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REVIEW ARTICLE

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A review on bioactive compounds and health benefits of *Baccaurea ramiflora*

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Abstract

The purpose of this review is to explore the underutilized and underexploited Burmese grape (*Baccaurea ramiflora*) as a valuable plant food crop grown in the northeastern region of India. Despite its seasonal availability, this fruit is used in various culinary applications and local delicacies. It is noteworthy for its abundant natural bioactive compounds that offer diverse health benefits. These bioactive compounds have demonstrated properties such as anti-inflammatory, antiobesity, cytotoxic, and antidiabetic effects. This review compiles and analyzes the most recent research findings concerning the bioactive compounds found in Burmese grape's leaves, fruit, and seeds. Additionally, it investigates the physicochemical properties and nutritional composition of the fruit pulp and seed oil. The synthesis of this information provides a comprehensive understanding of the plant's phytochemical content, including essential components like vitamin C, iron, potassium, alkaloids, saponins, and phenolic acids, which contribute to its medicinal and health-promoting attributes. The results presented in this review shed light on the potential applications of the Burmese grape and its bioactive compounds in various industrial sectors. With the growing interest in functional and nutraceutical products, the insights gathered here offer promising opportunities for leveraging the nutritional and health-enhancing benefits of this fruit in the food and pharmaceutical industries.

KEYWORDS

Baccaurea ramiflora, bioactive compounds, compositional value, health benefits, phytochemical profile

1 | INTRODUCTION

The Burmese grape belongs to the family "Euphorbiaceae," and it is a flower-bearing plant known for its sweet, acidic fruit known as *Baccaurea ramiflora* Lour. This fruit is renowned for its exclusive taste, flavor, and pale-rose-colored pulp. Burmese grape and its plant parts have been reported to possess medicinal properties, with people using them as folk medicine in countries like China for the prevention and treatment of various illnesses and injuries, such as arthritis, cellulitis, and episteme (Tao et al., 2007). The plant is enormous, growing up to 10 m in height, and its fruits are known for being rich sources of bioactive compounds. These compounds provide both fruits and medicinal plants that are used to overcome and treat a wide range of diseases. *B. ramiflora* is cultivated in the northeast regions of India (Assam, Tripura, Arunachal Pradesh), found in the Himalayan tract (Nepal to Sikkim), and also in the southern part of India, specifically in the Andaman and Nicobar Islands. Additionally, it is found in neighboring states like Bhutan, Tibet, Burma, Thailand, Peninsular Malaysia, Vietnam, Laos, and Cambodia, mostly inhabiting tropical moist forests (Sundriyal & Sundriyal, 2003). Fruit consumption is associated with several health benefits. Literature has reported that regular consumption of fruits helps prevent cancer, diabetes, neurodegenerative problems, and coronary heart disease (Brahma et al., 2013). *B. ramiflora* is an underutilized fruit; although many local people utilize this fruit and its plant parts, they may not be aware of the health benefits exerted by this fruit. The fruit is grown in Thailand; these fruits are widely consumed, and their plant parts are used for the

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preparation of various nutrient-rich food products and medicines to treat various health issues (Yang et al., 2007). Conversely, in Bangladesh, people consume the leaves of *B. ramiflora* for the preparation of vegetable curries due to the presence of bioactive compounds that add flavors, making them useful as flavoring agents in many foods (Pradhan et al., 2015). Research has indicated that *B. ramiflora* fruit crops are utilized more for medicinal purposes than for direct consumption as fruits. Although little research has been done on them, the majority of the plant's parts are loaded with bioactive compounds that offer tremendous health effects, requiring no special conditions for growth as they naturally thrive as forest plants. While the fruit may not be the primary focus of cultivation in backyard plantations, it is popular due to its high content of vitamin C, protein, and iron and its unique taste. Various parts of this plant are widely used in foods and medicine, particularly for the treatment of abscesses, injuries, and arthritis. Both the fruits and their plant parts have been tested on animal models, revealing various biochemical and pharmacological activities. Notably, an appreciable amount of saponin and alkaloids remains in the pulps (8.27% and 7.48%, respectively). Saponin-containing fruits are known for their anti-inflammatory activity (Mann et al., 2016), while the presence of alkaloids contributes to analgesic, antispasmodic, and antimicrobial properties, along with aiding in strengthening the immune system of the body (Kuete, 2014). Some fruits and vegetables, despite being underutilized, play a very crucial role in maintaining health and offer significant benefits. It has been reported that juice obtained from these fruits is consumed and utilized in the preparation of different food products, possessing excellent functional properties (Goyal et al., 2013). The bioactive compounds present in the Burmese grape are highly valuable in terms of their bioactivity and composition. However, there is still a research gap that categorizes this fruit as underutilized (Hasan & Hossain, 2009). Plants and their phytochemicals are natural boons for humans and animals, with these bioactive components present in stems, leaves, fruits, and vegetables playing a vital role in maintaining a healthy life. These bioactive compounds serve as a natural blueprint for the development of new drugs, with phytomedicine showing tremendous potential in the organic food market. While studies on *B. ramiflora* have reported on its ethnobotanical uses, seed biology, and chemical compounds found in the essential oil, there is limited research on this plant. Hence, to the best of our knowledge, we have compiled all available scientific and literature data to thoroughly explore the potential benefits of this fruit. Despite all the health-promising benefits possessed by the fruits and plant parts, the consumption and production of this food crop and related products remain very low, ultimately categorizing this fruit as underutilized. This review paper will emphasize analyzing the bioactive compounds and documented health benefits associated with the *B. ramiflora* fruit and its plant parts. This review paper will provide valuable insights for researchers and industries aiming to optimize the utilization of this plant in diverse applications related to *B. ramiflora* and its plant parts.

