



## Indian blackberry: Unveiling its health and organoleptic delights and use in beverage fermentation

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### Abstract

Recent years have witnessed a rise in interest in the fruit Indian blackberry, also known as Jamun or Jambu in the native language. Despite being in regular use at household levels, fruit, and other parts of the plant, have been investigated for its nutritional, biochemical and health values only recently. Several studies, spanning over the last decade, have reported various attributes of the fruit, especially the pulp, as having significant roles in combating diabetes, inflammation, reactive oxygen species (ROS), abdominal discomfort, infections and even cancer. These beneficial properties of Jamun are attributed to diverse arrays of bioactive anthocyanidins, polyphenols and ellagitannins- all of which are crucial plant secondary metabolites (PSMs). These PSMs have been correlated with the ferric reducing as well as ROS quenching activities, indicating antioxidant activity. Additionally, an important biochemical called jamboline also contributes to antioxidant activity as well as supposedly prevents solubilisation of starch in presence of sufficient glucose. Apart from being rich in important PSMs, the fruit itself is rich in carbohydrates, proteins, amino acids and vitamins that further contribute to its taste and aroma. As such, the fruit has been explored for its potential in producing functional food and beverages through microbial fermentations, especially wines. The potential for fermentation depends on the fact that jamun contains roughly 15-16 % w/w fermentable sugar. This review systematically summarizes the benefits of Jamun and its use as a fermentation substrate. Additionally, the possibility of using Jamun in fermentation of functional beverages other than wine has also been explored.

**Keywords:** Reactive Oxygen Species (ROS), Antioxidants, Anthocyanidin, Functional Beverage, Fermentation

### 1. Introduction

The jamun fruit, or *Syzygium cumini*, is a significant member of the Myrtaceae family. Cultivated in the Philippines, West Indies, and Africa, it is regarded as native to India and the West Indies [1]. The fruit has been popular since ancient times and finds noteworthy mentions in several Indian and Buddhist theological texts. Japanese Buddhist leaders have even affectionately referred to India as 'Jambudwipa' or the Land of Jambu tree up until 12th century A.D. The black jamun tree is a tropical plant with opposite, oblong, glossy, smooth leaves that smell like terpentine. This species grows quickly, reaching up to 30 meters in height and having a lifespan exceeding 100 years [2]. The plant has greenish yellow flowers and lance-shaped leaves. Ripe apricot flavour and aroma permeate the ripened fruit. Compared to fruits with white flesh, those with purple flesh are more astringent. The pulp and seeds of the fruit have tonic, cooling, sour, bitter, and sweet qualities. The bark has astringent sweet, sour, diuretic, digestive, and anthelmintic properties [3]. The fruits are a rich source of iron and have been shown to be a useful treatment for liver, heart, and diabetes.

There isn't a better jamun variety available for industrial production. Rajamun is the variety that is grown most frequently in northern India, though. This variety bears huge fruits that are accessible in June and July. The fruits are oblong and have deep purple colours, with little seeds [1]. A biochemical known as "jamboline" is present in the fruit, juice, and seed, and it is thought to prevent the abnormal conversion of starch to sugar in situations when there is an increase in glucose synthesis [4]. About 83% of ripe jamun is water, and the remaining 14% is virtually

solid and made up of a combination of fermentable sugar. Considerable amounts of fermentable sugar are present in jamun pulp, which can be utilized to ferment alcohol and other fermented drinks [5]. Owing to its abundant anthocyanin content, the jamun fruit also possesses antioxidative qualities [6].

Due to its numerous medicinal and therapeutic qualities, Jamun fruit is gaining prominence in food and beverage industry as a potential candidate for producing fermented products. Numerous studies in the recent past have explored this potential and healthy functional products such as red wine, jams, jellies, ice creams, etc have been produced at substantial scale. Additionally, these reports have successfully established the nutritional profile of the final fermented products and justified their organoleptic as well as health benefits. However, due to the limited availability or production of this fruit in the global market, there is still a long way to go before these products can be commercialized for use at a broader scale. Furthermore, the production of beverages such as red wine and jams often faces fierce competition from other fruits with similar value, that are more readily available or accessible. As such, there is need to delineate the superior qualities of the Indian Blackberry fruit so that it can be explored further for its application at a larger scale and thus, contribute to fresh employment opportunities. This review work underscores such important aspects of Indian Blackberry fruit as nutritional values, global production, potential as a fermentable substrate, research work that has reported various end products using the fruit as starting material and lastly, the potential of this fruit for producing novel beverages using a combination of various microbial consortia. For the current study, the literature was thoroughly surveyed through accessing such databases as Google Scholar and PubMed Central, using the following keywords: Indian Blackberry, Jamun, Java Plum, Fermentation, Phytochemical Composition, Nutritional Benefits and Fermented Products.

