

- A549 (human lung cancer cell line) [75]

Other Cell Lines

- PC-3 (prostate cancer)
- K562 (chronic myelogenous leukaemia)
- Fibroblast cell lines (NIH/3T3, Vero) [76]

Table 4: These cell lines provide a broad spectrum for evaluating the anticancer potential of *S. cumini* extracts.

Extract/ Plant Part	Cell Line	Reported IC50 Value	Observed Mechanism	Reference
Methanolic leaf extract	MCF-7 (Breast cancer)	80–120 µg/mL	Apoptosis induction and cell cycle arrest	[77]
Methanolic leaf extract	HeLa (Cervical cancer)	90–150 µg/mL	Nuclear fragmentation and ROS generation	[78]
Seed extract	HepG2 (Liver cancer)	70–110 µg/mL	Mitochondrial dysfunction and apoptosis	[79]
Seed extract	HT-29 (Colon cancer)	100–180 µg/mL	Inhibition of cell proliferation	[80]
Fruit extract	MCF-7	120–200 µg/mL	Anthocyanin-mediated apoptosis	[81]
Fruit pulp extract	HCT-116 (Colon cancer)	140–220 µg/mL	Anti-proliferative activity	[82]
Bark extract	A549 (Lung cancer)	150–250 µg/mL	Membrane damage and oxidative stress	[83]
Polyphenol-rich seed fraction	PC-3 (Prostate cancer)	60–100 µg/mL	Caspase activation and DNA fragmentation	[84]
Ethanolic leaf extract	K562 (Leukaemia)	100–170 µg/mL	ROS-mediated cytotoxicity	[85]
Aqueous seed extract	NIH/3T3 normal fibroblast cells	>300 µg/mL	Low toxicity toward normal cells	[86]

(b) Methods for Extracting Cytotoxicity Assessment

The capacity of S. cumini to kill cells has been considered using various extracts from its leaves, seeds, bark, and fruits. The ways we extract substances are very important because they help shape the types of plant chemicals and the effectiveness of the extracts we get.

Solvent-Based Extraction The thinners regularly applied contain:

- Methanol
- Ethanol
- Water
- Ethyl acetate

- Chloroform
- Hexane

The polar solvents like methanol and ethanol are excellent in the extraction of flavonoids and phenolics, which are famous for their ability to cause cancerous growth and their harmful impacts on living cells [87].

Fractionation and Purification

The crude extraction may be separated into various portions using solvent fractionation techniques. Such a technique is employed in order to ensure that the fraction obtained contains large quantities of certain kinds of phytochemicals. Modern techniques include column chromatography, HPLC, and preparative TLC, which are performed to separate biologically active substances to test for cell-killing ability [88].

Cytotoxicity Tests In Vitro

Numerous assays have been used to test for toxicity caused by the extracts of S. cumini on cells. The following factors, including cellular viability, proliferation, introduction of cell death, and cell series arrest, have been evaluated in such tests.

(c) MTT Test

The MTT assay is a widely recognized method based on colour change that is usually employed to determine the viability of cells. Its main principle lies in the ability of MTT (3-(4,5- dimethylthiazol-2-yl)-2,5diphenyltetrazolium bromide) to be converted into formazan crystals by mitochondrial enzymes present in viable cells. Research demonstrates that S. cumini extracts obtained from its leaves and seeds possess cytotoxicity against various types of cancerous cells, which intensifies with increasing dosage. The IC50 values for the extract were start to range from 50 to 250 µg/mL [89**].**

Trypan Blue Exclusion Assay

The trypan blue test helps in distinguishing between live and dead cells. Live cells reject the stain, but dead cells absorb it. The extracts of S. cumini have been observed to reduce the viability of many types of cancer cells, demonstrating their cytotoxicity properties [90].

SRB (Sulforhodamine B) Assay

SRB is a test that helps determine the number of cells based on their protein content. Several research works have applied the SRB test to validate the effect of jamun extracts in preventing cancer cell proliferation [91].

LDH Release Assay

The LDH Release Test is used to determine the presence of intact cell membranes. An increase in the level of LDH released will indicate damage to the cell membrane and, consequently, the presence of toxicity. According to reports, the extracts of S. cumini cause an elevation in LDH released [92].

Dose-Dependent Cytotoxicity Analysis

Several studies indicate that Syzygium cumini extract induces cytotoxic activity in various cancer cell lines depending on its concentration. High concentrations of S. cumini leaf, seed, fruit, and bark extracts considerably decrease survival rates and proliferation rates. That the cancer cell lines exhibit reduced IC50 value relative to normal fibroblast cells indicates that such substances are further poisonous to cancer cells than to healthy cells. S. cumini extract prepared using methanol and ethanol has a high toxicity rate due to the attendance of high concentrations of polyphenols and flavonoids. With an increase in extract concentration, Jamun extract stimulates apoptosis in cancer cells through the production of ROS, membrane mitochondrial depolarization, DNA degradation, and caspase activation. It can be concluded that the phytoconstituents obtained from S.

cumini may be used as natural anticancer agents [93].

(d) Cytotoxic Effects of Different Plant Parts

Leaves Extract

Leaf extracts from S. cumini plants exhibit strong cytotoxic activity due to the high presence of phenolics and flavonoids within these plants. The methanolic leaf extract from S. cumini has proven to be toxic to the growth of HeLa and MCF-7 cell lines by causing cell death. It has been found from research that cell structure deviations, like cell shrinkage, chromatin condensation, and nuclear fragmentation, are caused by leaf extracts, which are usually characteristic features of apoptosis [94].

Seed Extract

Several researchers have extensively conducted experiments on seed extracts to determine whether they can be effective for the prevention of cancer. The chemicals known as polyphenols and alkaloids originate in seeds play a significant part in the reduction of cellular proliferation. Laboratory research shows that seed extracts inhibit the proliferation of HepG2 and HT-29 cells depending on the dose administered [95].

Fruit Extract

The extracts obtained from Jamun fruits that contain anthocyanins have been found to cause negative impacts on breast and colon cancers in laboratory settings. Anthocyanins play a significant part in initiating cell death as well as preventing angiogenesis, a process involved in tumour growth [96].

Bark Extract

The effects of the extract on the toxicity of the cell have been proven, but it is not researched as extensively as that of leaf and seed extracts due to their content of tannin and triterpenoid compounds, which affect cell growth [97].

Mechanisms of Cytotoxic Action

Induction of Apoptosis

Apoptosis is defined as the physiological phenomenon where the cell undergoes death in a well-controlled manner. It plays a very critical role in eliminating unwanted or unhealthy cells from the body. It is established that extracts of S. cumini initiate cell death via either intracellular or extracellular mechanisms. Laboratory experiments have demonstrated that Jamun extracts lead to cell death via mitochondrial and non-mitochondrial mechanisms. These extracts help to reduce the charge across the membranes of mitochondria, cause the release of cytochrome c, activate caspases 9 and 3, and result in the breaking up of DNA. Furthermore, the phytochemical components of S. cumini assist in regulating the protein mechanisms responsible for causing programmed cell death through an increase in the protein components responsible for triggering programmed cell death, such as Bax and p53, and a decrease in anti-apoptotic protein components like Bcl-2. These molecular processes result in the targeted destruction of cancer cells while mostly leaving the nearby healthy tissues unharmed. This shows that Jamun has the potential to be a natural cancer treatment.

- Activation of caspase-3 and caspase-9
- Mitochondrial membrane depolarization
- DNA fragmentation
- Upregulation of pro-apoptotic proteins (Bax, p53)
- Downregulation of anti-apoptotic proteins (Bcl-2) [98]

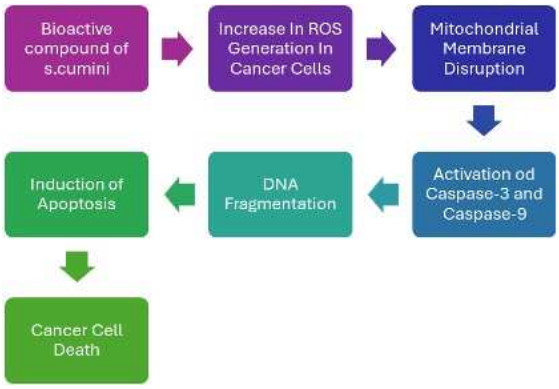


Figure 10: Apoptosis pathway

(e) ROS Generation Pathway

Mitochondrial Membrane Disruption The creation of reactive oxygen species (ROS) is an important process that plays a significant part in the cancer-fighting and harmful effects of Syzygium cumini. Even though the plant is well-known for its ability to fight off harmful substances, larger amounts of its polyphenols and flavonoids might actually cause stress to cancer cells specifically. Higher stages of sensitive oxygen species (ROS) inside cells lead to problems with mitochondria, damage to fats, oxidation of proteins, and harm to DNA. This process can eventually result in cell demise, then slow down the development of cancer cells. Research has shown that plant chemicals like quercetin, ellagic acid, and anthocyanins found in S. cumini can change the balance of oxidation and reduction in tumor cells and trigger signalling pathways related to oxidative stress. The aforementioned mechanism serves to be one of the most critical ways through which extracts of Jamun inhibit the proliferation of cancerous cells [99].

NF-κB (Nuclear Factor kappa B)

An important protein that helps control genes is important for inflammation, keeping cells alive, cell growing, and the development of cancer. The continuous beginning of NF-κB has been associated with chronic inflammatory diseases and tumor development. The natural components of Syzygium cumini, such as the flavonoids, anthocyanins, ursolic acid, and oleanolic acid, have been found to suppress NF-κB signal transduction pathways. By inhibiting NF-κB signalling, inflammatory intermediaries, with TNF-α, IL-6, COX2, and iNOS, prevented from being produced. As a result, there is reduced inflammation, inhibition of tumor growth, and stimulation of cell death in cancerous cells. Thus, the inhibition of NF-κB is an important mechanism that contributes to anti-inflammatory effects and antitumor activities in S. cumini extracts [100].

