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REVIEW

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Bioactive constituents and health promoting compounds of underutilized fruits of the northern Himalayas of India: a review

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Abstract

Wild and underutilized plants bearing fruits widely grow throughout the northern Himalayas, including Himachal Pradesh, Jammu and Kashmir, Ladakh, and Uttarakhand states of India. The fruits of these plants have the potential for rural development in Northern Himalayas by developing more commercial products. *Ficus auriculata*, *Rubus ellipticus*, *Myrica esculenta*, *Ficus palmata*, *Pyracantha crenulate*, *Prunus armeniaca*, *Berberis asiatiica*, *Pyrus pashia*, *Rubus niveus*, *Carissa spinarum*, *Cordia dichotoma*, *Flacourtia indica*, *Malus sikkimensis*, *Olea ferruginea*, *Elaeagnus latifolia*, *Corylus jacquemontii*, and *Pinus gerardiana* are some examples of the plant species. Local people mainly consume the fruits of these plant species and a few of them are used for different processed food items such as jam, jelly, juice, squash, and sauce on a small scale. Therefore, fruits of wild and underutilized plants have potential nutritional values. They are widely used as sources of protein, fat, carbohydrate, macronutrients, and micronutrients. These fruits also contain multipurpose and diversified classes of phytochemical compounds such as flavonoids, tannins, terpenoids, saponins, glycosides, and alkaloids, which are applied to treat various human and livestock health ailments. The extracts of underutilized fruits are widely applied to treat cold, fever, fertility disorders, diabetes, and skin diseases. Their phytochemical compounds also demonstrated antipyretic, analgesic, anti-inflammatory, anticancer, antimicrobial, antiplasmodial, and antinociceptive activities. Thus, this review highlights the current research status about the nutritional profiling, chemical composition, and utilization of these valuable fruits effectively/adequately to develop new food and pharmaceutical products.

Keywords Phytochemicals, Wild fruits, Nutritional value, Health diseases

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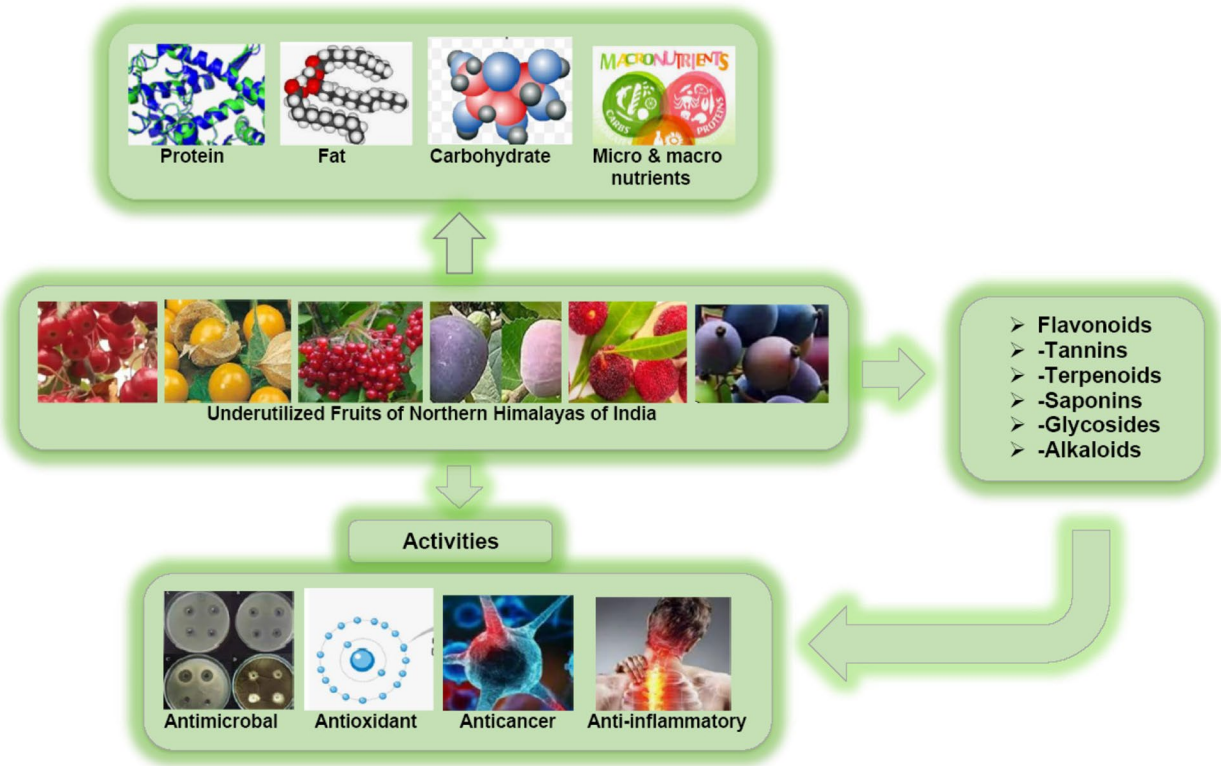
Graphical Abstract