## 2. Phytochemical and nutritional values of Indian blackberry

In the nations where jamun is said to grow, all parts of the tree, and the seeds in particular, have a long history of therapeutic usage in the various folk medical systems [7]. Jamun is also widely utilized in many traditional medical systems, including Ayurveda, Unani, Siddha, Sri Lankan, Tibetan, and homoeopathic systems of complementary and alternative medicine [8]. The jamun fruit is rich in anthocyanins and contains various antioxidants. It also contains a glycoside compound called jamboline, which is thought to prevent the abnormal conversion of starch to sugar if glucose production is elevated. This inhibition of diastatic conversion imparts anti-diabetic property to jamun; however the detailed mechanism of the said metabolic function still remains unclear. It also facilitates quicker healing, possibly due to reduction of blood glucose levels [9].

Research has demonstrated that the pulp as well as the seeds of the jamun plant is extremely nutrient-dense and contains- essential minerals such as calcium, phosphorus, iron, and zinc [10, 11]; water-soluble vitamins such as thiamine, ascorbic acid, and niacin; carbohydrates such as glucose, sucrose, maltose, fructose, galactose and mannose; and free amino acids such as alanine, asparagine, tyrosine, glutamine and cysteine [12]. Their fruit also contains different types of flavonoids, mostly quercetin and myricetin derivatives, and flavanones, flavan-3-ols, proanthocyanidins, ellagitannins and gallotannins [13, 14]. Anthocyanins and hydrolysable tannins are reported to be the most abundant phenolics in the fruit followed by flavanones, flavanols and flavan-3-ols. It is said that flavonoids have chelating and antioxidant properties [15]. Antioxidants are compounds that prevent oxidation and shield the body from the damaging effects of free radicals, which can cause aging. In simple terms, flavonoids shield the organism from reactive oxygen species (ROS) by halting damage brought on by free radicals [15, 16]. Albumen, fat, glycosides, an alkaloid called jambosine, resins such as ellagic acid, quercetin, and gallic acid are all present in jamun seeds. All these beneficial qualities make the Indian Blackberry fruit suitable for use in haemorrhage, vomiting, nausea, and bleeding disorders. Churna, or powdered jamun seeds, is used to treat diabetes, diarrhoea, and dysentery.

**Table 1** Exact compositions of some of the key ingredients present in Indian blackberry fruit.

Composition	Amount	Reference
Moisture (g/g)	85.9±1.4/100	[17]
Protein (g/g)	1.4±0.7/100	[18]
Fat (g/g)	0.6±0.2/100	[17]
Fibre (g/g)	0.6±0.06/100	[19]
Carbohydrates (g/g)	16.6±1.2/100	[17]
Maltose (mg/g)	210	[20]
Sucrose (mg/g)	95.5	[20]
Fructose (mg/g)	57.50	[12]
Galactose (mg/g)	52.50	[12]
Glucose (mg/g)	20	[12]

The average weight of completely mature Jamun fruit is approximately around 11.0 g, consisting of 8.8 g of pulp and 2.2 g of seed. It is found that there is about 20% waste and an 80% pulp yield. As shown in Table 1, the jamun also contains a little over 1.4 g of protein, 0.6 g of fat, 0.6 g of fibre, 95.5 mg of sucrose, 210 mg of maltose, 16.6 g of total carbohydrates and other materials such as fructose, galactose, and glucose [1]. The jamun, also known as the java plum, is a good source of several important elements and vitamins, including zinc, magnesium, potassium, iron (0.15 mg), calcium (21.5 mg), vitamin A (50 mg), and vitamin B (around 0.12 mg) as mentioned in the Table 2.