Cell Cycle Arrest

Stopping the cell cycle is another key way that cancer-fighting drugs prevent cancer cells from growing. Jamun extracts have been found to stop cancer cells during the G0/G1 or G2/M phases by controlling cyclins and cyclin-dependent kinases (CDKs) [101].

Oxidative Stress-Mediated Cytotoxicity

Even though S. cumini is recognized for its ability to fight free radicals, when polyphenols are present in high amounts, they can actually cause oxidative stress in cancer cells, resulting in cell death. In cancer cells that have been treated, there has been a rise in ROS production and a drop in how well the mitochondria work [102].

Anti-angiogenic and Anti-metastatic

Effects Research done in the lab shows that Jamun extracts can stop the creation of novel blood vessels and the movement of cancer cells by reducing the levels of VEGF and MMPs (matrix metalloproteinases). This prevents tumor growth and metastasis [103]

Cytotoxic Mechanism of *Syzygium cumini*

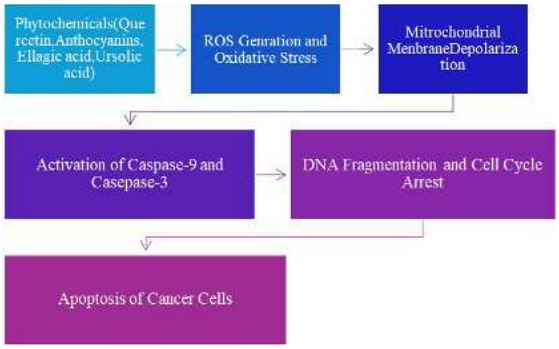


Figure 11: Cytotoxic mechanism of *Syzygium cumini*

(f) Cytotoxicity of Isolated Phytochemicals

Several separate compounds after *S. cumini* have been examined for their ability to kill cells.

Anthocyanins

Anthocyanins like delphinidin and cyanidin glycosides show powerful anticancer effects by causing cancer cells to die and stopping them from growing [105].

Flavonoids

Quercetin and kaempferol derivatives can stop the development of cancer cells by causing the cells to pause in their cycle and by triggering cell death.[106]

Triterpenoids

Ursolic acid and oleanolic acid can kill various cancer cells by causing apoptosis, which is a kind of automatic cell death, and by blocking the NF-κB signalling pathway [107].

Selective Cytotoxicity and Safety

One important element of the cytotoxic study is the fact that much attention has been paid to cancerous cells only, while healthy cells were left intact. Several studies are confirming the relatively low toxicity of extracts obtained from the *S. cumini*. That proves the good level of cytotoxic selectivity of these extracts. However, the excessive use of the extract may lead to the damaging effect on normal cells [108].

(g)Limitations of Current Cytotoxicity Studies

Despite these positive findings, there are numerous limitations that require attention.

- Most research is restricted to laboratory tests done outside of living organisms.
- Lack of standardized extraction methods • Different solvents and methods can cause changes in IC50 values.
- There are only a few studies that look closely at how things work on a molecular level.
- Absence of clinical validation [109]

(h)Future Perspectives Future research should focus on:

- Separation and identification of new harmful compounds that kill cells.
- Molecular mechanism studies using omics technologies
- In vivo anticancer studies
- Nano formulation-based delivery systems
- Clinical trials to validate anticancer efficacy

COMPUTER-BASED MOLECULAR DOCKING STUDIES OF SYZYGIUM CUMINI

(a)Introduction to In Silico Studies

An in-silico approach refers to computer-based approaches that assist in analysing and predicting the interactions between bioactive compounds and biological markers. These methods are now essential in today's drug discovery because they can quickly test many different compounds, lower the costs of experiments, and offer an understanding of how molecules work. Molecular docking is a popular computer-based method that helps predict how a ligand will attach to a target protein, including how they interact and how strongly they bind. In the past few years, scientists have looked closely at phytochemicals from Syzygium cumini using molecular docking methods to see how they might work as treatments for different illnesses like diabetes, cancer, inflammation, and infections caused by microbes.

(b)Principles of Molecular Docking

Molecular docking is a computer method that helps us understand how a small molecule, known as a ligand, attaches to a specific protein, called a receptor. The process involves two main components:

Search Algorithm

The searching algorithm examines how the ligand binds within the active pocket of the protein in various orientations. Typical searching algorithms include genetic algorithms, the Monte Carlo method, and systematic searches [110].

Scoring Function

The score function is meant to assess the strength of the binding of the ligand to the receptor molecule by estimating the binding energy. The less the binding energy is, the more stable and stronger the interaction will be; the opposite case applies for high binding energy. Docking studies provide valuable information regarding the interaction between the ligand and target protein based on hydrogen bonds, hydrophobic effects, Van der Waals interactions, and electrostatic connections [111]

Software and Tools Used in Docking Studies

Several software programs are usually employed in the analysis of the interactions between the phytochemicals found in S. cumini with other substances.

- Auto Dock and AutoDock Vina
- Glide (Schrödinger)
- GOLD (Genetic Optimization for Ligand Docking)
- Discovery Studio
- PyRx virtual screening tool Visualization tools like PyMOL and Discovery Studio Visualizer

are used for studying interactions between ligands and proteins [112].

(c)Target Proteins

Used in Docking Studies Studies on the interactions of the phytochemicals of *S. cumini* have been done on various target treatments**.**

Antidiabetic Targets

- α-Amylase
- α-Glucosidase
- Dipeptidyl peptidase-4 (DPP-4)
- Insulin receptor [113]

Anticancer Targets

- Epidermal growth factor receptor (EGFR)
- Vascular endothelial growth factor receptor (VEGFR)
- Topoisomerase I and II
- p53 tumor suppressor protein [114]

Anti-inflammatory Targets

- Cyclooxygenase-2 (COX-2)
- Lipoxygenase (LOX)
- Nuclear factor kappa B (NF-Kb) [115]

Antimicrobial Targets

- DNA gyrase
- β-lactamase
- Fungal enzymes [116]

(d)Connecting Key Plant Chemicals of *Syzygium cumini*

Several phytochemical compounds from S. cumini have undergone docking studies.

Quercetin

It has been shown that quercetin has an effective affinity for two specific enzymes, namely α-glucosidase and DPP-4. Quercetin forms an H-bond with the residues in the active site, indicating that quercetin may be used for treating diabetes [117].

Gallic Acid

Gallic acid has a moderate binding with the enzyme's alpha-amylase and COX-2. It acting a role in antioxidants and anti-inflammation [118].

Ellagic Acid

Ellagic acid shows a strong connection with cancer-related proteins like EGFR and topoisomerase, indicating that it might have properties that can fight cancer [119].

Rutin

Rutin shows a strong ability to bind with several targets, such as α-glucosidase and VEGFR, which suggests it has the potential to be used for various treatments [120].

Ursolic Acid

Ursolic acid has a strong effect on inflammatory enzymes like COX-2 and NF-κB, which helps to reduce inflammation [121].

Table 5: Molecular Docking Studies of Major Phytochemicals of *Syzygium cumini*

Compound	**Target Protein**	**Binding Energy (kcal/mol)**	**Key Interaction**	**Predicted Activity**	**Reference**
Quercetin	α-Glucosidase	8.5	Hydrogen bonding with active site residues	Antidiabetic	[122]
Quercetin	DPP-4	8.1	Hydrophobic and hydrogen bond interactions	Glucose regulation	[123]
Ellagic acid	EGFR	9.2	π–π stacking and hydrogen bonding	Anticancer	[124]
Ellagic acid	Topoisomerase II	8.8	DNA-binding pocket interaction	Antiproliferative	[125]
Gallic acid	COX-2	6.7	Hydrogen bonding with catalytic residues	Anti-inflammatory	[126]
Gallic acid	α-Amylase	6.9	Electrostatic interaction	Antidiabetic	[127]

Rutin	VEGFR	9.5	Multiple hydrogen bonds	Anti-angiogenic	[128]
Rutin	α-Glucosidase	8.9	Strong active site stabilization	Antidiabetic	[129]
Ursolic acid	NF-κB	9.0	Hydrophobic interactions	Anti-inflammatory	[130]
Ursolic acid	COX-2	8.4	Active site binding	Anti-inflammatory	[131]
Kaempferol	LOX	7.8	Hydrogen bonding	Anti-inflammatory	[132]
Myricetin	DNA gyrase	8.0	Binding with catalytic domain	Antimicrobial	[133]
Anthocyanins	VEGFR	8.6	Ligand–receptor stabilization	Anticancer	[134]
Oleanolic acid	p53 protein	8.3	Hydrophobic and electrostatic interaction	Apoptosis induction	[135]

Molecular Docking Interaction of Major Phytoconstituents



Figure 12: Molecular Docking interaction

A diagram showing how the main compounds found in *Syzygium cumini* interact with target proteins that are linked to cancer and metabolic diseases [136].

(e) Binding Interactions and Mechanisms

Research on docking shows that the plant chemicals from *S. cumini* connect with target proteins in different ways through various molecular interactions.

- Hydrogen bonding: stabilizes ligand–protein complex
- Hydrophobic interactions: enhance binding affinity
- π–π stacking: important for aromatic compounds
- Electrostatic interactions: contribute to specificity These interactions decide how stable and active the ligandprotein complex [137].

ADMET and Drug-Likeness

Prediction Moreover, in silico research methods include ADMET (Absorption, Distribution, Metabolism, Excretion, and Toxicity) analysis to examine the properties that make a chemical compound a potential pharmaceutical drug.

Key Parameters:

- Lipinski's Rule of Five
- Molecular weight
- Log P (lipophilicity)
- Hydrogen bond donors and acceptors

Most phytochemicals from S. cumini have good ADMET properties, suggesting they could be promising candidates for drugs [138].