2 | PHYTOCHEMICAL DESCRIPTION OF THE PLANT AND ITS PARTS

B. ramiflora is an evergreen subtropical plant that grows on a wide range of soils found to be dioeciously in nature and generally favors the shade condition to grow the plant very easily; it was observed that the growth is found to be slow in this plant. Burmese grape plants bear flowers during the summer season and the fruits are harvested during the rainy season and mostly end in the month of May–July (Mann et al., 2016). The pulp of the *B. ramiflora* fruit was reported to be loaded with numerous bioactive compounds, which include organic acids, phenolic acids, vitamins, and sugars, and these bioactive compounds are mainly responsible for its unique flavor (Chen et al., 2023). Fruits of these plants are seasonal in nature but known for providing a sweet acidic taste; the plant is known for its medicinal value; the different components of plants like leaves, roots, stems, and juice obtained from the fruit pulp are found to be very effective in overcoming the diseases like arthritis, constipation, and abscesses and maintaining the gut microflora active to inhibit or kill the pathogens, which is helpful in adopting new lifestyle; overall, it maintains good health (Goyal et al., 2013). The pulp of these fruits is reported to be consumed raw, and these can be processed into various food products like juice, jam, and wine (Chen et al., 2023). The phytochemical composition is present in all the different parts of Burmese grapes, and because of the presence of these compounds, they are used as medicine for the treatment of cellulitis, rheumatoid arthritis, and abscesses (Raghavan, 2018). The whole fruit itself has the potential to possess phytochemical activities as it was reported to have a good amount of protein, iron, and vitamin C content (Raghavan, 2018). The fruits and plant parts were reported to possess very good functional, medicinal, and nutritional properties. The utilization of these parts and their properties are listed below.

3 | BARK OF *B. RAMIFLORA*

The bark of the *B. ramiflora* plant appears brownish on the outer surface, and the inner surface appears to be light brown in color. The bark does not have any odor, and the taste appears nil in starting, but after some time, it appears slightly bitter (Hasan & Hossain, 2009). The bark contains approximately 1.45% moisture content and ash value of around 21.5%; the acid-soluble and water-soluble ash are 1.5% and 1.95%, whereas the sulfated ash value is around 20%. Generally, the bark is used for curing "constipation" and for treating skin-related problems (Altemimi et al., 2016). The stems of the

B. ramiflora are brown in color, whereas the branchlets change from hispid to glabrescent as the age increases, and the bark of this tree can be consumed, or juice from the bark is extracted and taken orally for the treatment of constipation (Raghavan, 2018).

4 | LEAVES OF *B. RAMIFLORA*

The leaves of the plant are alternately arranged with the petiole, and the shape is 10–20 × 4–9 cm. The leaf is green-yellowish in color, cuneate at the bottom, and glabrous on both surfaces, whereas the left blade is obovate–oblong and oblanceolate in shape (Raghavan, 2018). The length of the petiole is 1–8 cm, having lanceolated and fimbriated stipules. The leaves from this plant possess a compound named *Melatonin* (*N*-acetyl-5-methoxytryptamine) that regulates circadian rhythm and controls various functions of the body. This hormone is released by the body for sleep, but it is naturally found in the leaves of this plant. The melatonin content is reported to be 43.2 ng/g per dry weight, which makes this plant special, and this can be used for nutraceutical purposes (Ansari et al., 2010; Padumanonda et al., 2014). Rosmarinic acid is found in the leaves of *B. ramiflora* Lour, and the acid is a type of new polyphenol that possesses anti-inflammatory property and is also effective against inhibition of eicosanoids, infiltration of neutrophils, and its degranulation by reducing the concentration amount of arachidonic acid, which accounts for pain sensation in the body (Usha et al., 2014). The two new phenols, namely 6′-O-vanilloyltachioside and 6′-O-vanilloylisotachioside, possess significant DPPH radical-scavenging activity and also the potential antioxidant activities profound effect against H_2O_2 induced impairment in P12 cells and certain compounds are responsible for their antioxidant activity (Yang et al., 2007). Methanol extract of *B. ramiflora* plant leaves shows a very high, good, and significant effect on albino rats against diabetes. The leaves have the potential to decrease the concentration of triglyceride, cholesterol, and low-density lipoprotein and possess hypoglycemic, hypolipidemic, and antioxidant activities. These plant leaves were known for the cadmium removal from the natural water; thus, the leaves of this plant can be used for heavy metal absorption from the water resources (Borah et al., 2018; Obayed Ullah et al., 2012). The leaves of *B. ramiflora* contain a good amount of phyto-chemicals and a new polyphenol compound. The leaves of this plant have medicinal value; they are used for the treatment of various types of diseases (arthritis, anti-inflammatory) and help in decreasing the chances of metabolic disorder of diabetes mellitus, which has become a serious problem nowadays and is increasing dynamically (Obayed Ullah et al., 2012).