**Table 2** Nutrient, vitamin, and mineral content of Indian blackberry fruit.

Vitamins and minerals	Amount (mg/g)	Functions	Reference
Vit-A (B-Carotene)	50±5.9/100	Helps to maintain healthy vision, skin, and immune function.	[19]
Vit- C (Ascorbic acid)	30±6/100	Helps in cold and reduce infections by boosting immunity system	[19]
Vit- B			
1.Thiamine /vitB1	0.12±0.6/100	Essential for energy production, brain function, and maintain healthy skin and muscles.	[20]
2. Riboflavin/vitB2	0.06±0.02/100		
Iron (Fe)	0.15±0.01/100	Important for the formation of haemoglobin and oxygen transport in the blood	[6]
Calcium (Ca)	21.5±1.5/100	Essential for bone health, muscle function, and nerve signalling	[19]
Zinc (Zn)	0.28±0.0/100	Helps to activate the T-cells, immune cells that help to fight off viruses and bacteria	[20]
Magnesium (Mg)	49.8±1.2/100	Helps in energy production, muscle and nerve function, and maintaining a healthy immune system.	[19]
Potassium (K)	18.5±2.8/100	For the formation of bones and teeth, production of protein for growth and cell repair.	[20]

**Table 3** Bioactive phytochemicals in Indian blackberry and their key functions.

Component name	Part of the fruit found in	Function	Reference
Flavonoids (Quercetin, Myricetin)	Leaf, flower, fruit	Protect the heart against heart disease and cancer. Contain antioxidants and anti-inflammatory activity.	[21]
Phenolic acids (Gallic acids, Ellagic acid)	Seeds, fruit, stem bark	Associated with nervous system, helps inhibiting disease causing enzymes.	[22, 18]
Anthocyanins (Delphinidin, Petunidin, and malvidin)	Pulp (Pigments)	Provide the bright purple colour	[23- 27]
Tannins	Stem bark	Effective against the HCl/ethanol-induced gastric ulceration in rats	[28, 29]

The peel, pulp, and seed of the jamun are all significant sources of phytochemicals, including both phenolic and non-phenolic bioactive ones. In-vitro pharmacological research links phytochemicals to a range of therapeutic effects, including antioxidative, anti-tumorous, anti-diabetic, antibacterial, and radioprotective properties. Of these, the ameliorating effect on Type 1 and Type 2 diabetes has received the greatest attention.

Jamun is a seasonal, perishable, and underappreciated fruit with an appealing colour, astringent taste, and significant mineral and vitamin content. Traditional healers frequently utilize jamun to treat a variety of illnesses, most notably diabetes and its consequences.

Beyond its primary role of providing nutrients, jamun has tremendous potential to be used as a raw material for post-harvest processing and the development of functional foods with the ability to prevent disease [29].

### 3. World production of Indian blackberry

Fruits are a primary meal that is found in nature. Individuals of all ages enjoy these fruits as they are a great way to get vitamins, minerals, and enzymes. They have a cleaning impact on the blood and digestive system and

