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Phytochemistry, Pharmacology and Novel Delivery Applications of *Syzygium cumini* (L.)



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ABSTRACT

Syzygium cumini (L.) is a widely used medicinal plant for the treatment of various ailments. The plant contains anthocyanins, glucoside, ellagic acid, isoquercetin, kaempferol, and myricetin as its chief active constituents. These active constituents impart multiple pharmacological activities to the plant which includes antidiabetic, anticancer, antioxidant, antibacterial, antifungal and antidiarrhoeal activity. The present review presents specific information on botany, phytochemical constituents, traditional uses and pharmacological actions of *S. cumini* (L.). Further applications of *Syzygium cumini* (L.) in the field of novel drug delivery has been also elaborated in the review. Apart from its application in the treatment of various diseases there is need to explore chemical and toxicity concern of *S. cumini* (L.).



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1. INTRODUCTION

Syzygium cumini is an evergreen tropical tree in the flowering plant family *Myrtaceae*, native to Bangladesh, India, Nepal, Pakistan and Indonesia. It is also known as Jaam, Kalojaam, Jamun, Nerale Hannu, Njaval, Neredupandu, Jamblang, Jambolan, Black Plum, Plum, dhat Plum, Jambolan Plum, Java Plum or Portuguese Plum. It is also grown in other areas of southern and southeastern Asia including the Philippines, Myanmar, and Afghanistan (Srivastava S. and Chandra, 2013). The tree was also introduced to Florida, USA in 1911 by the USDA, and is also now commonly planted in Suriname. In Brazil, where it was introduced from India during Portuguese colonization, it has dispersed spontaneously in the wild in some places, as its fruits are eagerly sought by various native birds such as thrushes, tanagers, and the Great Kiskadee. Jamun trees start flowering from March to April. The flowers of Jamun are fragrant and small, about 5 mm in diameter. The fruits develop by May or June and resemble large berries. The fruit is oblong, ovoid, starts green and turns pink to shining crimson black as it matures. A variant of the tree produces white colored fruit. The fruit has a combination of sweet, mildly sour and astringent flavour and tends to colour the tongue purple (Swami et al., 2012). The seed is also used in various alternative healing systems like Ayurveda (to control diabetes, for example.), Unani and Chinese medicine for digestive ailments. The leaves and bark are used for controlling blood pressure and gingivitis. Wine and vinegar are also made from the fruit. Various parts of the plant *Syzygium cumini* have been shown in **Figure 1**.

Few studies have been focused on the identification of other phytochemical constituents of jambolan, which may also contribute to its various health properties, with only a partial and limited study of diverse phenolics, including some flavonols and flavanonols and tannins (Baliga et al., 2011). Furthermore, the contents of vitamin C and carotenoids jambolan have also been studied.

Syzygium cumini (L.) is known to possess a wide range of medicinal properties, which have been attributed to the presence of bioactive compounds in different parts of the plant. The leaves are used in dermopathies, constipation, leucorrhea, and diabetes; fruits are used in the treatment of pharyngitis and splenic diseases; whereas barks are used as astringents, anthelmintic, and carminative. Furthermore, seeds are used as astringents, diuretic, and especially in the treatment of diabetes. Pharmacological studies have expanded the biological activities of *Syzygium cumini* (L.), which include antihyperglycemic, anti-inflammatory,

antibacterial, cardioprotective, and antioxidant (Muniappan and Pandurangan, 2012; Bag et al., 2012).

The medicinal properties of powdered seeds and stem bark of *Syzygium cumini* (L.) have been reported in the treatment of diabetes (Singh and Khanuja, 2006; Ayyanar et al., 2013). Previous studies have demonstrated that *Syzygium cumini* (L.) essential oil has antioxidant (Elansary et al., 2012), antibacterial (Shafi et al., 2002) and antifungal activity (Badawy and Abdelgaleil, 2014).

Though *Syzygium cumini* (L.) has multiple pharmacological actions, its safe and effective delivery to the target site requires scientific approach with a view to enhance patient compliance and avoid repeated administration. This could be attained by designing novel drug delivery systems (NDDSs) for herbal constituents. NDDSs reduce the dosing frequency to overcome non-compliance and further aids to improve the therapeutic value by reducing toxicity and increasing the bioavailability (Pradhan et al., 2015). In this regard, very few researches have been done to explore the therapeutic potential of *Syzygium cumini* (L.) by incorporating it in suitable novel delivery systems.