Introduction

The world population is projected to reach 8 billion by November 2022 (UN report, World Population Prospects 2022). The output of crops must expand to feed the growing population, or the underutilized fruits and vegetables should be produced and utilized as daily food supplements. More than 7000 food species have been known, and only 30 crop species, mainly cereals and vegetables satisfy 95% of the world's food energy. However, fruits are the most underutilized crop in the world (Williams 2002). An earlier study demonstrated that almost all edible wild fruits possess various ethnomedicinal values and are in preparation for traditional medicines (Hazarika et al. 2016). Underutilized fruits are also reported for their potential food items and alternative commercial fruits (Dutta et al. 2018). Therefore, fruits play an essential role in the human diet and are also the source of many natural compounds that are antioxidants, antimicrobial, and anti-inflammatory agents (Slavin & Lloyd 2012; Husen 2021, 2022). They are also a source of dietary fibers, vitamins, and minerals, which increase their commercial value (Husen 2021, 2022). The health benefits and commercial importance can be seen in the recently published paper on different fruits, for instance, banana (Mengstu et al. 2021), papaya (Sharma et al. 2020), avocado (Jimenez et al. 2021), apple (Hammad & Rubeena 2021), sweet lime (Mahato et al. 2018), guava (Kumar, Tomar, et al. 2021), grapes (Hussain et al. 2021), and mango (Kumar, Saurabh, et al. 2021). Many published research reports also showed that fruits are the source of phytochemicals and minerals, and most are underutilized for one or more reasons. Underutilized fruits are seasonal and short-shelf-life crops. These characteristics are the biggest obstacles to these underused fruits' industrial and commercial applications (Kamboj et al. 2020; Lata et al. 2023). The Northern Himalayas region, including Jammu and Kashmir, Himachal Pradesh, Ladakh, and the Uttarakhand state of India, contain the diversified underutilized fruits of plant species. They are well recognized for their biodiversity,

cultural and spiritual values, and many medicinal plants and wild fruits (Panja et al. 2014; Kumar et al. 2016; Rymbai et al. 2016; Shri et al. 2018). Some of the wild fruits of plant species found in the Himalayas region are *Ficus auriculata*, *Rubus ellipticus*, *Myrica esculenta*, *Ficus palmata*, *Pyracantha crenulate*, *Prunus armeniaca*, *Berberis asiatiica*, *Pyrus pashia*, *Rubus niveus*, *Carissa spinarum*, *Cordia dichotoma*, *Flacourtia indica*, *Malus sikkimensis*, *Physalis peruviana*, *Ziziphus mauritiana*, *Viburnum mullahaa*, *Olea ferruginea*, *Elaeagnus latifolia*, *Corylus jacquemontii*, and *Pinus gerardiana* (Sharma et al. 2013; Khurram & Shalizi 2016; Chandran & Ravikumar 2017; Prakash et al. 2021). Local people consume underutilized fruits to fulfil their needs. Creating commercial and nutritional products from underutilized fruits in the Northern Himalayas region provides another option for exploiting these resources and encouraging new export channels (Kumari 2012). These fruits have been used as a folk medicine for the treatment of cough, cold, fever, skin disease, fertility disorders, and diabetes in the Northern Himalayas region since the ancient period of time (Oza & Kulkarni 2017; Saleem et al. 2018). A plethora of literature reviews are available on the phytochemicals, nutritional value, and some applications of the underutilized fruits of plant species found in the northern Himalayas region. For instance, the phytochemicals of underutilized fruits such as alkaloids, flavonoids, terpenoids, tannins, steroids, saponins, and glycosides have been reported for their potential treatment of diarrhoea, cough, tenderness, joint pains, dysentery, microbial infection, chest pains, epilepsy, cancer, arthritic swelling, skin disorders, inflammation, hepatic disorders, leucorrhoea, haemoptysis, lungs, and bladder diseases (Alqasoumi et al. 2014; Chauhan et al. 2014; Oza & Kulkarni 2017; Hanan et al. 2020; Zhang et al. 2021). However, all scientific data are scattered and need to be collected, organized, and reported concisely. Therefore, to summarize and present the most pertinent and trustworthy research findings and potential future commercial applications, this review article attempts to compile all the data about the medicinal, phytochemical, and nutritional value of these underutilized fruits of plant species on a single platform.