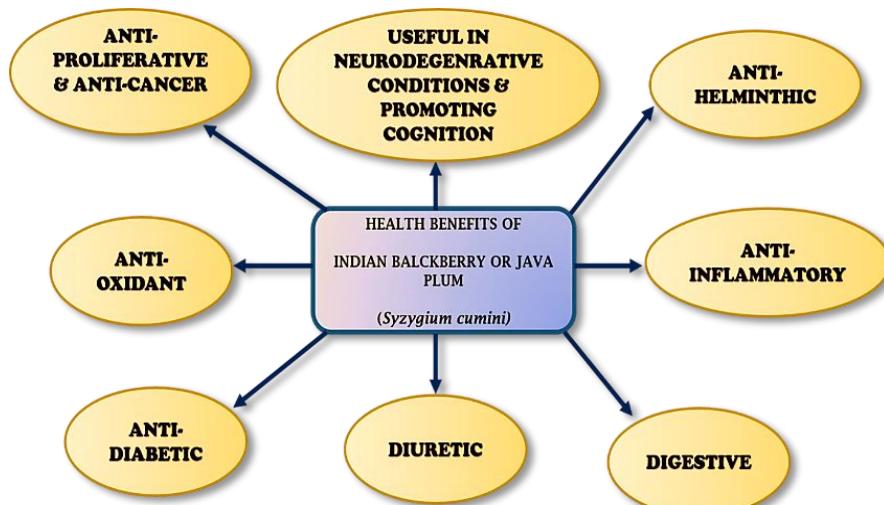
are readily absorbed. Approximately 20 million tonnes of food are produced in India each year. However, only 1.2% of this is used for processing and preservation, and handling, shipping, and a lack of cold storage facilities squander between 30 and 33% of the entire production [30]. Their high juice or water content makes them perishable. There is a glut in the market when a certain fruit is produced in greater quantities during a certain season. To increase the shelf life of fruits and enable them to be safely transported to consumers worldwide, not only those residing in the growing region but the food industry also employs a range of preservation and processing techniques [31]. Jamun, which is grown in the Philippines, the West Indies, and Africa, is said to be native to India and the West Indies. Tall and evergreen, its tree is typically cultivated as an avenue or as a wind direction, heading north to Tamil Nadu in the south. It can also be found in India's Kumaon hills and the lower Himalayan range. The fruits are a strong source of iron and have been shown to be a useful treatment for liver, heart, and diabetes. India ranks second globally in terms of fruit production. India contributes 15.4% of the estimated 13.5 million tonnes of jamun produced worldwide. It is presumed that India is the world's largest producer of jamun, although the data is somewhat obscure. The Indian states that generate the most jamun are Maharashtra, Tamil Nadu, Gujarat, Assam, and others. The most well-known type is the "Konkan bahadoli" variant which is particularly grown in the Konkan region. Due to the introduction of new cultivars and increased demand, jamun agriculture has become more productive during the past ten years. It is unknown where exactly jamun is produced. However, in the past ten years, it is expected that almost 5000 acres of jamun plantations have been completed. In drier parts of southern and western Indian states like Karnataka, Andhra Pradesh, Maharashtra, Gujarat, and Madhya Pradesh, the practice is becoming more and more widespread. Other than India, you may find these trees flourishing in Madagascar, Eastern Africa, South America, and the Asian subcontinent. They have even naturalized in the warmer parts of the United States (such Florida and Hawaii).

#### 4. Health Benefits of Indian blackberry

Due to its potential for therapeutic use, *S. cumini* has been prized in Siddha, Ayurvedic, and Unani medicine. In India, the entire plant is employed in several traditional medical systems [32].

Parts of the *S. cumini* have been shown to have hypoglycaemic, antibacterial, and anti-HIV properties through pharmacological testing [29, 33]. Different traditional medical systems have made use of Jamun plant parts such fruit, seeds, bark, and leaves for leucorrhoea, stomach-aches, fever, dermopathy, constipation, bleeding piles, liver problem and reduction of radiation-induced DNA damage also in anthelmintic antidiabetic, enlargement of the spleen, and chronic diarrhoea [32- 37]. Fruit extracts have been shown to have anti-oxidative activity, anti-inflammatory properties, antibacterial properties, anti-proliferative activities against human lung and breast cancer cells, pro-apoptotic effects against human breast cancer cells.

Different parts of the jamun trees have been used for different medical purposes for decades, mostly the pulp, skin of the fruit, bark, leaves, etc. Jamun fruit, or *Syzygium cumini*, has amazing effects on diabetics. This fruit is a natural blood purifier because of its high iron content. It has an astringent function and is made up of several organic acids such as gallic acid and oxalic acid. This attribute endows the fruit with the ability to combat malaria and a host of other microbial and bacterial infections. It can also be utilized to prevent cardiovascular disease, treat lung conditions including bronchitis, asthma, and cough, used for abdominal pain and dysentery as well [38- 42].

