

# From Neglect to Nutrient - Rich: A Comprehensive Review of Underutilized Fruits of India and their Antioxidant Profile

Pattan Farooqkhan<sup>1\*</sup>, Susmitha J<sup>1</sup>

<sup>1\*</sup>Ph. D. Scholar, Department of Genetics and Plant Breeding, Annamalai University, Chidambaram - 608002.  
Corresponding Author: [farooqkhan.gene\[at\]gmail.com](mailto:farooqkhan.gene[at]gmail.com)

<sup>1</sup>Ph. D. Scholar, Department of Genetics and Plant Breeding, Annamalai University, Chidambaram - 608002.

**Abstract:** Indian native fruits are distinct to a certain region and hold significant potential in bolstering food security and nutritional well-being. Underutilized fruits, by definition, represent those varieties with inherent value yet limited cultivation, scarcity in the market, and minimal commercial development. These underutilized foods have medicinal potential and are high in antioxidants, which when used properly can help prevent and control a wide range of degenerative disorders. Harnessing the latent potential of underutilized fruits could be a productive strategy to combat malnutrition. To address this issue comprehensively, a substantial array of underutilized fruits can be harnessed to bridge the prevailing nutritional deficit. Exploring the medicinal and nutritional attributes of underutilized fruits, including Ker (*Capparis decidua*), Karonda (*Carissa carandas*), Wood apple (*Limonia acidissima* L.), Indian cherry (*Cordia dichotoma*), Ber (*Zyziphus mauritiana*), Jamun (*Syzygium cumini*), Khirni (*Manikara hexandra*), among others, underscores the untapped potential residing within India's botanical diversity. These fruits exhibit promising prospects for enhancing dietary diversity, combating nutrient deficiencies, and promoting overall health, thereby warranting focused attention in the context of food security and nutritional intervention.

**Keywords:** Underutilized fruits, antioxidants, medicinal and nutritional profile

## 1. Introduction

India is a country with a tremendous biodiversity of Flora and Fauna. Indian native crops are specific to a particular area and have greater potential to support food security and provide required nutrition. The total population of India is 1.38 billion (17.5% share of world's total population) and there will be a steady growth in our population (Meena *et al.*, 2022). The concern of providing nutritional and quality food to the growing population is very important to address. Among the native crops grown in India, many fruit crops are not completely used to its potential to achieve food security and eradicate malnutrition. For a healthy diet, the recommended daily intake of fruits ranges from 1 - 1.5 cups for children and 1.5 - 2.5 cups for adults (Wallace *et al.*, 2020). However, many people in India fail to consume these quantities of fruits due to economic and other reasons. Underutilized fruits possess significant value when harnessed for local consumption to address nutritional requirements.

Due to their abundance of vitamins, phytochemicals, and minerals, fruits provide undeniable protective benefits. They are an exceptional source of soluble dietary fiber, which reduces cholesterol and adipose tissue levels and promotes gastrointestinal motility. Consistent consumption of nutrient-dense foods is crucial for preventing the onset of numerous diseases. Numerous fruits contain antioxidant properties, which are instrumental in mitigating the presence of free radicals in the body and preventing numerous diseases. Several underutilized fruits exhibit potent antioxidant and medicinal properties. The term "underutilized fruit" has been described in various ways that are not ignored by research and development organizations.

## 1.1 Primary Reasons for Under - Utilization of Certain Fruits

Domestic underutilized fruit crops were grown under an area of 6.56% whereas some fruits like mango, banana, apple, guava and citrus were extensively grown occupying 72% of total area that grows fruits (Meena *et al.*, 2022). The major reason behind the underutilization of our native fruits is the lack of indigenous knowledge caused by the communication gap between generations. Many people do not completely understand the value of indigenous knowledge. This led to less awareness about potential fruits in our country. In a growing world of urbanization, various ecosystems were destroyed leading to habitat loss, diversity loss, and genetic loss of the underutilized fruits. Some fruits have an acidic nature and astringent taste leading to their unacceptability of in marketplaces (Nandal *et al.*, 2014). Consuming a repetitive diet, such as one dominated by rice and a limited variety of fruits and vegetables, can result in a monotonous lifestyle that overlooks the nutritional benefits of traditionally enjoyed fruits in the local area.

