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Bioactive compounds in jamun (*Syzygium cumini* L.) Skeels

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Abstract

Jamun (*Syzygium cumini* L.) belongs to the category of minor or underutilized fruit crops and are nutritious having many pharmaceuticals properties. Jamun fruit is highly perishable and is mainly used for the diabetes patients and is well known as a traditional medicinal plant having essential bioactive compounds which are present in all parts of the plant. The major bioactive compounds present in the jamun skill (edible portion) are phytosterols, flavonoids, carotenoids, myricetin, oxalic acid, gallic acid, citronellol, cyanidin diglucoside, hotrienol, and polyphenols as well as micronutrients having many health benefits. It is also a good source of anthocyanin and effective against numerous health problems. and act as chemopreventive, radioprotective and demonstrating antineoplastic properties. The ripe fruits are pleasant, astringent taste and are eaten either raw or processed into different products mainly vinegar, jam, jellies and squash.

The jamun seed contains alkaloid, jambosine, and glycoside jambolin or antimellin, and this chapter describes different bioactive compounds in jamun and its medicinal, nutritional and health benefits.

Keywords: Bioactive compounds, diabetics, flavonoids, carotenoids

Abbreviations

DPPH	2,2-diphenyl- 1-1picrylhydrazyl hydrate.
LOO	lipid peroxy radicals
FRAP	Ferric reducing antioxidant power
GAE	Gallic acid equivalent
CE	Catechin equivalent
TAE	Tannic acid equivalent
AGEs	Acute gastroenteritis
CVD	Cardio Vascular Disease
AMD	Age Related Macular Degeneration

1. Introduction

Jamun (*Syzygium cumini* L.) belongs to poly-embryonic species of the family *Myrtaceae* or *Myrtle* is known as *Syzygium jambolanum* and *Eugenia cumini* Chase and Reveal, 2009 [15]. Other common names are Jambul, Black Plum, Java Plum, Indian Blackberry, is an evergreen tropical tree, native to the Indian subcontinent and found growing throughout the Asian subcontinent, Eastern Africa, South America, Madagascar, Australia and have also naturalized to Florida and Hawaii in the United States of America Swami *et al.*, 2012 [58]. Jamun fruit has oblong berries, having dark purple or bluish colour and light pinkish pulp (75%) rich in anthocyanins and single dark brown seed (25%).

Jamun fruit contains various essential chemical compounds and is a rich source of different nutritional and bioactive compounds. The fruit has carbohydrates, free amino acids, water soluble vitamins, minerals, and essential oils (Jadhav *et al.*, 2009; Sari *et al.*, 2009; Baliga *et al.*, 2011; Ayyanar and Subash-Babu, 2012; Luiz *et al.*, 2018) [21, 51, 8, 6, 29]. The color and flavor characteristic of the fruit are due to the different phenolic compounds present in the fruit Mercadante *et al.*, 2011 [33]. The fruit have high tannin content so its taste is astringent Radha and Mathew, 2007 [40]. The fruit is useful for the treatment of various diseases as an astringent, antiscorbutic, antidiabetic, antidiuretic, chronic diarrhea, antidiarrheal and enlargement of spleen. The fruit also gaining more popularity among consumers because of its balanced sugar, acid, and tannin contents Das, 2009 [20]. There are many phytochemicals present in the different plant parts, such as fruit pulp, seed, stem bark, leaves, flowers, and roots (Table 1).

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Table 1: Phytochemicals in different parts of Jamun