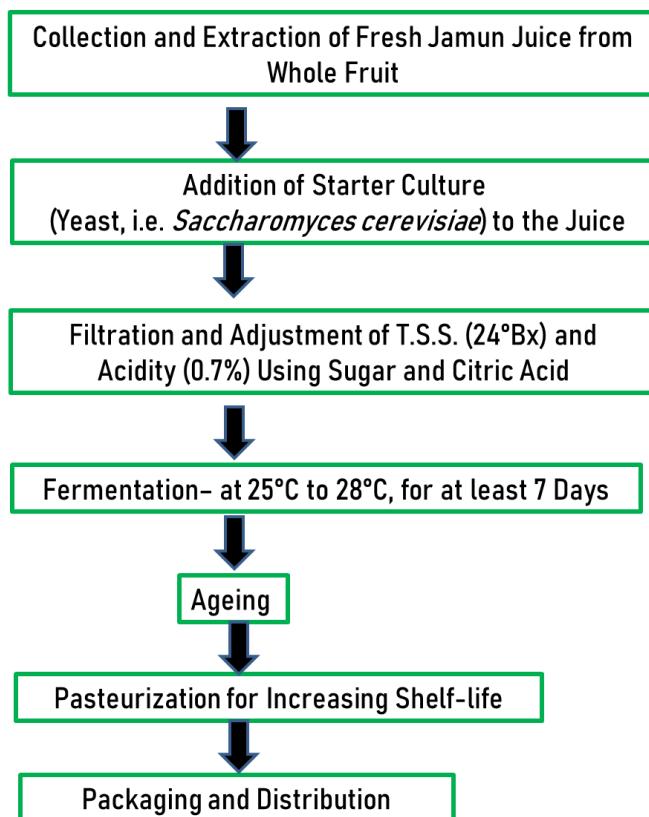


**Figure 1** Health benefits of Indian blackberry.

## 5. Use of Indian blackberry as a substrate for fermentation and brewing

Based on morphological and organoleptic characteristics, botanical studies have identified two primary morphotypes of jamun in the Indian subcontinent-- the Kaatha jamun, which is small and has slightly acidic taste, and the Ras Jamun, which is oblong, dark-purple, or bluish, with pink, sweet fleshy pulp and small seeds. For over a decade, the jamun fruit has been utilized as a starting substrate for wine fermentation due to its medicinal, therapeutic and organoleptic properties. About 80% of ripe jamun is water, and about 10% is a combination of fermentable sugars. There is a sizable amount of fermentable sugar in jamun pulp that can be utilized to ferment alcohol [1, 43]. According to Patil *et. al.*, 2012, alcohol percentage in the end wine typically ranges between 6.62 and 10.25 [1]. However, this is dependent on the fluctuating quantities of yeast inoculation (5%, 10%, 15% and 20% w/w, with respect to the total weight of the raw starting substrate) and total soluble sugar concentration (7.88% to 10.53%).

The jamun fruit's pulp and skin contain anthocyanin, which is rich in antioxidant properties and give the fruit its purple, bluish, or reddish colour, in turn aiding in imparting a natural red colour to red wine. Till now, jamun has been utilized to create a variety of alcoholic beverages using *Saccharomyces cerevisiae*, also known as Brewer's yeast, at a temperature around 25°C. Typically, ripe fruits are properly cleaned with tap water containing potassium metabisulphite, the pulp and seeds separated and then, using blender, the pulp is homogenized to create a fine pulp, for extracting the juice. The fundamental steps used involved in wine production from jamun juice have been schematically summarized in Figure 2.



**Figure 2** Schematic of wine fermentation from Jamun fruit.

### 5.1 Fermentation process

The Indian java plum is used to manufacture a variety of fermented drinks. Typically, the juice is extracted from the pulp (without the skin) and filtered using a fine and clean muslin cloth to clear out any impurities. Thereafter, TSS (24° Bx) and acidity (0.7%) are adjusted using sugar, citric acid, di-ammonium phosphate and sodium metabisulphite. After being inoculated by the yeast *Saccharomyces cerevisiae* at desired concentrations, the mix is left to ferment at 28°± 2.0° C for 7 days.

Jamun pulps are used to manufacture wine in some regions of India, and efforts should be made to support research aimed at improving the wine's colour, taste, and aroma so that industrial scale fermentation can be carried

out. Enhancing the quality and commercial viability of the different finished products made from jamun pulp (juice, jams, etc.) should also be the focus of research. To fully utilize the potential of this plant, emphasis should also be placed on enhancing the fruit quality and shelf life [44, 1].