5 | FRUITS OF *B. RAMIFLORA*

When the fruits are developed and matured enough, they become oval in shape; the immature green color of the fruit turns yellow to a yellowish-brown color and the red variety. Generally, the flowering of fruit starts normally at the start of the summer season. There are 3–4 segments inside the fruit based on the seeds available, overlapped by the leathery white pulp (N. Bhowmick, 2011). The physical characteristics of *B. ramiflora* are as follows: the length is found to be in the range of 0.84–3.14 cm and the breadth is 0.27–3.04 cm. The fruit is slightly acidic in nature and generally consumed in fresh form, and the generic name "*Baccaurea*" is given due to the golden-yellow color of the fruit (Bhanja Dey et al., 2016). The overall weight of the fruit was found to be in the range of 0.18–18.41 g. The fruit is found to be potentially antiviral and has shown antioxidant properties. Picrotoxin sesquiterpene ramifloside is a compound found in the fruit that has antifungal activity against *Colletotrichum gloeosporioides* (PanHuang et al., 2015). The fruit appears yellowish in color; the immature fruits are green in color, and finally, after ripening they change into yellowish or red from the outside in appearance and juicy and acidic sensorially. Fruit is composed of a high value of nutritional components like vitamin C, iron, and protein, and the phytochemical compounds present in this fruit make it unique and novel and can be used for fortification in many products and work as an additive. Studies proved that pulp and seed fraction of *B. ramiflora* has been proven to have health benefits as they possess analgesic, anti-inflammatory, CNS depressant, and anti-diarrheal activities (Nesa et al., 2018a).

6 | SEEDS OF *B. RAMIFLORA*

The seed that is found inside this fruit is covered by a pulp that is white in color, and the color of the three arils seeds is pinkish. The seed comes under the category of the nonedible portion, and a seed of this fruit has a tremendous and very rich source of oil. Tetrahydrofuran-lactone meroisoprenoid found in the seed kernel of *B. ramiflora* showed excellent inhibitory activity against pathogenic fungi like *Phytophthora oryzae, Collectotrichum gleosporioides, Helminthosporium oryzae, Alternaria solani, and Curvularia eragrostis* (Bordoloi et al., 1996). The seed of the fruit was also loaded with annatto dye (4.8%–6%) that was used for coloring various types of fabrics like silk and cotton to attain orange-red color (Farid Hossain, 2017). *B. ramiflora* is known by different names in different parts of the country; the English name is "Burmese grape." All the names from taxonomic classification to local names in different parts of the world of *B. ramiflora* are given in Table 1.

7 | SEED OIL

Oil is extracted from the *B. ramiflora* seed, which is discarded generally considering in the category of nonedible, but the seed contains a very good amount of oil. The increasing rate of demand causes to increase the rate of oil production, resulting in the depletion of the sources of fats and oil, so this seed oil that is unknown and unexploited sources is very helpful to fulfill our (human) needs and can be utilized in various type of industries for different purposes like soaps, cosmetics, medicinal uses, and in food industries. The physico-chemical properties of *B. ramiflora* seed oil are given in

TABLE 1 Different names of *B. ramiflora* (Dutta et al., 2013).

Taxonomic classification of B. ramiflora	
Kingdom	Plantae
Division	Magnoliophyta
Class	Magnoliopsida
Order	Euphorbiales
Family	Euphorbiaceae
Genus	*Baccaurea*
Names of Baccaurea ramiflora	
Synonyms	*Baccaurea cauli flora* Loureiro, *Baccaurea flaccida* Müll. Arg., *Baccaurea oxycarpa* Gagnep., *Baccaurea pierardi* Wall., *Baccaurea propinqua*Müll. Arg., *Baccaurea sapida* (Roxb.) Müll. Arg., *Baccaurea* wrayi King ex Hook.f., *Gatnaia annamica* Gagnep., *Pierardia fl accida* Wall., *Pierardia sapida* Roxb.
English names	Burmese grape, Lantern tree, Mafai.
Vernacular names	
China	Mu Nai Guo
Bangladesh	Kusumtenga
Myanmar	Kanazo, Kanaso & Krak-Hsu-Ro:Ni.
India(State-wise naming)	Assam = Lotqua, Bengal = Dojuka (Garo), Lutka, Latka, Kataphal, Lutco Megaalya(Shilong) = Moktok Manipur = Pangkai
Indonesia	Tampoi Kuning, Tampoi Merah (Kalimantan), Mafai Setambun, Tajam Molek, Pupor;
Khmer	Phnhiew
Loas	F'ai
Malaysia	Pupor, Tempui, Tampoi, Tampoi Kuning, Tampoi Merah, Rambai
Nepal	Kala Bogoti
Thailand	Mafai (General)
Vietnam	Dâu Da Đất, Giau Gia Dat, Giau Tien, Dzau Mien Dzu O'i.