Sr. No.	Plant Part	Phytochemicals	References
1.	Fruit pulp	Anthocyanins, diglucosides of delphinidin, petunidin, malvidin, peonidin, and cyanidin. Volatile oils (α -pinene, β -pinene, β -myrcene, cis-ocimene, trans-ocimene, terpinolene, linalool, 4 terpineol, α -terpineol, cis-dihydrocarvone, caryophyllene, α -humelene, cis- β -farnesene, cis- α -farnesene, trans- α -farnesene, cis-nerolidol, geranyl butyrate, globulol, widdrol, torreyol, neocedranol, β -bisabolol)	Aqil <i>et al.</i> , 2012 [3]; Li <i>et al.</i> , 2009 [27]; Veigas <i>et al.</i> , 2007 [61]; Vijayanand <i>et al.</i> , 2001 [62]
2.	Seed	Ellagitannins, Jambosine, gallic acid, ellagic acid, corilagin, 3, 6-hexahydroxy diphenoylglucose, 1-galloylglucose, 3 galloylglucose, quercetin, β -sitosterol, and 4,6 hexahydroxy diphenoyl glucose	(Aquil <i>et al.</i> , 2012; Sagrawat <i>et al.</i> , 2016; Rastogi <i>et al.</i> , 1990) [3, 48, 45]
3	Stem bark	Friedelin, friedelan-3- α -ol, betulinic acid, β -sitosterol, kaempferol, β -sitosterol-D-glucoside, gallic acid, ellagic acid, gallotannin, ellagitannin, and myricetine.	(Rastogi <i>et al.</i> , 1990) [45]
4	Leaves	β -sitosterol, betulinic acid, mycaminose, cratogenic (maslinic) acid, n-hepatcosane, n-nonacosane, n-hentriacontane, noctacosanol, n-triacontanol, n-dotricontanol, quercetin, myricetin, myricitrin and the flavonol glycosides myricetin-3-O-(4''-acetyl)- α -Lrhamnopyranosides. Essential oils (α -terpeneol, myrtenol, eucarvone, muurolol, α -myrtenal, 1, 8-cineole, geranyl acetone, α -cadinol, pinocarvone).	(Shafi <i>et al.</i> , 2002) [52]
5	Flowers	Flowers Oleanolic acid, ellagic acids, isoquercetin, quercetin, kampferol, and myricetin.	Sagrawat <i>et al.</i> , 2016 [48]
6.	Roots	Isohamnetin-3-O-rutinside and flavonoid glycosides.	Vaishnava and Gupta, (1990) [59]; Banarjee and Narendhirakannan, 2011) [10]

Jamun seeds are also having antimicrobial and antioxidant properties (Banarjee and Narendhirakannan, 2011; Bajpai *et al.*, 2005) [10, 7] which help to prevent skin cancer (Vasi and Austin, 2009) [60] and gastro intestinal (Chaturvedi *et al.*, 2007) [16]. This review describes an overview of the bioactive component of Jamun fruit and its functional, medicinal, nutritional and health aspects.

2. Nutritional characteristics of Jamun

2.1 Jamun Fruit: Jamun fruit shows different size and qualities depending on the variety and geographical locations. The fruit shows a very wide variation in the weight (4.8–17.6 g), diameter (1.66–3.04 cm), length (2.22–4.51 cm), pulp content (68.75–86.59%) and seed weight (1.3–2.36 g) (Binita *et al.*, 2017) [14]. Table 2 shows the chemical composition of Jamun Fruit.

Table 2: Chemical Composition of Jamun Fruit

Sr. No.	Proximate Analysis		Vitamins		Minerals	
1.	Moisture	83.70-85.80 g /100 g	β -Carotene	50 mg/100 g	Na	3.5 mg/100 g
2	Protein	1.4 \pm 0.7 g/100 g	Thiamine	0.12 mg/100 g	K	130 mg/100 g
3	Fat	0.6 \pm 0.2 g/100 g	Riboflavin	0.06 mg/100 g	P	18.5 mg/100 g
4	Fiber	0.6 g/100 g /100 g	Ascorbic acid	30 mg/100 g	Ca	21.5 mg/100 g
5	Ash	0.32 g/100 g			Fe	0.15 mg/100 g
6	Carbohydrate	14.00 – 16.00 g /100 g			Mg	49.8 mg/100 g
7	Sucrose	95.5 mg/g			Zn	0.28 mg/100 g
8	Maltose	210 mg/g			Cu	0.07 mg/100 g
9	Fructose	57.5 mg/g				
10	Galactose	52.5 mg/g				
11	Glucose	20 mg/g				

(Noomrio and Dahot, 1996; Paul and Sharma, 2004) [37, 38]

Jamun fruit is rich in raffinose, glucose, fructose, citric acid, mallic acid, gallic acid, delphinidin-3-gentiobioside, malvidin-3-laminaribioside, petunidin-3-gentiobioside, cyanidindiglycoside. It contains minerals like copper, sodium, potassium, calcium, phosphorous, iron and zinc; and water soluble vitamins like ascorbic acid, thiamine and niacin; carbohydrates like glucose, mannose, sucrose, maltose, fructose, galactose and mannose; free amino acids like alanine, asparagine, tyrosine, glutamine and cysteine (Srivastava 1953; Lewis *et al.*, 1956; Ramya *et al.*, 2012) [55, 26, 42].

