

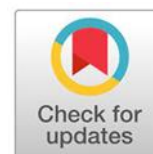
Underutilized Fruits of Northeast India and its Potential Benefits on Human Health - Review

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Abstract

The Indian Himalayas, a global biodiversity hotspot, is home to 2532 species from temperate regions of Europe, China, Burma, the Sahara, and Africa. India's plant biodiversity includes 21 agroecosystems, including farmed fruit and wild, underutilized fruit crops. These underutilized fruit crops have potential but are rarely planted, infrequently available on the market, or not farmed commercially. They are disease-resistant and adapted to heat and cold extremes, blessing tropical nations like India. Underutilized fruit crops have medicinal properties and are often used by Native Americans to heal ailments and for the financial well-being of tribal people in rural regions. The use of wild fruits as nutritional supplements or less expensive alternatives to commercial fruits is growing worldwide. Identifying and utilizing underutilized species is crucial for a diverse and nutritious diet, especially for rural poor and socially vulnerable populations in emerging countries. India's North-Eastern Hill region is an agrobiodiversity hub characterized by diverse ethnic and cultural backgrounds. It is rich in wild agricultural plant relatives, particularly underutilized fruit crops, and mixed temperate, tropical, and subtropical fruits from various genera. Fruits, vegetables, and other plants naturally produce important polyphenol metabolites that influence their sensory and nutritive qualities, potentially curing various conditions.



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Introduction

The Indian Himalayas, a global biodiversity hotspot, is divided into four main areas: the eastern and north-eastern Himalayas, the eastern flank, and the northwest Himalayas. The Himalayas have the rarest crop biodiversity and the highest agroecosystem on Earth. India's plant biodiversity includes 2532 species from temperate regions of Europe, China, Burma, the Sahara, and Africa. 6.5% of the 2252 genera found in India are indigenous. The Himalayas are home to five identified 21 agroecosystems, including farmed fruit and wild, under-utilized fruit crops. (Lata et al., 2023). Underutilized fruit crops have potential but are rarely planted, are infrequently available on the market, or are not farmed for commercial purposes (Agent, 1994). Scarcer, less often consumed, or region-specific fruits can also be underutilized (William and Haq, 2002). The popularity of these fruit crops varies from crop to

crop and region to region; publicity can, however, boost them more. Native Americans generally use underutilized fruits to heal a range of ailments. Still, they are also essential to the financial well-being of tribal people in rural regions since they may be used to manufacture furniture, firewood, fodder, dyes, oils, and other high-value commodities. The underutilized fruits are naturally disease-resistant and adapted to heat and cold extremes, barely equatorial temperature ranges. A range of underutilized fruits that are naturally cultivated is a blessing for tropical nations like India (Dutta et al., 2018).

It is common knowledge that fruits from tropical and subtropical climates have medicinal properties. In addition to the more popular fruits, other less popular fruits are included in traditional meals, especially in rural regions. As sources of antioxidants, they have yet to receive as much attention as commercial fruits since they are less

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famous, untested, and unknown (Loganayaki & Manian, 2010). Worldwide, the use of wild fruits as possible nutritional supplements or less expensive alternatives to commercial fruits is growing in popularity (Rawat et al., 2011; Zhang et al., 2017). Identifying and utilizing underutilized species is crucial for a diverse and nutritious diet, especially for rural poor and socially vulnerable populations in emerging countries. Reclaiming these species' potential can significantly enhance nutrient intake as local knowledge diminishes, especially for rural poor and socially vulnerable populations. (Kour et al., 2018).

India's North-Eastern Hill (NEH) region is an agrobiodiversity hub characterized by diverse ethnic and cultural backgrounds. It is rich in wild agricultural plant relatives, particularly underutilized fruit crops, and mixed temperate, tropical, and subtropical fruits from various genera. The region's biological richness is significant. Various genera are available in the northeastern region such as *Pyrus*, *Rubus*, *Prunus*, *Garcinia*, *Phyllanthus*, *Averrhoa*, *Persia*, *Elaeagnus*, *Myrica*, *Passiflora*, *Calamus*, *Dimocarpus*, *Annona*, *Rubus*, *Dillenia*, *Baccaurea* and others (Deka et al. 2012, 2014; Singh et al. 2014 Bachheti et al. 2023 Hazarika et al. 2015).