## 2. Potential role of underutilized fruits in food security and better nutrition

Many different species of underutilized fruits are grown all over India. Those species are highly adaptable ones which can stand adverse tensions by biotic and abiotic factors. The farming community started to experience the effects of climate change in agricultural production. In addition to this, Malnutrition also poses a severe threat to food security and providing necessary nutrition in everyday basis. India ranks 107 out of 121 countries in the Global Hunger Index Rankings. The underutilized fruits could be the best solution

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to draw a solution for malnutrition. Our native grown, highly adaptable fruits also contain various biomedical properties and nutraceutical composition. Different nutrient composition of some underutilized fruits was discussed in table 2. The underutilized fruits available in each season locally can be consumed along with vegetables to meet out the daily nutrient requirements of humans. Replacement of repetitious diet with diversified diet including underutilized regionally available fruits will assure the food security of our nation. The food shortage among the rural population could be completely eradicated by creating consistent efforts in research and development of underutilized fruits. Some of the important underutilized fruits and their characteristics are listed below.

### 2.1 Ker (*Capparis decidua*)

*Capparis decidua*, a plant belonging to the Capparaceae family, is a significant and underexplored botanical resource within the arid regions of India. Its native range spans the Indian subcontinent, the Middle East, and Africa. This plant is valued for its diverse applications, including its use in pickling and dehydration processes. Ker boasts a rich nutritional profile characterized by high protein, phosphorus, potassium, calcium, and magnesium content. Beyond its nutritional attributes, *C. decidua* exhibits various medicinal properties, such as laxative, astringent, and vermifuge effects (Mall, 2017). Ker fruit has a wide array of bioactive compounds, including glycosides, terpenoids, alkaloids, and fatty acids. These compounds contribute to its bioactivity, endowing it with anti - allergenic, anti - arteriosclerotic, and antioxidant properties. The root bark of *C. decidua* has been identified as a source of spermidine alkaloids, notably capparidisine, capparisinine, and isocodonocarpine (Attar *et al.*, 2021). This fruit has cancer - preventive properties of isothiocyanates. Further chemical characterization of *C. decidua* has revealed the presence of salicylic acid, vanillic acid, hydroxybenzoic acid, sinapic acid, protocatechuic acid, syringic acid, gentisic acid, and 2 - hydroxy - 6 - methoxybenzoic acid in its leaves. The aqueous, n - hexane, and acetic extracts of *C. decidua* leaves have been found to contain phenolic substances, flavonols, and flavonoids (Nazar *et al.*, 2020).

### 2.2 Karonda (*Carissa carandas*)

*Carissa carandas*, a robust evergreen shrub native to rainfed regions, belongs to the Apocynaceae family. Its fruit, characterized by a sour and astringent taste, is notably rich in iron and vitamin C. Ripe carissa fruits find culinary use in desserts, jellies, sauces, creams, and salads, with carissa wine being a popular choice among enthusiasts (Kour *et al.*, 2018). Caronda fruit exhibits antiscorbutic properties, aids in addressing anemia and stomach ailments, and serves as an anthelmintic. Pewlong *et al.* (2014) reported the highest DPPH scavenging activity in Carrisa carandas leaf extract, followed by fully - ripe fruit extract and unripe fruit extract. Ripe caronda fruits, owing to their high pectin content, are utilized in the production of various products like jelly, jam, squash, syrup, tarts, and chutney, which have a global market demand (Wani *et al.*, 2013). Carissa leaves are used in treating fever, diarrhea, and earaches, while its roots serve as stomachics, vermifuges, itch alleviators, and insect

repellants (Singh and Uppal, 2015). Traditionally, they were to address various health issues, including malaria, epilepsy, nerve disorders, pain relief, headache management, fever, and as blood purifiers. The fruits contain beneficial compounds such as carisol, caryophyllene, carissone, carissic acid, carindone, carinol, lupeol, and sitosterol, which play crucial roles in treating conditions like scabies, intestinal worms, pruritus, biliousness, and exhibit antiscorbutic and anthelmintic properties (Virmani *et al.*, 2017).