Methods

More than 100 publications were used as primary source of information for this review paper. Journal articles, review papers, proceedings, short communication, book, and book chapters were downloaded from databases such as Google Scholar, Scopus, and Web of science. Keywords include underutilized fruits of the northern Himalayas of India, nutritional value, the medicinal value of underutilized fruits of the Northern Himalayas of India, and phytochemicals from underutilized fruits of the Northern Himalayas of India were used to search for the information. Additional important articles were also examined based on the reference list of the retrieved papers.

Distribution, botany, and use of underutilized fruits of the northern Himalayas of India

The distribution, botany, and uses of underutilized fruits are presented in Fig. 1a, b, and Table 1.

Berberis asiatica (Family: Berberidaceae; English name: Indian or Asian barberry)

B. asiatica is an upright, spiny and glabrous bush. This shrub grows wildly in the sub-Himalayan tract at an altitude of 600–2700 m. This plant is native to the Himalayas and Himachal Pradesh. It occurs in subtropical to temperate regions: Bilaspur, Hamirpur, Mandi, Solan, Nahan, Nalagarh, Dere Gopipur, Nurpur, Kangra, Sirmaur, Kullu, Shimla, and Chamba (Shri et al. 2018). Its fruit has a blood-red color and potential nutraceutical values. The fruit extract possesses a potential source of polyphenolic, mainly anthocyanin compounds, which are responsible for treating inflammation diseases (Neag et al. 2018).

Carissa spinarum (Family: Apocynaceae; English name: Conkerberry, wild karanda or bush plum)

C. spinarum is a minor evergreen bush rising all over India in dry areas. This shrub is distributed in tropical Asia, Africa, and Australia. In India, it occurs wild and in semi-arid areas and Kangra, Hamirpur, Bilaspur, Una, Mandi, Solan, and Sirmaur districts of Himachal Pradesh. Its fruit extracts demonstrated antioxidant and antidiabetic properties (Shri et al. 2018; Jamkhande et al. 2013).

Cordia dichotoma (Family: Boraginaceae; English name: glue berry/Indian Cherry)

C. dichotoma is one of the old-style therapeutically significant deciduous plants obtainable in India. It is native plant species to China and grows in the sub-Himalayan tract and its outer ranges (Shri et al. 2018). *C. dichotoma* is a minor to medium-sized deciduous bush with a little curved stem, small trunk, and dispersal peak. The ripe fruit of *C. dichotoma* yields a jelly-like, tacky bulk. Fruits of *C. dichotoma* are eatable with gummy flesh build. Joshanda polyherbal formulations are extensively cast off by many in India to manage cold, coughs, respiratory problems, and fevers. Unani's method of medication drug habits houseplant as antiseptic, antiviral, and antitussive. Its fruits are a rich source of polysaccharides. Fruits are potential sources of phytochemicals with antibacterial and antioxidant activities (Rahayu et al. 2017).