The present review highlights the role of *Syzygium cumini* (L.) for the treatment of various diseases and its application in the field of novel drug delivery system with a view to enhance its safety, efficacy and patient compliance.

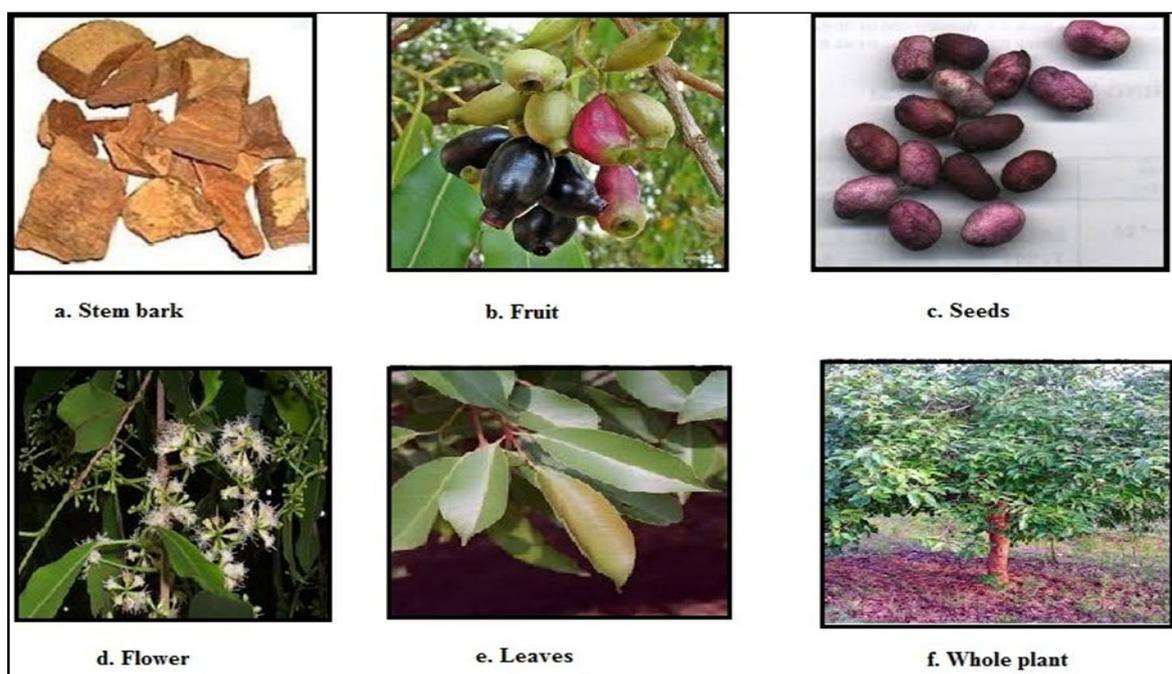


Figure 1. Various parts of the plant *Syzygium cumini*

2. Phytochemistry

Photochemical studies have identified gallic acid, cyanidin glycoside, glycoside jamboline, triterpenoids, tannins, gallitanins, essential oils, myricetine, β -sitosterol, myricyl alcohol etc. Compounds isolated from the leaf, fruit, seed, flower, stem bark and edible pulp of the plant has been discussed below.

Stem Bark: Stem bark of *Syzygium cumini* contain betulinic acid, β -sitosterol, friedeanol, epi-friedeanol and eugenin. It also contains β -sitosterol-D-glucoside, Kamepferol-3-O-glucoside, quercetin, myricetin, astragalin, and gallic acid (Sengupta and Das, 1965; Bhargava et al., 1974). The chemical structure of the major active constituents present in stem bark has been shown in Fig. 2.