Table 2, which show that seeds of *B. ramiflora* are rich in oil content (Raghavan, 2018). The color of seed oil was reported to be light brown, which may be due to some compound that is not reported in the literature, whereas the acid value corresponds to the fatty acid profile of the oil. The moisture content of the oil is reported to be 0.103, which is relatively low; ultimately, low moisture content makes this oil of good quality and should have a high shelf life by reducing the chances of rancidity (Dutta et al., 2013). GC-MS of *B. ramiflora* was studied and different fatty acids were reported. It is found that saturated fatty acid is present in oil, accounting for more than 60%, such as palmitic acid (33.67%), stearic acid (19.38%), and arachidonic acid (9.69%), and the unsaturated fatty acid found is oleic (24.48%) and 11-*trans*-eicosenoic acid (12.75%) in the seed oil of

TABLE 2 Mineral concentration found in *B. ramiflora* (Kermasha et al., 1987b).

Minerals	Concentration (mg/100 g) dry weight
Calcium (Ca)	169
Magnesium (Mg)	504
Phosphorus (P)	117
Potassium (K)	1370
Sodium (Na)	49.7
Iron (Fe)	100
Boron (Br)	18.6
Manganese (Mn)	4.5
Zinc (Zn)	4.41
Copper (Cu)	1.91

B. ramiflora (Dutta et al., 2013). Bioactive components that have their specific activities are found in different parts of the plant *B. ramiflora*, which can be utilized for various product developments and provide nutritional and nutraceutical benefits to humans as the leaf, seed oil, and fruit are used as medical foods and functional foods and in pharmaceuticals. Seed oil from *B. ramiflora* reported the presence of omega-9 fatty acids, which are known to reduce the risk of cardiovascular diseases and stroke by increasing the HDL (Raghavan, 2018).

8 | COMPOSITION OF *B. RAMIFLORA* FRUIT

The average yield of *B. ramiflora* fruit from the plant is around 70–80 kg/year/plant. The *B. ramiflora* fruit contains 44.5% edible portion, whereas 55.5% of the portion found in the fruit is not edible, which contains the seeds, peel, and so forth; the carotenoid content in the fruit is 218 μg/100 g in the edible portion of the fruit (Tariqul Islam Shajib et al., 2013). *B. ramiflora* is loaded with a nourishing amount of nutrients that are present in all the parts of fruit (peel, pulp, and seed). The fruit pulp and peel contain a good amount of protein content and as well as a potential source of bioactive compounds and other well-known nutrients.

9 | MACRONUTRIENTS OF *B. RAMIFLORA* FRUIT

Burmese grape is loaded with plenty of macronutrients, which are known to possess health-beneficial activity. Raghvan (2018) reported the nutritional composition of *B. ramiflora* and observed that fruit contains a high amount of carbohydrate and protein content of 51% and 5.58%, respectively. Similarly, researchers from different parts of the world reported that this fruit is loaded with numerous bioactive compounds; however, the difference in the concentration depends upon many external factors (Hossain & Hossain, 2023; Saha et al., 2016). The pulp of this fruit is very low in fat content, while the seeds of this

fruit contain a high amount of oil in comparison with peel and pulp. The high amount of moisture in pulp has a positive impact on the processing industry as in the local region it is utilized for the production of various products like juices, wines, and so forth (Mu et al., 2012). Studies proved that dietary fiber has various benefits, as it reduces the chances of obesity and maintains healthy bowel movement and weight management; overall, it helps to manage good health (Panghal et al., 2021; Yannakoulia et al., 2019). Generally, *B. ramiflora* is consumed without peel because the peel is thick and protects the pulp portion of the fruit. Peel of this fruit is reported to be high in protein and dietary fiber, containing 9.31 and 3.51 g/100 g, respectively. On the other hand, the peel is very thick in width; therefore, it can be utilized in animal foods, and by some processing techniques, the peel can be converted into functional foods and utilized by human beings for better health. Some researchers worked on the peel to extract the phytochemicals from the peel and used them as functional foods rich in bioactive compounds (Roy et al., 2023).

10 | MICRONUTRIENTS OF *B. RAMIFLORA* FRUIT

The micronutrients present in the Burmese grape are the minerals and other bioactive compounds. The mineral profile of *B. ramiflora* fruit is given in Table 3 (Kermasha et al., 1987a; Sundriyal & Sundriyal, 2003). The iron content was found to be highest in *B. ramiflora*, whereas the magnesium and phosphorus contents are also in a good amount, making the fruit good for maintaining the body healthy. The phytochemical composition of the *B. ramiflora* fruit and its parts were studied and food products are also been consumed by some local people. The fruit that is developed properly but is in unripe condition yields pectin, 14.1%, which is a very good source and is utilized in jams, jellies, and other various food products. *B. ramiflora* contains a good amount of moisture content that replenishes the water in the body and maintains good health. Moisture content is an important factor as it decides the shelf life of the fruit and reflects the value of solid content, freshness, and nutritional factors (Vinha et al., 2013). The other nutrients like minerals are very important for maintaining a healthy life, which are shown in Table 3. *B. ramiflora* contains a good amount of moisture that will help the body by replenishing the liquids for body fluids with an adequate amount of protein to maintain the body well. The seeds, skin, and pulp of the fruit are reported to be a very good source of phytochemicals; however, the concentration of the phytochemicals varies depending upon the part of the fruit (Hossain & Hossain, 2023).