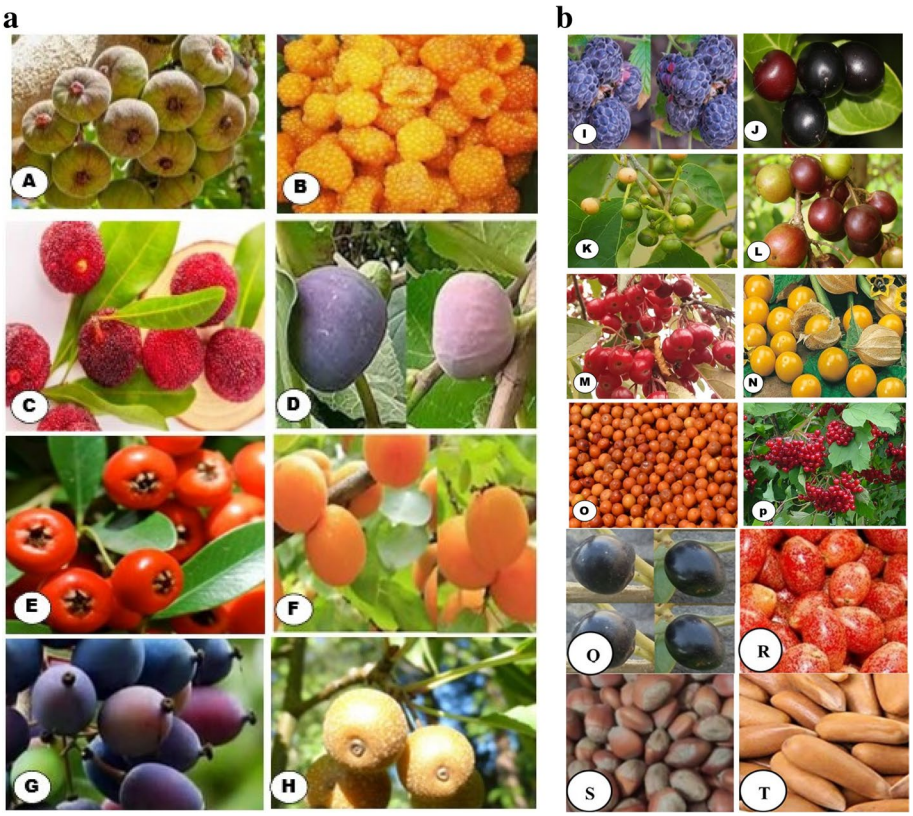


Fig. 1 **a** Images of important underutilized fruits of the northern Himalayas (A) *Ficus auriculata*, (B) *Rubus ellipticus*, (C) Myrica esculenta, (D) *Ficus palmata*, (E) Pyracantha crenulate, (F) *Prunus armeniaca*, (G) Berberis asiatiica and (H) Pyrus pashia. **b** Images of important underutilized fruits of the northern Himalayas (I) *Rubus niveus*, (J) Carissa spinarum, (K) *Cordia dichotoma* (L) *Flacourtia indica*, (M) *Malus sikkimensis*, (N) *Physalis peruviana*, (O) *Ziziphus mauritiana* and (P) Viburnum mullahaa (Q) *Olea ferruginea*, (R) Elaeagnus latifolia, (S) Corylus jacquemontii, and (T) *Pinus gerardiana*

Corylus jacquemontii (Family Betulaceae; English name: Jacquemont's Hazel)

C. jacquemontii is a deciduous nut-bearing tree around 21 m high, it flowers from April to May, and its seeds ripen from September to October. The plant species is one of the most esteemed tree nuts of the western Himalayan region (Kumar et al. 2016). It is distributed worldwide, mainly in Turkiye, Italy, Spain, France, Greece, India, Iran, Azerbaijan, and China. It is an important aromatic plant species containing nutritional and therapeutic properties (Nengroo et al. 2022). *C. jacquemontii* is of great importance because of its multipurpose use as food, fuel, fodder, and medicine (Paul et al. 2019). The fruit of this plant is required as a diet due to its richness in oleic acid, α-tocopherol, β-sitosterols, polyphenols, and squalene (Nengroo et al. 2022).

Elaeagnus latifolia (Family Elaeagnaceae; English name: Bastard oleaster)

E. latifolia is a deciduous shrub growing to a maximum height of 3 m and expands maximally to 3 m with a growing speed of medium rate. Its fruit is a wild edible found in northeast India, Thailand, and Vietnam (Panja et al. 2014). The fruit of *E. latifolia* (wild olive) is unpreserved and stays only for a short duration of 4–5 weeks in September/October (Basumatary et al. 2020). The fruit of the plant species is oblong in shape with a dark pink color at the time of ripening and eaten raw, as well as used for making chutney, jam, jelly, and refreshing drinks. It is a rich source of essential fatty acids, vitamins, minerals, and other bioactive compounds (Panja et al. 2014).