The composition per 100 grams of edible portion for fruits freshly picked has: Moisture, 85.9 gm; ether extract, 0.15 gm; crude fiber, 0.3 gm; nitrogen, 0.129 gm; ash, 0.32 gm; calcium, 8.3 mg; phosphorus, 16.2 mg; iron, 1.62 mg; carotene, 0.004 mg; thiamine, 0.008 mg; riboflavin, 0.009 mg; niacin, 0.290 mg; total ascorbic acid, 5.7 mg (Manjeshwar *et al.*, 2011) [32].

The Jamun fruit has a specific gravity, of 1.0184; total acidity

(as acetic acid), 5.33 per 100 cc; volatile acidity (as acetic acid), 5.072 per 100 cc; fixed acidity, 0.275% as citric; total solids, 4.12 per 100 cc; ash, 0.42; alkalinity of ash, 32.5 (N/10 alkali); nitrogen, 0.66131; total sugars, 0.995; reducing sugars, 0.995; non-volatile reducing sugars, 0.995; alcohol, 0.159% by weight; oxidation value (KMnO₄, 186.4); iodine value, 183.7; ester value, 40.42 (Manjeshwar *et al.*, 2011) [32].

2.2 Jamun Seed

There are many phytochemicals compounds present in the jamun seeds like Jambosine, gallic acid, ellagic acid, corilagin, 3,6-hexahydroxy diphenoylglucose, 1-galloylglucose, 3-galloylglucose, quercetin, β -sitosterol, 4,6 hexahydroxydiphenoylglucose (Chauhan, 2015) [17]. The jamun seed contains (per 100 g) carbohydrates (41.4 g), protein (6.3–8.5 g), fat (0.83–1.18 g), ash (2.04 g), fiber (2.3–16.9 g), calcium (0.41 mg), phosphorus (0.17 mg), polyphenols (361.40mg), fatty acids (palmitic, stearic, oleic and linoleic), starch (41%), dextrin (6.1%), a trace of

phytosterol, and 6 to 19% tannin i.e. 168.24 mg (Raza *et al.*, 2015; Ranjan *et al.*, 2011) [46, 44].

2.3 Jamun leaf

The leaf of jamun tree contains protein (9.1 g), fat (4.3 g), crude fiber (17.0 g), phosphorus (0.19 mg), calcium (1.3 mg) per 100 g and essential oils which are contributing the pleasant smell (Ramteke *et al.*, 2015; Sah and Verma, 2011) [41, 50]. The jamun leaf extracts can be employed as a viable, sustainable alternative to the hazardous reductant such as sodium borohydride for synthesis of nanoscale zero-valent iron (Rana *et al.*, 2018) [43]. The leaves of Jamun were found to contain betulinic acid, cratogenic acid, n-dotricontanol, n-hentriacontane, n-heptacosane, mycaminose, myricetin, myricitrin, myricetin 3-O-(4''-acetyl) - α -L-rhamnopyranosides, n-nonacosane, quercetin, β -sitosterol, noctacosanol, n-triacontanol, triterpenoids, tannins, eicosane, octacosane and octadecane (Morton, 1987; Rastogi and Mehrotra, 1990) [35, 45].

2.4 Jamun fruits and seeds

Jamun fruit contains broad spectrum of phytochemicals which belong to different phytochemical class. The Alkane, Carbohydrate, Phenylpropanoid, Monoterpene, Benzenoid and others. The jamun seed contains tannin, benzenoid, coumarin, flavonol, phenylpropanoid, lignan, coumarin, proteid and lipids (Jagetiya, 2017) [23].

3. Bioactive compounds of Jamun

The composition of bioactive compound in Jamun fruit is dependent on the age of the plant and maturity level of the fruit. The anthocyanins increase throughout maturation, whereas ellagitannins, flavonols, gallic acid and ellagic acid decrease as the fruit ripens (Lestario *et al.*, 2017) [25]. The Bioactive compounds like total phenols 116-180 mg GAE/100g; flavonoids 75.5 - 106.9 mg CE/100 g; tannins 3.1 - 4.7 mg TAE/100 g; ascorbic acid 0.01 mg/100 g and total carotenoids 83.8-94.6 μ g/100 g are present in Jamun fruits (Adelia *et al.*, 2011) [1]. Seed is the most studied part of the jamun plant which is high in hexahydroxydiphenic (HDDP) acid derivatohydrolysable tannins, terpenes like as α -terpineol, eugenol, betulinic acid, and many phenolic acids (Bhatia and Bajaj, 1975; Ramya *et al.*, 2012) [13, 42]. Jamun flowers also contain similar chemical composition like seeds (Baliga *et al.*, 2011) [8].

