

A Review on Botanical Characteristics, Bioactive Compounds and Traditional Uses of Some Selected Unconventional Fruits of Upper Brahmaputra Valley, Assam

Bristy Borgohain^{1,*}, Aandriша Borthakur¹, Bijoy Neog¹, Pranit Saikia²

¹Department of Life Sciences, Dibrugarh University, Dibrugarh, Assam, INDIA.

²Centre for Biotechnology and Bioinformatics, Dibrugarh University, Dibrugarh, Assam, INDIA.

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ABSTRACT

Background: Unconventional fruits are the least concerned and least exploited fruits and require a scientific investigation. Assam is rich in biodiversity in terms of rare and endemic flora and fauna of this region. Over-exploitation of these species without any knowledge and checklist may lead to the endangerment of these species in wild. Keeping in view of such a problem, five locally available unconventional fruits viz. Bon-pitha (*Chrysophyllum roxburghii*), Heloch (*Antidesma acidum*), Korja-tenga (*Carissa carandas*), Bilombi-tenga (*Averrhoa bilimbi*), Thereju (*Prunus jenkinsii*) were studied for their morphological, nutritional, phytochemical and traditional use as food and folkloric medicines, which would be the highlight of this paper. **Materials and Methods:** For writing this review, data were generated using various online databases viz. Google Scholar, ScienceDirect, ResearchGate etc. A total of 135 articles were retrieved, out of which only 49 were selected due to the exclusion criteria. These articles provide a detailed idea about these unconventional fruits and their immense nutritional importance. **Results and Conclusion:** Detailed analysis of the gathered articles revealed that unconventional fruits are rich in various macro and micronutrients. Phytochemical investigations of their various parts showed the presence of phenols, flavonoids, terpenes along with other related compounds. These fruits have several traditional uses including folkloric medicines, but they received very less attention in pharmacological industries. Moreover, due to a lack of people's knowledge, many of these unconventional fruits are on verge of extinction. So, further scientific studies are needed in order to conserve and increase their potential values.

Keywords: Assam, Biodiversity, Traditional medicine, Underutilized fruits.

Correspondence:
Ms. Bristy Borgohain,
Department of Life
Sciences, Dibrugarh
University,
Dibrugarh-786004,
Assam, INDIA.

Email id: rs_bristyborgohain@dibru.ac.in

INTRODUCTION

Assam is blessed with a huge diversity of flora including herbs, medicinal trees, climbers, and fruit crops due to its uniqueness in soil, climate and physiography. It is also a habitat of many endemic and threatened plant species.^[1] The region is rich in a variety of fruits which are either cultivated largely for commercial purposes or some are

found in wild. These wild fruits are consumed locally as unconventional or minor fruits and are sometimes cultivated, and traded on a very small scale. Though these fruits are not popular, but are a rich source of vitamins, minerals, proteins, and fibres and hence provide a vital role in nutritional security and livelihood of local people of the region. Since time immemorial, these fruits have been used as food supplements, condiments, spices, ailments, and medicines by local people. Different parts of these fruit trees (pulp, leaves, roots) are used in many traditional and folklore medicines by the tribal people of rural areas.^[2] Tripathi, 2021 in his paper, mentioned medicinal and therapeutic uses of some minor fruits such as Bael, Bilimbi, Aonla, Rose apple, Malayan apple

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etc.^[3] According to Narzary *et al.* 2013, the consumption of wild edible fruits can lessen the risk of several problems relating to the heart, kidneys, nerves, blood pressure, diabetes etc.^[4]

Unconventional fruit trees are generally found in wild, but some are found in semi-domesticated conditions and also in homestead gardens. They are capable of enduring environmental stresses and are easy to cultivate.^[5] These fruits are a potential source of nutraceuticals, raw materials for food processing industries, pest management, timber, oils, waxes, and fodder for cattle or other livestock. Despite its immense potential, no proper scientific exploration has been carried out on these fruit trees. Also, due to recent changes in climate and forest habitats for increasing human activities such as industrialization, and deforestation, many of these fruit trees are on verge of extinction.^[6] Therefore, it is very much necessary to explore, identify, document, conserve and popularise these unconventional fruits in order to utilise their maximum benefits for future reference.