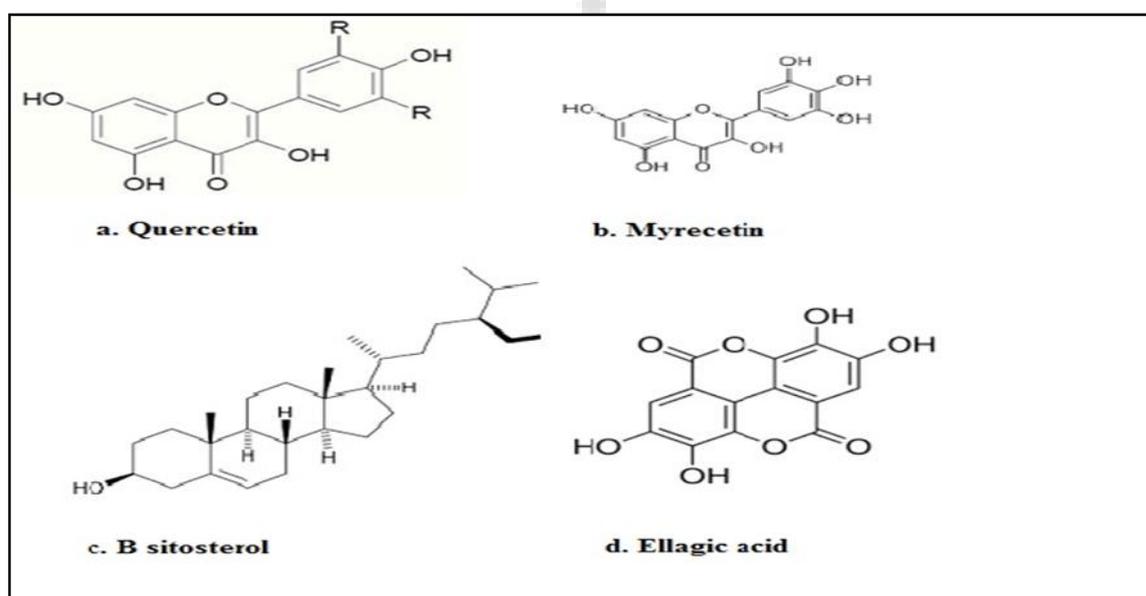


Figure 2: Chief active constituents of stem bark of *Syzygium cumini* (L.) .

Fruit: Fruit of *Syzygium cumini* contains malic acid and a small quantity of oxalic acid as its acid constituent. Gallic acid and tannins present in the fruit account for its astringency. The presence of Cyanidine and diglycoside (Fig. 3) imparts purple color to the fruit. It further contains glucose, fructose, mannose, and galactose as the principal sugar moieties. The mineral constituents are also reported to present which includes Ca, Mg, Na, K, Cu and vitamins such as thiamine, riboflavin, nicotinic acid etc (Veigas et al., 2007; Vijayanand et al., 2001).

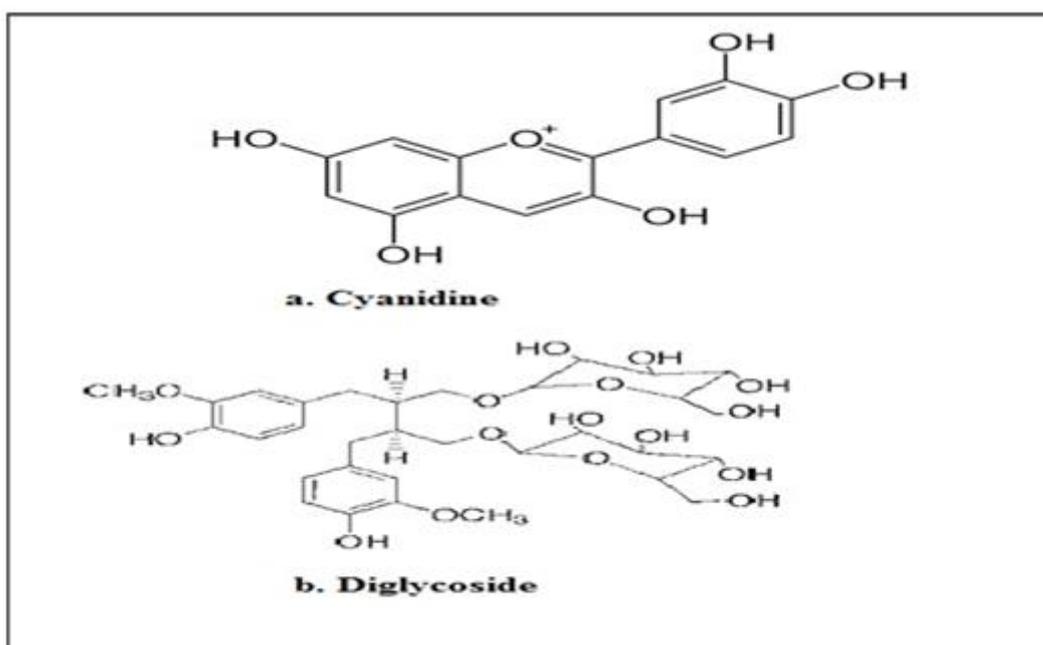


Figure 3. Chief active constituents of fruit of *Syzygium cumini* (L.)