### 5.2 Nutritional profile of fresh fruit pulp and the fermented end product

Fresh Java plums or Indian blackberries have a high moisture content of about  $85.9 \pm 1.4$  g/100 g. They also contain around  $1.4 \pm 0.7$  g/100g of protein,  $0.6 \pm 0.2$  g/100 g of fat,  $0.6$  g/100 g of fibre,  $16.6 \pm 1.2$  g/100 g of carbohydrates,  $95.5$  mg/g of sucrose, and various vitamins and minerals including calcium, zinc and iron. Additionally, antioxidants such as gallic acid, anthocyanins (like delphinidin, petunidin, and malvidin) are also found, although their content shows variation in substrate and end product stage. Following ethanol fermentation for wine production, all the fruit's sugar is converted to alcohol, and the pH ranges from 3.90 to 4.2 [5, 11, 17, 20]. Anthocyanin, a significant anti-oxidizing compound that imparts the typical colour to jamun-fermented wine, reportedly shows a drop to about  $60 \pm 4.5$  mg/100 mL of finished wine, from its starting concentration; however, it still continues to impart substantial anti-oxidizing propensity to the end product as understood from DPPH and Ferric Reducing assays [44].

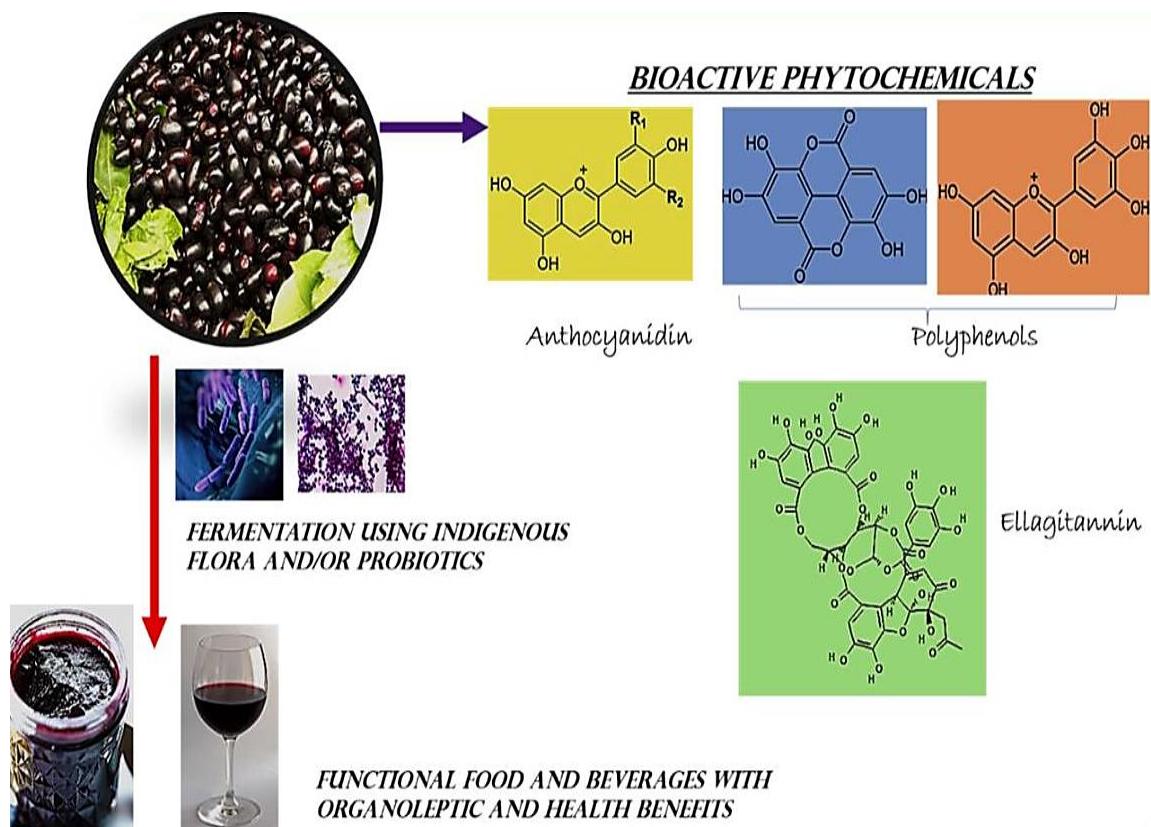
The concentration of different biomolecule and bio-active compounds vary depending on factors such as—variety of jamun used, number of days allowed for fermentation, post-fermentation strategies such as maturing, filtering, etc., concentration and type of starter culture used, etc. Various techniques are employed for extraction and estimation of these crucial components in the fruit as well in fermented end product such as Gas Chromatography- Mass Spectroscopy, High Performance Liquid Chromatography- Mass Spectroscopy, UV-Visible Spectroscopy estimation of phenolics as Gallic Acid Equivalents, etc.