TABLE 3 Physiochemical characteristics of *B. ramiflora* seed oil (Dutta et al., 2013).

Parameters	Values
Color	Light brown
Oil content (wt.%)	25
Density (g/cm^3)	0.8674
Acid value (mg KOH/g)	1.127
Iodine value (g/100 g)	80.32
Refractive index	1.4672
Moisture (%)	0.103

11 | MINERAL CONTENT

Fruits are meant to be a natural source of vitamins and minerals. The mineral content of the *B. ramiflora* is very impressive. The mineral content like calcium, manganese, sodium, and copper is reported to be in a good amount and all these macro- and micronutrients are required by an organism for normal metabolism. If there is a lack or deficiency of these bioactive compounds in the body, it will lead to disorders and organisms become more prone to occurring disorders in health; consumption of these minerals with the bioactive compounds is reported to show promising health benefits (Chhikara & Panghal, 2021; Haque et al., 2010).

12 | IRON

Iron is the most important mineral as it is involved in many metabolic reactions in the body; for example, iron participates in a variety of functions in plants, microbes, and animals, including oxygen transport and its storage, electron transfer, substrate oxidation–reduction, hormone synthesis, DNA replication, repair and cell cycle control, nitrogen fixation, and protection from reactive oxygen species (ROS) in plants, animals, and microorganisms (Abbaspour et al., 2014; Dlouhy & Outten, 2013). According to the United States, the required amount of iron for 6–12 months of age is 6.9 mg, and for adults, it is 6 mg (Saini et al., 2016). The iron content found in *B. ramiflora* is 100 mg, which is more than six times the recommended values.

13 | POTASSIUM

B. ramiflora contains many essential macro- and micronutrients in ample amounts that are helpful and maintain a normal, healthy lifestyle. A major mineral found in potassium is present in a very high amount (730 mg). In clinical research, it is found that the mineral potassium is very helpful in controlling heart-related problems like cardiac arrest and lowering blood pressure. The recommended mean intake for phosphorus in the United States is 4700 mg for an adult (DeSalvo et al., 2016). Therefore, this fruit contains a good amount of phosphorus that will help adults to maintain good health.

14 | MAGNESIUM

Magnesium is an important mineral that works as a cofactor for many cellular enzymes for the conversion of a different product generally in energy metabolism, sensitivity in insulin, and supporting the normal vascular

tone. Clinical trials show evidence that a diet low in magnesium has a good impact on lowering cardiac ischemia (DeSalvo et al., 2016). In *B. ramiflora* fruit, magnesium was reported to be 504 mg, which is a very good amount if consumed to provide enough nutrition. Magnesium was found to be the inhibitor for the absorption of fat that will help to improve postprandial hyperlipidemia in healthy subjects (Kishimoto et al., 2010). Every mineral is specifically known for its health-beneficial properties; this fruit contains macro- and microminerals and iron and manganese in a very high amount, even more than that of the recommended dietary allowance (RDA).