Most studies have discussed several indigenous fruits' geographical distribution and ethnomedical uses. These fruits have several bioactive compounds, although few have been identified. Fruits are rich in polyphenols, which have antioxidant and redox properties. These chemicals help combat reactive oxygen and nitrogen species (ROS and RNS), essential for physiological functions. However, excessive ROS can lead to oxidative stress, increasing the risk of diseases like diabetes, cancer, obesity, and cognitive issues. In hypoxic conditions, nitric oxide can produce RNS, leading to lipid peroxidation and reactive aldehydes. Oxidative excess can cause cancer and inflammation, resulting from altered transcriptional parameters, protein modification, and DNA damage. (Dutta et al. 2018). Fruits, vegetables, and other plants naturally produce important polyphenol metabolites that influence their sensory and nutritive qualities. They are primarily responsible for the antioxidant activity in many fruits (Li et al. 2012). The prevention of gastrointestinal illnesses, colon cancer, obesity, and heart disease has been related to polyphenols. They also fight against oxidizing substances and free radicals, which preserve fatty acids from oxidative degradation (Ignat et al. 2011). It is firmly considered that

consistent consumption of phytochemicals produced from plants may tip the scales in favor of the body's proper antioxidant state [Mahomoodally et al. 2012].

Polyphenols, including flavonoids, phenolic acids, and tannins, are essential antioxidants in citrus fruits, tomatoes, and aromatic plants. Flavonoids protect plants from harmful UV rays, fungi, and oxidative cell damage. Anthocyanins, flavones, isoflavones, flavanones, and flavonols are different types of flavonoids. Anthocyanins are water-soluble pigments found in plant tissues that act as antioxidants by halting the growth of new radicals. Phenolic acids, including hydroxycinnamic and oxybenzoic acids, impact biological systems and prevent degenerative illnesses. Fruits with higher phenolic content have more potent antioxidant qualities. These phytochemicals have been investigated for their potential to cure various conditions, including cancer, chest pains, epilepsy, leucorrhea, hemoptysis, hepatic disorders, skin disorders, inflammation, leucorrhoea, joint pains, and dysentery. (Ignat et al. 2011; Bachheti et al. 2023).

Interest in natural antioxidants, particularly plant-derived ones, has increased recently, leading to their inclusion in preservation technology and modern healthcare. This review article aims to gather information on the therapeutic, phytochemical, and nutritional value of underutilized plant fruits, presenting relevant research findings and potential commercial applications.

Morphology and general distribution of some underutilized fruits

***Baccaurea ramiflora* Lour. (Latkan)**

The plant is native to Southeast Asia, namely the sub-Himalayan region that stretches from Nepal through Sikkim, Darjeeling Hills, Arunachal Pradesh, Tripura, Assam, Bhutan, Burma, Peninsular Malaysia, Tibet, and the Andaman Islands. *Baccaurea ramiflora* Lour., syn. *Baccaurea sapida* (Roxb.) Muell. Arg. is under the family Phyllanthaceae. The name of the genus is derived from the Latin word "*Baccaurea*" and relates to the golden-yellow color of the fruits (Goyel et al. 2022). It is a small to medium-sized, ten m-tall, semi-deciduous tree. Ripe fruits are first yellow and edible before changing to ivory, yellowish, pinkish-buff, or even brilliant red. Near the seeds, the pulp is pale and occasionally deep pink; its flavor can be either acidic or sweet. (De et al. 2017)

***Passiflora edulis* Sims. (Passion fruit)**

Passion fruit is the most prominent genus in the Passifloraceae family, with roughly 500 species. The *Passiflora edulis* stands out among them due to its commercial and therapeutic significance. It is grown in some areas of the Northeastern region, like Mizoram, Manipur, Nagaland, and Sikkim. The diameter of the golden passion fruit is 4–7 cm, and its length is 6–12 cm. The peel is thick, and a brilliant yellow color. Brown marks may be seen on the seeds. The pulp has a robust, fragrant flavor and is acidic. The purple passion fruit is tiny (4–9 cm long and 3–7 cm in diameter). The seed is black, while the peel is purple (He et al. 2020).

