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Nutraceutical and Medicinal Potential of Underutilized Fruits in India

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A B S T R A C T

India possesses a remarkable diversity of indigenous and underutilized fruit crops that have traditionally formed an important component of rural diets, indigenous healthcare systems and local economies. Despite their nutritional richness and adaptability to diverse agro-climatic conditions, many of these fruits remain confined to specific geographical regions and are cultivated or collected largely for local consumption. Aonla, bael, ber, phalsa, karonda, jamun, wood apple and tamarind and other underutilized fruits i.e. lasoda, chironji etc. represent important examples. These fruits contain appreciable quantities of vitamins, minerals, dietary fibre and diverse phytochemicals, including phenolics, flavonoids, tannins, anthocyanins, terpenoids, alkaloids and other secondary metabolites. Several investigations have demonstrated antioxidant, antimicrobial, anti-inflammatory, antidiabetic, hepatoprotective, gastroprotective and other pharmacological activities, although the strength of evidence varies substantially among species and between experimental models. Their nutritional and bioactive attributes provide a scientific basis for their development as functional foods, nutraceutical ingredients and value-added products. However, inadequate domestication, limited systematic cultivation, high perishability of several fruits, lack of standardized postharvest practices, insufficient processing infrastructure, weak market linkages and inadequate clinical validation restrict their wider utilization. This review critically examines the taxonomy, nutritional composition, antioxidant and medicinal potential, traditional uses and value-addition opportunities of selected underutilized fruits of India. Conservation of genetic resources, systematic characterization of bioactive compounds, standardization of processing technologies, assessment of bioavailability and well-designed human studies are identified as major research priorities for transforming these neglected fruit resources into commercially viable nutraceutical and functional-food resources.

Introduction

India is recognized as one of the important centers of diversity for fruit crops and possesses a large number of indigenous and lesser-known fruit species. In addition to

commercially established fruits, numerous indigenous fruits occur naturally or under cultivation in tropical, subtropical, arid, semi-arid, tribal and forest ecosystems. Many of these fruits have traditionally been consumed by rural and tribal communities and have been incorporated into indigenous systems of medicine. However, their contribution to organized fruit production and national fruit markets remains disproportionately small in relation to their biological and nutritional potential.

The term "underutilized" crop has been defined in various ways in world literature, most of these have been given importance to ethno-botanical features, among others pertaining with the ancient cultural heritage of the locality, multiple uses, traditional crops in localized areas lesser known and neglected by agricultural research and development agencies (Thakur, 2014). In the Indian context, underutilized fruits may include species with restricted commercial cultivation, localized consumption, inadequate market development or insufficient scientific improvement. Their importance is therefore not necessarily determined by biological rarity but by the degree to which their nutritional, economic and therapeutic potential remains underexploited. Underutilized food crops are properly utilized, they may help to contribute in food security, nutrition, health, income generation and environmental services when properly utilized

Underutilized or neglected crops species are often indigenous ancient crop species which are still used at some level within the local, national or even international communities, but have the potential to contribute further to the mix of food sources than they currently do (Mayes *et al.,* 2011). Since time immemorial, edible wild fruits have played a very crucial role in supplementing the diet of the people of Indian Subcontinent. Apart from customary use as food, wild underutilized edible fruits have various health advantages as it potentially imparts immunity to many diseases. Prevention and cure of digestive disorders through the use of medicinal plants (Sidhu K., 2007). Several underutilized fruits in arid India identified species such as Kair, Lasora, Jhar Ber, Pilu, Phalsa, Bael and Karonda emphasized their hardiness, ability to withstand environmental stresses and potential contribution to nutrition and rural livelihoods.

The term "nutraceutical" was coined by combining the terms "nutrition" and "pharmaceutical" by Stephen Defelice, chairman of the Foundation for Innovation in Medicine (New Jersey, 1989). Nutraceuticals were described as "food or part of a food that provides health benefits and are used for prevention or treatment of a disease" (Srivastava *et al.,* 2015). The concepts of nutraceuticals, dietary supplements, functional foods, medical foods, and dietary supplements are confusing and the terms are often used interchangeably. Nutraceuticals are described as products extracted, purified, or produced from a plant, animal, or marine source (e.g., antioxidants from blueberries, elk velvet, or fish oils), or produced from dried, powdered, or pressed plant material. They have a demonstrable physiological benefit or provide protection against chronic diseases (Prabu *et al.,* 2012; Srivastava *et al.,* 2015).