15 | BIOACTIVE COMPOUNDS

Burmese grape is a fruit loaded with various types of phytochemicals, and the composition of these phytochemicals differs in different parts of the plant. However, a common aspect is that these compounds are known to provide proven health benefits (Raghavan, 2018). Studies reported that *B. ramiflora* is loaded with polyphenols and all other phytochemicals (flavonoid and phenolic acid), which are beneficial and reduce the effects of various diseases (Wright et al., 2008). Uddin et al. studied the phytochemical composition of the seed, pulp, and peel part of the Burmese grape fruit and reported that extract prepared in the methanol shows very good antioxidant properties and primary and secondary metabolites like carbohydrates, proteins, fats, alkaloids, flavonoids, glycosides phenols were present in the sample (Uddin et al., 2018). Bioactive compounds, especially phenolic acids, are the secondary metabolites exerted by plants that possess the power of antioxidant and show radical scavenging properties; thus, when consumed, they reduce the chances of a number of diseases like CVD (cardiovascular diseases), diverse type of cancers, and other pathologies (Chhikara & Panghal, 2021; Rodriguez-Mateos et al., 2014; Rohilla et al., 2023). Different solvents methanol, acetone, and water were used to determine the best solvents for the detection of phenolic components and different phenolic tests were to evaluate the phenolic profile of the pulp and peel of the fruit. Methanol was found to be the best solvent for the extraction, followed by acetone and then water; phenolic content was 32.78 ± 0.10, 16.86 ± 0.30, and 20.13 ± 0.20 GAE µg/mg extract for methanol, acetone, and water, respectively, and flavonoid was 71.61 (methanol), 42.33 (acetone), and 53.00 ± 1.0 (water) retinol equivalent (RE) µg/mg dry extract (Mann et al., 2016). *B. ramiflora* is characterized as a medium phenolic content fruit ranging from 100 to 500 mg/100 g of the fruit; bioactive components were detected in this fruit (Saikia et al., 2016). Crude methanol extract of the pulp of *B. ramiflora* fruit possesses superior antioxidant activity because of its high amount of phenols and flavonoid content; total antioxidant capacity is reported to be highest in pulp, followed by seed, and it is lowest in peel. The reported phenolic content in the peel, pulp, and seed are 47.23 ± 0.30, 124.36 ± 2.07, and 12.96 ± 0.76, respectively, which is quite high; however, the total flavonoid content found in the peel, pulp, and seed was found to be 20.72, 107.53, and 12.96, respectively (Uddin et al., 2018). Both phenolics and flavonoids are very important in maintaining a healthy lifestyle and are known for curing various health problems. Moreover, flavonoids are known for possessing antioxidant activities like antimutagenic, antibacterial, and antiviral properties. However, the presence of these bioactive compounds plays an important role in protecting the plant as well as the consumer from any compounds (Mahadevan et al., 2016; Uddin et al., 2018). The particular phenolic acids that were reported in the *B. ramiflora* fruit pulp with the help of reverse-phase high-performance liquid chromatography (RP-HPLC) extract from increasing to decreasing order are gallic acid of 3.62 mg/100 g, ascorbic acid of 0.28 mg/100 g, followed by catechin, coumaric acid, and caffeic acid of 1.24, 1.06, and 0.45 mg/100 g, while the other phenolic acids like syringic acid, ferulic acid, chlorogenic acid, rutin hydrate, kaempferol, and quercetin are not detected in the research reported (Saikia et al., 2016). *B. ramiflora* shows the change in the biochemical properties during the maturation of the fruit. The TSS (total soluble solids), total sugar, reducing sugar, and specific gravity are increased in the fruit when ripened to its last stage. Phenolic acid is a phytochemical released by plants; they are composed of many compounds together and released by plants as a secondary metabolite that takes part in the structural and metabolic reactions inside both the flora and fauna that are known to suppress the diseases from the outer surrounding environment, which is not favorable for the body (Simón-Grao et al., 2014). Phenols play the main role in contributing to antioxidant properties; antioxidants are those compounds whose presence, even in low concentration, can delay or inhibit the oxidation in the biological system; therefore, they are ultimately helpful in controlling dreadful degenerative health conditions and provide other health benefits as shown in Figure 1 (Shahidi & Ambigaipalan, 2015). Antioxidants are divided into two groups based on their mode of functions, namely, chain-breaking (primary), which scavenge the free radicals, and preventative (secondary), which are metal chelators and reductants that prevent the oxidation of certain product generally under in vivo conditions (Namiki, 1990).

16 | HEALTH BENEFITS

B. ramiflora is a citrus fruit known for its highly sweet acidic taste. The sweet acidic taste of this fruit is because of its high polyphenolic compounds, minerals, vitamins, and other bioactive compounds. Bioactive compounds from the *B. ramiflora*, especially rosmarinic acid, are able to reduce the level of arachidonic acid, which indicates how powerful the antioxidant activity of these fruits is (Usha et al., 2014). *B. ramiflora* is used for the treatment of various diseases in many parts of the world; in the literature, it is reported that extracts obtained from *B. ramiflora* seeds and pulp have cytotoxic, anti-inflammatory, antidiarrheal, and neuropharmacological properties in nature (Nesa et al., 2018a). Similarly, Goyal and his group (Goyal et al., 2022) reported that *B. ramiflora* and its parts are known for possessing a wide range of pharmacological activities like thrombolytic, neuropharmacological, cytotoxic, hemolytic, hypoglycemic, hypolipidemic, insecticidal, analgesic,