3.1 Antioxidants

Jamun seed contain large amount of antioxidant properties and phenolic content. Polyphenols of jamun fruit have shown superior antioxidant capacities when compared to the standard polyphenols (Singh *et al.*, 2016) [54]. Jamun contains a high amount of anthocyanin reveal its potency to reduce the oxidative stress in pathogenesis and radical scavenging activity (Aqil *et al.*, 2012; Yadav *et al.*, 2013) [3, 63].

3.2 Flavonoids

Flavonoids are mainly present as glycosides in plants and are having low molecular weight compounds (Chhikara *et al.*, 2018) [19]. Flavonoid extracted from jamun leaf inhibit the carbohydrate hydrolyzing enzymes which are able to obstruct the key enzyme in the polyol pathway and prevent the formation of AGEs (Manaharan *et al.*, 2012) [31]. In this context, Jamun leaves flavonoid content of the methanolic extract is 451.50 \pm 9.85 mg/g (Ruan *et al.*, 2008) [47].

3.3 Phenolic compounds

Total phenolic content in jamun varies from 2133.50 to 2250 mg GAE per 100 g. [46]. Jamun contains different phenolic compounds e.g. the seed contain corilagin, 3,6-hexahydroxydi phenoylglucose, 1-galloylglucose glucoside, 3-galloylglucose and 4,6-hexahydroxy diphenoylglucose; the bark and stem contain 3,3,4-tri-o-methyl ellagic acid, 3,3-di-o-methyl ellagic acid, ellagic acid and gallic acid; the jamun flowers contain ellagic acid and jamun pulp contains gallic and ellagic acid (Srivastava and Chandra, 2013) [56]. Jamun and its processed products is significant source of phenolic compounds. The total phenolic content of different jamun products like pulp powder, seed powder, jam, squash and RTD are ranged from 25 to 42 mg GAE g⁻¹ DW (Shahnawaz *et al.*, 2010) [53]. Jamun leaves consist total phenolic content in methanolic extract was 610.32 \pm 9.03 mg/g (Zhi *et al.*, 2008) [64].

3.4 Anthocyanins

The Anthocyanins like Delphinidin 3,5-diglucoside, Cyanidin 3,5-diglucoside, Petunidin 3,5-diglucoside, Peonidin 3,5-diglucoside, Delphinidin 3-glucoside, Malvidin 3,5-diglucoside, Delphinidin acetyl-diglucoside, Cyanidin 3-glucoside, Petunidin 3-glucoside, Malvidin 3-glucoside are present in Jamun fruit (Adelia *et al.*, 2011) [1]. Jamun pulp powder contains 0.54% anthocyanins, 0.17% ellagic acid/ellagitannins and 1.15% polyphenolics (Aiyar *et al.*, 2008) [2]. There is negligible amount of anthocyanins found in jamun seed but it contains higher amounts of ellagic acid/ellagitannins (0.5%) and total polyphenolics (2.7%) than the jamun pulp powder. The five anthocyanidins were found in jamun pulp i.e. malvidin (44.4%), petunidin (24.2%), delphinidin (20.3%), cyanidin (6.6%), and peonidin (2.2%). Jamun is the only berry that contains aglycones of five anthocyanidins and appreciable amounts of ellagic acid/ellagitannins also jamun seeds are rich in ellagic acid/ellagitannins in addition to other unidentified polyphenolics (Aqil *et al.*, 2014) [4]. Jamun seeds contain no detectable anthocyanins but are enriched in ellagic acid/ellagitannins.

Anticancer property of anthocyanins in Jamun fruit was reported (Nazif, 2007) [36]. The four anthocyanins were isolated from acidic alcoholic extract of jamun fruit and the crude extract was found to exhibit potent cytotoxic activity on several types of human cancer cell lines. The crude extract of Jamun fruits inhibited growth and induced apoptosis in cervical cancer cell lines HeLa and SiHa in a dose and time-dependent manner (Barh and Viswanathan, 2008) [11].