Wild food plants have become very important for the food industry as they can be used to replace synthetic chemicals and nutraceuticals (Sadia *et al.,* 2014); however, the nutritional, economic, and sociocultural potential of neglected and underutilized natural food resources have yet to be fully exploited and are suffering from a lack of research interest (Beccaro *et al.,* 2015, Donno *et al.,* 2014). For

example, data on the antioxidant properties of several plant resources, in particular plants not used in nutrition and medicine, are still lacking. Therefore studies on these plants may be of interest in the search for novel sources of natural antioxidants, functional foods, and nutraceuticals (Donno *et al.,* 2015).

Some indigenous fruit trees yield a crop in poor rainfall years, thereby improving food security for rural households (Mojeremane and Tshwenyane, 2004). In addition to their roles as sources of food, indigenous wild plants serve as medicines, fodder, fire wood, craft and cash products and building materials for rural communities. Most of them are important sources traditional beverages, food recipes, oil, carbohydrates and proteins (FAO, 1982; Maghembe *et al.,* 1994). Like vegetables, wild fruits are valuable sources of vitamins and minerals essential for proper maintenance of food health (Saka, *et al.,* 1994). In some of the poorest nations in the world, people depended among other things, the wild fruits and vegetables to ensure food security. Unfortunately, utilization of indigenous food plants has steadily declined mainly due to lack of knowledge of their nutrient value, resulting from limited research done (Kiremire *et al.,* 2001). The present review therefore focuses on selected Indian underutilized fruits, particularly aonla, bael, ber, phalsa and karonda, while incorporating information on jamun, wood apple, chironji, tamarind and other regionally important fruits where relevant. The review examines their taxonomy, nutritional and phytochemical composition, antioxidant and medicinal potential, traditional applications and prospects for value addition.

Materials and Methods

A comprehensive literature review was conducted to collect, evaluate, and synthesize published information on minor and underutilized fruit crops, with particular emphasis on their nutritional, nutraceutical, medicinal, socioeconomic, and commercial importance. Relevant scientific literature published in peer-reviewed journals, books, book chapters, conference proceedings, institutional reports, and other authoritative sources was considered.

Results and Discussion

Diversity and importance of underutilized fruits in India

India, the centre of origin for many tropical fruit tree species, most of which are not commercially cultivated but provides significant source of livelihood support for many rural communities. The tribal inhabitants of Western Ghats, Maharashtra and North Eastern States of India were traditionally reliant on non-timber forest products and favoured local fruit species like tamarind, jackfruit, Indian gooseberry, ber etc., instead of arable food crops apart from mango and cashew, for establishing agri-horti-forestry for their livelihoods. Innumerable wild species of Citrus, Musa, Pyrus and Malus were also prevalent in the North Eastern regions. Conversely, most of these species are in a state of neglect, while a trivial number of them are under cultivation in their native tracts by local communities for specific household uses only. These species were rendered “Underutilized” by the fact that even though they are locally abundant, they are restricted to their geographical location with dearth of scientific knowledge about them, and their current use is linked to their economic potential. These species were immensely constructive by surviving harsh agro-climatic conditions, and can be established on degraded lands, which are presently being underutilized either due to poor soil fertility or moisture scarcity. Due to unsustainable market pressures and rapid

urbanization, majority of these species have come to near extinction. A holistic approach is hence proposed which includes both in-situ and ex-situ conservation strategies, as well as re-governance of the market chain. Reinforcement of their domestication through standardization of cultivation practices, facilitation for supply of planting material and increasing the demands for the produce by exploring their uses, creation of awareness among consumers and establishing a good distribution network are also crucial for attaining sustainability (Diengngan S, Hasan MA, 2015).