Seed: It contains a glucoside jamboline, a new phenolic substance, a trace pale yellow essential oil, chlorophyll, fat, resin, gallic acid, ferulic acid, guaicol, resorcinol, dimethyl ether and corilagin. The seeds are fairly rich in the protein, and calcium (Daulatabad et al., 1988, Gupta and Agrawal., 1970).

Leaves: They contain gallitanins, essential oil (terpenes, 1-limonene and dipentene), monoterpenoid terpinene, terpenolene, borbeneol, terpineol and eugenol, complicated mixture of polyphenol such as gallic acid, methylgallate, kaempferol, ellagic acid, ellagitannin, nilocitin, myrecetin 3-O-D- glucaronopyranoside, 3-O-β D-glucuronopyranoside and two flavanol glycosides such as mearsetin 2-O-(4''-O-acetyl)-α-L rhamnopyranoside, and myricetin 4''-O-acetyl''-2-O-gallate (Timbola et al., 2002; Bhatia et al., 1974; Kumar et al., 2004).

Flowers: They contain kaempferol, quercetin, myricetin, isoquercetin (quercetin-3-glucoside), myricetin-3-L-arabinoside, quercetin-3-D-galactoside, dihydromyricetin, oleanolic acid, acetyl oleanolic acid, eugenol-triterpenoid A and eugenol-triterpenoid B (Sagrawat et al., 2006).

Roots: The roots are rich in flavonoid glycosides and isorhamnetin 3-O-rutinoside.

3. Pharmacological activity

- **Anti- Diabetic activity:**

Diabetes is becoming the third 'killer' of mankind, after cancer and cardiovascular diseases, because of its high prevalence, morbidity and mortality (Kim et al., 2006).

The oral hypoglycaemic agents currently used in antidiabetic therapy are associated with serious side effects. So, there is an utmost requirement to explore newer anti-diabetic agents that hold therapeutic efficacy and are free of such side effects (Li et al., 2004).

In this regard antidiabetic potential of various parts of *Syzygium cumini* (L.) has been explored by different researchers.

Kumar et al., 2008 isolated and identify the supposed antidiabetic compound from the *Syzygium cumini* (L.) [SC] seed. They isolated mycaminose from SC seed extract and investigated anti-diabetic activity against streptozotocin (STZ)-induced diabetic rats. They reported that mycaminose exhibited significant ($p < 0.05$) reduction in blood glucose level. Glibenclamide the standard drug (1.25 mg/kg) also produced significant ($p < 0.05$) reduction in blood glucose level against STZ-induced diabetic rats. Conclusively they demonstrated that isolated compound mycaminose possess anti-diabetic activity against STZ-induced diabetic rats.

Tripathi and Kohli 2014, studied antidiabetic activity of bark extract of *Syzygium cumini* (L.) on streptozotocin (STZ)-induced diabetic Wistar albino rats. They reported that 30 minutes prior administration of *Syzygium cumini* (L.) extracts before oral glucose loading significantly decreased ($p < 0.001$) the rise in postprandial blood glucose levels in treated rats as compared to control rats however the result was less significant than glibenclamide. Every day, continuous oral treatment of STZ-induced diabetic with various *Syzygium cumini* (L.) extract for 3 weeks lead to significant reductions in fasting blood glucose levels as compared to diabetic controls.

Singh and Gupta 2007, investigated the effects of ethanolic extract of *Syzygium cumini* (L.) (Linn) seed powder on pancreatic islets of alloxan diabetic rats. They reported that ethanolic extract of seeds of *Syzygium cumini* (L.) significantly decreased blood sugar level in alloxan diabetic albino rats. Further the histological studies showed definite improvement in the histopathology of islets. They also reported that the blood sugar level once dropped to normal

levels after extract feeding was not elevated when extract feeding was discontinued for 15 days.

- **Anti-Leishmania activity:**

Leishmaniasis is a complex parasitic diseases caused by more than 20 protozoa species of the genus *Leishmania*, affecting about 12 million people throughout the world (Kolodziej and Kiderlen, 2005; Machado et al., 2012). The life cycle of these parasites includes two distinct forms: a motile extracellular promastigote form found in the sand fly vector and a nonflagellated intracellular amastigote form which can be found within the mononuclear phagocytes in the mammalian host (De Almeida et al., 2003; Chappuis et al., 2007).