### 2.3 Wood apple (*Limonia acidissima L.*)

Wood apple belonging to the Rutaceae family, is a tropical fruit indigenous to India and Sri Lanka (Rodrigues *et al.*, 2018). The fruit pulp is brown, mealy, and possesses various sensory attributes such as odor, astringency, acidity, and occasional sweetness. The seeds are notable for their high content of unsaturated fatty acids and non - bitter oil (Thakur *et al.*, 2020). In traditional Indian medicine, it is widely used as a liver and cardiac tonic. When unripe, it serves as a remedy for conditions like diarrhea, dysentery, hiccough, sore throat, and gum disease (Kerker *et al.*, 2020). The fruit pulp contains bioactive compounds with anti - inflammatory, antipyretic, antioxidant, anticancer, anti - diabetic, antibacterial, and hepatoprotective properties. The seeds of the wood apple are rich in phytochemical components such as psoralen, bergapten, orientin, vitexin, and saponarin, which find application in treating a range of ailments including acidity, ulcers, urinary difficulties, hemorrhoids, diarrhea, ringworm, and chronic skin infections (Thakur *et al.*, 2020). It has phenolic compounds, nitrogen compounds, and vitamins in the methanolic extract of bark, imparting its antioxidant, antibacterial, anti - inflammatory, color pigment, diuretic, and anti - asthmatic properties. Ripe pulp is said to be rubbed to relieve discomfort from poisonous strings. wood apple is a versatile fruit with a rich array of pharmacological and therapeutic properties, making it a valuable resource in traditional medicine and potentially for value addition in the beverage industry (Thakur *et al.*, 2020).

### 2.4 Indian Cherry (*Cordia dichotoma*)

*Cordia dichotoma*, commonly known as Lasoda or Indian cherry and belonging to the Boraginaceae family, is a widely cultivated fruit - bearing tree in India. Its immature fruits are versatile, finding use as vegetables, in pickling, and as a dried product for off - season consumption. The nutritional analysis of Lasoda pulp reveals significant levels of crude protein, fiber, carbohydrates, and minerals. Specifically, it contains ash (6.7 g), crude protein (8.32 g), fat (2.2 g), crude fiber (25.7 g), carbohydrates (57.08 g), and provides an energy value of 281.4 Kcal per 100 grams of dry weight. Moreover, Lasoda is a notable source of ascorbic acid, with a content of 40 mg per 100 grams of dry weight (Yadav *et al.*, 2018). Beyond its nutritional value, Lasoda exhibits various medicinal properties. It is recognized for its anthelmintic, diuretic, demulcent, and expectorant qualities, making it useful in the treatment of chest and urinary tract diseases. Lasoda's kernels are used externally to address ringworm infections. The bark of the tree is decocted and used to treat dyspepsia and fevers. The mucilaginous pulp of the Lasoda fruit also has industrial

applications, being used to produce glue (Krishna *et al.*, 2019). Lasoda and its various plant components have been employed in traditional medicine to address a range of ailments, including skin disorders, dropsy, diarrhea, dyspepsia, cholera, and headaches (Meghwal *et al.*, 2020).

## 2.5 Ber

*Zyziphus mauritiana*, commonly known as Ber, is an indigenous fruit of India belonging to the Rhamnaceae family. It is called as "poor man's fruit" and is renowned for its exceptional nutrient density. Beyond its appeal as fresh fruit, Ber finds versatile culinary applications in chutney, dried forms, murabba, jam, and even wine production. Table 1 presents an array of compelling health benefits associated with the consumption of Ber. The decoctions derived from the root and bark exhibit efficacy in treating dysentery and diarrhea, while a leaf decoction serves as a gargle for alleviating sore throats and bleeding gums (Kour *et al.*, 2018). The fruit is particularly rich in vitamin C, containing approximately 85 - 95 mg per 100 g, with higher concentrations identified in the apple-like flesh surrounding the seed compared to the fruit skin. Table 2 provides a comprehensive breakdown of the nutrient composition of Ber fruit. It boasts a range of pharmacological and therapeutic attributes. Phenolic compounds and secondary metabolites are present in Ber fruits, including flavonoids, glycosides, saponins, lignins, sterols, and phenols, which exhibit antimicrobial properties. Various plant components, such as roots, bark, leaves, blossoms, and seeds, have been employed for medicinal purposes, serving as both blood purifiers and appetizers (Rathore *et al.*, 2012). Ber fruit has also been investigated for its potential antioxidant, anti-inflammatory, and anti-cancer properties, making it a subject of interest in the realm of natural medicine and dietary supplementation.