Advantages of In Silico Docking Studies

- Rapid screening of compounds
- Cost-effective approach
- No ethical issues
- Provides molecular-level insights
- Reduces experimental workload [139].

(f)Critical Analysis and Current Limitations of Molecular Docking Studies

Although molecular docking studies of Syzygium cumini Phytochemicals have shown a lot of promise for treatment, there are still some limitations and gaps in research that need to be addressed. Most of the docking studies that are available right now are early computer-based research and do not have enough experimental proof to support their findings. In several reports, the results of docking are often explained just by looking at the binding affinity values, without a thorough examination of how ligands and proteins interact, how stable the binding is, or how it relates to biological significance. Because of this, the

healing importance of many plant chemicals is still not clear. Another major weakness is that there are no standardized docking protocols. There is variation between various studies regarding the software used, scoring systems employed, grid parameters applied, and even the conformation of the protein structure. As a result, scoring values for docking become highly variable from one research to another, which makes comparison of findings difficult. Furthermore, most of the docking studies consider rigid ligand conformations, although in nature, proteins are highly flexible and versatile. Disregarding this fact might influence the accuracy of docking studies' results. Moreover, most of the literature does not provide detailed information concerning hydrogen bonds, hydrophobic interactions, crucial residues in the active site, and structural alterations during ligand-receptor interactions. Important information regarding docking parameters, such as RMSD values, docking validation, and reliability of binding poses, is also missing in the majority of literature reviews. Moreover, only a few plant compounds of S. cumini have been investigated; numerous potentially beneficial molecules have remained unknown to date [140]. An important aspect to consider is the discrepancy between the strength of the binding during docking and the actual biological activity when studied in the laboratory and animal testing. Such factors as the absorption of the substance, its metabolism, its toxic properties, permeability, and distribution affect the efficacy of treatment substantially, but they tend to be neglected by scientists who only study docking. Although certain research projects deal with ADMET predictions, there are no comprehensive studies concerning the pharmacokinetic effects of the substances under discussion. Molecular docking should be coupled with molecular dynamics (MD) simulations, QSAR, network pharmacology, and machine learning algorithms to ensure future success in the field of docking studies. Molecular dynamics simulations will give us an idea about how stable or flexible the interaction between the protein and ligand becomes when it occurs under circumstances that resemble physiological conditions. Similarly, the importance of toxicity testing through experiments on cellular levels, inhibitory assays on enzymes, and in vivo testing cannot be ignored. New studies can also focus on identifying novel target proteins associated with cancer, diabetes, inflammation, and ailments related to brain and nerve damage. Positive control experiments with existing drugs may increase the credibility of results from such scientific investigation by means of docking analysis. Moreover, visualization and analysis of complex intermolecular interactions are an essential step for better comprehension of the biological action mechanisms of compounds extracted from S. cumini. In general, studies using molecular docking give useful early information about the possible medical benefits of S. cumini's bioactive compounds. However, to successfully discover drugs and apply them in clinical settings, a combination of computer-based methods and practical experiments is needed [141].

TOXICITY AND SAFETY PROFILE OF SYZYGIUM CUMINI

Syzygium cumini has remained used for an extended time in Ayurvedic and Unani medicine, and it is generally recognized as a safe herb when taken in the right amounts. Early research shows that dissimilar portions of the shrub, such as the fruits, seeds, leaves, and bark, have a good safety record. Studies on severe toxicity show that at therapeutic doses, there is very little toxicity, and it does not significantly change behaviour or affect mortality. Long-term use seems to have no noticeable harmful belongings on dynamic organs like the liver, kidneys, and heart, based on sub-chronic and chronic studies, and biochemical markers remain within normal limits. However, because it has strong antidiabetic effects, taking too much of the seed extracts can lead to low blood sugar levels. Taking higher doses can lead to moderate stomach issues, such as feeling sick and having diarrhoea. Safety can be affected by differences in the chemicals found in plant-based solutions due to changes in location and the methods used to extract them. Right now, there isn’t much clinical data involving humans, even though earlier trials in the lab showed that it is quite safe. Hence, there is a need for additional research on toxicity and establishing appropriate standards for dosage. Care must also be taken by patients on antidiabetic medications, as well as by pregnant or lactating women, since there might be a possibility of interaction with herbs [142].

THERAPEUTIC APPLICATIONS OF SYZYGIUM CUMINI

(a)Application in Diabetes Management

Diabetes mellitus is one of the utmost widespread diseases in the world today. It may cause various complications such as kidney, nerve, and heart disorders. Use of *Syzygium cumini* in treating blood sugar levels is an old tradition in Ayurvedic medicine. Various applications, including seed powder, herb mixture, and aqueous extract of Jamun, have often been used by people for the management of diabetes patients. Scientific studies and clinical trials prove that regular consumption of Jamun preparations can result in effective blood sugar regulation and lipid metabolism. Being traditionally recognized and attributed to curative properties, *S. cumini* is considered to be one of the most valuable medicinal plants for the treatment of metabolic disturbances [143].

(b)Therapeutic Role in Cardiovascular Disorders

Heart disease has remained one of the major causes of mortality across the globe. The major contributors to heart disease include oxidative stress, elevated levels of cholesterol in the blood, and inflammation within the blood vessels. Jamun products have remained popular for centuries due to their ability to improve heart health and maintain fatty acid levels. Research indicates that consumption of Jamun fruits and the extraction from the seed could be instrumental in regulating cholesterol levels in the blood. S. cumini plays an essential role in the protection of blood vessels, hence reducing the chances of experiencing arteriosclerosis and hypertension [144].

(c)Potential Use in Cancer Therapy

Natural compounds continue to play a crucial role in cancer research and cancer therapy. The *Syzygium cumini* tree has received attention because it may contribute to the reserve of tumor development and the anticipation of cellular damage. Compounds extracted from the seed, leaves, fruit, and bark are useful in combating different types of cancer cell models. The fruit is rich in anthocyanins and polyphenolic compounds, which are considered vital in cancer prevention. Scientific studies suggest that Jamun components may be useful in cancer therapy through the reduction of oxidative stress and the prevention of abnormal cell growth. Although there is little evidence of clinical relevance, the plant could prove useful in producing drugs to combat cancer [145].

(c)Applications in Neurodegenerative Disorders

The prevalence of neurodegenerative diseases, especially Alzheimer's and Parkinson's, is increasing in many countries. This is mainly because of aging, coupled with other lifestyle issues that are responsible for the emergence and progression of these ailments. Older approaches in the medical field have involved the use of plants that contain a lot of antioxidants and are effective in enhancing the health of one’s brain and its capacity for memory formation. It was revealed in experiments that extracts of Jamun fruit and leaves had been helpful for the protection and enhancement of brain performance in laboratory tests. Antioxidants from the plant material can prevent nerve cells from oxidative damage as well as from the effects of aging [146].

(d)Use in Liver and Digestive Disorders

The complications related to the liver due to the effects of poisons, infections, and free radicals are significant health concerns. The usage of herbal medication in folk medicine is widespread in the form of bark and seed extracts of S. cumini for enhancing liver functions and improving digestion. Several studies have proved its effectiveness in reducing liver toxicity and restoring biochemical values. The jamun tree has been previously used to treat diarrhoea, dysentery, indigestion, and stomach irritations. The benefits provided by the bark and seed extract are believed to promote digestion [147].

(e)Role in Microbial and Inflammatory Diseases

Inflammation and microbial infections are still prevalent today despite advances in the field of medicine. Extracts from jamun have been widely used in treating skin infections, oral problems, wounds, and inflammatory ailments since ancient times. Leaves and bark from the tree are commonly used as traditional medicines for alleviating irritation, inflammation, and infection. The plant is used in herbal mouth rinses as well as traditional methods for maintaining oral hygiene. It becomes evident through all of the above applications that the significance of *S. cumini* in treating infections and inflammatory diseases [148].

(f)Nutraceutical and Functional Food Applications

The fruits are highly nutritious and are often consumed as foods for health purposes. They contain several nutrients like vitamins, minerals, fiber, and natural antioxidants that are helpful in maintaining good health. Several health products, such as juices, powders, capsules, syrups, and supplements, have been produced by using jamun fruits and their seeds. Due to the nutritional and antioxidant properties associated with the fruits, there has been an increasing interest in functional food and nutraceutical studies [149].

(g)Anti-obesity and Metabolic Syndrome

Being overweight and having metabolic syndrome are worldwide health issues linked to diabetes, heart disease, and cancer. Extracts from *Syzygium cumini* have been established to help reduce obesity by managing how fats are processed in the body. Research has shown that extracts from Jamun seeds can help lower weight gain, fat buildup, and fat levels in the blood in animal studies. Polyphenols influence the enzymes that help break down fats and the development of fat cells. So, *S. cumini* might be seen as a possible natural option for managing obesity [150].

(h)Dermatological and Wound Healing Applications

Traditional medicine uses the leaves, besides the bark of S. cumini, to treat skin problems and wounds. The plant has properties that fight germs, reduce oxidation, and lessen inflammation, which help in healing wounds. Research has indicated that Jamun extracts help produce more collagen, lower the chances of infections from germs, and speed up the curative procedure of cuts in animal studies. Flavonoids and tannins support defending the membrane and consume belongings that fight aging [151].

(I)Oral and Dental Health

S. cumini helps in treating disorders of the mouth and teeth, such as gingivitis and dental caries. Antimicrobial activities against microorganisms found in the mouth, including Streptococcus mutans, have been noted. The extracts of the leaves of Jamun are an ingredient in natural mouth rinses and toothpaste since it is effective in reducing inflammation and bacteria [152].

(j)Traditional Medicine and Ethnopharmacological Applications

S. cumini is also used for treating diabetes, digestive disorders, infectious ailments, inflammation, and metabolic disorders in Ayurvedic, Unani, and Siddha medicine. The significance of the Jamun tree in folk medicine clearly proves its potential for novel therapeutics [153].

