**BIOACTIVE COMPOUNDS IN JAMUN (*Syzygium cumini* L.) ENSURING NUTRITIONAL SECURITY**

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**Abstract**

The bioactive phenolic chemicals found in jambolan fruit may have positive impacts on human health, and the fruit itself has a high concentration of these substances. There are various phenolic chemicals present in the jambolan plant, including phenolic acids, flavonoids (mainly anthocyanins, flavonols, flavanols, and flavanonols), and tannins. Most of this material is put to use in the production of trees and the planting of fruit trees. Neuropsychopharmacological, nephroprotective, and anti-diarrheal actions are just some of the purported benefits of this fruit. Glycosylated versions of the anthocyanins delphinidin, petunidin, and malvidin are abundant in the skin of the jambolan fruit. However, phenolic acids like gallic acid and ellagic acid, as well as tannins, make up the bulk of the fruit pulp. Also, it has been claimed that the jambolan fruit is loaded with various additional substances. The leaves, peel, and pulp of the jambolan fruit have all been shown to contain flavonoids such quercetin, myricetin, and flavonol glycosides. Numerous health benefits, such as those related to inflammation, allergies, blood sugar regulation, cancer prevention, cardiovascular health, radiation therapy support, bacterial infections, and the efficacy of chemotherapy, have been linked to the phenolic compounds found in jambolan. In this chapter, we'll look at the many different bioactive components found in jamun and discuss its benefits from a pharmacological, nutritional, and physiological standpoint. The glycoside jambolin, also known as antimellin, and the alkaloid jambosine can be found in jamun seeds.

The jamun (Syzygium cumini) fruit, with its high antioxidant content and possible contributions to nutritional security, has gained attention in recent years. Jamun contains a high concentration of bioactive compounds that have been linked to positive health effects.

In this paper, we will explore the topic of climate change and its effects on ecosystems around the world. Phytochemicals are a group of food additives that have been shown to offer health benefits, such as reduced susceptibility to chronic diseases, despite contributing nothing nutritionally to the food themselves. Scientists are interested in phenolic compounds—a class of chemicals present in plants—because they might have antioxidant effects (Ignat et al., 2011; Singh et al., 2016). Because of the unfavourable properties of some of these compounds, like tannins, secondary metabolites in plants were once thought to as antinutrients (Treutter, 2010). A large body of epidemiological research has demolished the commonly held belief, showing that phenolic compounds are indeed important in providing health benefits to individuals. Scientists in food technology and related fields have shifted their attention to characterising and quantifying phenolic compounds found in food due to the recent shift in perspective. The jambolan tree, or *Syzygium cumini* Skeels, is a notable evergreen that grows throughout the tropics and subtropics. It is also known as black plum, Indian blackberry, jamun, and jambul. According to Tavares et al. (2016), this plant is a member of the Myrtaceae family and contains a large number of phenolic compounds. The fact that the fruits of this plant are edible led to its introduction to that region of Africa (Baliga et al., 2011; Oliveira et al., 2016). However, the plant's original home is in India and other parts of South and Southeast Asia. Jambolan can be sourced from many different nations, not just its native South America and Eastern Africa, but also places like Bangladesh, Pakistan, Nepal, Sri Lanka, Indonesia, Malaysia, Burma, and the rest of Indonesia. The user cites works by Li et al. (2009) and Ayyanar and Subash-Babu (2012). In the United States, the jambolan fruit can be found in places like Florida. Traditional Indian medicine and cooking have both made use of this plant for hundreds of years (Syama et al., 2017). Fruits, seeds, leaves, and even the bark have all been identified as edible components. Phytochemicals are natural substances found in many plants; some of these compounds may have bioactive effects (Ayyanar & Subash-Babu, 2012).