## 2.6 Jamun

*Syzygium cumini*, commonly referred to as Jamun, is a fruit crop indigenous to India, and it belongs to the Myrtaceae family. Jamun fruits lend themselves to diverse culinary applications, including the creation of beverages, squash, jam, jelly, and even wine. Notably, every part of the Jamun tree holds medicinal value, with a particular focus on the seeds for their efficacy in managing various ailments like diabetes mellitus. Gallic and ellagic acids found in Jamun seeds play a pivotal role in starch-to-sugar conversion, resulting in the reduction of blood glucose levels (Kumar *et al.*, 2023). Jamun has therapeutic potential in treating inflammation, ulcers, and diarrhea. The fruit pulp of Jamun stands out due to its high anthocyanin content, which imparts the characteristic color to the fruit. This natural pigment holds promise as a source of food colorants for the food processing industry (Chaudhary and Mukhopadhyay 2012). Beyond its coloring properties, anthocyanin is renowned for its robust antioxidant capacity and its potential to mitigate the risk of various ailments (Singh *et al.*, 2013). Jamun has also found application in blood purification, diabetes management, diarrhea alleviation, eczema treatment, and even strychnine poisoning (Meghwal *et al.*, 2020). It acts as a stomachic, carminative, diuretic, and blood pressure regulator. Jamun seed powder has been

associated with a reduction in urinary sugar concentration. When ripe, Jamun fruits are characterized by their high juiciness, minimal odor, and somewhat astringent flavor. The fruit pulp is generally used in the production of jams, jellies, juices, vinegars, and puddings.

## 2.7 Khirni

Khirni or Rayan, scientifically known as *Manikara hexandra* Roxb. Dubard, is a relatively lesser-known fruit tree belonging to the Sapotaceae family. This tree is valued for its nutritional richness and therapeutic potential. As shown in Table 2, Khirni fruits are abundant in carbohydrates, minerals, proteins, and vitamin A, alongside other essential nutrients. Traditionally, various parts of the Khirni tree, including the fruit, bark, stem bark, root, leaves, and latex, have been harnessed for their nutritional and medicinal attributes, particularly by India's elderly and tribal communities (Parikh *et al.*, 2017). The health benefits of Khirni fruit are elaborated in Table 1. The trunk bark and fruits of the Khirni tree have found application in the treatment of various human ailments such as ulcers, dyspepsia, bronchitis, and leprosy (Meghwal *et al.*, 2022). The bark, in particular, is used in treating fever, jaundice, helminthiasis, and flatulence (Gopalakrishnan *et al.*, 2014). Khirni exhibits bioactive properties including anticancer, antioxidant, and antibacterial attributes, owing to its diverse polyphenolic chemical composition. Khirni, often underappreciated, represents a valuable resource of nutritional richness and therapeutic versatility.

## 2.8 Elephant Apple fruit

Elephant apple (*Dillenia indica*) is an underutilized horticulture crop grown primarily in north-eastern India. The plant parts leaf, bark, and fruit have been employed in traditional medicine because they have therapeutic properties (Nayak *et al.*, 2016). Fruit sepals have a sour taste and are commonly used as a flavouring component in curries as well as in the manufacture of jam and jelly. The fruits are nutrient-dense and could be processed into commercial items such as ready-to-drink beverages, squash, jam, and jelly (Nayak *et al.*, 2016). The fruit is traditionally used in Ayurvedic medicine to relieve uneasiness, stomach pain, and weariness. According to literature evaluations, the plant contains antibacterial, antioxidant, analgesic, anti-inflammatory, and antidiabetic properties. The fleshy sepals of the fruit are high in vitamin C, tannins, malic acid, arabinogalactan, and glucose. They also have botulin, botulinic acid, and flavonoids in them (Talukdar *et al.*, 2012).

## 2.9 Conkerberry/Bush Plum:

Underutilized fruits, while rich in vitamins, minerals, and energy, often exhibit a limited shelf life compared to more commonly consumed fruits. Among these lesser-known fruits is *Carissa spinarum* L., colloquially known as 'Wild Karanda', 'Conker berry', or 'Bush plum', belongs to the Apocynaceae family (Bussman *et al.*, 2021). Ethnobotanically, the *Carissa spinarum* plant has been employed for medicinal purposes to address a diverse range of ailments. Its fruits are esteemed for their nutritional value



and mineral content, particularly rich in phosphorus and iron. Ripe fruits are extensively used in the preparation of jams, jellies, and pickles (Fatima *et al.*, 2013). The nutritional composition of the fruits is as follows: moisture content at  $81.05 \pm 1.97$  percent, protein content at  $2.07 \pm 2.04$  percent, fat content at  $1.30 \pm 0.01$  percent, carbohydrates at  $18.66 \pm 0.25$  percent, calcium at  $29.57$  mg/100 g, phosphorus at  $32.1 \pm 0.05$  mg/100 g, iron at  $3.45 \pm 0.00$  mg/100 g, total phenolics at  $5.31 \pm 0.21$  mg TAE/g, and total flavonoids at  $0.44 \pm 0.00$  mg QE/100 g (Chauhan *et al.*, 2015). Table 1 enumerates a myriad of health benefits associated to the consumption of bush plum, shedding light on its potential as a valuable dietary and medicinal resource.