(k)Clinical Studies and Human Trials

There have been several laboratory and animal studies that prove that *Syzygium cumin*i could be useful for therapeutic purposes. Nevertheless, there are very few clinical studies that involve human subjects regarding this plant. Several initial human studies prove that the seed extract of Jamun and Jamun fruit extract are beneficial for diabetic patients as they are capable of reducing fasting blood glucose level, post-prandial blood glucose level, and HbA1c. According to some research, it was also proven that the consumption of Jamun fruits regularly can result in a better fat profile in the bloodstream and antioxidants. While such results are promising, most of the clinical trials analysed involve small sample sizes, limited treatment durations, and various formulations that are different from each other, which poses serious doubts regarding their credibility and wider applicability. In addition, insufficient research has been conducted to provide a comprehensive picture of the absorption, pharmacokinetics, and general safety of this drug in terms of its prolonged use. Little evidence is available in relation to its effectiveness as an anticancer agent, neuroprotectant, cardio- protectant, and hepatoprotective agent. Consequently, large-scale randomized control scientific trials would be necessary to prove its efficacy as a medicinal agent, its dose, safety, and any drug interactions and herb-drug interactions associated with it. Standardization of the extracts and development of formulations grounded on scientific data will be vital for the successful integration of the extracts into current medical practice [154].

(l)Limitations and Challenges in Therapeutic

Despite the abundance of research related to *Syzygium cumini*, there are still certain deficiencies in the scientific literature on this topic. The current body of research on *S. cumini* consists predominantly of initial trials performed in vitro or on animals. There are not enough high-quality clinical studies performed on human subjects. Inconsistency is possible due to the difference in the extraction process, the solvents used, the geographical location of plants studied, and their chemical composition. This, in turn, leads to difficulties with comparing the results of different studies. Additionally, most studies focus on antioxidant and antidiabetic properties of S. cumini; however, the mechanisms by which they protect from cancer, neurotoxicity, and cardiovascular diseases are currently unknown. There has been very little data available on the process of metabolism, absorption, and the safety concerns of isolated phytochemicals from S. cumini with regard to the risks associated with chronic administration of these plants. Also, there have been very few reports available regarding the integration of phytochemical analysis, cellular toxicity assays, and molecular docking into one comprehensive approach. Hence, the need for further multi-disciplinary research integrating these approaches is necessary. Such studies will require the application of standardized herbal extract preparations, cutting-edge molecular techniques, omics technology, and clinical trials to verify the curative potential of *S. cumini* [155].

FUTURE PROSPECTIVES

Although there have been many studies conducted about *S. cumini*, there remain several issues that need to be addressed before this plant's full potential is understood in relation to treatment. The following topics deserve particular focus in future studies**:**

(a)Standardization of Extracts and Quality Control

There is a need to come up with standard extraction procedures for consistent results.

(b)Isolation and Characterization of Bioactive Compounds

There is a need to employ novel approaches to the extraction and identification of medicinal substances by means of chromatography and spectroscopy**.**

(c)Pharmacokinetic and Bioavailability Studies

It remains unclear how phytochemicals of *S. cumini* get absorbed by the organism, distributed in different body organs, metabolized and eliminated.

(d)Toxicological and Safety Evaluation

Studies need to be completed on the short-term, mid-term, and long-term toxicity in order to establish safe dose levels for human beings.

(e)Clinical Trials

The completion of well-coordinated randomized controlled trials is essential to prove the efficacy of *S. cumini* in treating diabetes, cancer, cardiovascular diseases, and neurological disorders**.**

(f)Drug Development and Formulation

Nanotechnology-based drug delivery methods can be considered and combined with existing drug treatment to increase the efficacy of treatment.

(g)Nutraceutical and Functional Food Applications

Production of healthy food products and supplements out of Jamun would provide affordable benefits to consumers.

(h)Biotechnological and Genomic Approaches

Omics-focused studies, such as genomics, proteomics, and metabolomics, may aid in comprehending the functioning of molecules and discovering possible indicators for medical purposes.

(I)Clinical Future Scope

Though some positive impacts have been demonstrated by *Syzygium cumin*i in scientific literature, the application of S. cumini within clinical medicine is limited due to the unavailability of human trials and the absence of standardized medicines. The future clinical studies of this herb should focus on conducting largescale randomized controlled trials, which will evaluate the efficiency, effectiveness, dosage of *S. cumini*, and its long-term impact on the treatment of diabetes mellitus, cancers, cardiovascular diseases, and neurological disorders. It is essential to develop standardized formulations supplemented with specific bioactive compounds to ensure reliable clinical results. In addition, application of modern drug delivery systems such as micellar formulation and phytosomes will significantly enhance the absorption rate and therapeutic effect of phytochemicals. The use of *S. cumini* extract in conjunction with other traditional drugs may be considered for increasing efficacy and reducing adverse effects. Additionally, studies involving the examination of the chemical constituents of the plant, its molecular interactions, its pharmacokinetics, as well as human clinical trials, will allow for the creation of scientifically-backed herb-based medicines and supplements using S. cumini.

CONCLUSION

Syzygium cumini is an important medicinal herb, which has many healing properties as well as drug-making capabilities due to the presence of various beneficial phytochemicals within its structure. Some of them are flavonoids, phenolic acids, anthocyanins, tannins, alkaloids, and terpenoids. Different parts of this medicinal plant, including its fruits, seeds, leaves, and bark, have been researched for their numerous health-improving properties and application in traditional medicine. There are many therapeutic characteristics of *Syzygium cumini*. The medicinal herb has anti-oxidant, antidiabetic, antimicrobial, anti-inflammatory, hepatoprotective, cardioprotective, neuroprotective, and anticancer properties. Various chemical studies on plants have identified some useful phytochemicals such as quercetin, gallic acid, ellagic acid, rutin, and anthocyanins. These phytochemicals help deliver the therapeutic properties of the plant. Studies conducted in a cell toxicity laboratory have demonstrated promising results on cancer cells. This is achieved through mechanisms such as programmed cell death, altering the oxidative stress state, inhibition of cell proliferation, and cell cycle arrest. In addition, computer-based molecular docking studies have revealed comprehensive information on the binding interactions between the phytochemicals of *S. cumini* and protein targets involved in diabetes, cancer, inflammation, and microbial infections. These computational approaches may suggest that phytochemicals in Jamun may play a significant part in drug detection and development in the future. While there may have been encouraging findings from various research conducted previously, much of it relies on laboratory, animal, and computer-based investigations. There are not sufficient carefully designed human clinical trials done regarding the use of alternative treatments for various conditions. The disparities in extraction processes, chemical structure of the herbal components, and lack of standardized treatment are still major factors hindering the clinical application of these therapeutic modalities. Further research must be done regarding the study of standardization, pharmacokinetics, testing for toxicity, mechanism of action, and extensive clinical trials. Overall, the combination of pharmacological investigations of phytochemicals, toxicity testing, and molecular docking techniques proves that *Syzygium cumini* is a promising therapeutic agent. With continued scientific research and pharmaceutical development efforts, *Syzygium cumini* can become a valuable natural resource in developing medicinal products and drugs for the treatment of various chronic illnesses.

REFRENCES

1. Prabhakaran S, Gotha dam KM, Sivashanmugam K. Phytochemical and antimicrobial properties of *Syzygium cumini*, an ethnomedicinal plant of Javadhu Hills. Res Pharm. 2011;1(1):22–32.

2. Karunamoorthi K, Jegajeevanram K, Vijayalakshmi J, Mengistie E. Traditional medicinal plants: a source of phytotherapeutic modality in resource-constrained health care settings. J Evid Based Complementary Altern Med. 2013;18(1):67–74. doi:10.1177/2156587212460241.

3. Ugbabe GE, Ezeunala MN, Edmond IN, Apev J, Salawu OA. Preliminary phytochemical, antimicrobial and acute toxicity studies of the stem bark and leaves of a cultivated *Syzygium cumini* Linn.