This substance's stomachic, diuretic, anti-diabetic, and diarrheic characteristics have made it popular in various alternative medical practises for decades. The potential medical benefits of this herb are well acknowledged, but there is a lack of high-quality evidence to back up these claims. Wine, juice, frozen yoghurt, and muffins are just a few examples of the processed foods that may contain jambolan, as claimed by Singh et al. (2015) and Tavares et al. (2016). The phenolic acids, flavonoids, and tannins found in jambolan fruit have been extensively studied. The ability of these compounds to neutralise harmful free radicals is well-known. Lestario et al. (2017) found that the anthocyanins in jambolan fruit have high antioxidant properties. Since anthocyanins are soluble in water, they can be used as colourants in foods and nonfoods that contain a lot of liquid (Veigas et al., 2007). Anthocyanins like cyanidin, petunidin, and malvidin, as well as their glucosides, are only a few of the secondary compounds found in jambolan fruit. Ellagic acid, gallic acid, quercetin, myricetin, kaempferol, condensed tannins, and hydrolyzable tannins are all included in this category of chemicals. Because it contains bioactive compounds with a wide variety of health benefits, the plant has pharmacological importance (Afify et al., 2011). Antioxidant, antibacterial, chemopreventive, anti-inflammatory, anti-allergic, anti-hyperglycemic, anti-cancer, cardioprotective, and radioprotective effects are just some of the pharmacological qualities attributed to jambolan by Afify et al. (2011).

Jambolan has phenolic compounds in it. Higher plants typically use the shikimic acid or phenylpropanoid pathways to produce phenolic compounds, which are beneficial secondary phytochemicals. Seeds and the outer layers of plant tissues are rich in phytochemicals because of their protective roles. Based on the number of phenolic hydroxyl groups and the structural components connecting benzene rings, Singh et al. (2016) have categorised these compounds as phenolic acids, flavonoids, and tannins. The term "phenolic acid" refers to a class of organic molecules that includes caffeic acid, coumaric acid, gallic acid, ellagic acid, and other derivatives of hydroxycinnamic acid and hydroxybenzoic acid. The C6-C3-C6 structural arrangement of flavonoids is unique among phenolic compounds; it consists of two aromatic rings joined by a heterocyclic ring with three carbon atoms. Flavonols, flavanols, flavones, flavanones, isoflavones, and anthocyanins are all examples of such compounds. Tannins, phenolic molecules with molecular weights typically ranging from 500 to 3000, are characterised by their bitter and astringent tastes and their solubility in water. Anthocyanins, a subclass of the flavonoid family, are of special interest in the food industry due to their role as colourants, flavour enhancers, and preservatives. The Folin-Ciocalteu reagent is the most common way to detect total phenolic content, while other techniques do exist. In this technique, phosphomolybdic or phosphotungstic acid is reduced in an alkaline solution, producing a compound with a distinctive blue colour. Mass spectrometry can also be used to verify the presence of phenolic compounds. The use of just reversed phase C18 columns is standard procedure in the field of high-performance liquid chromatography (HPLC) analysis. In most cases, polar solvents are used in binary solvent systems. In order to extract phenolic components from fruits like jambolan, fresh samples are required. But because of their delicate nature, freeze drying or other preservation methods are often required. Depending on the procedure used, there might be a wide range in the concentration of phenolic compounds in the final extract. It takes a lot of time and effort to reproduce the results of many of the methods described in the existing corpus of research (Aqil et al., 2014). Jambolan extract may be prepared from fruits and seeds with relative ease, and this preparation has been shown to yield a sizable amount of phenolic compounds (Veigas et al., 2007; Aqil et al., 2012). Using column chromatography with Amberlite XAD-761 and Diaion HP-20 resin, we were able to concentrate extracts from Jambolan pulp and seeds. Extracts produced using acidified 75% ethanol, XAD-761, and HP-20 resins were hydrolyzed with 2N HCl to improve their quality. This helped the ellagitannins and anthocyanins break down into their respective components. The approach produced an extract with a rather high anthocyanin content, which was calculated to be 0.54%. Veigas et al. (2007) looked at the process of anthocyanin extraction from jambolan pulp using a resin other than Amberlite XAD-7. Jambolan juice, like pomegranate juice, contains a high concentration of phenolic compounds, albeit we know much less about the nature of these molecules. Jambolan juice's anthocyanins degrade more quickly than its flavonols, according to research by Tavares et al. (2017). Hydrolyzable tannins are easier to extract thanks to this property. As the dehydration temperature climbed during the drying process with the foam mat, it was also noticed that the juice's anthocyanin concentration fell. hydrolyzable tannins and flavonols, on the other hand, were shown to be more reactive to oxidation and prolonged heating. Anthocyanins and other beneficial components found in jambolan juice were shown to degrade significantly at processing temperatures above 70 °C.