Aonla is a deciduous fruiting plant grown in many states of India. The tree is hardy, prolific bearer and a suitable choice for arid regions of the country (Mitra, SK. 1999). It is also reported on the presence and significance of this fruit in hilly regions of India. Bael is native to India and Pakistan and spread throughout South-East Asia. Being one of the oldest cultivated fruits in India, it has a mythological significance viz. leaves are used for worshiping Lord Shiva. This fruit is also commonly found in the hilly regions of India (Das *et al.,* 2013). Pomegranate is a native of Middle East and in ancient Greek mythology, it is known as the "fruit of the dead". In India, Jackfruit is considered to be the native of this country. This is an important fruit crop of humid tropical and near-tropical climatic regions. Wood apple/Kath Bel is originated in India and belongs to the family Rutaceae. Jamun is an important indigenous fruit of commercial value in the country. It belongs to the family Myrtaceae. The tree is ideally suited for windbreak and roadside plantations. Ber/Indian Jujube belongs to the family Rhamnaceae. It is an ideal fruit tree for arid and semi-arid regions in tropical and subtropical climate where most of the fruit crops cannot be grown either due to lack of irrigation facilities or adverse climatic and soil conditions (Krivencov VI *et al.,* 1970). Fig was an important food crop in ancient civilization. Karonda is a hardy, evergreen, spiny and indigenous shrub which thrives well as rainfed crop. The fruit belongs to the family Apocynaceae. Pummelo/Jambura is the largest citrus fruit and belongs to the family Rutaceae. It is also known as "Shaddock" and locally called "Jambura". It is a mono embryonic species which is native to Malaysia and Polynesia. Tamarind is native to Tropical Africa and belongs to the family Fabaceae. It is the 'Indian date' and is one of the most important fruits of India. In Tripura, it is locally called "tentul" (Das *et al.,* 2013). Passion fruit is native to tropical America.

A wide range of wild, temperate fruits occurs in the Indian Himalayas. The agro-ecological niches and variation in altitude in North-Western Himalaya are suitable for adaptation of minor temperate fruits like *Rubus, Ribes, Viburnum, Pyrus and Prunus* {Joshi *et al.,* 1994, Sharma *et al.,* 1997 (a) and Sharma *et al.,* 1998 (b)}. Species of pome fruits, in addition to cultivated fruits like apple and pear, viz. *Malus, Pyrus, Sorbus, Cydonia, Cotoneaster, Crataegus, Pyracantha, Diospyrus and Docynia* are also prevalent (Sharma *et al.,* 2005).

Nutritional attributes of underutilized fruits

Minor fruits are rich source of antioxidants. The antioxidants play an important role in health-promoting biochemical pathways. Oxidative stress, resulting from imbalance among the reactive oxygen species including free radicals and antioxidant defences in living organisms produces oxidative changes to proteins, fatty acids, and DNA molecules in the living cells, which encourage the initiation of ailments, e.g., inflammation, liver cirrhosis and vascular diseases (Aruoma, 1998). Phenolic compounds are the largest group of phyto-chemicals found in the plants. Phenols,

as the major bioactive substances in fruits, play a vital role as antioxidant. Phenolic compounds are good antioxidants found in the flesh of fruits including phenolic acids and flavonoids, where as flavonoids and lignans are found in the seeds or kernel. Among the phenolic acids, gallic acid is the major component of plant. Fruits are rich source of vitamins and minerals. Besides, nutritional importance, these fruits havemedicinal and theraptic values. Fruits contain several chemical ingredients such as flavonoids, quinolizidine, alkaloids, tritepenes, stilbenes, tannins, steroids, coumarin, and saponins,quinolizidine, triterpenoids, glycosides, fatty acids, taraxerone, cryptoxanthin, taraxerol, Beta-carotene,(24R)-24-ethylcholest-5-en-3 Beta -ol glucoside, and Beta-sitosterol, etc. These exhibited varied biological effects like anti-inflammatory, analgesic, antidiabetic, antipyretic, antioxidant, hypoglycemic, hepatoprotective, and anticancer, dysentery, cholera, wounds, and sores (Doka *et al.*, 2014; Ebbo *et al.*, 2014; Ibragic and Sofic, 2015 and Goyal, 2012). Depending on species and maturity stage, these fruits provide carbohydrates, dietary fibre, organic acids, minerals, vitamins and a range of phytochemicals. A major advantage of these fruits is that nutritional diversity occurs across species. Aonla is particularly valued for its high vitamin C content and tannin-associated antioxidant characteristics. Bael provides carbohydrates, fibre and several phytochemicals. Ber contributes sugars, vitamin C, minerals and fibre, whereas the intensely coloured fruits of phalsa and jamun provide anthocyanins and other phenolic compounds.