***Phyllanthus acidus* (L.) Skeels (Star aonla)**

Phyllanthus is one of the largest genera of the Phyllanthaceae family, represented worldwide by some 700 well-known species, mainly distributed in the tropics and subtropics (Banerjee et al. 2022). It is present in the southern and northeastern regions, especially in Mizoram. It is a 2–9 m tall shrub or tree with a spreading, bushy crown and rough main branches that are appealing and striking. Dioecious or monoecious flowers with many bracts are borne alone or in pairs in axillary fascicles (De et al. 2017).

***Elaeagnus pyriformis* Hook.f. (silverberry)**

E. pyriformis, often known as Silverberry or Oleaster, is a member of the family Elaeagnaceae. The only *Elaeagnus* species identified in India are *E. pyriformis*, *E. angustifolia*, *E. latifolia*, and *E. umbellata*, according to Sharma and Kumar (2006). A deciduous shrub, *E. pyriformis*, is mainly found in northeastern India. In the Himalayan area, these species are found at heights of 1500 meters. It is common in Sibsagar (Dikho valley of Assam), Naga Hills (Nagaland), Khasi, Jaintia Hills of Meghalaya, and Sikkim, all Northeastern states. It is a big, woody, evergreen shrub with rusty-shiny thorns. Bees pollinate the hermaphrodite blooms to produce them. When fully ripe, the fruits of *E.*

latifolia are rectangular and dark pink, while *E. pyriformis* is pyriform and have minor points on both ends. (De et al. 2017).

***Prunus bracteopadus* Koehne (*Prunus nepalensis* Hook.f.) (Khasi cherry)**

The Rosaceae family includes the underutilized wild fruit *Prunus nepalensis*, abundantly grown in the Indian state of Meghalaya's Khasi and Jaintia Hills. It is a dark purple fruit resembling a cherry with distinct organoleptic qualities (color, aroma, and flavor). It is also known as the Khasi cherry and may be processed or eaten raw. Even though it is very popular as a nutritious fruit among the local tribes, there is no scientific information available on the physicochemical characterization and value-addition of the fruit. It is naturally distributed in East Khasi Hills, West Khasi Hill, and Jaintia Hills district of Meghalaya between 1500 and 2000 m altitude. The highest diversity of Sohiong trees is observed in the East Khasi Hills District. It is distributed in the Khadar shnong area comprising villages like Dewlieh, Nongstraw, Wah Sohra, Diengsong, Tyngiar, Mawtuli, Kshaid, Phong Shnongpdei, Kharang, Krohiawhiar, Puhbsein and Nohshut. It is also observed in Mawsynram, Mawkyntrew, Myllem, Mawphlang, Mawplot, Pynursla, Pongkung, and Mawryngkneng. Some trees are also found in adjoining areas of Shillong in an isolated manner. It is an essential indigenous, nutritionally rich, underutilized fruit of temperate areas. The fruit is locally called Sohiong in Khasi (Meghalaya). The tree is medium to tall and evergreen, grown to 15–20 m. It starts bearing fruits after seven years of planting. Flowers are white, borne in terminal racemes or auxiliary. Fruits are drupe, fleshy, dark purple at full ripe, and green to pinkish in the immature stage. The fruit surface is smooth and round. Usually, the fruit shape resembles black grapes. Stone is hard and round with a smooth surface, but some other genotypes grown in mid-hills have rough stone surfaces, and the seed looks just like a peach. The stone size varies with genotype. (De et al. 2017).