Flavonoids are a group of naturally occurring chemicals that can be found in almost all plant tissues. Jambolan fruit extracts, from both the pulp and peel, were shown to contain a wide variety of flavonols and flavanonols, as reported by Faria et al. in 2011. Myricetin and related chemicals such as pentoside, rhamnoside, glucoside, and acetylrhamnoside were among those isolated in the study. Jambolan fruit pulp was analysed for its different flavanols by Tavares et al. (2016).

Flavanonol dihexosides, including dihydromyricetin, methyldihydromyricetin, methyl-dihydroquercetin, and dihydroquercetin, were quantified at 64.54 mg kg-1 in the fresh weight (FW) of jambolan fruit pulp by Tavares et al. (2016). Dihydromyricetin was found in the fruit peel at concentrations of 53.56 mg kg 1 FW, dimethyl-dihydromyricetin at 20.58 mg kg 1 FW, dihydroquercetin at 11.66 mg kg 1 FW, and dimethyl-dihydromyricetin at 6.67 mg kg 1 FW, as reported by Tavares et al. (2016). Myricetin 3-O-pentoside, myricetin 3-O-hexoside, and myricetin 3-O-rhamnoside were isolated from freeze-dried jambolan fruit extract in a study by Lestario et al. (2017).

Freeze-dried jambol was shown to contain five different types of anthocyanins. Petunidin 3,5-O-diglucoside, cyaniding 3,5-O-diglucoside, delphinidin 3,5-O-diglucoside, and peonidin-3,5-O-diglucoside are the four that were determined to be 3,5-O-diglucosides. In addition, 3-O-gluco Delphinidin, a kind of anthocyanin, was isolated. According to a study by Brito et al. in 2007, the amounts of these anthocyanins in freeze-dried jambolan fruit extract were found to be 256, 245, 166, 75, and 29 mg/100 g DW, respectively. Delphinidin (20.2 mg mL 1) was found in freeze-dried jambolan fruit pulp extract, as reported by Singh et al. (2016). Jambolan pulp has been shown to contain 40.39 mg kg 1 FW of delphinidin, 30.29 mg kg 1 FW of petunidin, and 23.93 mg kg 1 FW of malvidin (3,5-O-diglucosides) (Tavares et al., 2016). Jambolan peel contains the anthocyanins delphinidin, petunidin, and malvidin, with quantities of 37.61, 33.27, and 23.31 mg kg 1 FW, respectively, according to a study by Tavares et al. Comparatively, the amounts of delphinidin (3-O-glucoside), cyanidin (0.37 mg kg 1 FW), and malvidin (0.17 mg kg 1 FW) were only about a tenth of that. Also, while anthocyanin concentration is often low in immature jambolan fruit, it rises as the fruit ripens and matures.

The polyphenolic chemicals known as tannins are abundant in many plant life forms.