This review focuses on the botanical description, nutritional and phytochemical constituents along with the traditional uses of five unconventional fruits of upper Assam *viz.*: Bon-pitha (*Chrysophyllum roxburghii*), Helos (*Antidesma acidum*), Korja-tenga (*Carissa carandas*), Bilombi-tenga (*Averrhoa bilimbi*), Thereju (*Prunus jenkinsii*).

MATERIALS AND METHODS

Literature searches

For reviewing this article, related literature was retrieved through online search engines such as Google Scholar, ResearchGate, ScienceDirect and PubMed. A combination of keywords such as 'unconventional fruits', 'minor fruits', 'underutilized fruits', 'traditional use', 'folkloric medicines', 'phytoconstituents' and 'nutritional value' with 'of Assam' were interchangeably used for searching. Boolean Operators such as 'AND' and 'OR' were used in order to get more productive results relating to the topic.

Eligibility criteria

Inclusion criteria: Articles which were related to the title, abstract, keywords, introduction and the overall content of this review were selected. Works which were published only between the year 2001-2020 were screened. Focused is mainly given to the articles which include a) nutritional properties of unconventional fruits b) phytochemical analysis and c) traditional medicinal uses of the wild edible fruits of Upper Assam.

Exclusion criteria: The criteria considered for exclusion were as follows: a) Articles which were not published in the English language b) works published before 2001 c) Data from unreliable sources d) Articles that cannot be viewed in full-text files.

Selection strategy

The authors critically assessed the works, articles and studies related to this topic of interest. They selected only those journals which were most relevant and falls under the eligibility criteria. The final evaluation was done and any discrepancies found were settled through a discussion with all authors.

Data extraction

For extraction of data, the authors went through a wide range of relevant papers and the following factors were taken into consideration such as author's name, year of publication, unconventional fruits, morphology, nutritional profile, phytoconstituents, traditional uses, which were necessary to create this review. Along with these, introduction, discussion and conclusion of some other journals also provide supplementary informations. Figure 1 illustrates an idea about the methodology of literature selection.

RESULTS

A total of 331 records were retrieved from online search engines/databases including Google Scholar, ResearchGate, ScienceDirect, PubMed etc for initial screening. Redundant or duplicate records ($n=188$) were then removed which reduced the records upto 143. The authors then assessed the title and abstract, leaving the

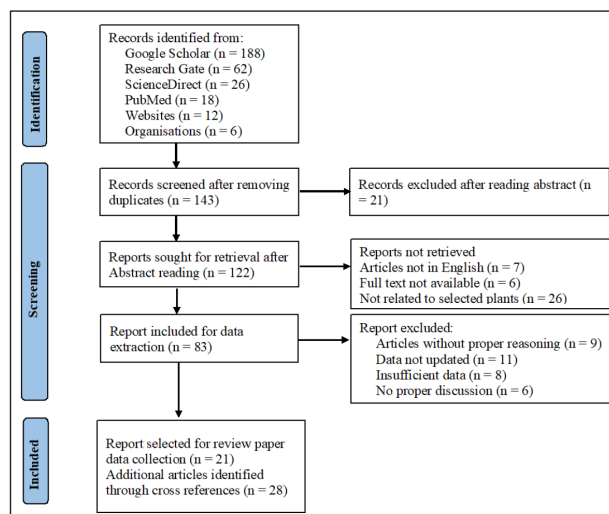


Figure 1: Flow chart for selection strategy and exclusion/inclusion criteria of literature methodology.

articles to 83. After complete evaluation of the full-text of the eligible records, only 49 reports fulfill both the inclusion and exclusion criteria (Figure 1). Out of these 49 reports, 21 reports were used for writing the botanical description of the selected unconventional fruits, 8 reports were used for nutritional profiling (Table 1 and 2), 15 records were used for phytochemical analysis (Table 3) and 5 reports were used for traditional uses.