(Myrtaceae) in Nigeria. Afr J Biotechnol. 2010;9(41):6943–6947.
4. Tabassum N, Hamdani M. Plants used to treat skin diseases. Pharmacogn Rev. 2014;8(15):52–60. doi:10.4103/0973-7847.125531.
5. Mohiuddin AK. A brief review of traditional plants as sources of pharmacological interests. Open J Plant Sci. 2019;4(1):001–008. doi:10.17352/ojps.000015.
6. Chhikara N, Kaur R, Jaglan S, Sharma P, Gat Y, Panghal A. Bioactive compounds and pharmacological and food applications of *Syzygium cumini*: a review. Food Funct. 2018;9(12):6096–6115. doi:10.1039/C8FO00654G.
7. Prasad SB, Gurav AM, Prasad GP, Mangal AK, Srikanth N. Pharmacognostic and preliminary phytochemical evaluation of leaf of *Syzygium cumini* (L.) Skeels. Int J Ayurvedic Med. 2021;12(3):684–688. doi:10.47552/ijam.v12i3.1857.
8. Hasanuzzaman M, Islam W, Islam MB. Phytochemical screening of *Syzygium cumini* extracts in different solvents. J Bio-Sci. 2016;24:11–18. doi:10.3329/jbs.v24i0.37483.
9. Anjali V, Sindhu G, Girish C. A review on pharmacology and phytochemistry of *Syzygium cumini*. Indian J Pharm Biol Res. 2017;5(4):24–28. doi:10.30750/ijpbr.5.4.5.
10. Agarwal P, Gaur PK, Tyagi N, Puri D, Kumar N, Kumar SS. An overview of phytochemical, therapeutic, pharmacological and traditional importance of *Syzygium cumini*. Asian J Pharmacogn. 2019;3(1):5–17.
11. Sowjanya KM, Swathi J, Narendra K, Krishna SA. A review on phytochemical constituents and bioassay of *Syzygium cumini*. Int J Nat Prod Sci. 2013;3(2):1–11.
12. Sudomo A. Habitat characteristics and population of *Syzygium cumini* L. in private forest and customary forest of Yogyakarta. IOP Conf Ser Earth Environ Sci. 2021;648(1):012054.
13. Singh S, Singh AK, Saroj PL, Mishra S. Research status for technological development of jamun (*Syzygium cumini*) in India: a review. Indian J Agric Sci. 2019;89(12):1991–1998.
14. Khadivi A, Mirheidari F, Saeidifar A, Moradi Y. Selection of the promising accessions of jamun (*Syzygium cumini* (L.) Skeels) based on pomological characterizations. Food Sci Nutr. 2023;11(1):470– 480.
15. Morton JF. The jambolan (*Syzygium cumini* Skeels): its food, medicinal, ornamental and other uses. Proc Fla State Hortic Soc. 1963;76:328–337.
16. Singh AK, Bajpai A, Singh VK, Ravishankar H, Tandon DK, Reddy BM. The jamun (*Syzygium cumini* Skeels). Rehmankhera: Central Institute for Subtropical Horticulture (ICAR); 2009. p. 1–28.
17. Chander S, Kumar S, Kavino M, Bora L. Effect of seasonal variation on softwood grafting under different environmental conditions in jamun (*Syzygium cumini* Skeels). Res Crops. 2016;17(3):1–6.
18. Bijauliya RK, Alok S, Sabharwal M, Chanchal DK. *Syzygium cumini* (Linn.): an overview on morphology, cultivation, traditional uses and pharmacology. Int J Pharm Sci Res. 2018;9(9):3608– 3620. doi:10.13040/IJPSR.0975-8232.9(9).3608-20.
19. Tripathi P. Jamun cultivation. ResearchGate. 2020. doi:10.13140/RG.2.2.25154.20160.
20. Pati A. Jamun: history, cultivation, nutritive value, medicinal properties and processing and value addition. In: Prasad SM, editor. Lesser Known Fruits and Vegetables. 1st ed. Bhavnagar: Krishna Publication House; 2021. p. 25–49.
21. Ghosh P, Pradhan RC, Mishra S, Patel SA, Kar A. Physicochemical and nutritional characterization of jamun (*Syzygium cumini*). Curr Res Nutr Food Sci. 2017;5(1):25–35. doi:10.12944/CRNFSJ.5.1.04.
22. Bukya A, Madane L. Preparation and standardization of jamun jam (*Syzygium cumini* L.): chemical and storage studies. World J Pharm Sci. 2018;7(4):876–885.
23. Aung EE, Kristanti AN, Aminah NS, Takaya Y, Ramadhan R. Plant description, phytochemical constituents and bioactivities of *Syzygium* genus: a review. Open Chem. 2020;18(1):1256–1281. doi:10.1515/chem-2020-0175.
24. Ayyanar M, Subash-Babu P. *Syzygium cumini* (L.) Skeels: a review of its phytochemical constituents and traditional uses. Asian Pac J Trop Biomed. 2012;2(3):240–246. doi:10.1016/S22211691(12)60050-1.
25. Ramos IL, Bandiola TM. Phytochemical screening of *Syzygium cumini* (Myrtaceae) leaf extracts using different solvents. Der Pharm Lett. 2017;9(2):74–78.
26. Kumar M, Zhang BH, Nishad J, et al. Jamun (*Syzygium cumini* (L.) Skeels) seed: nutritional profile, functional food properties, health-promoting applications, and safety aspects. Processes. 2022;10(11):2169. doi:10.3390/pr10112169.
27. Madani B, Mirshekari A, Yahia EM, Golding JB, Hajivand S, Dastjerdy AM. Jamun (*Syzygium cumini* L. Skeels): a promising fruit for the future. Hortic Rev. 2021;48:275–306. doi:10.1002/9781119750802.ch5.
28. Sehwag S, Das M. Nutritive, therapeutic and processing aspects of jamun (*Syzygium*

cumini)—an overview. Indian J Nat Prod Resour. 2014;5(4):295–307.
29. Singh Y, Bhatnagar P, Kumar S. A review on bio-active compounds and medicinal strength of jamun (*Syzygium cumini* Skeels). Int J Chem Stud. 2019;7(4):3112–3117.
30. Arya SS, Pegu K, Sadawarte PD. Bioactive compounds and health benefits of jamun (*Syzygium cumini*). In: Mérillon JM, Ramawat KG, editors. Bioactive Molecules in Food. Cham: Springer; 2019. p. 2297–2315.
31. Li D, Miao L, Tian M, Zhou J, Yang W, Yang F. Differences in eco-physiological responses to the removal of adventitious roots between *Syzygium nervosum* and *Syzygium cumini* saplings under waterlogging. Ann For Sci. 2023;80(1):13.
32. Muruganandan S, Srinivasan K, Chandra S, Tandan SK, Lal J, Raviprakash V. Anti-inflammatory activity of *Syzygium cumini* bark. Fitoterapia. 2001;72(4):369–375.
33. Ketylin FM, Mello JC, Higa OZ, Rodas AC, Corrêa MA, Mendes-Giannini MJ, et al. Antimicrobial and cytotoxic activity of fruit extract from *Syzygium cumini* (L.) Skeels. Lat Am J Pharm.
2010;29(5):725–730.
34. de Carvalho Bernardo WL, Boriollo MF, Tonon CC, da Silva JJ, Cruz FM, Martins AL, et al. Antimicrobial effects of silver nanoparticles and extracts of *Syzygium cumini* flowers and seeds. Arch Oral Biol. 2021;125:105101.
35. Ahmed R, Tariq M, Hussain M, Andleeb A, Masoud MS, Ali I, et al. Phenolic contents-based assessment of therapeutic potential of *Syzygium cumini* leaves extract. PLoS One. 2019;14(8):e0221318.
36. Chaudhuri AN, Pal S, Gomes A, Bhattacharya S. Anti-inflammatory and related actions of *Syzygium cumini* seed extract. Phytother Res. 1990;4(1):5–10.
37. Jagetia GC. Phytochemical composition and pleotropic pharmacological properties of jamun, *Syzygium cumini* Skeels. J Explor Res Pharmacol. 2017;2(2):54–66.
38. Gibbert L, Sereno AB, de Andrade MT, da Silva MA, Miguel MD, Montrucchio DP, et al. Nutritional composition, antioxidant activity and anticancer potential of *Syzygium cumini* and *Syzygium malaccense* fruits. Res Soc Dev. 2021;10(4):e5210413743.
39. Qamar M, Akhtar S, Ismail T, Yuan Y, Ahmad N, Tawab A, et al. *Syzygium cumini* fruit extracts: in vitro and in vivo anti-inflammatory properties. J Ethnopharmacol. 2021;271:113805.
40. Benherlal PS, Arumughan C. Chemical composition and in vitro antioxidant studies on Syzygium cumini fruit. Journal of the Science of Food and Agriculture. 2007 Nov;87(14):2560-9.
41. Margaret E, Shailaja AM, Rao VV. Evaluation of antioxidant activity in different parts of *Syzygium cumini*. Int J Curr Microbiol Appl Sci. 2015;4(9):372–379.
42. Kumar A, Ilavarasan R, Jayachandran T, Deecaraman M, Aravindan P, Padmanabhan N, et al. Antidiabetic activity of *Syzygium cumini* and its isolated compound against streptozotocin-induced diabetic rats. J Med Plants Res. 2008;2(9):246–249.
43. Qamar M, Akhtar S, Ismail T, Yuan Y, Ahmad N, Tawab A, Ismail A, Barnard RT, Cooper MA, Blaskovich MA, Ziora ZM. Syzygium cumini (L.), Skeels fruit extracts: In vitro and in vivo antiinflammatory properties. Journal of Ethnopharmacology. 2021 May 10;271:113805.
44. Oliveira GF, Furtado NA, Silva Filho AA, Martins CH, Bastos JK, Cunha WR, et al. Antimicrobial activity of *Syzygium cumini* leaves extract. Braz J Microbiol. 2007;38(2):381–384.
45. Islam M, Hussain K, Latif A, Hashmi FK, Saeed H, Bukhari NI, Hassan SS, Danish MZ, Ahmad B. Evaluation of extracts of seeds of Syzygium cumini L. for hepatoprotective activity using CCl4induced stressed rats.
46. Srivastava S, Chandra D. Pharmacological potentials of *Syzygium cumini*: a review. J Sci Food Agric. 2013;93(9):2084–2093.
47. Song JG, Tang W, Wang X, Su JC, Huang XJ, Shi L, Ye WC, Wang Y. Phloroglucinol-derived lipids from the leaves of Syzygium cumini and their neuroprotective activities. Fitoterapia. 2021 Sep 1;153:104968.
48. Adithya BS, Nayeem M, Sagar NA, Kumar S. Therapeutic potentials of Jamun (Syzygium cumini) and its integration into modern food technologies: A review. International Journal of Food Science. 2025;2025(1):8197889.
49. Gaikwad KP, Chandak CS, Ambhore JP, Narkhede MB, Ashwini A. A review of the pharmacological and bioactive compounds of syzygium cumini. IP International Journal of Comprehensive and Advanced Pharmacology. 2024;9(3):166-76.
50. Katiyar D, Singh V, Gilani SJ, Goel R, Grover P, Vats A. Hypoglycemic herbs and their polyherbal formulations: a comprehensive review. Med Chem Res. 2015;24(1):1–21.
51. Jabeen K, Javaid A. Antifungal activity of *Syzygium cumini* against *Ascochyta rabiei*. Nat Prod Res.
2010;24(12):1158–1167.
52. Mastan SK, Saraseeruha A, Gourishankar V, Chaitanya G, Raghunandan N, Reddy GA, et al. Immunomodulatory activity of methanolic extract of *Syzygium cumini* seeds. Pharmacologyonline. 2008;3:895–903.
53. Abdulrahman MD, Hama HA. Anticancer potential of genus *Syzygium*: a systematic review.