Ficus auriculata (Family Moraceae; English name: Roxburgh Fig)

F. auriculata is a kind of fig seen throughout Asia, indicated by its extensive and curved leaves. The plant is native to the Himalayas. It occurs in sub-tropical areas: Bilaspur, Hamirpur, Mandi, Nahan, Nalagarh, Dere Gopipur, Nurpur, and Kangra of Himachal Pradesh (Shri et al. 2018) and Garhwal (Chamoli, Dehradun, Haridwar, Pauri, Rudraprayag, Tehri and Uttarkashi) and Kumaun (Almora, Bageshwar, Champawat, Nainital, Pithoragarh)

Table 1 Flowering and Fruiting information of underutilized fruits of the Northern Himalayas

Scientific name and family	Local name	Location	Flowering time	Fruiting (Harvest) time	Key reference
Artocarpus lacucha (Moraceae)	Lakooch (Hindi) Dheu (Kangri)	Himachal Pradesh	March -April	June - September	(Vanajakshi et al. 2016; Shri et al. 2018)
Berberis asiatiica (Berberidaceae)	Darhaldi (Hindi), Kashmal (Kangi), Kashmir (Garhwali)	Himachal Pradesh	From mid of March to end of April	May to June	(Neag et al. 2018)
Carissa spinarum (Apocyanaceae)	Garna (Kangri) Jangli karonda (Hindi)	Jammu and Kashmir, Himachal Pradesh	March-May	June – September	(Ansari & Patil 2018; Ansari & Patil 2018; Fatima et al. 2013)
Cordia dichomata (Boraginaceae)	Lasoora (Kangri)	Jammu and Kashmir and Himachal Pradesh	March-May	July – September	(Ansari & Patil 2018; Aimey et al. 2020)
Corylus acquemontii (Betulaceae)	Thangi, Bhotiya Badam, Urmuni, Sharoli and Sharod	Lahaul and Spiti, Kinnaur, Chamba, and Kullu	April-May	September-Octomber	(Kumar et al. 2016)
Cydonia oblonga (Rosaceae)	Beeddana (Dogri)	Kashmir	January - March	June-July	(Al-Snafi 2016; Kurian & Sankar 2007; Prajapati et al. 2003)
Elaeagnus latifolia (Elaeagnaceae)	SohShang, Sibsagar	Meghalaya	September-October	March-April	(Panja et al. 2014; Rymbai et al. 2016)
Ficus auriculata (Moraceae)	Timla (Pahadi)	Uttarakhand and Himachal Pradesh	Starting the primary week of March and endures till the April last	June - August	(Ansari & Patil 2018; Chandran & Ravikumar 2017)
Flacourtia indica (Salicaceae)	Kakoa (Dogri)	Jammu and Kashmir	December - April	March - July	(Slathia et al. 2017)
Ficus palmata (Moraceae)	Bedu (Dogri) Dudha (Pahadi)	Uttarakhand, Himachal Pradesh, Jammu and Kashmir	March to April	Mid-June to mid-July	(Joshi et al. 2014)
Hippophae sps. (Elaeagnaceae) *rhamnoides* (Ladakh and Himachal Pradesh) *salicifolia* and *tibetana*. (Uttarakhand)	Suri and Chharma (Dogri)	Ladakh (Mainly), Himachal Pradesh and Uttarakhand	June-July	October-November	(Shri et al. 2018; Slathia et al. 2017; Sankhyan et al. 2004)
Malus sikkimensis (Rosaceae)	Jangli Sev (Hindi)	Himachal Pradesh	April-May	September	(Shri et al. 2018)
Myrica esculenta (Myricaceae)	Kafal (Garhwali) Kaiphal (Dogri)	Uttarakhand and Himachal Pradesh, Jammu and Kashmir	From February to second week of April	May-June	(Kumari 2012)
Olea ferruginea (Oleaceae)	Kahoo	Himachal Pradesh	March-September	August-November	(Sharma et al. 2013)
Physalis peruviana (*Solanaceae*)	Dophalu (kagri) Rasbhari (Hindi)	Himachal Pradesh	August- October	October-November	(Shri et al. 2018; Singh et al. 2019; Chandran & Ravikumar 2017)
Pinus gerardiana (Pinaceae)	Chilgoza	Sutlej, Ravi and Chenab valley (India),	May-June	August-September	(Haq et al. 2013; Kumar et al. 2013; Khurram & Shalizi 2016)
Prunus armeniaca (Rosaceae)	Khubani (Hindi) Zardalu (Pahadi), Chuli (Dogri)	Uttarakhand and Himachal Pradesh	March to April	May to mid-August	(Shri et al. 2018; Rai et al. 2016)
Pyracantha crenulate (Rosaceae)	Ghigharu (Kumauni)	Uttarakhand	April to May	June to September	(Weber 2017)
Pyrus pashia (Rosaceae)	Kainth (Pahadi)	Himachal Pradesh and Jammu and Kashmir	February - March	July to September	(Shri et al. 2018; Prakash et al. 2021)
Rubus ellipticus (Rosaceae)	Hisalu (Pahadi), Hisol (Kangri)	Uttarakhand	January-April	May-June	(Sharma et al. 2019)
Rubus niveus (Rosaceae)	Kala Hinsalu (Kangri)	Himachal Pradesh	May - June	August - September	(Shri et al. 2018; Pancholi & Rana 2020)