Phytochemicals and Nutraceutical significance

The nutraceutical potential of underutilized fruits is largely associated with secondary metabolites. These include phenolic acids, flavonoids, tannins, anthocyanins, carotenoids, terpenoids and other compounds. These constituents may act through several mechanisms, including free-radical scavenging, modulation of oxidative stress, interaction with enzymes, regulation of inflammatory pathways and modification of carbohydrate and lipid metabolism. However, their biological effects depend on concentration, chemical form, absorption, metabolism and bioavailability. The nutritional potential of different minor fruits is described below:

Aonla: a concentrated source of antioxidant phytochemicals

Aonla is the most concentrated form of vitamin C (500-600mg/100g) found in the plant kingdom, and when the whole fruit is used rather than an active ingredient, the vitamin C is easily assimilated by the human body and has been found to have great antioxidant properties. It also contains proteins and minerals like calcium, phosphorus and iron. The high vitamin C content of fruit makes its wide use in Ayurvedic medicine. The tree has been regarded as sacred in India, worshipped as the Mother Earth and is believed to nurture humankind by its nourishing taste and also believed to stimulate purity. Aonla has traditionally been incorporated into Ayurvedic preparations and is also processed into numerous products including preserve, candy, juice, squash, powder and dried products. The combination of high antioxidant potential and relatively strong traditional acceptance makes aonla particularly suitable for functional food development.

Bael: nutritional and therapeutic potential

Bael fruits consist of moisture (61.5%),

protein (1.8%), fat (0.3%), minerals (1.7%), fibre (2.9%) and carbohydrates (31.8%) per 100g of edible portion. Its vitamin and mineral contents include calcium, phosphorus, iron, carotene, thiamine, riboflavin, niacin and vitamin C. (Hasan *et al.,* 2010). Bael has strong potential as a functional food and source of bioactive ingredients, while claims of therapeutic efficacy require further clinical validation. Bael pulp is also suitable for processing into beverages, pulp products, powder, jam, nectar and other value-added products. Its thick rind and relatively stable pulp provide opportunities for processing compared with highly perishable soft fruits.

Ber: nutritional value and adaptability

Fruits are greenish yellow to reddish brown. It has a high amount of vitamin C (85-95mg per 100g). More vitamin C was found in the fruit flesh near the seed rather than near the skin of the fruit (Krivencov VI, 1970). It is also a rich source of vitamin A and B-complex. The fruits can also be used for making several products like chutney, dried ber, murabba, jelly, etc. Wines can also be prepared from the fruits. Different maturity stages have different culinary and nutritional applications. Fresh ber can be consumed directly, whereas mature fruits can be processed into dried products, candy, preserves, beverages and other products. Because the crop is relatively hardy, its wider promotion may simultaneously address nutritional diversification and climate-resilient horticulture. The major limitations are variability in fruit quality, inadequate cultivar standardization, limited organized marketing and insufficient postharvest infrastructure.

Phalsa: an anthocyanin-rich minor fruit

Phalsa is a small berry fruit with considerable potential as a functional-food ingredient. Its attractive colour and acidic-sweet flavour make it particularly suitable for beverages. The phalsa seed, fruit, and pulp contain numerous functional phytochemicals that can be used to treat various diseases, and have be found to be highly effective in improving respiratory and cardiac functioning. Its cultivation has been limited to subsistence cultivation and it is sold in the form of raw fruit mostly (Khan *et al.,* 2019). Fresh fruits have a short marketable life, and therefore conversion into squash, syrup, juice, nectar, RTS beverages, jam, jelly and other products can substantially increase utilization. The nutraceutical significance of phalsa is especially promising in the beverage sector because anthocyanin-rich fruit ingredients can combine sensory appeal with functional-food positioning.

Karonda: an underexploited functional fruit

It is a hardy, evergreen, spiny and indigenous shrub which thrives well as rainfed crop. The fruit belongs to the family Apocynaceae. Fruits, sour and astringent in taste, are a very rich in iron contains a good amount of vitamin C. They also contains protein, carbohydrates, fat, fibre and calcium. The ripened fruits may be eaten as dessert or used for the preparation of jelly, sauce, carissa cream or jellied salad. Unripe fruits are used for making pickles, sauces and chutney. The dried fruits may act as a substitute for raisins (Cheema and Cheema, 1971). The wine prepared from ripe fruits contains about 14.5 to 15% alcohol and is very much liked by wine fanciers. (Nalwadi *et al.,* 1975).

Jamun: antioxidant and metabolic-health potential

Jamun, *Syzygium cumini*, is one of India's most recognized medicinally associated minor fruits. Its deep purple colour is indicative of anthocyanin-rich pigmentation. Jamun is

highly amenable to processing into juice, RTS beverages, squash, jam, jelly, wine, fermented beverages.