3.5 Carotenoids

Around 700 types of natural carotenoids, have been identified of which only 50 can be absorbed, transported, and deposited by the human body. In Jamun fruit about 48 mg/100 g β -carotenoid content has been reported (Suradkar *et al.*, 2017) [57].

3.6 Essential oils

Jamun leaves contains 82% of total essential oils (Chikara *et al.*, 2018) [18]. The important essential oil such as Aromadendrene, β -caryophyllene, α gurjeuene and guaiol are the prominent components present in jamun leaf [Table 3]. Jamun Pulp contains α -muurolol, terpineol, eucarvone, myrtenol, α -myrtenal, α -cadinol, geranyl acetone and pinocarveolesential oils.

Table 3: Essential oil present in Jamun

Sr. No.	Jamun Leaf		Jamun Pulp	
	Constituents	Amount (%)	Constituents	Amount (%)
1	Hexanal	0.21	Pinocarveol	15.1
2	β -Pinene	0.16	α -Terpineol	8.9
3	Camphene	0.09	Myrtenol	8.3
4	β -Myrcene	0.30	Eucarvone	6.6
5	α -Terpinene	0.81	Muurolol	6.4
6	o-Cymene	0.54	Myrtenal	5.8
7	DL-Limonene	4.04	Geranyl acetone	5.6
8	cis-Ocimene	0.90	α -Cadinol	4.6
9	trans-Ocimene	0.50	Pinocarvone	4.4
10	γ -Terpinene	0.09	trans-Pinane	3.8
11	δ -Elemene	0.44	δ -Cadinol	3.5
12	α -Copaene	0.56	para-Cymen-8-ol	2.7
13	β -Elemene	0.31	cis-Carveol	2.2
14	β Caryophyllene	6.96–16.00	Limonene oxide	1.8
15	γ -Elemene	0.24	Longipinene epoxide	1.6
16	β -Guaiene	0.70	Carvone	1.4
17	Aromadendrene	6.62	Bornyl acetate	1.2
18	α -Caryophyllene	7.15–25.24	Isopropyl formate	0.9
19	Germacrene-D	4.07	cis-3-Hexen-1-01	0.9
20	Clovene	0.10	cis-3-Hexenyl acetate	0.9
21	α -Selinene	5.20	Dihydrocarvyl acetate	0.9
22	α -Gurjuene	38.35	Perilla alcohol	0.8
23	α -Amorphene	0.33	α -Pinene	0.8
24	α -Muurolene	0.13	Fenchol	0.8
25	Cadinene	1.39	β -Terpineol	0.7
26	Caryophyllenyl alcohol	0.11–3.90	β -Pinene	0.7
27	Guaiol	7.0	Benzyl acetate	0.7
28	δ -Eduesmol	0.40	trans- β -Caryophyllene	0.6
29	β -Eduesmene	0.35	Globulol	0.6
30	α -Eduesmol	0.40	cis-2-Heptenal	0.5
31	Bulnesol	1.41	Acetic acid	0.5
32	--		Verbenol	0.4

(Suradkar *et al.*, 2017; Machado *et al.*, 2013; Jirovets *et al.*, 1999) ^[57, 30, 24].

The essential oil β -Caryophyllene present in jamun leaves exhibits anti-inflammatory properties while caryophyllene oxide possesses anti-mycobacterial properties (Machado *et al.*, 2013) ^[30]

3.7 Terpenes and tannins

Terpenes phytochemicals are present in every part of jamun plant i.e. in seed, pulp, bark, leaf and also in flower. Terpenes have pleasant odor and can be used in fragrance, as additives in food, and pharmaceutical industries. Jamun fruit contains betulinic and oleanolic acids as major terpenes. The betulinic acid has many health benefits like anti-inflammatory, anti-HIV, anti-neoplastic, anti-malarial and chemo-preventive

activities (Sah and Verma, 2011) ^[50]. Terpenes present in Jamun are monoterpenoids (1,8-cineole, linalool oxide, mysterol, nerol, terpinolene, α -terpeneol, α -terpene, β -phellandrene, β -pinene, citronellol, eugenol and triterpenoids (acetyl oleanolic acid, betulinic acid, oleanolic acid, β -sitosterol) (Jager and Hoferl, 2016) ^[22].