The chemotherapy currently available for the treatment of leishmaniasis is far from satisfactory. Different strategies have been attempted to obtain novel compounds effective against *Leishmania* (Lee et al., 2003). A number of natural products with diverse structural classes showed anti-*Leishmania* properties, including monoterpenes, sesquiterpenes, and other constituents of essential oils, demonstrating that such substances may be promising research options for the development of new drugs (Angel et al., 2014). In this context several studies confirmed the anti-*Leishmania* activity of *Syzygium cumini*.

Rodrigues et.al., 2015 examined the effects of *Syzygium cumini* (L.) essential oil (ScEO) and its major component α -pinene on *Leishmania (Leishmania) amazonensis*. Anti-proliferative effect on *Leishmania*, effects on promastigote and axenic amastigote forms were assessed using tetrazolium salt (MTT) assay. The intramacrophagic amastigotes were exposed to ScEO and α -pinene to evaluate the survival index. Results revealed that α -Pinene was effective against *Leishmania amazonensis* promastigote forms, having 50% inhibitory concentration (IC₅₀) value of 19.7 μ g/mL. α -Pinene was more active (IC₅₀ values of 16.1 and 15.6 μ g/mL against axenic and intracellular amastigotes, respectively) than ScEO (IC₅₀ values of 43.9 and 38.1 μ g/mL against axenic and intracellular amastigotes, respectively). The finding suggested that the anti-*Leishmania* effects were mediated by immunomodulatory activity, as evidenced by increase in both phagocytic and lysosomal activity.

- **Anti-inflammatory activity**

Inflammation can be defined as a generalized, nonspecific but beneficial tissue response against injury. It comprises a complex array of adaptive responses to tissue injury which are both local and systemic. The local responses lead to staffing of phagocytic cells and removal

of endogenous or foreign material. The systemic responses may alter the environment interior to permit these processes to occur more proficiently (Barbosa-Filho et al., 2006).

Natural products have long been recognized as an important source of therapeutically effective medicines. In this regard *Syzygium cumini* (L.) has also been reported to possess anti-inflammatory activity.

Muruganandan et al., 2001 evaluated ethanolic bark extract of *Syzygium cumini* (L.) was for its anti-inflammatory activity in animal models. The extract did not exhibit any toxicity up to a dose of 10.125 g/kg, p.o. in mice. Significant anti-inflammatory activity was found in carrageenin (acute), kaolin-carrageenin (subacute), formaldehyde (subacute)-induced paw oedema and cotton pellet granuloma (chronic) tests in rats. The extract did not stimulate any gastric lesion in both acute and chronic ulcerogenic tests in rats. Overall they concluded that *Syzygium cumini* (L.) bark extract possess a potent anti-inflammatory action against different phases of inflammation without any side effect on gastric mucosa.

Siani et.al., 2013 examined the anti-inflammatory activity of the essential oils from the leaves of *S. cumini* of their terpene-enriched fractions (+V = more volatile and -V = less volatile) obtained by vacuum distillation. Anti-inflammatory activity was accessed in the lipopolysaccharide-induced pleurisy model, by measuring the inhibition of total leukocyte, neutrophil and eosinophil migration in the mice pleural lavage, after oil treatment with the oils at 100 mg/kg. Results revealed that eosinophil migration was inhibited by SC (67%), SC (+V) (63%), PG (76%), PG (+V) (67%) and PG (-V) (74%). Conclusively they demonstrated that essential oils from *S. cumini* may be useful to treat inflammatory diseases by mechanisms that include the inhibition of eosinophil migration.

Kumar et al., 2008 evaluated anti-inflammatory activity of ethyl acetate and methanol extracts of *Syzygium cumini* (L.) seed in carrageenan induced paw oedema in wistar rats at the oral dose level of 200 and 400 mg/kg. Both the extracts presented significant anti-inflammatory activity supporting anti-inflammatory activity of the seed of *Syzygium cumini* (L.).

- **Anti-diarrhoeal activity**

Diarrheal diseases are a key problem in Third World countries and are responsible for the death of millions of people each year. Diarrhoea refers to an alteration in normal bowel movement and is characterized by an increase in the water content, volume, or frequency of

stools. Plants have long been a vital foundation of novel drugs. Several plant species have been screened for presence of compounds having therapeutic activity.

For achieving success in this area, international organizations including the World Health Organization (WHO) have encouraged studies concerning the treatment and prevention of diarrheal diseases using traditional medicinal plants.