### 2.10 Velvet Apple

*Diospyros blancoi*, often known as 'velvet apple,' is native to the Philippines and is found in tropical and warmer temperate locations around the world (Yadav *et al.*, 2018). The fruit's surface is covered in a powdery velvety texture. Immature fruits are astringent, whereas ripe fruits are sweet-smelling, tasty, and commonly used as dessert fruit. The tree was introduced to Java and Malaya. In Malaya, it is known as butter fruit, scarlet fruit. Hung *et al.* (2016) discovered moisture in Mabolo fruit by nutrient analysis: 84.4 g/100 g; ash: 0.8 g; calories: 62 kilocalories/100 g; Carbohydrate (g/100 g): 13.8; Dietary fiber (g/100 g): 3.2; Crude protein (g/100 g): 0.4; Calories from fat (kcal/100 g): 5.4; Crude fat (g/100 g): 0.6; Vitamin C (mg/100 g): 2.2; Vitamin E (mg/100 g): 0.59; Vitamin B3 (mg/100 g). Green fruits offer medical potential because immature fruit juice is used to treat ulcers and diarrhea. The fruit is an excellent source of calcium, vitamin B, iron, and protein, as well as various phenolic chemicals, terpenoids, and flavonoids that contribute to its antioxidant and anti-diabetic properties. Wounds, diarrhoea, dysentery, aphthous stomatitis, snakebites, heart issues, hypertension, spider bites, stomach aches, diabetes, and dermatitis are all traditional applications (Haque *et al.*, 2020). Analgesic, anti-inflammatory, antioxidant, anti-diarrheal, and antibacterial effects were discovered in pharmacological research (Howlader *et al.*, 2012).

### 3. Conclusion

Apart from nutritional benefits, the fruit crops reviewed have a variety of medicinal characteristics. Increasing awareness of the benefits of underutilized fruits would provide a long-term and sustainable approach to the treatment of nutrition-related diseases and disorders. These crops have significant potential for use in a wide range of appealing value-added products for the food and nutraceutical industries. As a result, systematic production of these items and effective use of marketing methods will contribute to people's health improvement.

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**Table 1:** Health benefits of various underutilized fruits

Common Name	Scientific Name	Family	Health Benefits	References
Ker	<i>Capparis decidua</i>	Capparaceae	Sharp hot astringent to bowel movement, it destroys foul breath, biliousness and urinary purulent discharges, anti - cancer properties.	Singh <i>et al.</i> , 2011
Karonda	<i>Carissa carandas</i>	Apocynaceae	Anti - scorbutic, useful in curing anaemia, stomach ache and is anthelmintic.	Kour <i>et al.</i> , 2018
Wood apple	<i>Limonia acidissima</i>	Rutaceae	Cardiac and liver tonic, curing diarrhea, effective treatment for cough, sore throat, and pulp has antidiabetic, antioxidant and anticancer properties.	Thakur <i>et al.</i> , 2020
Indian Cherry	<i>Cordia dichotoma</i>	Boraginaceae	Antidiabetic activity, Anthelmintic activity, Gastroprotective and antiulcer effect.	Jamkhande <i>et al.</i> , 2013
Ber	<i>Ziziphus mauritiana</i>	Rhamnaceae	The decoction from root and bark is good for dysentery and diarrhoea and leaf decoction is useful as gargle in sore throat and in bleeding gums.	Kour <i>et al.</i> , 2018
Jamun/Java Plum	<i>Syzygium cumini</i>	Myrtaceae	Fruit has antidiabetic, hypolipidemic, anti - clastogenic, anti - pyretic, anti - inflammatory, anticancer, antiarthritic and antiscorbutic properties.	Chhikara <i>et al.</i> , 2018
Khirmi/Rayan	<i>Manikara hexandra</i>	Sapotaceae	Daily consumption of fruits cures diseases such as cardiovascular, cataract, diabetes, and neurodegenerative diseases like Alzheimer's and Parkinson's	Parikh <i>et al.</i> , 2017
Elephant Apple	<i>Dillenia indica</i>	Dilleniaceae	Fruit is used to treat nervousness, abdominal stress, fatigue and it has antimicrobial, antidiabetic and anti - inflammatory properties	Nayak <i>et al.</i> , 2016
Conkerberry/ Bush plum	<i>Carissa spinarum</i>	Apocynaceae	It is used to treat arthritis, leprosy, viral infection and has anticancer properties.	Bussman <i>et al.</i> , 2021
Velvet Apple	<i>Diospyros blancoi</i>	Ebenaceae	Traditionally used to treat diarrhea, dysentery, aphthous stomatitis, snakebites, heart problems, hypertension, spider bites, stomach aches, diabetes, and eczema	Akter <i>et al.</i> , 2015