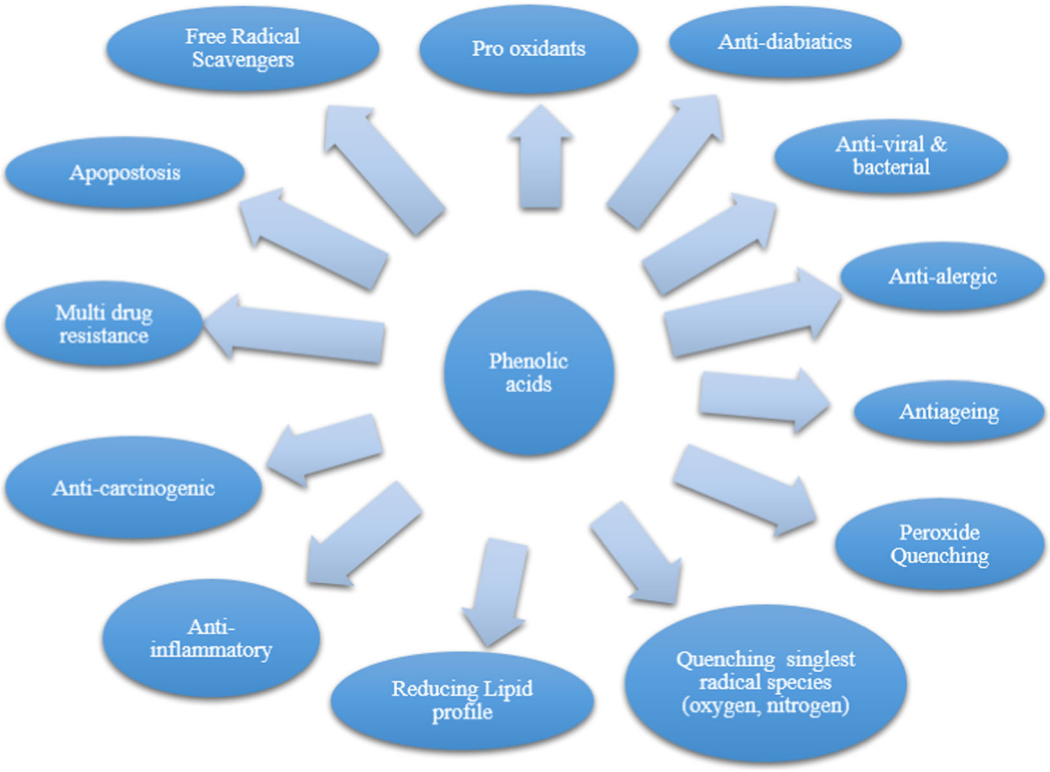


FIGURE 1 Phenolic acids' protective beneficial effects (de Beer et al., 2017; Garcia-Salas et al., 2010).

anthelmintic, antidiarrheal, and anti-inflammatory activities. As these bioactive compounds are capable of maintaining the healthy lifestyle of the consumer and provide extra function beyond the nutrients, this food comes under the category of functional food, and numerous products have been developed and reported so far (Sultana et al., 2022). The health benefits possessed by this fruit, which are reported so far, are listed below.

17 | HYPOGLYCEMIC AND HYPOLIPIDEMIC ACTIVITY

Methanolic extracts of *B. ramiflora* leaves were prepared to check the hypoglycemic and hypolipidemic activity against the rats (Obayed Ullah et al., 2012). Results reported that the blood glucose level of the rats is found to be decreased when a specific dose of the extract was given to rats; a decrease in the cholesterol level, triglycerides, and low-density lipoproteins have shown a significant difference against the control, and high-density lipoprotein is found to be increased in the rats. The lower lipid levels are associated with the effect of extract of *B. ramiflora* because of its radical scavenging activity, as the scavenging activity may be related to flavonoids, steroids, terpenes, or other bioactive compounds that are present in the body (Obayed Ullah et al., 2012). Similar results of a decrease in the hypolipidemic and hypoglycemic were also reported from the sample taken from Dhaka, Bangladesh (Nesa et al., 2018b). The increase in the HDL level in the lipid profile can be directly related to the good health of the heart by reducing the diseases like atherosclerotic and coronary risk (de Beer et al., 2017; Dreher & Davenport, 2013; Garcia-Salas et al., 2010).

18 | ANTIFUNGAL ACTIVITY

Antifungal activity from the berried of *B. ramiflora* was reported against *C. gloeosporioides* and the activity is good enough to control the spread. Nor-picrotoxin glycoside (amiloride) was the first new compound that was reported from the plant origin found in the berries of *B. ramiflora*, and the other two picrotoxin sesquiterpenes reported are sapidolide A and picrotoximaesin; all of them were reported to be anti-fungal in nature. Three picrotoxin sesquiterpenes were isolated from the berries and all the compounds show antifungal activity with the minimum inhibitory concentration of 12.5, 12.5, and 50 mg/ml (Pan et al., 2015). Pulp of this fruit contains vitamin C in good amounts (178 mg/100 g) and vitamin C is known for its anti-browning action as well as antifungal activity (Haque et al., 1970). Vitamin C is reported to be 273 mg/100 g of pulp from the *B. ramiflora* from Sikkim, India region (Raghavan, 2018).

19 | ANTI-INFLAMMATORY PROPERTY AND ANALGESIC PROPERTY

Studies have been done on the anti-inflammatory properties of the *B. ramiflora* fruit and parts of the plant. Inflammation refers to natural damage in the immune system by external stimuli because of pathogens, allergens, infections, irritants, and ultraviolet irradiation and chronic inflammation related to various forms of cancer (Du et al., 2018; Joseph et al., 2016; Phull & Kim, 2017). The extracts were prepared from the seeds and pulp portion of the fruit, and these extracts were given to mice; as a result, it is reported that the extract is able

to reduce neurogenic and inflammatory pains. The presence of analgesic compounds in the extract removes chronic and acute pain, and extract of *B. ramiflora* shows the inhibitory effect to reduce pain that works peripherally or centrally (Nesa et al., 2018a). *B. ramiflora* extract has enough potential to inhibit neurogenic pain at both the first and second phases induced by formalin, which ultimately possesses significant prostanoid mediators of inflammation (Hunskaar & Hole, 1987). Bioactive compounds like flavonoids, steroids, and triterpenes are known to possess anti-inflammatory properties (Panghal et al., 2021), and pulp and seeds of *B. ramiflora* have been reported to show peripheral mechanisms in the analgesic actions (Nesa et al., 2018b).