Table 1. General information of some underutilized fruits

FRUIT NAME	LOCAL NAME	FLOWERING SEASON	FRUITING TIME
<i>Baccaurea ramiflora</i> Lour.	Latkan	during the summer months.	rainy season, i.e., July to August month
<i>Passiflora edulis</i> Sims.	Soh-brab	April - June	June - September
<i>Phyllanthus acidus</i> (L.) Skeels	Arbari	March-April	December -January
<i>Elaeagnus pyriformis</i> Hook.f.	Soshang	September-December	March-April
<i>Prunus bracteopadus</i> Koehne (= <i>Prunus nepalensis</i> Hook.f.)	Sohiong	November-March	July-October

Phytochemical constituents and nutritional status of underutilized fruits

Fresh *Baccaurea ramiflora* fruit and peel were described as fresh, juicy, tropical, grassy, fruity, and green and were noted as being predominantly sensory. It also had a smell that was evocative of green coconut, melon, cherry, and berries. It was discovered that lauryl alcohol significantly contributes to the fruit's fragrance characteristic and gives it a flowery scent after dilution. It has been utilized as a food ingredient that enhances the flavor and produces medicinal surfactants and monolithic polymers. The fragrance, flavor, and cosmetic sectors can all benefit from using more chemical constituents (Mann et al. 2016). The fruits were discovered to be a possible source of sapidolide A, picrotoximaesin, and ramifoside. These fruits are rich in nutritious components and famous for their sweet-sour flavor. Fruits of *B. sapida* have been shown to contain oleic and palmitic acids (Goyel et al. 2022). From the MeOH extract of fresh fruit pulp and peel, several other phytoconstituents, including nonanoic acid, octadecanoic acid, lauric acid, isovaleric acid, D-allose, and D-galactose, were discovered. People are increasingly turning to plant-based foods to fulfill their daily needs, and *B. ramiflora* is among them. Over time, people have been interested in the fruit of *B. ramiflora* because it is sweet-sour. The fruit is a good source of vitamin C and nutritional fiber. The fruits have low levels of fat, ash, and protein. However, they are rich in a variety of minerals, including calcium (Ca), magnesium (Mg), phosphorus (P), potassium (K), sodium (Na), iron (Fe), molybdenum (Mo), zinc (Zn), copper (Cu), and manganese (Mn). If included in the diet, *B. ramiflora* fruit, a good provider of nutritious components, can assist in reducing the adverse effects of malnutrition. (Goyel et al. 2022).

Passion fruit commonly called "the king of fruits," is consumed raw or juiced. High quantities of polyphenols, fiber, and trace elements in the peels make them ideal for processing feed and wine or tea, cooking, and extracting pectin and other therapeutic compounds. The edible seeds are rich in protein and oil mainly composed of linoleic, oleic, and palmitic acids. Several pharmaceutical preparations based on components have been produced and utilized in folk medicine in addition to being a culinary item. Polyphenols, triterpenes and their glycosides, carotenoids, cyanogenic glycosides, polysaccharides, amino acids, essential oils, microelements, and squalene are the main components of *P. edulis*. Among these compounds,

luteolin, apigenin, and quercetin derivatives are the most reported. Most importantly, passion fruit contains nutritionally valuable compounds like vitamin C, dietary fiber, B vitamins, niacin, iron, phosphorus, etc. (He et al. 2020)

Due to their high acid content, mature fruits are often acidic and sour. Fruits are a source of several nutrients and have a high moisture content. The fruit contains acids, sugars, and phenolics. The fruit also contains traces of vitamin B (thiamine, 0.01 mg/100 g, riboflavin, 0.05 mg/100 g), ascorbic acid (36.7 mg/100 g), and other nutrients (Brooks et al. 2020). Minerals can be found in abundance in *P. acidus* fruit. Numerous study teams revealed the existence of microelements, including calcium, magnesium, potassium, and phosphorus, as well as microelements like iron, copper, zinc, and manganese. There are reports of significant phytochemicals such as beta-sitosterol and D-glycoside. (Tan et al. 2020)

In terms of nutrition, *E. pyriformis* contains a sizable amount of macro elements like nitrogen, phosphorus, potassium, calcium, magnesium, and sodium, as well as microelements like iron, zinc, copper, and manganese that have the potential to have enormous therapeutic significance (Valvi & Rathod, 2011; Uprety et al. 2016). Numerous phyto-compounds, including the sugar (D-allose), ketone (Furylhydroxymethyl ketone), aldehydes (4-Methoxymethoxy-4-methyl-hex-2-ynal), fatty acids (3-Hydroxydecanoic acid), phenolics (4-Mercaptophenol), and flavonoids (4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl) were reported. Kar et al. 2016.