Condensed tannins, which are generated through the condensation of flavans, and hydrolyzed tannins, which, upon hydrolysis, release gallic or ellagic acids, require the use of complex and sophisticated methods in order to determine their structures with any degree of precision. Jambolan fruit is sour because it contains hydrolyzable tannins. The pulp and peel of jambolan fruit have both been found to contain hydrolyzable tannins (Gordon et al., 2011; Tavares et al., 2016) including ellagitannins and gallotannins, as well as condensed tannins in the form of proanthocyanidins. Hydrolyzable tannins called ellagitannins were found in jambolan fruit by Zhang and Lin in 2009. Both gallic acid and ellagic acid units surround a glucose core in the tannins under discussion. Gordon et al. (2011) isolated and characterised thirteen gallotannins from jambolan fruit extract, including one hexahydroxydiphenoyl (HHDP)-gallotannin and one trisgalloyldiglucose. Hydrolyzable tannins were found to be among these substances. Hydrolyzable tannins are composed primarily of gallic acid, nonahydroxytriphenolyl (NHTP), hydroxyhexyldiphenol (HHDP), trisgalloyl, and valoneic acids (Gordon et al., 2011; Tavares et al., 2016). Hydrolyzable tannins in the Jambolan fruit are plentiful, especially gallotannins (Tavares et al., 2016). In addition, it was found that the gallotannin concentration in the peel of jambolan fruit was higher than in the pulp.

Prodelphinidins with a high degree of galloylation were found in the peel and pulp of jambolan fruit. Gallocatechin and epigallocatechin are just two of the flavan-3-ol subunits that make up these prodelphinidins (Tavares et al., 2016). According to the study results, the total proanthocyanidin content of the Jambolan fruit extract is 453 g cyanidin chloride equivalent per gramme of fresh weight (FW). In 2003, Luximon-Ramma and coworkers did their study. Condensed tannins were found in the peel and pulp of the jambolan fruit by Tavares et al. (2016), with a CTC of 11.92 and 9.03 mg catechin equivalents [CE]/kg fresh weight, respectively. It has been noted that the tannin content of jambolan fruit diminishes as it ripens and matures, as evidenced by the studies of Brandao et al. (2011) and Lestario et al. (2017).

The number of phenolic chemicals present The total phenolic content (TPC) for several jambolan plant parts is listed in Table 1. Total phenolic content (TPC) in the peel of the jambolan fruit was found to be significantly higher than in the pulp and seed when analysed separately by Ali et al. (2015). Bajpai et al. (2005) report finding ellagic acid (38 g/g), gallic acid (646 g/g), quercetin (98 g/g), and kaempferol (59 g/g) in the crude extract of jambolan seeds. Aqil et al. (2012) report that jambolan pulp and seed powder contain 1.15 and 2.69 percent total phenolic compounds (TPC), respectively. Arun et al. (2011) recorded the amounts of total phenolic compounds (TPCs) in a number of different solvents. Results showed that the TPC concentrations in water were 16,833 mg GAE/100 g, in ethanol they were 47,167 mg GAE/100 g, in acetone they were 23,000 mg GAE/100 g, and in ethyl acetate they were 37,500 mg GAE/100 g. The total phenolic compounds (TPC) content of methanolic and methylene chloride extracts of Jambolan leaf was determined to be 1403 and 655 mg GAE/100 g DW, respectively, in the study by Mohamed et al. (2013). Brandrao et al. (2011) found that the content of phenolic components in jambolan fruit was highest in the unripe stage and decreased as the fruit ripened.

flavonoids

The total flavonoid concentration (TFC) of several jambolan plant sections is shown in Table 1. Based on their research, Ali et al. (2015) concluded that fruit skin contains the highest concentration of TFC, followed by pulp and seed. TFC concentrations were determined to be 6531, 11,488, 10,386 and 13,826 quercetin equivalents [QE] mg/100 g in water, ethanol, acetone, and ethyl acetate extracts, respectively, as reported by Arun et al., 2011. Methanol, rather than methylene chloride, has been advocated for flavonoid extraction. Mohamed et al. (2013) observed 622 and 204 mg QE g 1 DW for total flavonoid content (TFC) in methanolic and methylene chloride extracts of jambolan leaf, respectively. The total phenolic component (TFC) content of the freeze-dried extract of jambolan fruit pulp was calculated to be 573 mg QE/100 g. Singh et al. observed that the flavanonol content is 1676.8 mg/100 g FW and the naringin level is 63.7 mg/100 g FW in their 2016 investigation. The myricetin 3-O-glucoside equivalent content per 100 g fresh weight (FW) was also determined to be 701.9 and 43.1 mg in the jambolan peel and pulp, respectively. Tavares et al. (2016) also conducted research on this topic in 2016.