Explor Target Antitumor Ther. 2023;4(2):273–290.
54. Atale N, Rani V. *Syzygium cumini*: an effective cardioprotective via its antiglycoxidation potential. Int J Pharm Sci Rev Res. 2016;37(1):42–51.
55. Kumar V, Khatri N, Kumar D, Shekhawat M, Garg V, Kumar A, et al. Modern perspectives on the traditional uses, phytochemical profiles, and therapeutic benefits of *Syzygium cumini*. Integr Med Discov. 2025;9:e25007.
56. Kirshteyn I, Srivastav M, Grace K, Cescato V, Bommareddy A. Major plant-based compounds for the prevention and treatment of melanoma—a mini review. Biology. 2025;14(12):1772.
57. Barh D, Viswanathan G. *Syzygium cumini* inhibits growth and induces apoptosis in cervical cancer cell lines: a primary study. Ecancermedicalscience. 2008;2:83.
58. Fiqri H, Arda AG, Adrebi K, Proborini WD, Widyanto RM. Evaluation of total phenolic, total flavonoid, and in vitro cytotoxic activity of *Syzygium cumini* extract in cervical cancer cell. J Phys Conf Ser. 2020;1665(1):012033.
59. Figueiredo Júnior EC, Wanderley Cavalcanti Y, Brito Lira A, Freire Pessoa HD, Silva Lopes W, Romário da Silva D, et al. Phytochemical composition, antifungal activity, in vitro and in vivo toxicity of *Syzygium cumini* leaves extract. Bol Latinoam Caribe Plant Med Aromat. 2021;20(5):1–12.
60. Kumar A, Ilavarasan R, Jayachandran T, Deecaraman M, Aravindan P, Padmanabhan N, Krishan MR. Anti-diabetic activity of Syzygium cumini and its isolated compound against streptozotocin-induced diabetic rats. Journal of Medicinal Plants Research. 2008 Sep 1;2(9):246-9.
61. Mohammed S, Harikumar KB. Cancer immunology of Syzygium cumini. InThe Genus Syzygium 2017 Apr 7 (pp. 163-170). CRC Press.
62. Nadeem A, Mohammad N, HusainMohammad KM, Husain KM. Medicinal Potential of Jamun (Syzygium cumini Linn): A Review. Journal of Drug Delivery & Therapeutics. 2019 Sep 1;9(5).
63. Jayachandra K, Maheswaran A, Murali M. In-vitro evaluation of nitric oxide scavenging activity of methanolic and aqueous extract of Syzygium cumini linn. bark (Myrtaceae). International journal of pharmaceutical sciences and research. 2012 Feb 1;3(2):615.
64. Katiyar D, Singh V, Ali M. Recent advances in pharmacological potential of Syzygium cumini: A review. Advances in Applied Science Research. 2016;7(3):1-2.
65. Saini P, Gangwar M, Kalia A, Singh N, Narang D. Isolation of endophytic actinomycetes from Syzygium cumini and their antimicrobial activity against human pathogens. J Appl Nat Sci. 2016;8(1):416-22.
66. Siddika A, Das PK, Asha SY, Aktar S, Tareq AR, Siddika A, Rakib A, Islam F, Khanam JA. Antiproliferative activity and apoptotic efficiency of Syzygium cumini bark methanolic extract against EAC cells in vivo. Anti-Cancer Agents in Medicinal Chemistry-Anti-Cancer Agents). 2021 Apr 1;21(6):782-92.
67. Yadav SS, Meshram GA, Shinde D, Patil RC, Manohar SM, Upadhye MV. Antibacterial and anticancer activity of bioactive fraction of Syzygium cumini L. seeds. HAYATI Journal of Biosciences. 2011 Sep 1;18(3):118-22.
68. Li L, Mangali S, Kour N, Dasari D, Ghatage T, Sharma V, Dhar A, Bhat A. Syzygium cumini (jamun) fruit-extracted phytochemicals exert anti-proliferative effect on ovarian cancer cells. Journal of Cancer Research and Therapeutics. 2021 Oct 1;17(6):1547-51.
69. Prasad R, Swamy VS. Antibacterial activity of silver nanoparticles synthesized by bark extract of Syzygium cumini. Journal of Nanoparticles. 2013;2013(1):431218.
70. Banerjee J, Narendhirakannan RT. Phytochemical analyses, antibacterial, in vitro antioxidant and cytotoxic activities of ethanolic extract of Syzygium cumini (L.) seed extract. Int J Pharm Sci Res. 2011 Jul 1;2(7):1799-806.
71. Eldin Elhawary SS, Elmotayam AK, Alsayed DK, Zahran EM, Fouad MA, Sleem AA, Elimam H, Rashed MH, Hayallah AM, Mohammed AF, Abdelmohsen UR. Cytotoxic and anti-diabetic potential, metabolic profiling and insilico studies of Syzygium cumini (L.) Skeels belonging to family Myrtaceae. Natural product research. 2022 Feb 16;36(4):1026-30.
72. Barh D, Viswanathan G. Syzygium cumini inhibits growth and induces apoptosis in cervical cancer cell lines: a primary study. Ecancermedicalscience. 2008 Aug 21;2:83.
73. Rayzah M, Elderdery AY, Alzerwi NA, Alzahrani B, Alsrhani A, Alsultan A, Idrees B, Rayzah F, Bakhsh Y, Alzahrani AM, Subbiah SK. Syzygium cumini (L.) Extract-Derived green titanium dioxide nanoparticles induce caspase-dependent apoptosis in hepatic cancer cells. Plants. 2023 Sep 5;12(18):3174.
74. Khodavirdipour A, Zarean R, Safaralizadeh R. Evaluation of the anti-cancer effect of Syzygium cumini ethanolic extract on HT-29 colorectal cell line. Journal of gastrointestinal cancer. 2021 Jun;52(2):57581.
75. Gibbert L, Sereno AB, de Andrade MT, da Silva MA, Miguel MD, Montrucchio DP, de MessiasReason IJ, Dantas AM, Borges GD, Miguel OG, Kruger CC. Nutritional composition, antioxidant activity and anticancer potential of Syzygium cumini (L.) and Syzygium malaccense (L.) fruits. Research, Society and Development. 2021 Mar 30;10(4):e5210413743-.

76. Solai Prakash AK, Devaraj E. Cytotoxic potentials of S. cumini methanolic seed kernel extract in human hepatoma HepG2 cells. Environmental Toxicology. 2019 Dec;34(12):1313-9.
77. Mujawah A, Rauf A, Bawazeer S, Wadood A, Hemeg HA, Bawazeer S. Isolation, structural elucidation, in vitro anti-α-glucosidase, anti-β-secretase, and in silico studies of bioactive compound isolated from *Syzygium cumini*. Processes. 2023;11(3):880.
78. Smruthi G, Mahadevan V, Vadivel V, Brindha P. Docking studies on antidiabetic molecular targets of phytochemical compounds of *Syzygium cumini*. Asian J Pharm Clin Res. 2016;9(3):287–293.
79. Gupta K, Singh SP, Manhar AK, Saikia D, Namsa ND, Konwar BK, et al. Inhibition of *Staphylococcus aureus* and *Pseudomonas aeruginosa* biofilm and virulence by active fraction of *Syzygium cumini* leaf extract: in vitro and in silico studies. Indian J Microbiol. 2019;59(1):13–21.
80. Silva SD, Abreu IC, Silva GF, Ribeiro RM, Lopes AD, Cartágenes MD, et al. Toxicity evaluation of *Syzygium cumini* leaves in rodents. Rev Bras Farmacogn. 2011;22(1):102–108.
81. Prasad M, Venugopal SP, Alagarsamy V, Sridevi C. Preliminary phytochemical analysis and oral acute toxicity study of stem bark of *Syzygium cumini*. Int J Pharm Sci. 2016;8(1):209–213.
82. Katiyar D, Singh V, Ali M. Recent advances in pharmacological potential of *Syzygium cumini*: a review. Adv Appl Sci Res. 2016;7(3):1–12.
83. Ames BN, Gold LS, Willett WC. The causes and prevention of cancer. Proc Natl Acad Sci U S A. 1995;92(12):5258–5265.
84. Parmar J, Sharma P, Verma P, Goyal PK. Chemopreventive action of *Syzygium cumini* on DMBAinduced skin papillomagenesis in mice. Asian Pac J Cancer Prev. 2010;11(1):261–265.
85. Kharat SN, Ansari N, Mendhulkar VD. HPTLC screening for Flavonoids content in leaf extracts of Syzygium cumini (Linn.) and its Antimicrobial activity. Research Journal of Pharmacy and Technology. 2020 Jun 1;13(6):2720-6.
86. Balyan U, Sarkar B. Aqueous extraction kinetics of phenolic compounds from jamun (Syzygium cumini L.) seeds. International journal of food properties. 2017 Feb 1;20(2):372-89.
87. Inthorn J, Sornmanee S, Keawbankrud W. Potential of Syzygium cumini L. Seed as Cosmetic Bioactive Compounds: Matrix Metalloproteinases Inhibition, Antioxidant Activities, Cytotoxicity, and Safety Assessment. Trends in Sciences. 2025 Aug 5;22(11):10833-.
88. Artanti N, Maryani F, Dewi RT, Handayani S, Dewijanti ID, Meilawati L, Filaila E, Udin LZ. In vitro antidiabetic, antioxidant and cytotoxic activities of Syzygium cumini fractions from leaves ethanol extract. Indonesian Journal of Cancer Chemoprevention. 2019 Feb 28;10(1):24-9.
89. Ezhilarasan D, Apoorva VS, Ashok Vardhan N. Syzygium cumini extract induced reactive oxygen species-mediated apoptosis in human oral squamous carcinoma cells. Journal of Oral Pathology & Medicine. 2019 Feb;48(2):115-21.
90. Banerjee J, Narendhirakannan RT. Phytochemical analyses, antibacterial, in vitro antioxidant and cytotoxic activities of ethanolic extract of Syzygium cumini (L.) seed extract. Int J Pharm Sci Res. 2011 Jul 1;2(7):1799-806.
91. Singla R, Soni S, Patial V, Kulurkar PM, Kumari A, S M, Padwad YS, Yadav SK. Cytocompatible antimicrobial dressings of s yzygium cumini cellulose nanocrystals decorated with silver nanoparticles accelerate acute and diabetic wound healing. Scientific reports. 2017 Sep 5;7(1):10457.
92. Chandran R, Abrahamse H, Parimelazhagan T. Cytotoxic, analgesic and anti-inflammatory properties of Syzygium calophyllifolium bark. Biomedicine & Pharmacotherapy. 2018 Jul 1;103:1079-85.
93. Siddika A, Das PK, Asha SY, Aktar S, Tareq AR, Siddika A, Rakib A, Islam F, Khanam JA. Antiproliferative activity and apoptotic efficiency of Syzygium cumini bark methanolic extract against EAC cells in vivo. Anti-Cancer Agents in Medicinal Chemistry-Anti-Cancer Agents). 2021 Apr 1;21(6):782-92.
94. Devi HJ, Gnanasekaran P, Kumar AM, Siva D, Devi YA. Unveiling the antibacterial, antifungal, and cytotoxic potential of selenium nanoparticles synthesized with Syzygium cumini leaf extract. Journal of Cluster Science. 2025 Feb 22;36(2):60.
95. Ezhilarasan D, Apoorva VS, Ashok Vardhan N. Syzygium cumini extract induced reactive oxygen species-mediated apoptosis in human oral squamous carcinoma cells. Journal of Oral Pathology & Medicine. 2019 Feb;48(2):115-21.
96. Qamar M, Akhtar S, Ismail T, Wahid M, Abbas MW, Mubarak MS, Yuan Y, Barnard RT, Ziora ZM, Esatbeyoglu T. Phytochemical profile, biological properties, and food applications of the medicinal plant Syzygium cumini. Foods. 2022 Jan 28;11(3):378.
97. Siddika A, Das PK, Asha SY, Aktar S, Tareq AR, Siddika A, Rakib A, Islam F, Khanam JA.
Antiproliferative activity and apoptotic efficiency of Syzygium cumini bark methanolic extract against EAC cells in vivo. Anti-Cancer Agents in Medicinal Chemistry-Anti-Cancer Agents). 2021 Apr 1;21(6):782-92.