**Table 4** Nutritional profile of fresh fruit and fermented juice.

Parameter	Fresh fruit pulp	Fermented end product	Reference
Moisture (g/g)	$85.9 \pm 1.4/100$	-	[17]
pH	3.79–4.83	$4.2 \pm 0.03$	[11]
Sucrose (mg/g) (mg/g)	95.5	$42 \pm 0.02$	[20]
Calcium (mg/g)	$21.5 \pm 1.5/100$	-	[5]
Zinc (mg/g) (mg/mL)	$0.28 \pm 0.03/100$	0.067	[5]
Alcohol (mg/mL)	-	$8 \pm 0.02$	[11]
Retinol (g)	3 IU/100	-	[11]

## 6. Summary

This review paper has summarized the health benefits of the fruit Indian Blackberry, also known as Jamun or Jambolan or Java Plum, and also discussed about the various bioactive compounds that contribute to its versatile role in human health. While the fermentation of Jamun still stands as an underexplored territory, it comes as no surprise that its exploration for health and therapeutics has been rising. Various in-vitro and in-vivo studies have already proven its properties of anti-oxidation, anti-diabetic, anti-helminthic, hypolipidemic, etc. As established through various chromatography, spectroscopy and biochemical tools and techniques, the beneficial compounds found in Jamun fruit pulp, seed as well as leaves, are present in significant quantities, and owing to this important aspect of this plant, it has contributed to various medicinal systems, particularly homeopathic formulations. These studies, performed on animal models, have only served to justify the use of Jamun in human society since ancient times. As such, the utility of Jamun can definitely extend beyond the conventional consumption of the fruit or medicinal preparations of the plant parts, and potentially be employed by the fermentation industries in Figure 3.



**Figure 3** Graphical summary: Major bioactive compounds in Jamun, and fermentation of functional beverage and/or food.

## 7. Challenges and Future Prospects

The multifarious nutritional and health benefits of Indian Blackberry have attracted the attention of many across the globe. Especially known for its rich colour due to anthocyanin and polyphenol laden pulp, the fruit is a potential source or substrate for fermentation, that also brings about end products with several health benefits. While the Indian Blackberry has been extensively employed in the fermentation of red wine using brewer's yeast, and also in production of jams, jellies, ice creams, etc, that may not require additional microorganisms (probably other than the indigenous flora), it has not yet been tested for fermentation with other microorganisms or their consortia. The beneficial roles of probiotics in fermented foods and beverages are not unknown, and if these microorganisms are employed for fermenting fresh Jamun pulp or juice, it may yield novel end products of nutraceutical value [45, 46]. This in turn can add to the product's market value, thereby making way for start-up companies. Various microorganisms, clustered as Symbiotic Culture of Bacteria and Yeast (SCOBY) have been reported to play roles in producing fermented foods and beverages with bioactive compounds from different starting materials. These SCOBY often come with probiotic potential, attributed to their versatile physiology and metabolism [45-48]. However, the use of SCOBY in fermentation of Jamun pulp and juice remains under-explored. As such, future efforts can be channelized in the direction of utilizing Jamun as a substrate for fermentation using various combinations of beneficial SCOBY [44, 47, 48]. The use of probiotics can also be encouraged in this regard, thereby adding to the nutraceutical value of the final fermented product.

The main challenge in this aspect lies with the cultivation of Jamun: Jamun plantations being limited to only a small part of the world, and there being risks imposed due to transportation, storage and handling, the availability of a substantial amount of starting material for fermentation at a reasonable price may become difficult. Additionally, the rising threat on crops and plantations across the world due to climate changes and anthropogenically-influenced biotic and abiotic stress has further impacted the production of jamun, thereby disrupting the demand-supply chain of this fruit. As such this issue too needs to be addressed in near future by the human society at large, in hopes of creating employment opportunities through the fermentation industry.

## 8. Conflict of Interests

None declared.

## 9. Author Contributions

Arpita Ghosal: Investigation, Data Curation, Writing Original Draft, Visualization. Puja Agnihotri: Conceptualization, Review & Editing, Visualization, Supervision.

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