Botanical description of the selected unconventional fruits of Upper Assam

***Chrysophyllum roxburghii* (Bon pitha):** *Chrysophyllum roxburghii* is an evergreen tree that can grow upto a height of 1400m. The bark is grey or light brown in colour. The bark is smooth in texture with vertical cracks. Leaves are simple, alternate and without stipules with slender and pubescent petioles, acute leaf base and acuminate or caudate-acuminate leaf apex. The leaf margins are entire and venation is intercostal reticulate. The bisexual flowers are green or greenish

white in colour and contain 5-6 calyx lobes, imbricate, 5-6 stamens are present and the ovary is superior. The fruit is a berry, globose and yellowish green in colour and the seeds are brownish yellow.^[7] The plant is found in Madagascar, India, Sri Lanka, Myanmar, southern China, New Guinea, the Philippines, Solomon Islands and northern Australia. In India, it is found in western ghats and in Assam (Lakhimpur, Jorhat, Nagaon and Cachar).^[8] Flowering occurs from April to June and fruit ripening occurs from November to February (Table 4).^[9,10] The fruits are consumed raw by the local people.^[11-13] The plant is also used as fodder and timber.^[14]

Antidesma acidum (Heloch)

Antidesma acidum is a large shrub (Table 5). It is a dioecious plant distributed in India, Pakistan, Bangladesh, China, Thailand, Nepal, Myanmar, Jawa, Vietnam and Cambodia. In India, it is mainly found in Assam. Its synonyms are *Antidesma diandrum*, *Antidesma lanceolarium*, *A. parviflorum*, *A. sylvestre*, *A. wallichianum*, *Stilago diandra* and *Stilago lanceolaria*.^[15] They are about 6-10m tall, leaves

Table 1: Major Nutritional parameters in the pulp of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

Nutritional components	<i>Chrysophyllum roxburghii</i> ^[36]	<i>Antidesma acidum</i> ^[16]	<i>Carissa carandas</i> ^[20,23]	<i>Averrhoa bilimbi</i> ^[37,38]	<i>Prunus jenkinsii</i> ^[29]
Moisture Content	60.9%	79.9%	83%	94.7%	87%
Ash	1.4%	9.3%	0.72%	0.4%	0.5%
Ascorbic Acid	54 ppm	480 ppm	90-110 ppm	155 ppm	145 ppm
Total Carbohydrate	19.9%	12.5%	0.51-0.94%	0.05%	7.8-8%
Total Fibre	--	5.8%	0.62-1.81%	0.6%	1.9%
Total Proteins	2.3%	11.8%	0.39-0.66%	0.61%	0.6%
Lipid Content	--	2.5%	2.57-4.63%	--	0.2%

-- indicates data not available

Table 2: Distribution of minerals(mg/100g) in the fruit pulps of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

Nutritional components	<i>Chrysophyllum roxburghii</i> ^[36]	<i>Antidesma acidum</i> ^[16]	<i>Carissa carandas</i> ^[20,23]	<i>Averrhoa bilimbi</i> ^[37,38]	<i>Prunus jenkinsii</i> ^[29]
N	--	55	--	222	780
P	46.8	19	28	11.1	60
K	586.5	251	81.26	103.03	35
Ca	56.3	40	21	20.14	70
Mg	21.2	2.4	--	5.25	16
Fe	3.0	5.5	10.33	3.21	1.9
Mn	3.4	7.1	0.2	0.25	1
Zn	0.2	0.8	2.26	0.08	1.9
B	0.3	--	--	26.75	2.3
Cu	0.3	0.4	1.92	0.07	0.3
Na	4.2	36	--	5.3	16

-- indicates data not available

Table 3: Major Bioactive compounds present in *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