There are almost 30 terpenoids present in ethyl acetate extract of Jamun seed. The 24 sesqui-terpenoids and 6 tri-terpenoids showed antimicrobial activity against *Staphylococcus aureus* (Liu *et al.*, 2017) ^[28]. Tannic acid is about 13.4% in bark of jamun plant which is having gastro-protective and antiulcer effects (Bandiola *et al.*, 2017) ^[9].

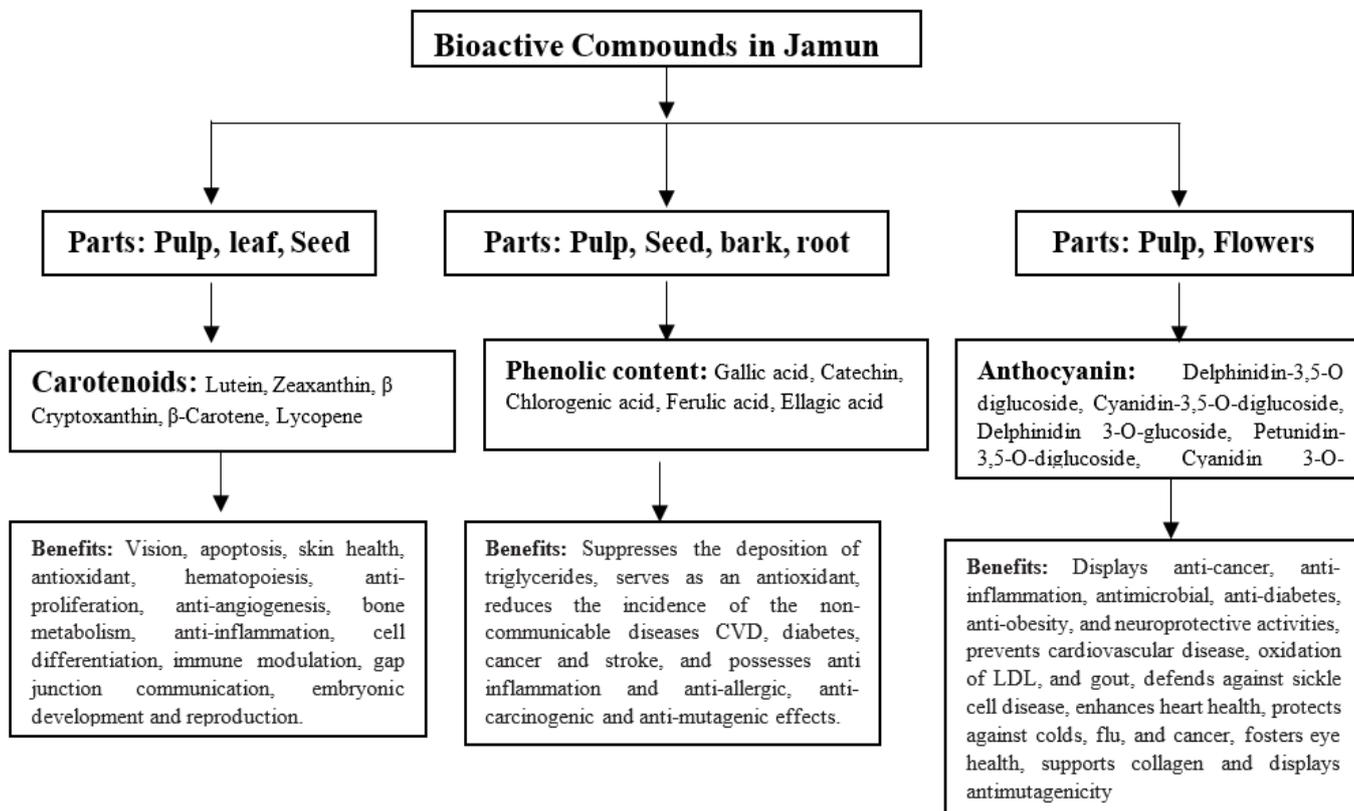


Fig 1: Major bioactive compounds in Jamun and their benefits

4. Health Benefits

Jamun fruit is rich in polyphenolic compounds which are effective against cancer, heart diseases, diabetes, asthma and arthritis. It plays vital role against various digestive disorders i.e. flatulence, bowel spasm, stomach disorders and dysentery. Jamun contains jamboline, a type of glucose, having major role to control the conversion of starch into sugar and helps to maintain blood sugar in normal range. The extract of the bark, seeds and leaves are beneficial in decreasing of sugar in urine (glycouria). Jamun also cures leucoderma after stimulating the melanin (Modak *et al.*, 2007) [34]. Jamun contains vitamin C, iron and potassium which is

beneficial for skin diseases and helps to increase the hemoglobin count and also purify the blood which is beneficial for peoples suffering from anemia and jaundice and also helps to reduce different heart diseases (Prince *et al.*, 1998) [39].