It is said to be an excellent source of dietary bioactive substances. Total polyphenol concentration (1131.30, mg/100 g GAE), anthocyanin content (293.33mg/100gm), beta-carotene, and antioxidant capacity (IC50 0.612 mg/mL) are high in sohiong. Fruits like sohiong are quite acidic; their pH ranges from 3.50 to 3.60. It was discovered that Sohiong has much glucose (1.52g/100gm) and fructose (1.64g/100gm). Sohiong was discovered to have high ascorbic acid (46 mg/100 g) and beta-carotene (0.215 mg/100 g) levels compared to all other peach and plum types. Sohiong was discovered to have unusually high concentrations of minerals, including calcium, magnesium, zinc, and iron. Numerous minerals, such as calcium, are essential for the body's regular operation, which is crucial for strong bones and teeth, blood pressure control, blood clotting, and good neuron function. Magnesium is necessary for protein production, nerve conduction, and muscle

contraction. Many bodily cellular processes, including sperm formation and sexual development, depend on zinc. Iron is a component of the hemoglobin in red blood cells, which transports oxygen throughout the body. Because sulfur is present in protein molecules, the high sulfur level of Sohiong may be the source of its high protein concentration. The fruit's phenolic components, which include flavonoids, other phenolic acids, and anthocyanidins, may have a higher antioxidant activity (Vivek et al. 2018).

Medicinal and health-beneficial role of some underutilized fruits

Fruits are the most prevalent sources of vital micronutrients, including vitamin C, tocopherol, carotenoids, polyphenolics, flavonoids, etc., which have nutritional value, protect the body from oxidative damage, and give health benefits. Fruit polyphenols have a variety of roles due to their redox characteristics, including hydrogen donation, singlet oxygen quenching, metal chelation, and reducing agents. Residents of the Morang District of Assam, India, consume the fruit juice of *B. ramiflora* orally as an antidote for snake venom.

B. ramiflora fruit juice is a pleasant beverage with excellent health advantages. Its antioxidative capabilities showed its promise as a reasonably priced health beverage in various settings. Due to its limited cytotoxic and hemolytic impact, BRJ has few side effects. (Saha et al. 2016). Therefore, the current study demonstrates that Latkan fruit, like other commonly used berries, is suited for creating decent wine. Additionally, since fruit has a relatively limited shelf life, creating wine is an excellent solution to avoid fruit waste. The current study also clarifies that wine is a good source of natural antioxidants such as phenols, flavonoids, and proanthocyanidins, which can benefit health if eaten in moderation. (Goyel et al. 2013)

Passion fruit is especially well-liked due to its alluring nutritional and sensory features for consumer health and well-being worldwide. Due to its multiple health advantages, high commercial worth, and application in food, cosmetics, and medicine, secondary metabolites in passion fruit have drawn much interest. Due to their abundance in biologically active chemicals, passion fruit peels, which make up about 50% of the entire fruit, have a significant potential for usage as functional additives. Numerous nutritional and medicinal advantages of passion fruit have been seen and documented due to its distinctive bioactive components.

The different extracts from the various parts of *P. edulis* showed a wide range of pharmacological activities, including antioxidant, analgesic and anti-inflammatory, antimicrobial, anti-hypertensive, hepatoprotective and lung-protective, anti-tumor, antidiabetic, hypolipidemic, antidepressant and anxiolytic-like capacities, and are therefore used in phytotherapeutic remedies. According to research on acute and subacute toxicity, a rationalized daily amount of passion fruit is most likely safe to eat. These remarkable findings imply that passion fruit may provide a variety of health advantages, including managing neurological and inflammatory conditions and preventing some chronic illnesses, including hypertension and hyperlipidemia (He et al. 2020).