Fruit species	Plant parts	Phytoconstituents
<i>Chrysophyllum roxburghii</i>	Leaves	Total phenolic content (79.05mg Gallic acid equivalents/g); Tannins, alkaloids and terpenoids. ^[39]
	Fruits	Carotenoids (mgkg ⁻¹ wet weight) - violaxanthine (31.3±5.5); neoxanthin (113.3±17.2); lutein (0.4±0.1); β-carotene (1.4±0.3). ^[30]
<i>Antidesma acidum</i>	Roots	Acidumonate, 4-((E)-3,3-dimethylpenta-1,4-dienyl)-phenol, antidesmol (3), mellein, sitosterol, stigmaterol, 5-cholesten-3β-ol, 4-cholesten-3-one, 3-(1,1-dimethylallyl)-scopoletin, (-)- 5,7-dihydroxy-2-eicosyl-chromone, 2,5-dimethoxy-1,4-benzoquinone, barbatumol A, N-trans-feruloyltyramine, syringic aldehyde, p-hydroxybenzoic acid, taxifolin, (+)-catechin and gallicocatechin. ^[40]
	Leaves	Clauszoline B, clauszoline H, mukonal, 7-methoxymukonal and heptaphyline, 5-demethyltoddaculin, xanthoxyletin, and alloxanthoxyletin; flavons, tannins, coumarin, saponin, alkaloids, reducing sugar, oil. ^[16,41]
	Roots	alkaloids, flavonoids, saponins, cardiac glycosides, triterpenoids, phenolic compounds, tannins, 2-acetyl phenol, lignan, carinol, sesquiterpenes (carissone, carindone), lupeol, β-sitosterol, 16-β-hydroxybetulinic acid, β-amyirin, β-sitosterolglycoside, des-N-methylnoracronycine, scopoletin, 4-Amino-1-(4-amino-2-oxo-1(2H)-pyrimidinyl)-1,4-dideoxy-b-Dglucopyranuronic acid. ^[18,33]
<i>Carissa carandas</i>	Stem	Sesquiterpene, glucosides and alkaloids. ^[33]
	Leaves	triterpenoid, tannins, carissic acid, carandinol, betulinic acid, 4-hydroxybenzoic acid β-sitosterol-3-O-β-d-glucopyranoside, ursolic acid and oleanolic acid. ^[33]
	Flowers	myrcene, limonene, camphene, carene, dipentene, farnesol, nerolidol, α-terpeneol, citronellal, β-ionone, linalool, geranyl acetate, Menthol, p-Cymene, piperitone, neryl acetate and dihydrojasmone. ^[20,21]
	Fruits	carisol, epimer of α and β-amyirin, linalool, β-caryophyllene, carissone, carissic acid, carindone, ursolic acid, carinol, ascorbic acid, lupeol, β-sitosterol, 2-phenyl ethanol, isoamyl alcohol, isobutanol, benzyl acetate, Rutin, epicatechin, quercetin, kaempferol, piceatannol, resveratrol, syringic acid, vanillic acid, p-Coumaric acid, caffeic acid, ellagic acid and chlorogenic acid. ^[23,42]
	Seed	Hexadecanoic acid, Octadecanoic acid, eicosanoic acid, 9Z,12Z-Octadecadienoic acid, 9Z-Octadecenoic acid, fatty acids (66.42% palmitic acid, 9.36% stearic acid, 2.04% oleic acid and 0.99% linoleic acid). ^[21]
<i>Averrhoa bilimbi</i>	Barks	Alkaloids, saponins, flavonoids. ^[43]
	Leaves	Squalene, 3-(6,10,14-trimethylpentadecan-2-yl) furan-2 (5H)-one, 2,3-bis (2,6,10-trimethylundeca-1,5,9-trienyl) oxirane, phytol, 3,4-Dihydroxyhexanedioic acid, malonic acid, and 4,5-Dihydroxy-2-methylenehydroxybenzaldehyde; alkaloid, tannins, saponins, flavonoids, cardiac glycosides, glycosides, triterpenes, phenols, and carbohydrates. ^[43,44]
<i>Prunus jenkinsii</i>	Fruits	Oxalic acid (8.57 to 10.32 mg/g), 2-furaldehyde (19.1%), and (Z)-9-octadecenoic acid (10.2%); nicotinate (1.6%) and hexyl nicotinate (1.7%); nonanal (2.7 mg/kg), (Z)-3-hexenol (0.48 mg/kg), hexadecanoic acid (0.31 mg/kg), octane (0.29), tricosane (0.27 mg/kg), (E)-2-decenal (0.26 mg/kg), nonanoic acid (0.25 mg/kg), (Z)-9-pentacosene (0.24 mg/kg), 2-furfural (0.18 mg/kg), and (Z)-9-tricosene (0.11 mg/kg); 2,4-dihydroxy-6-((4-methylpentyloxy) methyl) benzaldehyde. ^[24,44]
	Leaves and seeds	No thorough phytochemical screening of this plant species have been done till date. But few research mentioned that compounds such as amygdalin and prunasin are present in most of the members of the genus <i>Prunus</i> , which on breakdown in water produces hydrocyanic acid. So, <i>P. jenkinsii</i> might contain cyanogenic glycosides such as amygdalin and prunasin in its leaves and seeds. ^[45,46]