Jamun contains many bio-chemical and phytochemical compounds, like polyphenols, flavonoids, essential oils, gallic acid, oxalic acid, malic acid, betulic acid due to which it prevents liver diseases such as necrosis and fibrosis and also beneficial in managing and treating of many human diseases and also consist of lipid peroxidation inhibition activity (Benherlal and Arumughan, 2007; Arya *et al.*, 2018) [12, 5].

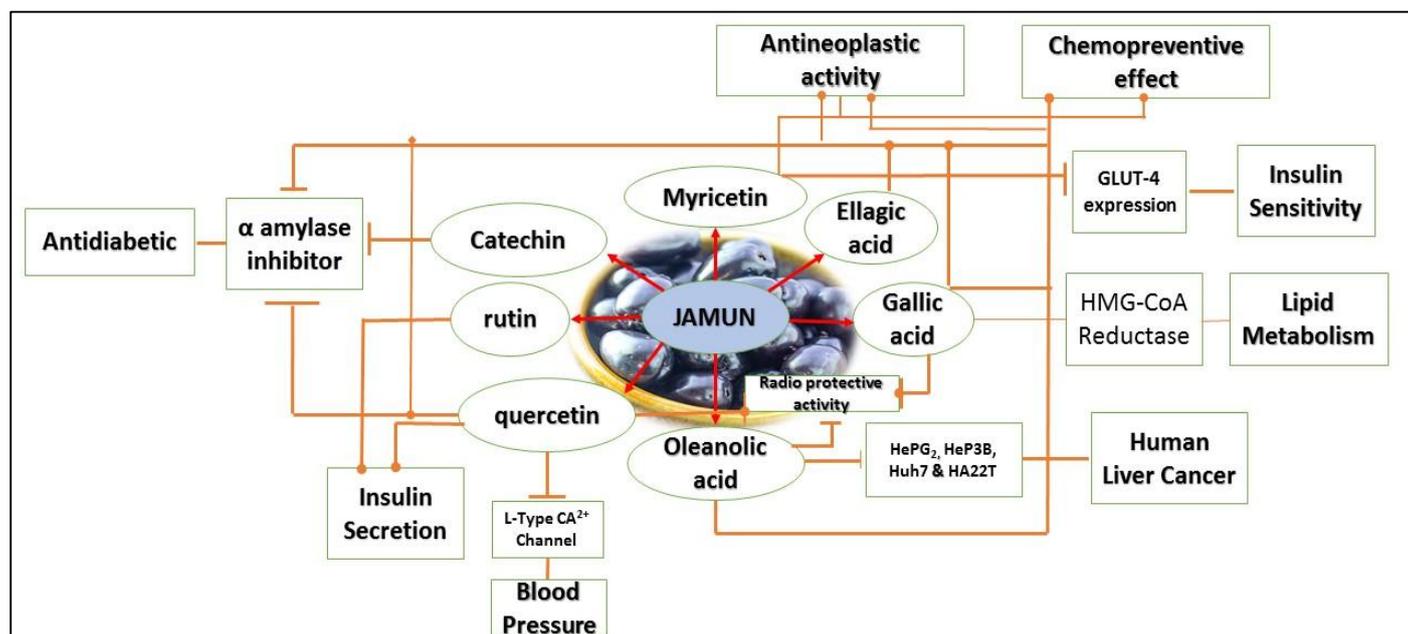


Fig 2: Health Benefits of Phytochemical Agents in Jamun

5. Conclusion

Studies have suggested the importance of the different bioactive compounds present in Jamun are effective to reduce the various disorders associated with cardiac, gastrointestinal, and nervous system. The antioxidants, flavonoids, anthocyanins, carotenoids, essential oil, terpenes, tannins and phenolic compounds in jamun provide diversified therapeutic effect like antioxidative, anticancerous, antidiabetic, antimicrobial and radioprotective effect. This traditional medicinal plant which having many bioactive compounds must be carried out for further studies on phytochemical and clinical research for the production of safer drugs that can be utilized for treating different diseases.

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