**Table 2:** Nutrition composition of various underutilized fruits

Common Name	Protein content (g/100g)	Fat content (g/100g)	Calcium (mg/100g)	Iron (mg/100g)	Ascorbic Acid (mg/100g)	Potassium (mg/100g)	References
Ker	14.32±0.2	6.19±0.5	14.1	8.18	7.8	2969.6	Alrasheid <i>et al.</i> , 2018
Karonda	2.14	10	1.60/2.92	3.9	62.93	-	Dhatwalia <i>et al.</i> , 2021
Wood apple	7.14±0.24	1.45±0.09	130	0.48	2	0.07±0.002	Thakur <i>et al.</i> , 2020
Indian Cherry	8.32	2.05±0.01	55	6	40	-	Meghwal <i>et al.</i> , 2015
Ber	0.8	0.07	25.6	0.76 - 1.8	65.8 - 76.0	-	Singh <i>et al.</i> , 2019
Jamun/Java Plum	0.70 - 0.13	0.15 - 0.30	8.3 - 19	0.19 - 1.62	5.70 - 18.00	55 - 79	Chhikara <i>et al.</i> , 2018
Khirmi/Rayan	0.48	2.42	83	0.92	-	15.62	Krishna <i>et al.</i> , 2019
Conkerberry/ Bush plum	1.24	5.33	83.54	3.45	17.74	816.69	Siyum and Meresa, 2021
Velvet Apple	0.74	0.01	-	2.74	18.6	18.9	Haque <i>et al.</i> , 2009
Monkey Jack Fruit	-	-	-	15.09	171.07	785	Yadav <i>et al.</i> , 2018

**Table 3:** Antioxidant activity of different underutilized fruits

Common Name	DPPH Radical Scavenging Activity	FRAP	Total Phenolics (mg/100g)	Total Flavonoids (mg/100g)	References
Ker	29.0	-	106	196.41	Krishna <i>et al.</i> , 2019
Karonda	1634.0	157.8 ± 7.5	3.3 ± 0.4	9.8 ± 2.6	Loganayaki <i>et al.</i> , 2010
Wood apple	78.99 ± 0.03	47.55 ± 0.40	38.61 ± 0.08	-	Sonawane <i>et al.</i> , 2013
Indian Cherry	45.67	-	137.56	434.28	Krishna <i>et al.</i> , 2019
Ber	78.57 ± 0.16	3.51 ± 0.05	94.70 ± 0.27	7.48 ± 0.01	Kavitha <i>et al.</i> , 2015
Jamun/Java Plum	532.1 ± 20.1	253.6 ± 16.9	6.0 ± 0.1	11.9 ± 1.0	Loganayaki <i>et al.</i> , 2010
Khirmi/Rayan	189.68 ± 8.26	803.13 ± 88.76	190.19 ± 6.69	117.78 ± 0.97	Parikh <i>et al.</i> , 2017
Elephant Apple	45.7 ± 1.7	30.9 ± 1.3	31.7 ± 2.30	3.90	Dutta <i>et al.</i> , 2018
Conkerberry/ Bush plum	51.3 ± 3.1	-	162.2	52.1 ± 1.6	Mundaragi <i>et al.</i> , 2017
Velvet Apple	93.05 ± 0.003	2.23 ± 0.032	504 ± 23	320 ± 11	Khan <i>et al.</i> , 2016

\*DPPH - 2, 2 - diphenyl - 1 - picrylhydrazyl; FRAP - Fluorescence Recovery After Photobleaching