Table 4: Fruit parameters of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii* with seasonal availability.

Name	Shape	Colour (at maturity)	Average weight	Ripening period
<i>Chrysophyllum roxburghii</i> ^[30,31]	Globose to oval	Yellowish-green	57.44 g	November- February
<i>Antidesma acidum</i> ^[32]	Ovoid	Purplish red	-	March-May
<i>Carissa carandas</i> ^[22,33]	globose to broadly oval	Reddish purple	1.6 to 4.7 g	May-December
<i>Averrhoa bilimbi</i> ^[24,34]	Ellipsoid to obovoid or nearly cylindrical	Yellowish-green	18.6 g	December-January
<i>Prunus jenkinsii</i> ^[27,29,35]	Broadly ellipsoid to ovoid	Dark purplish to black	23 g	March-April

Table 5: General classification and local names of the unconventional fruits of Upper Brahmaputra Valley, Assam.

	Order	Family	Vernacular Name
<i>Chrysophyllum roxburghii</i>	Ericales	Sapotaceae	Bon pitha (Ass) Thaibon-buphang (Kach) Theipabon (Kuki)
<i>Antidesma acidum</i>	Malpighiales	Euphorbiaceae	Heloch, Horu Heloch, Abutenga, Nekhong-tenga (Ass) Lapha-sakho (Mech) Aburok (Garo) Dieng-japeu, Chouding (Khashi) Ing-sum-arong (Mikir)
<i>Carissa carandas</i>	Gentianales	Apocynaceae	Karenja or Korja tenga (Ass) Karonda (Ben)
<i>Averrhoa bilimbi</i>	Oxalidales	Oxalidaceae	Bilombi tenga (Ass)
<i>Prunus jenkinsii</i>	Rosales	Rosaceae	Bon-thereju, Thereju (Ass) Dieng-soh-satang-hi (Khashi)

*Assamese (Ass), Kachari (Kach), Bengali (Ben)

are glabrous, obovate to elliptic-oblong with acute or obtuse base, apex acuminate or rounded. Inflorescence is simple, axillary, staminate inflorescence are 5–14cm long and cup shaped whereas pistillate flowers are 2–3 cm long. Fruits are small, and acidic in taste (Table 4).^[16]

***Carissa carandas* (Korja tenga)**

Carissa carandas locally known as Korja tenga in Assam is a large, evergreen, dichotomously branched, deciduous shrub with stems containing white, milky latex and hard spines (Table 5).^[17,18] This plant is native to India and distributed throughout the tropical and subtropical regions of the country.^[19] Flowers of this plant occur in clusters of 2-5 and are small, white in colour, showy and scented.^[20] Leaves are oblong, opposite, shiny, dark green on the top and pale brown below. Whenever the leaves or stems of this plant get injured, white milky latex comes out which is a characteristic feature of this plant. Fruiting occurs during the month of March-August and matures during May-December (Table 4).^[21] Fruits are fleshy, berry-like, occur in clusters of 3-10 and

are very attractive. They are greenish-white in colour while young and became reddish-purple at the time of maturity.^[22] Unripe fruits taste extremely sour while fully ripen fruits taste sweet to acidic with a characteristic aroma and bear many seeds about 3-5 in a single fruit.^[23]

***Averrhoa bilimbi* (Bilombi tenga)**

Averrhoa bilimbi is a short tree about 5-10 m tall (Table 5). The leaves are alternate and clustered at the tips. The inflorescence is a pendulous panicle with about 60 small purplish red flowers. Fruits are about 4 – 10cm long, ellipsoid to obovoid in shape and yellowish green in colour (Table 4).^[24] Nearly, 6-7 seeds are present in a single fruit. *Averrhoa bilimbi* is also known as *A. obtusangulata* and *A. obtusangula*.^[25] It is distributed in Indonesia, the Philippines, Singapore, Malaysia, Thailand, Myanmar, Bangladesh and India.