Table 1 (continued)

Scientific name and family	Local name	Location	Flowering time	Fruiting (Harvest) time	Key reference
Viburnum mullaha (Viburnaceae)	Molo (Pahadi) Ghenu (Dogri)	Uttarakhand and Himachal Pradesh	April-May	June-July	(Shri et al. 2018; Maikhuri et al. 2012)
Ziziphus mauritiana (Rhammnaceae)	Ber (Hindi) Jharberi (Pahadi)	Himachal Pradesh	June to September	November to February	(Shri et al. 2018; Prakash et al. 2021)

region of Uttrakhand. *F. auriculata*, Coconut strawberry is one of the best attractive figs; all the fig fruits are edible. On ripening, fruits turn light yellow to purple. The fruit is a fleshy receptacle that contains many natural fruits. Phenolic compounds are the main components of fruit extracts (Gaire et al. 2011).

Ficus palmata (Family: Moraceae; English name: Wild Himalayan fig)

F. palmata is originated as rising harsh in the Himalayan area of North Western India. This plant species occurs in Garhwal as well as kumaun region of Uttarakhand and also in sub-tropical to sub-temperate areas of Himachal Pradesh: Bilaspur, Hamirpur, Jogindernagar area of Mandi, Nahan, Nalagarh, Dere Gopipur, Nurpur and Palampur and Dharamsala of Kangra district, Dalhousie area of Chamba district (Shri et al. 2018). The whole fruit, along with the seeds, is edible. The fruits treat inflammation, analgesic, and pathogenic bacterial ailments (Shi et al. 2014).

Flacourtia indica (Family: Salicaceae; English name: Aarlia of Panjali)

F. indica is found in Africa and Asia, where it is widespread. It is present in South and Southeast Asia, including India, China, and South Indonesia. It is a native medicinal plant extensively scattered in India. This plant species treat functional disorders like rheumatoid arthritis and gout. Its berries are eatable; the bark triturated in sesamum oil is used as alignment in rheumatism. Similarly, the extract of its fruit has diuretic, hepatoprotective, and antidiabetic properties (Patro et al. 2013).

Malus sikkimensis (Family: Rosaceae; English name: Crab Apple)

M. sikkimensis is native to China, Nepal, Bhutan, and part of India, mainly in the Himachal Pradesh districts. Its fruits are dark red color at the maturation stage and are edible. Fruits are the primary source of dietary dihydrochalcones and flavonoids. The extract of the fruit of *M. sikkimensis* showed protective and therapeutic properties (Shri et al. 2018).

Myrica esculenta (Family Myricaceae; English name: Bayberry)

The berries of *M. esculenta* are globose, succulent drupes (Kumari 2012). *M. esculenta* is native to Northern India. It is mainly distributed in Uttarakhand, subtropical to sub-temperate areas of Himachal Pradesh: Bilaspur, Hamirpur, Jogindernagar area of Mandi, Nahan, Nalagarh, Dere Gopipur, Nurpur and Palampur and Dharamsala of Kangra district, Dalhousie area of Chamba district and also in Jammu and Kashmir. It is a popular wild edible fruit in the Himalayan region of India. Polyphenols, carotenoids, and vitamin C are some phytochemicals screened from the fruits of *M. esculenta*. The extract of the fruit of plant species was reported to lower oxidative stresses (Shri et al. 2018).

Olea ferruginea (Family: Oleaceae; English name: Indian olive)

O. ferruginea species grows widely in the Himalayas from Kashmir to Kumaun, between 500 and 2000 m above sea level. *Olea* species grow commercially in India, Pakistan, China, and Nepal (Hassan et al. 2022). It is one of the 35 species in *the Olea* genus: evergreen shrubs and trees. This plant species produce edible fruits. The fruits of plant species contain a biologically important oleanolic compound isolated from the chloroform extract (Anwar et al. 2013). The ripened fruits of *O. ferruginea* serve as a source of natural antioxidants due to their potential total phenolic compounds (Sharma et al. 2013). Traditionally, the fruit of *O. ferruginea* is supplied as medicine (Hassan et al. 2022).