Wood apple

Wood apple, *Limonia acidissima*, is another important Indian underutilized fruit. The fruit has a hard shell, aromatic pulp and characteristic flavour. It is consumed fresh or processed into beverages, chutneys, preserves and other products. The pulp contains 18.1% carbohydrate, 7.1% protein, 3.7% fat, 5.0% fibre and 1.9% mineral matter. The pulp is a rich source of calcium, phosphorus, iron and vitamins like carotene, riboflavin, niacin, thiamine and vitamin C. It is also used for making chutneys, jam, jelly and squash.

Tamarind

Tamarind, *Tamarindus indica*, is a widely recognized multipurpose fruit tree whose culinary importance has allowed it to achieve greater commercial acceptance than many other underutilized species. It is a large sized, long-lived evergreen tall tree with a spreading crown. It is an excellent tree for social forestry and agro forestry. This crop is highly suitable for wastelands due to its multi ferrous uses and capacity to withstand adverse agro-climatic conditions. It also acts as a good wind break. Almost every part of the tree finds some uses but fruit is the most useful which contains the sweet acidic pulp. The pulp has low water content and high levels of proteins, carbohydrates and minerals. The pulp is also the principal souring agent for squashes, chutney, beverages, etc. (Roy *et al.*, 1988).

Medicinal and therapeutic potential

Traditional medicine provides important leads for nutraceutical research. Several underutilized fruits have been consumed traditionally for gastrointestinal disorders, fever, inflammation, metabolic disorders and other ailments. Aonla is the richest source of vitamin C and is a diuretic, aperient and laxative. It cures insomnia, scurvy, constipation, used as a cooling agent to reduce the effects of sun strokes. It is also useful for haemorrhage, leucorrhoea and discharge of blood from uterus (Hasan *et al.*, 2010). The bael tree is one of the most useful medicinal plants.

The fruit is used as ayurvedic remedy against diarrhea, dryness of the eye and common cold (Ramma, 2006). The fruit's medicinal value is very high when it just begins to ripen. The fruit is aromatic, cooling and laxative. It arrests secretion or bleeding. It is also useful in preventing scurvy and strengthens the stomach and promotes its actions (Joshi *et al.*, 2004).

The unripe fruit is good for digestion and is perhaps the most effective remedy for chronic diarrhoea and dysentery where there is no fever (Barkha *et al.*, 1997).

Karonda fruit is considered to be antiscorbutic and is also very useful in curing anaemia, stomach ache and is anthelmintic. Root extracts are used in lumbago, chest complains and venereal diseases (Achenbach *et al.*, 1989). Jamun has attracted considerable interest because of its reported hypoglycemic activity. Tamarind is used in the Indian medicine as a refrigerant, carminative, antiscorbutic and laxative and is also prescribed for bilious disorders (Roy *et al.*, 1988). The active constituents present are furunone, phenyl acetaldehyde and tartaric acid. The products of the seeds are used mostly for manufacture of sizing powders (Rao, 1959). Phalsa and other minor fruits also possess reported antioxidant and therapeutic potential.

Table.1 Important underutilized fruits of India

Fruit	Botanical name	Family
Aonla	*Emblica officinalis* L.	Phyllanthaceae
Bael	*Aegle marmelos* (L.)	Rutaceae
Ber	*Ziziphus mauritiana* Lam.	Rhamnaceae
Phalsa	*Grewia asiatica* L.	Malvaceae
Karonda	*Carissa carandas* L	Apocynaceae
Jamun	*Syzygium cumini* (L.) Skeels	Myrtaceae
Wood apple	*Limonia acidissima* L.	Rutaceae
Tamarind	*Tamarindus indica* L.	Fabaceae
Source: Book of Glaustas Horticulture by P. Muthukumar and R. Selvakumar, New Vishal Publication		

Table.2 Composition of important underutilized fruits (Gopalan *et al.*, 1978).