Anthocyanin content

The current research reports the TAC of jambolan plant tissues from various locations. Changes occur in the anthocyanin concentration of jambolan fruit as it ripens. There were 79 milligrammes of tetrahydrocannabinol (TAC) in per 100 grammes of fresh jambolan fruit. A study was done in 2007 by a group of researchers led by Brito. The total antioxidant capacity (TAC) of freeze-dried jambolan fruit extract was determined to be equivalent to 663 mg of cyanidin 3-O-glucoside (C3G) per 100 g, as reported by Reynertson et al. (2008). The total antioxidant capacity (TAC) of fruit extract, including peel and pulp, was determined to be 31.55 mg/100 g fresh weight (FW) in a study conducted by Tavares et al. (2016). Malvidin 3,5-O-diglucoside equivalents were used as the unit of measure for this. Total acidity content (TAC) is relatively low in unripe jambolan fruits but shows a steep rise as fruits ripen. Unripe jambolan fruits have a very low total antioxidant capacity (TAC), however this TAC increases dramatically when the fruit achieves full ripeness. The total phenolic content (TAC) of green-yellow, green-pink, pink, red, light purple, dark purple, and fully ripe black jambolan fruit was calculated to be 28.5 mg/100 g DW by Lestario et al. (2017).

Anthocyanins and flavonoids, found in many fruits, have stronger antioxidant capabilities than regular phenols. In addition to halting the formation of free radicals, these chemicals can also thwart their removal from the body by scavenging or deactivation (Singh et al., 2016; 2017). Jambolan's phenolic content is where its antioxidant properties come from. Due to a higher concentration of bioactive components, the peel of fruits has greater antioxidant activity than the pulp and seed. Jambolan fruit peel, pulp, and seed were tested for their antioxidant characteristics and found to have scavenging efficiencies of 90.6%, 82.5%, and 85.2%, respectively, according to research by Ali et al. (2015). Lestario et al. (2017) state that the jambolan fruit's high anthocyanin content is responsible for its many health benefits, including its high antioxidant and natural colourant content.

The jambolan fruit extract showed 970 lmol TE/g of Trolox equivalent antioxidant capacity (TEAC) at pH 7.0 and 1640 lmol TE/100 g of ORAC at pH 7.4. Faria et al.'s 2011 research demonstrated that the antioxidant capacity of hemiacetals and/or chalcones, the colourless variants of anthocyanins, obtained in phosphate buffer at pH 7.0 or 7.4 is higher than that of the flavylium cation. The ORAC values of jambolan pulp were found to be 144.5 mM TE/100 g, as stated by Aqil et al. (2012), while the values of jambolan seed hydrolysates were found to be 337.9 mM TE/100 g. The methyl ether of kaempferol is an effective free radical scavenger, as reported by Afify et al. (2011). Aqil et al. (2012) found that the pigments formed from cyanidin and delphinidin had cis-diols in their ellagic acid/ellagitannins, catechol (orthodihydroxyl), and pyrogallol (vicinal trihydroxyl) groups.

Jambolan leaf extracts in methanol had a FRAP value of 1314 mg ascorbic acid equivalents (AAE) per 100 g dry weight (DW), but the same extracts in methylene chloride had a value of 122 mg AAE per 100 g DW, as reported by Mohamed et al. (2013). Total phenolic content (TPC) and total flavonoid content (TFC) were found in high concentrations in polar extracts, particularly methanolic extracts, of jambolan leaves. Jambolan fruit extract in ethanol contains tannins with significant ability to lower free radical levels. Jambolan compounds with antioxidant qualities have been proven to be effective in preventing gastrointestinal ulcers in rats when administered at a dose of 20 g/kg body weight, as reported by Ramirez and Roa (2003). Numerous medicinal plants' extracts have been studied for their potential scavenging effects. In contrast, a 2007 study by Sultana et al. found that an extract made from jambolan bark was exceptionally effective at lowering peroxidation. Veigas et al. (2007) found that jambolan fruit peel extract had a DPPH scavenging activity of 78.2%, indicating that it was highly effective at neutralising free radicals. Remarkably, this potent antioxidant activity was measured at concentrations as low as 2.5 ppm. Based on these results, jambolan fruit peel extract may be a useful natural source of antioxidant compounds.