98. Aini NS, Ansori AN, Widyananda MH, Kharisma VD, Murtadlo AA, Herdiansyah MA, Rebezov M, Burkov P, Gudz P, Derkho M, Bezhinar T. Molecular Docking Analysis of Flavonoids from Syzygium cumini (L.) Skeels: Proapoptotic Potential as an Anticancer Mechanism. Borneo Journal of Pharmacy. 2025 Aug 30;8(3):252-62.
99. Atale N, Chakraborty M, Mohanty S, Bhattacharya S, Nigam D, Sharma M, Rani V. Cardioprotective role of Syzygium cumini against glucose-induced oxidative stress in H9C2 cardiac myocytes. Cardiovascular toxicology. 2013 Sep;13(3):278-89.
100. Syama HP, Sithara T, Krishnan SL, Jayamurthy P. Syzygium cumini seed attenuates LPS induced inflammatory response in murine macrophage cell line RAW264. 7 through NF-κB translocation.
Journal of Functional Foods. 2018 May 1;44:218-26.
101. Siddika A, Das PK, Asha SY, Aktar S, Tareq AR, Siddika A, Rakib A, Islam F, Khanam JA. Antiproliferative activity and apoptotic efficiency of Syzygium cumini bark methanolic extract against EAC cells in vivo. Anti-Cancer Agents in Medicinal Chemistry-Anti-Cancer Agents). 2021 Apr 1;21(6):782-92.
102. Said AH, Shaibah F, Moustafa M, Elamary RB. Plant-mediated nickel oxide nanoparticles show species-dependent antibacterial, antioxidant, anti-inflammatory and antidiabetic activities. Scientific Reports. 2025 Aug 24;15(1):31096.
103. IKRAM R, AHMED QS, ASLAM A, UMER A, MEHMOOD A, AWAN MR, BATOOL L, QURESHI
A. Green Guardians: the Role of Medicinal Plants in Combating Oxidative Stress.
104. Pereira JV, Freires IA, Castilho AR, da Cunha MG, Alves HD, Rosalen PL. Antifungal potential of Sideroxylon obtusifolium and Syzygium cumini and their mode of action against Candida albicans. Pharmaceutical biology. 2016 Oct 2;54(10):2312-9.
105. Nazif NM. The anthocyanin components and cytotoxic activity of Syzygium cumini (L.) fruits growing in Egypt. Natural Product Sciences. 2007;13(2):135-9.
106. Li L, Mangali S, Kour N, Dasari D, Ghatage T, Sharma V, Dhar A, Bhat A. Syzygium cumini (jamun) fruit-extracted phytochemicals exert anti-proliferative effect on ovarian cancer cells. Journal of Cancer Research and Therapeutics. 2021 Oct 1;17(6):1547-51.
107.Banerjee J, Narendhirakannan RT. Phytochemical analyses, antibacterial, in vitro antioxidant and cytotoxic activities of ethanolic extract of Syzygium cumini (L.) seed extract. Int J Pharm Sci Res. 2011 Jul 1;2(7):1799-806.
108. Swami SB, Thakor NS, Patil MM, Haldankar PM. Jamun (Syzygium cumini (L.)): A review of its food and medicinal uses. Food and Nutrition Sciences. 2012 Aug 28;3(8):1100-17.
109. Watia W, PamudjiWidodoa G, Herowati R. Syzygium cumini. Jurnal Kimia Sains dan Aplikasi23. 2020;6:189-95.
110. Gupta K, Singh SP, Manhar AK, Saikia D, Namsa ND, Konwar BK, Mandal M. Inhibition of Staphylococcus aureus and Pseudomonas aeruginosa biofilm and virulence by active fraction of Syzygium cumini (L.) Skeels leaf extract: in-vitro and in silico studies. Indian journal of microbiology. 2019 Mar 5;59(1):13-21.
111. Sofiatul Aini N, Dhea Kharisma V, Hermawan Widyananda M. In silico screening of bioactive compounds from Syzygium cumini L. and moringa oleifera L. against SARS-CoV-2 via tetra inhibitors.
112. Aini NS, Darmanto W. Unveiling the Anticancer Potential of Syzygium cumini: In Silico Insights into its Mechanistic Action Against Non-Small Cell Lung Cancer. Karbala International Journal of Modern Science. 2026;12(1):4.
113. Sofiatul Aini N, Dhea Kharisma V, Hermawan Widyananda M. In silico screening of bioactive compounds from Syzygium cumini L. and moringa oleifera L. against SARS-CoV-2 via tetra inhibitors.
114. Aini NS, Ansori AN, Widyananda MH, Kharisma VD, Murtadlo AA, Herdiansyah MA, Rebezov M, Burkov P, Gudz P, Derkho M, Bezhinar T. Molecular Docking Analysis of Flavonoids from Syzygium cumini (L.) Skeels: Proapoptotic Potential as an Anticancer Mechanism. Borneo Journal of Pharmacy. 2025 Aug 30;8(3):252-62.
115. Arba M. The Therapeutic Potential of Methanolic Leaf Extract of Syzygium cumini in Managing Type 2 Diabetes Mellitus based on Network Pharmacology Study. Turkish Computational and Theoretical Chemistry. 2025(Advanced Online Publication):101-9.
116. Shidiki A, Vyas A. Molecular docking and pharmacokinetic prediction of phytochemicals from Syzygium cumini in interaction with penicillin-binding protein 2a and erythromycin ribosomal methylase of Staphylococcus aureus. Biotechnologia. 2022 Mar 24;103(1):5.
117. Shidiki A, Vyas A. Molecular docking and pharmacokinetic prediction of phytochemicals from Syzygium cumini in interaction with penicillin-binding protein 2a and erythromycin ribosomal methylase of Staphylococcus aureus. Biotechnologia. 2022 Mar 24;103(1):5.
118. Sofiatul Aini N, Dhea Kharisma V, Hermawan Widyananda M. In silico screening of bioactive compounds from Syzygium cumini L. and moringa oleifera L. against SARS-CoV-2 via tetra inhibitors.