Fruits	Moisture (%)	Protein (g)	Fat (g)	Minerals	Fibre (g)	Carbohydrates (g)	Carotene (µg)	Vitamin (mg)
Aonla	81.8	0.5	0.1	0.5	3.4	13.7	9	600
Bael	61.5	1.8	0.3	1.7	2.9	31.8	55	8
Jamun	83.7	0.7	0.3	0.4	0.9	14.0	48	18
Phalsa	80.8	1.3	0.9	1.1	1.4	14.7	419	22
Wood apple	64.2	7.1	3.7	1.9	5.0	18.1	61	3
Tamarind	20.9	3.1	0.1	2.9	5.6	67.4	-	-

Role in nutritional security

Underutilized fruits can contribute to nutritional security through dietary diversification rather than by replacing staple foods. Their importance is particularly evident in rural and tribal communities where fruits are locally available at comparatively low cost. Their cultivation can also complement conventional horticulture because many species tolerate marginal environments. This is especially relevant in dryland areas where crop diversification is necessary to reduce climatic risk.

Socio-economic significance:

- **Farm diversification:** introduction of hardy fruit species into marginal lands.
- **Income generation:** sale of fresh fruits and processed products.
- **Women and rural employment:** processing of preserves, beverages, pickles and other products.
- **Tribal livelihood support:** improved value chains for forest-derived fruits.
- **Nutritional improvement:** increased availability of micronutrient- and phytochemical-rich foods.
- **Biodiversity conservation:** economic value can encourage conservation of neglected species.
- **Agro-ecological resilience:** hardy perennial species can contribute to sustainable farming systems.

Research gaps

Standardization of phytochemical data

Different studies frequently report different concentrations of phenolics, flavonoids and

antioxidant activity. Differences may arise from genotype, environment, maturity and extraction methodology. Standard protocols are therefore necessary.

Bioavailability

A high concentration of a compound in fruit tissue does not necessarily mean high physiological availability.

Digestion, absorption, metabolism and interaction with other dietary components need greater attention.

Clinical validation

Most medicinal claims require stronger human evidence. Controlled clinical trials should be conducted before making disease-specific nutraceutical claims.

Genotype × environment interactions

The nutritional and phytochemical composition of underutilized fruits can vary among genotypes and production environments.

Systematic germplasm characterization is required.

Processing-induced changes

More research is needed to determine how drying, heating, fermentation, pulping and storage affect bioactive compounds and their bioavailability.

Product standardization

Many value-added products remain at household or small-scale levels. Standardization of formulations, packaging, shelf life and sensory characteristics could facilitate commercialization.

Future prospects

The future of Indian underutilized fruits lies not simply in increasing their cultivation but in creating an integrated "farm-to-functional-food" value chain. A strategic approach should include:

- Conservation Of Indigenous Germplasm;
- Identification Of Elite Nutritionally Superior Genotypes;
- Establishment Of Standardized Cultivation Practices;
- Development Of Quality Planting Material;
- Nutritional And Phytochemical Profiling;
- Non-Destructive Maturity Assessment;
- Improved Postharvest Handling;
- Development Of Functional Foods;
- Characterization Of Bioactive Compounds;
- Bioavailability Studies;
- Farmer-Oriented Processing Units;
- Geographical Branding And Certification; And
- Stronger Linkage among Farmers, Researchers, Processors and Markets.

The opportunity is particularly significant because several underutilized fruits are already culturally accepted. Therefore, product development can build upon existing consumption patterns rather than attempting to create entirely new food habits.

Conclusion

Indian underutilized fruits represent a valuable but incompletely exploited component of the country's horticultural biodiversity. Aonla, bael, ber, phalsa, karonda, jamun, wood apple, tamarind and several other indigenous fruits provide combinations of vitamins, minerals, dietary fibre and biologically active phytochemicals. Their antioxidant and pharmacological properties, documented through traditional

knowledge and experimental studies, provide a scientific basis for their consideration as functional-food and nutraceutical resources. Among the selected fruits, aonla is particularly notable for its vitamin C and tannin-rich profile; bael for its diverse phytochemicals and gastrointestinal applications; ber for its nutritional value and adaptation to dry environments; phalsa for its pigmented phenolic-rich fruit and beverage potential; karonda for its hardiness and processing versatility; and jamun for its anthocyanin-rich profile and extensive experimental investigation of metabolic-health-related properties. Greater utilization of these fruits could simultaneously contribute to nutritional diversification, functional-food development, biodiversity conservation, climate-resilient horticulture and rural livelihood improvement. Their transformation from neglected resources into scientifically validated nutraceutical commodities will require coordinated efforts in crop improvement, cultivation, postharvest management, food technology, pharmacology, nutrition and market development.

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