In this context Shamkuwar et al., 2012 evaluated anti-diarrhoeal activity of aqueous extract of *Syzygium cumini* (L.) seed in mice. They tested antidiarrhoeal, antimotility and antisecretory activity *Syzygium cumini* (L.) seed extract. The method of castor oil induced diarrhoea was performed for investigating antidiarrhoeal activity; whereas charcoal meal test and castor oil induced intestinal secretions were used for testing antimotility and antisecretory activity in mice. They reported that aqueous *Syzygium cumini* (L.) extract (ASC) exhibited a significant and dose dependent antidiarrhoeal, antimotility, and antisecretory effect. Overall they concluded that antidiarrhoeal effect of ASC might be because of its antimotility and antisecretory effect.

- **Antioxidant activity**

Free radicals are species that contain unpaired electrons. The oxygen radicals, such as superoxide radical (O_2^-), hydroxyl radical ($*OH$) and non-free radical species, such as H_2O_2 and singlet oxygen (1O_2), are different types of activated oxygen, generated as a result of numerous redox reactions. They are trapped and destroyed by specific enzymes, such as superoxide dismutase, catalase and glutathione peroxidase. Excessive production of free radicals, together with A, C and E avitaminosis and a reduced level of the above mentioned enzymes, is considered to be the main contributor to oxidative stress. Therefore extensive research is being carried out to search antioxidant compound of plant as natural antioxidant compound lies on such herbs and plants (Ellnain-Wojtaszek et al., 2003).

Ruan et al., 2008 evaluated antioxidant activity of *Syzygium cumini* (L.) leaf extracts investigated using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical-scavenging and ferric-reducing antioxidant power (FRAP) assays. The methanolic extract and its four fractions namely water, ethyl acetate, chloroform, and n-hexane were isolated and examined for antioxidant activity. Results revealed that the ethyl acetate fraction possessed strong antioxidant activity as compared to other extracts. Conclusively significant linear relationship

between antioxidant potency, free radical-scavenging ability and the content of phenolic compounds of leaf extracts supported this observation.

Banerjee et al., 2005 carried out in vitro study of antioxidant activity of *Syzygium cumini* (L.) fruit. Antioxidant activity of the fruit skin was analysed using different assays, such as hydroxyl radical-scavenging assay, based on the benzoic acid hydroxylation method, superoxide radical-scavenging assay, based on photochemical reduction of nitroblue tetrazolium (NBT) in the presence of a riboflavin-light-NBT system, DPPH radical-scavenging assay, and lipid peroxidation assay, using egg yolk as the lipid-rich source. Further total antioxidant ability was examined by the assay based on the reduction of Mo (VI)–Mo (V) by the extract and subsequent formation of a green phosphate/Mo (V) complex. They reported that a significant correlation existed between concentration of the extract and percentage inhibition of free radicals or percentage inhibition of lipid peroxidation in all the systems. They suggested that antioxidant property of *Syzygium cumini* (L.) fruit skin might be due to the presence of antioxidant vitamins, phenolics or tannins and anthocyanins.

- **Anti microbial activity:-**

Following the rebellion in the “golden era”, while about all groups of vital antibiotics (tetracyclines, cephalosporins, aminoglycosides and macrolides) were discovered and now a days and these exciting compounds are in danger of losing their efficacy because of the increase in microbial resistance.

For such motive, discovery of new antibiotics is an utterly vital objective. Nowadays natural products remain one of the key sources of new drug molecules. Plants and other natural sources can provide a huge range of complex and structurally diverse compounds. Recently, researchers are being focusing on investigating plant and essential oils, microbial extracts, pure secondary metabolites and novel synthesized molecules as budding antimicrobial agents (Balouirin et al., 2016).

Gawri and Vasantha, 2008 examined antibacterial activity of crude methanol and aqueous extracts of the leaves of *Syzygium cumini* (L.) against standard strains and clinical isolates of some bacteria using the disc diffusion method. The extracts exhibited inhibitory activity against clinical isolates of gram negative bacteria such as *Salmonella enteritidis*, *Salmonella typhi*, *Salmonella typhi* A, *Salmonella paratyphi* A, *Salmonella paratyphi* B, *Pseudomonas aeruginosa* and *Escherichia coli*. and gram positive bacteria such as *Bacillus subtilis*, and

Staphylococcus aureus. They reported that the methanol extracts was more potent than the aqueous extracts.