119. Sofiatul Aini N, Dhea Kharisma V, Hermawan Widyananda M. In silico screening of bioactive compounds from Syzygium cumini L. and moringa oleifera L. against SARS-CoV-2 via tetra inhibitors.
120.Andhiarto Y, Sukardiman S, Suciati S, Rosandy AR, Muslikh FA, Riwanti P. In Silico and In Vitro
Studies of Rutin from Syzygium cumini (L.) Skeels. var. album as an Antidiabetic α-Glucosidase Enzyme Inhibitor. Trends in Sciences. 2025;22(2):9047-.
121. Hidayah H, Amal S, Frianto D, Yuniarsih N, Ruswanto R. Identifikasi Senyawa Dalam Ekstrak Etanol
Kulit Batang Syzygium Cumini L. Skeels Menggunakan Lc-Ms/Ms Dan Aktivitasnya Terhadap
Reseptor Esterogen A (Er-A) Melalui Docking Dan Dinamika Molekuler. Skeels Menggunakan Lc-
Ms/Ms Dan Aktivitasnya Terhadap Reseptor Esterogen A (Er-A) Melalui Docking Dan Dinamika Molekuler.
122. Kavino M, Rajagopal B, Seenivasan P, Latheef A, Rajesh S. Multi-target anti diabetic potential of Syzygium cumini phytochemicals: An in silico analysis. Pharmacological Research-Natural Products. 2025 Dec 27:100482.
123. Patil VS, Deshpande SH, Harish DR, Patil AS, Virge R, Nandy S, Roy S. Gene set enrichment analysis, network pharmacology and in silico docking approach to understand the molecular mechanism of traditional medicines for the treatment of diabetes mellitus. Journal of Proteins and Proteomics. 2020 Dec;11(4):297-310.
124. Sofiatul Aini N, Dhea Kharisma V, Hermawan Widyananda M. In silico screening of bioactive compounds from Syzygium cumini L. and moringa oleifera L. against SARS-CoV-2 via tetra inhibitors.
125. Aini NS, Ansori AN, Widyananda MH, Kharisma VD, Murtadlo AA, Herdiansyah MA, Rebezov M, Burkov P, Gudz P, Derkho M, Bezhinar T. Molecular Docking Analysis of Flavonoids from Syzygium cumini (L.) Skeels: Proapoptotic Potential as an Anticancer Mechanism. Borneo Journal of Pharmacy.
2025 Aug 30;8(3):252-62.
126. Tijjani H, Zangoma MH, Mohammed ZS, Obidola SM, Egbuna C, Abdulai SI. Polyphenols: Classifications, biosynthesis and bioactivities. InFunctional foods and nutraceuticals: Bioactive components, formulations and innovations 2020 Aug 25 (pp. 389-414). Cham: Springer International Publishing.
127. Syama HP, Arun KB, Sinumol G, Dhanya R, Suseela Anusree S, Nisha P, Ravi Shankar L, Sundaresan A, Jayamurthy P. Syzygium cumini seed exhibits antidiabetic potential via multiple pathways involving inhibition of α-glucosidase, DPP-IV, glycation, and ameliorating glucose uptake in L6 cell lines. Journal of Food Processing and Preservation. 2018 Feb;42(2):e13464.
128. Beñanil K, Abayon RB, Albes NB, Bagtasos AJ, Bautista EA, Bonrostro MJ, Bulalacao AJ, Cano EA. Carcinogenesis Inhibition of Phenolic Derivatives in Duhat (Syzygium cumini); An in Silico Analysis. Asian Pacific Journal of Cancer Biology. 2025 Oct 26;10(4):781-98.
129. Chandel S, Sharma I. Predictive ADMET and Swiss Dock-Based Toxicity Profiling of Syzygium cumini and Allium cepa Bioactives for Neuroprotective and Antidiabetic Safety.
130. Dayrit FM, Guidote Jr AM, Gloriani N, de Paz-Silava SL, Villaseñor IM, Macahig RA, Tan MA, Chua JR, Sia IC. Philippine medicinal plants with potential immunomodulatory and anti-SARS-CoV-2 activities.
131. Ahmad G, Gupta V, Kumar Y, Singh G. SYZYGIUM CUMINI: A NATURAL REMEDY EXPLORED THROUGH ETHNOBOTANICAL AND SCIENTIFIC PERSPECTIVES.
132.Smruthi G, Mahadevan V, Vadivel V, Brindha P. Docking studies on antidiabetic molecular targets of phytochemical compounds of Syzygium cumini (L.) skeels. Asian J Pharm Clin Res. 2016 Dec 1;9(3):287-93.
133. Alsayed DK, Elhawary SS, El Raey MA, Ahmed GF, Marrez DA, Essa AF, Alshehri SA, Rabeh MA, Elmotayam AK. Eco-friendly fabrication of ZnO quantum dots using Brassica rapa (L.): metabolomic profiling and antimicrobial efficacy against foodborne pathogens supported by in-silico insights. Scientific Reports. 2025 Aug 6;15(1):28738.
134. Li S, He J, Hu H, Wang G, Tang J, Yao J, Shen J, Li X. Unraveling anti-atherosclerosis mechanism of anthocyanins from Xinjiang wild cherry plum (Prunus divaricata Ledeb) via network pharmacology and molecular docking. Bioresources and Bioprocessing. 2025 Jun 6;12(1):53.
135. Aini NS, Darmanto W. Unveiling the Anticancer Potential of Syzygium cumini: In Silico Insights into its Mechanistic Action Against Non-Small Cell Lung Cancer. Karbala International Journal of Modern Science. 2026;12(1):4.
136. Konappa N, Udayashankar AC, Krishnamurthy S, Pradeep CK, Chowdappa S, Jogaiah S. GC–MS analysis of phytoconstituents from Amomum nilgiricum and molecular docking interactions of bioactive serverogenin acetate with target proteins. Scientific reports. 2020 Oct 2;10(1):16438.
137. David T, Adelakun N, Omotuyi O, Metibemu D, Ekun O, Inyang O, Adewumi B, Enejoh O, Owolabi R, Oribamise EI. Molecular docking analysis of phyto-constituents from

Cannabis sativa with pfDHFR. Bioinformation. 2018 Dec 27;14(9):574.
138. Vardhan S, Sahoo SK. In silico ADMET and molecular docking study on searching potential inhibitors from limonoids and triterpenoids for COVID-19. Computers in biology and medicine. 2020 Sep 1;124:103936.
139. Saikia S, Bordoloi M. Molecular docking: challenges, advances and its use in drug discovery perspective. Current drug targets. 2019 Apr 1;20(5):501-21.
140. Sahu MK, Nayak AK, Hailemeskel B, Eyupoglu OE. Exploring recent updates on molecular docking: Types, method, application, limitation & future prospects. International Journal of Pharmaceutical Research and Allied Sciences. 2024;13(2-2024):24-40.
141. Bandiola TM, Ignacio GB, Yunson EG, Bandiola PD. Syzygium cumini (L.) Skeels: a review of its phytochemical constituents, toxicity studies, and traditional and pharmacological uses. Int. J. Appl. Pharm. Biol. Res. 2017;2(6):15-23.
142. Inthorn J, Sornmanee S, Keawbankrud W. Potential of Syzygium cumini L. Seed as Cosmetic Bioactive Compounds: Matrix Metalloproteinases Inhibition, Antioxidant Activities, Cytotoxicity, and Safety Assessment. Trends in Sciences. 2025 Aug 5;22(11):10833-.
143. Swami SB, Thakor NS, Patil MM, Haldankar PM. Jamun (Syzygium cumini (L.)): A review of its food and medicinal uses. Food and Nutrition Sciences. 2012 Aug 28;3(8):1100-17.
144. Chhikara N, Kaur R, Jaglan S, Sharma P, Gat Y, Panghal A. Bioactive compounds and pharmacological and food applications of Syzygium cumini–a review. Food & function. 2018;9(12):6096-115.
145. Kumawat M, Damor J, Kachchhwaha J, Garg AK, Singh C. Pharmacological properties and therapeutic potential of Syzygium cumini (Jamun): A review. World Journal of Pharmaceutical Sciences.
2018;7(3):312-22.
146.Rajkumar M, Davis Presley SI, Thiyagarajulu N, Girigoswami K, Janani G, Kamaraj C, Madheswaran B, Prajapati B, Ali N, Khan MR. Gelatin/PLA-loaded gold nanocomposites synthesis using Syzygium cumini fruit extract and their antioxidant, antibacterial, anti-inflammatory, antidiabetic and anti-
Alzheimer's activities. Scientific Reports. 2025 Jan 15;15(1):2110.
147. Chhikara N, Kaur R, Jaglan S, Sharma P, Gat Y, Panghal A. Bioactive compounds and pharmacological and food applications of Syzygium cumini–a review. Food & function. 2018;9(12):6096-115.
148. Swami SB, Thakor NS, Patil MM, Haldankar PM. Jamun (Syzygium cumini (L.)): A review of its food and medicinal uses. Food and Nutrition Sciences. 2012 Aug 28;3(8):1100-17.
149. Ayenampudi SB, Verma R, Adeyeye SA. The potential health benefits and food applications of jamun (Syzygium cumini L.), an indigenous fruit of India. Nutrition & Food Science. 2023 Jul 5;53(5):793809.
150. Rizvi MK, Rabail R, Munir S, Inam-Ur-Raheem M, Qayyum MM, Kieliszek M, Hassoun A, Aadil RM. Astounding health benefits of jamun (Syzygium cumini) toward metabolic syndrome. Molecules. 2022 Oct 24;27(21):7184.
151. Abdelazim EB, Abed T, Goher SS, Alya SH, El-Nashar HA, El-Moslamy SH, El-Fakharany EM, Abdul-Baki EA, Shakweer MM, Eissa NG, Elsabahy M. In vitro and in vivo studies of Syzygium cumini-loaded electrospun PLGA/PMMA/collagen nanofibers for accelerating topical wound healing.
RSC advances. 2024;14(1):101-17.
152. Bernardo WL, Boriollo MF, Tonon CC, da Silva JJ, Oliveira MC, de Moraes FC, Spolidorio DM. Biosynthesis of silver nanoparticles from Syzygium cumini leaves and their potential effects on odontogenic pathogens and biofilms. Frontiers in microbiology. 2022 Sep 29;13:995521.
153. Ayyanar M, Subash-Babu P. Syzygium cumini (L.) Skeels: A review of its phytochemical constituents and traditional uses. Asian Pacific journal of tropical biomedicine. 2012 Mar 1;2(3):240-6.
154. Helmstaedter A. Syzygium cumini (L.) SKEELS (Myrtaceae) against diabetes–125 years of research. Die Pharmazie-An International Journal of Pharmaceutical Sciences. 2008 Feb 1;63(2):91-101.
155. Suhail SM, Anand A, Biswas AS, Ahmad S, Manjula SN, Mruthunjaya K. Therapeutic Horizons of Syzygium cumini L.: An Insight into its Antioxidant, Anti-inflammatory, Anti-cancer Bio Actives and Related Molecular Pathways. Current Drug Research Reviews. 2026.