***Prunus jenkinsii* (Thereju)**

Prunus jenkinsii is a semi-domesticated plant that occurs mainly in Upper Assam (Sivasagar and Lakhimpur districts) and other parts of the North-east (Table 5).

It is also found in Andhra Pradesh extending eastwards upto Bangladesh, China and North Myanmar.^[26] *P. jenkinsii* is an evergreen, deciduous, medium-sized tree attaining a height of about 20-25 m with dark brown-grey branchlets. Leaves are simple, smooth, lanceolate-oblong lanceolate, without serrations and generally green in colour but at the time of falling, it turns yellow. As a result, two colours of leaves can be seen in a single tree. Flowering occurs during October-November and flowers are white in colour, solitary or arranged in axillary inflorescence.^[27,28] Fruits are fleshy, drupe, bearing only one seed, glabrous and rounded at the apex (Table 4). At the time of maturity, fruits turn into dark purplish-black colour. Raw fruits are acidic in taste and ripe fruits can be eaten fresh.^[29]

Nutritional composition of fruits

Fruits are considered as an excellent source of nutrients in the human diet due to their high quality edible proteins, fibres, water, Vitamin C and sugars. In addition to the commercially cultivated fruits, unconventional fruits are also a very rich source of iron, Vitamins (especially A, B, C) and minerals including proteins, carbohydrates, calcium, potassium, phosphorous, magnesium etc (Tables 1 and 2).^[3]

A comparison of ascorbic acid in the pulp among the species showed to be highest in *A. acidum* (about 48 mg/100 g) and lowest in *C. roxburghii* (about 5.4 mg/100 g). Whereas, total carbohydrate in the pulp was observed to be highest in *C. roxburghii* (about 19.9%) and lowest in *A. bilimbi* (about 0.05%). Total protein in the fruit pulp was highest in *A. acidum* (about 11.8%) and lowest in *C. carandas* (about 0.53%) (Figure 2).

Comparative analysis for available data of the major element in the fruit pulp of these fruits showed the highest presence of nitrogen, phosphorus and calcium in *P. jenkinsii*, potassium and magnesium in *C. roxburghii* (Figure 3 and Table 2). Trace elements *viz.* Fe, Zn and Cu were highest in *C. carandas* and Mn in *A. acidum* (Figure 4 and Table 2).

Phytochemistry of the fruit plants

Plants possess a wide range of phytoconstituents distributed in their roots, leaves, branches and fruits. The major phytochemical groups reported are alkaloids, flavonoids, phenols, saponins, steroids, glycosides, triterpenoids, and tannins.^[3] Unconventional fruits are a rich source of secondary metabolites, some of which are unique to a particular species and some may be present in most species. Their quantity may vary depending upon the plant part and also from plant to plant (Table 3).

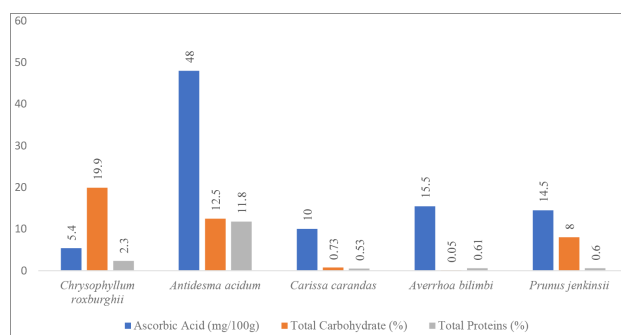


Figure 2: Comparison of Ascorbic acid content, total carbohydrate and total protein in the fruit pulp of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