The phenolic acids found in jambolan fruit and seed have been linked to a variety of health benefits, including antioxidant, anti-diabetic, anti-cancer, anti-inflammatory, antibacterial, anti-allergic, and free radical scavenging activities (Aqil et al., 2016; Singh et al., 2016; Ghosh et al., 2017; Seraglio et al., 2018). According to Ayyanar and Subash-Babu (2012), traditional medicine used jambolan fruits and seeds to cure a wide range of illnesses, including diarrhoea, colds, coughs, fevers, skin issues, gastrointestinal disorders, and more. Researchers have found that using jambolan fruit extracts may reduce the risk of developing cancer (Li et al., 2009) and diabetes (Grover et al., 2000; Ravi et al., 2005; Sharma et al., 2006; Helmst€adter, 2008). Hydrochloric acid-hydrolyzed extracts from jambolan pulp and seed suppressed the growth of human lung cancer A549 cells, as reported by Aqil et al. (2012). After enrichment, the 30% extractability of Jambolan pulp powder was reduced to 4%. Extractability was just 3% for the enhanced seed powder. It has also been noted that eating jambolan fruit has a relaxing effect on the digestive system. The anti-allergic effects of jambolan leaf extract were investigated by Brito et al. (2007). According to their results, the extract protected mice from developing oedema, histamine and serotonin synthesis, mast cell degranulation, and eosinophil buildup. Due to their potential to block enzymes involved in cell activation and the synthesis of inflammatory mediators, the flavonoid glycosides contained in jambolan leaf extract have been linked to anti-inflammatory and anti-oedematogenic properties. Using the bioactive compounds found in jambolan can protect against radiation-induced DNA damage (Jagetia et al., 2008). These chemicals effectively neutralise superoxides, protecting cell membranes from potential damage. The extract from jambolan seeds was shown to have radioprotective properties in a study by Jagetia et al. (2005). Dichloromethane and methanol were used in the synthesis of the extract. Mice were subjected to varying levels of c-radiation as part of the experiment.

Jambolan seed extract, given to mice at a dose of 80 milligrammes per kilogramme of body weight, significantly reduced the severity of disease and mortality caused by c-radiation. Extracts of jambolan seeds have been shown to have radioprotective effects because they contain bioactive components with free radical scavenging activities, such as flavonoids and ellagic acid. The use of Jambolan leaf extract showed protection against DNA damage caused by gamma radiation in human peripheral cells grown in vitro and exposed to a dose of 3 Gy, as reported by Jagetia et al. (2008).

Conclusion

Jambolan's phenolic content and antioxidant qualities make it a useful ingredient in the creation of healthful and purposeful food products. However, a thorough investigation of the physiological benefits of these compounds requires a thorough comprehension of their bioavailability. Numerous questions remain unanswered, and most of what is known about the security of these drugs comes from in vitro and animal model trials. Numerous educational establishments provide advanced degrees in this field. Clinical trials and in-depth epidemiological studies are required to fully understand the potential benefits of the phenolic compounds found in jambolan. In order to preserve the beneficial components of jambolan fruits throughout processing, more research into the methods currently in use is necessary. Since there isn't an established market for jambolan and its derivatives in developing countries, they haven't caught on there. The developed world also hasn't made the most of this chemical's potential. Clinical research and phytochemical analysis can help raise this plant's profile in the pharmaceutical and medical communities.

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Declaration of Conflict of Interest

The authors declare that they have no conflict of interest.

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