20 | ANTIDIARRHEAL ACTIVITIES

The methanol extracts are prepared from the pulp and seeds of *B. ramiflora* fruit. Studies reported that the extract of pulp and seeds can reduce chances of diarrhea for the test animal to the inhibitions of 59.7% and 63.03%, respectively, of the extracts. The number of feces of the test animals decreases within the 4 h of time frame. The dose of 100 mg/kg showed moderate inhibitory activity against defecations, but 200 mg/kg of the dose can inhibit the activity similar to the drug loperamide. Therefore, it is reported that these fruit extracts will be consumed for the treatment of diarrhea (Nesa et al., 2018a). With all of the potential health benefits, the Burmese grape and its plant parts are very important and possess compounds that are known to possess antidiarrheal properties.

21 | APPLICATIONS

Various products are obtained from the Burmese grape such as wine that shows good amount of phenols, pigments, flavonoids, flavonols, and good antioxidant properties, and these products, especially wine, are consumed in Malaysia and India. The fruit juice and wine made from the Burmese grape contain proanthocyanidins that are known for improving the urinary tract and reducing the chances of cardiovascular diseases. Wine is a popular fermented drink that is generally made with the help of fruits (SinghPhurailatpam et al., 2017). The juice is extracted from the fruit and subject to fermentation with the help of the microorganisms, and the development of alcohol in a controlled manner by converting the sugars will lead to development in the flavor, taste, and aroma. It can be easily done in the home itself and consumption is too high generally in the cold areas. Seeds of the Burmese grape are used to extract the annatto dye, which is used in food products as the coloring agent and in various textile materials like silk and cotton (Gogoi, 2017). Different bioactive compounds that are reported in the different segments of plants are given in Table 4. A group of researchers studied the development of biochar using Burmese grape seeds and reported that biochar developed using seeds has excellent capacity to treat wastewater and is recommended for sustainable wastewater treatments (Roy et al., 2023). Sultana et al. (2022) studied the valorization of the peel and reported that phytochemicals extracted from the peel possess high concentrations of phytochemicals and developed the yogurt by incorporating the extracted bioactive compounds to develop the functional food. Reported bioactive compounds in parts should be utilized in food or for the pharmaceutical industry for the treatment of health disorders by traditional industry.

TABLE 4 Bioactive compounds reported in different parts of the plant.

Name of the plant part	Bioactive components
Steam	4′-O-(6-O-vanilloyl)-β-D-glucopyranosyl tachioside D
	6′-O-vanilloylpicra-quassioside D
	6′-O-vanilloylicariside B5 (Yang et al., 2010)
Fruit peels	2,3,4-tri-O-Me xylose
	2,3-di-O-Me xylose
	2-O-Me xylose (alkaline extraction of pretreated fruit peels) (Dey & Pal, 2015)
Wine and fruit juice	Total phenols
	Flavonoids, flavones, proanthocyanidins, antioxidants (Goyal et al., 2013)
Seed	Tetrahydrofurano-lactone meroisoprenoid (sapidolide A) in the medium polar fraction of the crude extract of seed kernels (Bordoloi et al., 2010)

22 | CONCLUSION

The market demand for products derived from *B. ramiflora* is poised for significant growth, primarily driven by evolving consumer preferences and emerging market trends in the food and pharmaceutical industries. Consumer interest in natural and health-promoting products has been on the rise, with a growing emphasis on incorporating functional and nutraceutical ingredients into their diets. Burmese grape, with its wealth of bioactive compounds, perfectly aligns with this trend. The fruit's nutritional composition is noteworthy, featuring substantial amounts of iron, magnesium, potassium, and various vitamins. This unique nutritional profile makes the Burmese grape stand out as a valuable source of essential nutrients, appealing to health-conscious consumers. Moreover, the presence of pectin in the fruit opens up possibilities for its utilization in the production of a wide range of food products, such as jams, jellies, and confectionery items. This versatility further enhances its commercial appeal. The seed oil extracted from *B. ramiflora* seeds finds applications not only in the food industry but also in the cosmetic sector. Its high oil yield underscores the economic viability of this underutilized fruit. As a result, there is a compelling case for raising awareness about the fruit's nutritional value and functional properties and encouraging its commercialization. Furthermore, the juice derived from Burmese grape contains proanthocyanidins, known for

their cardiovascular benefits, which could capture the attention of health-conscious consumers looking for heart-healthy options. The presence of phytochemicals in the fruit contributes to its potential to reduce various health-related problems. The extensive presence of bioactive compounds in *B. ramiflora* makes it an enticing prospect for future use. Its nutritional richness, functional properties, and versatility in different industries, notably the food and pharmaceutical sectors, underscore its commercial potential. The unique combination of essential nutrients, bioactive compounds, and their demonstrated health benefits positions the Burmese grape as a valuable candidate for commercialization, with the potential to address the evolving demands of the modern market.

AUTHOR CONTRIBUTIONS

Shubham Rohilla: Conceptualization; data curation; investigation; methodology; resources; software; validation; visualization; writing—review & editing.

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CONFLICT OF INTEREST STATEMENT

The author declares no conflict of interest.

ETHICS STATEMENT

None declared.

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