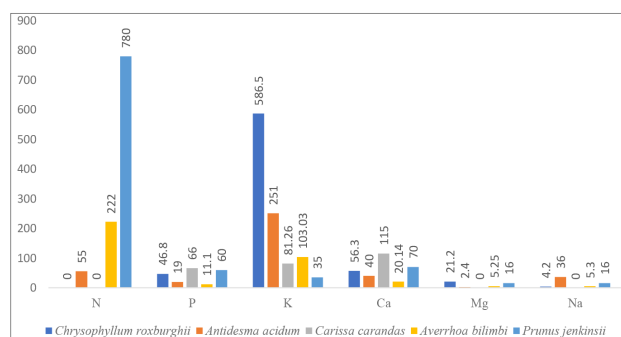


Figure 3: Distribution of major elements in the fruit pulp of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

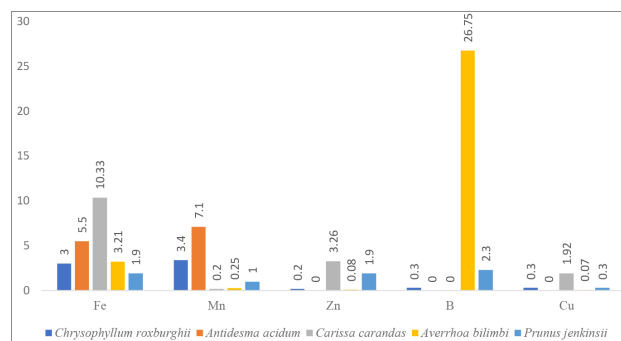


Figure 4: Distribution of trace elements in the fruit pulp of *C. roxburghii*, *A. acidum*, *C. carandas*, *A. bilimbi* and *P. jenkinsii*.

Traditional uses of the fruits

Cryosophyllum roxburghii

Roots and leaves of *C. roxburghii* have been used traditionally for the prevention and treatment of tooth decay, oxidative stress, obesity and cancer.^[39] Barks are used as a remedy to health issues like gastro-intestinal disorders, articular rheumatism and high blood sugar level. Bark decoction can be used as a cure for malaria

and yellow fever.^[47] In Sivasagar of Assam, seed formulations are used for the treatment of pneumonia.^[8]

Antidesma acidum

Leaf decoction of *A. acidum* is used against the treatment of stomach aches in children, digestion-related issues and diabetes, and headaches. Leaves are also eaten as vegetables by the bodo tribe of Assam.^[32] Stems are used to treat menstrual problems in women, and also as fuel wood.^[48] Ripe berries are eaten raw or used to prepare pickles, red wine, and juices; fruit decoction is used against anaemia, topical application of fruit is used to treat abdominal edema.^[49]

Carissa carandas

Leaves of *C. carandas* are used against fevers, earache, rheumatism, biliary Dysfunction, snake bite poisoning and syphilitic pain.^[19] Roots are used to reduce blood pressure, cure stomach disorders, scabies, diabetes, and ulcers, improve digestion, and kill intestinal worms.^[20] Decoction of stems is used to strengthen tendons.^[20] Fruits are eaten raw or used to prepare pickles, jams, jellies, candies, juices, squash, chutneys etc. Ripe fruits are used for the treatment of scurvy and burning sensations, anorexia nervosa, pruritus, and other skin related diseases. Unripe fruits are a remedy for anaemia.^[21]

Averrhoa bilimbi

Leaf pastes are applied on itches, boils, syphilis, swellings of mumps and rheumatism, and on skin eruption and bites of poisonous creatures.^[24] Fresh or fermented leaves are used as a treatment for sexually-transmitted diseases. Leaves are also used in coughs and used after childbirth. Leaf decoction is used to relieve rectal inflammation.^[44] Flowers are used against coughs and thrush. Flower pastes are used for fever.^[25] Fruit juice is used against scurvy, whooping cough, mumps, hypertension, obesity, and diabetes.^[34] Fruit Syrup is used for fever, and inflammation and to minimize rectal bleeding and alleviate piles; It also act as an antibacterial and astringent agent.^[37]

Prunus jenkinsii

Infusion of the crushed leaves is taken orally against kidney trouble.^[28] Stems are used for making handles for various household tools.^[14] Ripe fruits are eaten raw or used in making tarts, chutneys, jams, jellies and juices.^[20]