Prateek et al., 2016 studied antimicrobial activity of *Syzygium cumini* (L.) fruit and leaf extract against bacterial stains such as *Staphylococcus aureus*, *Staphylococcus saprophyticus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Rouletella planticola*, *Proteus vulgaris* and fungal stains namely *Aspergillus niger* MTCC 282, *Penicillium chrysogenum* MTCC 161, *Candida albicans* MTCC 183, *Fusarium solani* MTCC 9667. They reported antibacterial activity against all used bacteria. Maximum zone of inhibition was observed for *Rouletella planticola* (25 mm) and minimum zone of inhibition was observed against *Pseudomonas aeruginosa* by using fruit extract (14 mm). The plant extract showed maximum zone of inhibition (18 mm) against fungal strains *Penicillium chrysogenum* and minimum (7mm) against *Candida albicans*. Conclusively they demonstrated that *Syzygium cumini* (L.) extract possess potential antibacterial and antifungal activity.

- **Anticancer activity:**

Cancer is a public health problem all around the world. Exploration for anticancer agents from plant origin dates back to 1947, when the cytotoxic properties of podophyllotoxin from *Podophyllumpeltatum* (Berberidaceae) were detected (Kelly & Hartwell 1954). The discovery of the antileukemic properties of vinblastine and vincristine from *Catharanthus roseus* (Apocynaceae) shortly went behind (Noble et al. 1958) and offered the desire for broad investigations of plant extracts and plant-derived compounds for possible anticancer activity. In the case of human cancers, thus far, nine plant-derived compounds have been approved for clinical use in the United States. They include vinblastine, vincristine, the camptothecin derivatives-topotecan and irinotecan, and paclitaxel. Numerous agents such as betulinic acid, roscovitine and silvestrol are in clinical or preclinical stage of development. Few reports have indicated potential of *Syzygium cumini* (L.) fruits to combat cancer.

Afify et al., 2011 investigated anticancer activity of *Syzygium cumini* (L.) fruit extracts using cell viability assay of leukemia cancer cell line. They prepared successive extracts of hexane, chloroform, ether, ethyl acetate, ethanol, and water and evaluated for anticancer activity. They reported that the ethanol extract exhibited stronger anti-leukemia activity as compared to other ones. Spectroscopic findings of active ingredients separated from ethanol extract showed that fruit extract of *Syzygium cumini* (L.) contained phenolic compounds namely

Kaempferol 7-O-methylether and sterols such as γ -Sitosterol was responsible for their anticancer activity.

Nazim, 2007 isolated four anthocyanins pelargonidin-3-O-glucoside, pelargonidin-3,5-O-diglucoside, cyanidin-3-O-malonyl glucoside, and delphenidin-3-O-glucoside from the acidic alcoholic extract of *Syzygium cumini* (L.) fruits. They performed cytotoxic activity of total alcoholic extract of the fruits against various tumor cell lines using the SRB assay. Results revealed that they showed significant cytotoxic activity for MCF7 (breast carcinoma cell line) (IC₅₀ = 5.9 μ g/mL), while the IC₅₀ was > 10 μ g/mL for both Hela (Cervix carcinoma cell line), HEPG2 (liver carcinoma cell line), H460 (Lung carcinoma cell line) and U251 (Brain carcinoma cell line).

4. Novel approach for delivery of *Syzygium cumini* (L.) extracts and its isolated active constituents

Herbal remedies and natural products are being used to cure the diseases since early time. Phytotherapeutics requires scientific approach with a view to safely and effectively deliver the active moiety in a sustained manner. This leads to enhance patient compliance and avoid repeated administration. This could be attained by designing novel drug delivery systems (NDDSs) for herbal constituents. NDDSs reduce the dosing frequency to overcome non-compliance and further aids to improve the therapeutic value by reducing toxicity and increasing the bioavailability (Pradhan et al., 2013; Pradhan et al., Singh et al., 2013).

The action of herbal medicines lies on the overall function of a variety of active constituents because each component offers synergistic action to enhance the therapeutic value. Nevertheless, mostly herbal drugs are insoluble in nature which leads to reduced bioavailability and increased systemic clearance requiring increased dosing frequency or higher dose. This makes the drug a poor contender for therapeutic use. Development of NDDSs (Polymeric nanoparticles, liposomes, pro liposomes, solid lipid nanoparticles, nanoemulsion, etc.) owe numerous advantages for herbal drugs, including enhancement of solubility and bioavailability, defense from toxicity, stability enhancement, improving tissue macrophages distribution, sustained delivery, shielding from physical and chemical degradation, etc (Singh et al., 2015). Therefore, the nano-sized drug delivery systems of herbal drugs have a budding prospect for enhanced activity with avoidance of problems associated with plant medicines. In this regard very few researches have been done to explore

the therapeutic potential of *Syzygium cumini* (L.) by incorporating it in suitable novel delivery systems.