The herb has long been utilized in several folk remedies to cure various human illnesses. Pharmaceutical Applications Traditional medicine uses *P. acidus* to treat various illnesses. These include rheumatism, diabetes, hypertension, hepatic illness, bronchitis, asthma, and respiratory disorders. Fruit extracts have qualities that are hypoglycemic, anti-diarrheal, analgesic, antibacterial, and anesthetic. The fruit is consumed as a liver tonic in India, while it is used as a laxative in Myanmar. According to (Banerjee et al. 2022), fruit juice can potentially alleviate gentamicin-induced renal dysfunction and kidney disorders.

Native inhabitants of this area (from Assam, Meghalaya, Arunachal Pradesh, Nagaland, etc.) take these fruits to improve their diets and fend off numerous illnesses. *Elaeagnus* is highly well-liked by indigenous people. *E. pyriformis*, often known as Oleaster or Silverberry, is a member of the *Elaeagnaceae* family (Banerjee et al. 2022). These plants are crucial for medicine and commerce in addition to being actinorhizal. Kar et al. 2016 reported that *Elaeagnus pyriformis* has several bioactive compounds (4H-Pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl, D-Allose, 5-Hydroxymethylfurfural, n-Hexadecanoic acid, Fumaric acid) which shows anti-microbial, anti-inflammatory, anti-cancer, antioxidant, Hypocholesterolemia, anti-fungal activities. *Elaeagnus pyriformis* also has neuroprotective activity against renal injury (Kar et al. 2019).

Important bioactive substances found in *Prunus nepalensis* include Quercetin, quinic acid, rutin, scopoletin, naringenin, and palmitoleic acid. With its distinctive taste, flavor, and color, the Sohiong fruit is popular among locals. It also makes squash, ready-to-serve drinks, jams, preserves, and wine.

The fruits are also abundant in phytochemicals such as rutin, purpurin, tannic acid, methyl gallate, reserpine, gallic acid, ascorbic acid, and catechin that can chelate iron and have the exceptional ability to scavenge free radicals, delaying the start and progression of degenerative illness. (Lata et al. 2023).

Due to the existence of pigments and other bioactive substances, the food, pharmaceutical, and textile sectors may benefit. Numerous degenerative disorders, including edema and diuresis, are routinely treated with these fruits (Vivek et al. 2017).

Conservation strategies of underutilized fruit of Northeast India

Indo-Burma Region in Northeast India is a biodiversity hotspot, with underutilized and unexploited fruits being beneficial for health benefits, revenue-generating, and eradicating poverty. Climate change, deforestation, changing farming, urbanization, and construction projects, however, are endangering these resources. The scientific community must research all plant resources and create techniques for culture, multiplication, regeneration, and propagation to preserve these genetic riches. *Ex situ* and *in situ* conservation techniques should be used to safeguard vulnerable species and help them recover. Cryopreservation, *in vitro* seed storage, and field gene banks are examples of *ex-situ* conservation techniques. On-farm conservation, natural reserves, gene sanctuaries, and the integration of underutilized and unexploited fruit species in the social forestry system are examples of *in situ* conservation initiatives. The protection and sustainable use of these priceless plants require implementing a national strategy, action plan, and program. A comprehensive inventory and documentation of the species that are currently accessible, their chemical components, antioxidants, habitats, and potential use as raw materials should be prioritized.

Conclusion

These fruits, not used as much yet, have excellent nutritional and therapeutic significance. However, despite the abundance of germplasm in India, the creation of standard cultivars remained constrained. They can survive in challenging climatic and edaphic circumstances thanks to their flexibility and tolerance. These fruits have the potential to aid in sustainable farming. Large populations of individuals in poor nations have long used herbal medications as an essential component of their

healthcare systems. However, in recent years, affluent nations have also begun to favor herbal treatments due to a perception that they are secure. The market is currently flooded with several medications made from plants. These underutilized fruits do have a wide range of pharmacological effects. The information now available on this medicinal plant may be the foundation for further research into its mechanism of action, safety effectiveness, toxicity, therapeutic relevance, and potential for developing innovative pharmaceuticals. Research and development efforts, farmer knowledge, and the viability of cultivating these lesser-known fruits should be considered.

Author contributions

Swarnendra Banerjee: Investigation, Writing – original draft. **Arnab Sen:** Conceptualization, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare no conflict of interest.

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