DISCUSSION

In Upper Brahmaputra Valley of Assam, *Chrysophyllum roxburghii*, *Antidesma acidum*, *Carissa carandas*, *Averrhoa bilimbi* and *Prunus jenkinsii* were found in wild-condition or in backyard gardens of local people. They utilise

these fruits in day-to-day life for various purposes such as food (pickles, beverages, juices, sweets, tarts, jellies, candies etc.), fooder and medicines. However, scientific knowledge of these unconventional fruits about their morphology, nutritional and phytochemical analysis is essential to identify, promote and expand the utilisation of these fruits for commercial purposes.^[3]

Studies on nutritional profiling of these fruits showed the presence of many essential micronutrients (Boron, Zinc, Iron, Manganese, Copper, Sodium) and macronutrients (Nitrogen, Phosphorus, Calcium, Potassium, Magnesium). These nutrients are required in a healthy diet for proper functioning of body. Also, phytochemical screening of different parts of these fruit plants showed the presence of many important bioactive compounds such as alkaloids, carotenoids, phenols, flavonoids, tannins, glycosides, saponins etc. These phytoconstituents are vital in pharmaceutical industries as they are capable of regulating metabolic processes and shows biological activities such as antioxidant, antimicrobial, anti-inflammatory, neuroprotective, anti-diabetic, anti-hypertensive etc. Prashith, et al. 2014 showed the radical scavenging activity of leaves and ascorbic acid of *Chrysophyllum roxburghii*, which were found to be (IC₅₀ 2.29µg/ml) and (IC₅₀ 3.54µg/ml) respectively. Itankar, et al. (2011) reported that the methanolic extracts of unripe fruits of *Carissa carandas* and its ethyl acetate soluble fragments significantly lowered increasing blood glucose levels by 48% and 64.5% when compared to diabetic control. Siddique, et al. (2013) revealed that the bark extracts of *Averrhoa bilimbi* shows moderate thrombolytic and antimicrobial activities and hence can be used to design different antimicrobial and thrombolytic agents. Thus, these unconventional fruits are a source of dietary nutrients and phytoconstituents, imparting many health benefits as like other commercially cultivated fruits.

CONCLUSION AND RECOMMENDATION

In this article, we have accounted for the nutritional benefits, important phytochemicals and the various traditional uses of the unconventional fruits found in Upper Assam. Studies on the phytochemistry and nutritional profiling of these fruits are limited. During the acquisition of publications for this article, it has been seen that not much research has been done on the species specially *Chrysophyllum roxburghii* and *Prunus jenkinsii*. We could get only a few papers on these two species due to which we have included some papers from before the period that we have taken for review. Even though it can be seen that all these fruits are rich

in minerals, vitamins and several phytochemicals but proper knowledge about their usefulness are limited. All five fruits are used in traditional medicine for various diseases but they are consumed and used as medicine in only those areas where they are found. Moreover, there is no clear evidence about the use of these fruit species in the pharmacological industry. Because of this lack of knowledge about the species, there is no proper conservation strategy for the fruits. As this article has described all the studies on these species, it will help in understanding their importance and need for conservation. However, more research needs to be done to understand the important constituents and their use in pharmaceuticals. This will make all five species more beneficial to mankind.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

N: Nitrogen; **P:** Phosphorus; **K:** Potassium; **Ca:** Calcium; **Mg:** Magnesium; **Fe:** Iron; **Mn:** Manganese; **Zn:** Zinc; **B:** Boron; **Cu:** Copper; **Na:** Sodium.

SUMMARY

Unconventional fruits are generally non-cultivated crops which lacks market value. In this review, some of the unconventional fruits of Upper Brahmaputra valley, Assam were taken into account for studying their nutritional, phytochemical and traditional uses. Literature searches revealed that these fruits have immense nutritional properties and they possess many important bioactive compounds. Studies also showed that these fruits have been used traditionally for various purposes. Different parts of these fruits have been used in folkloric medicines for curing diseases such as diabetes, obesity, kidney troubles, skin infections, hypertension etc. since from a very long time. Thus, these plants could be a potential source of raw materials in nutraceutical and pharmaceutical industries in future.

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