Bitencourt et al., 2016 prepared an aqueous extract (ASc) of *Syzygium cumini* (L.) seeds and developed polymeric nanoparticles containing ASc (NPASc). They evaluated *in vitro* efficacy and *in vivo* toxicity against the problem of Diabetes mellitus (DM). NPASc were prepared by the emulsification/evaporation solvent technique, employing poly- ϵ -caprolactone, a biocompatible polymer. The antioxidant activity of both ASc and NPASc was examined by the scavenging of DPPH radicals and by the ferric reducing antioxidant power assay (FRAP). The *in vitro* efficacy of both formulations against oxidized LDL particles (ox-LDL) and fungal species was also assessed.

NPASc were observed to be compatible with nanometric systems, and chromatogram analysis suggested that the composition of *Syzygium cumini* (L.) was not affected. The antioxidant properties of the extract were also preserved in the developed novel formulation. To be sure, both formulations exhibited high protection against ox-LDL. The antifungal activity of NPASc against *Candida guilliermondii* and *Candida haemulonii* was observed better than that of ASc. Further, the absence of toxicity of nanoparticles designated NPASc a safe contender for drug delivery systems.

Mittal et al., 2014 developed and characterized silver nanoparticles (AgNPs) of *Syzygium cumini* (L.) fruit extract *in vitro*. The size of newly synthesized silver nanoparticles and their size were observed to be 10-15 nm. Important findings of this study were the recognition of biomolecules accountable for the synthesis of silver nanoparticles and the mechanism of biosynthesis. Presence of flavonoids in *Syzygium cumini* (L.) was mainly responsible for the reduction and stabilization of nanoparticles. The nanoparticles were observed to devastate Dalton lymphoma cell lines *in vitro*. Silver nanoparticles (100 μ g/mL) were found capable to reduce Dalton lymphoma (DL) cell lines viability up to 50%.

Banerjee and Narendhirakannan, 2011 developed silver nanoparticles of *Syzygium cumini* (L.) seed extract and investigated *in vitro* antioxidant activities. The developed silver nanoparticles were characterized with scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), X-ray Diffraction (XRD) and Fourier transform infrared spectroscopy (FTIR). Results of *in vitro* antioxidant properties of the silver nanoparticles revealed that the silver nanoparticle exhibited higher antioxidant capacity as compared to that of plain seed extract. Conclusively they demonstrated that the developed novel system could

be used as a potential radical scavenger against harmful damages originated from the free radicals.

Kumar et al., 2012 fabricated gold nanoparticles (GNP) of *Syzygium cumini* (L.) leaf extract (LE) and seed extract (SE). LE and SE as well as their polar (water) fractions showed potential for GNP synthesis. Comparative study on synthesis kinetics and morphological characterization studies suggested the synthesis of smaller sized GNP by LE than SE. Only polar (water) fractions showed potential for GNP synthesis, which were observed to be smaller in size as compared to their respective extracts. SE contained more polyphenols and biochemical constituents than LE, so they exhibited higher synthesis rate and bigger sized GNP. Atomic force microscope and scanning electron microscope analysis suggested that both extracts and their fractions catalyzed the synthesis of spherical GNP. The average size of GNP synthesized by LE, leaf water fraction (LWF), SE and seed water fraction (SWF) were observed to be 24, 23, 35 and 32 nm, respectively. Fourier transform infrared analysis identified the biomolecules involved in the synthesis and stability of GNP. This study documented the potential of *Syzygium cumini* (L.) for the synthesis of GNP in addition to silver nanoparticles (SNP). Nevertheless, character and kind of polyphenols involved in GNP synthesis appear to be diverse from that concerned in SNP synthesis. This might be the probable motive for lesser sized GNP as compared to SNP.

5. CONCLUSION

Syzygium cumini (L.), a traditional plant medicine having multiple pharmacological actions possess considerable potential value clinically. The plant has many imperative compounds which present the nearly all characteristics of the plant. Though many works on pharmacological activities of phytochemical constituents of *Syzygium cumini* (L.) has been carried out, still much more is remaining to work on the development of novel drug delivery systems of *Syzygium cumini* (L.) extract and its isolated compounds. Further more attention should be paid to the chemical and toxicity studies of *Syzygium cumini* (L.).

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