Physalis peruviana (Family: Solanaceae; English name: Rasbhari)

P. peruviana is known as cape gooseberry. This plant is native to Brazil but became naturalized in tropical to sub-tropical regions of the world. In Himachal Pradesh, the plant is distributed in tropical and sub-tropical areas: Bilaspur, Hamirpur, Mandi, Nahan, Nalagarh, Dere Gopipur, Nurpur, and Kangra (Shri et al. 2018). They possess exotic goldenberry and multifunctional fruits. Its fruit extracts antioxidant and anti-inflammatory properties (Shah & Singh Bora 2019).

Pinus gerardiana (Family: Pinaceae; English name: Pine nuts)

P. gerardiana has a restricted ecological distribution in the North-Western Himalayas. It is found in the dry temperate region between 1600 and 3000 m above sea level (Kumar et al. 2013). *P. gerardiana* is mainly distributed in India, Pakistan, and Afghanistan. Dry fruits of *P. gerardiana* are rich in dietary nutrients, minerals, and phytochemical compounds. Pine nuts are a promising linoleic and oleic acid source, which inherit antioxidant properties (Haq et al. 2013). According to the earlier in vitro and animal disease model studies, the phytochemicals obtained from the solvent extract of pine nuts showed potential antioxidant and antidiabetic activities (Zulfqar et al. 2020).

Prunus armeniaca (Family: Rosaceae; English name: Wild apricot)

P. armeniaca is a wild apricot and significant seasonal tree in the thirsty reasonable parts of the North-Western

Himalayas. It is native to East Asia and occurs in sub-temperate: Palampur and Dharamsala of Kangra District, Jogindernagar area of Mandi district, and Dalhousie area of Chamba district to temperate parts: of Mandi, Solan, Chamba, Kangra, Sirmaur, Kullu, and Shimla of the Himachal Pradesh and Uttarakhand in India (Shri et al. 2018). Its fruits are rich in polyphenols, vitamins, and minerals and show anti-oxidative properties (Rai et al. 2016).

Pyracantha crenulate (Family: Rosaceae; English name: Himalayan firethorn)

P. crenulate is a native range from North to Northwest Pakistan, India, and China. In India, it occurs wildly in the Nainital, Almora, Pithoragarh, Champawat, Bageshwar, and Ranikhet districts of Uttarakhand (Shri et al. 2018). The plant is used in herbal drugs and is usually collected from forest areas for unrelated therapeutic arrangements, such as brews of dehydrated fruits, fluid sources, and tinctures. Its fruits are a virtuous basis of nutrition for wild faunas. *P. crenulate* is valuable in tumbling the risks of heart failure, cardiac issues, and hypertension. When eaten with yogurt, Berries help recover from bloody dysentery (Singh et al. 2012).

Pyrus pashia (Family: Rosaceae; English name: Wild Himalayan Pear)

P. pashia is native to Southern Asia and occurs in Jammu and Kashmir and sub-tropical to temperate areas of Himachal Pradesh: Bilaspur, Hamirpur, Mandi, Solan, Nahan, Nalagarh, Dere Gopipur, Nurpur, Kangra, Sirmaur, Kullu, Shimla and Chamba (Shri et al. 2018). *P. pashia* trees are found between 750 and 2600 m in the Himalayas. Its fruits are light green-blackish-brown in colour. The fruits are a source of phenolic compounds with potential scavenging activities (Shri et al. 2018; Prakash et al. 2021).

Rubus ellipticus (Family: Rosaceae; English name: Yellow Himalayan Raspberry)

R. ellipticus is native to India and South Asia. It occurs in Uttarakhand and sub-tropical to temperate: Bilaspur, Hamirpur, Mandi, Nahan, Nalagarh, Dere Gopipur, Nurpur, and Kangra of Himachal Pradesh (Lowe et al. 2000; George et al. 2013; Shri et al. 2018). The fruits of *R. ellipticus* are edible (Wu et al. 2014; Pandey & Bhatt 2016). The fruits are golden yellow and important nutraceutical and functional foods. The fruit extracts of *R. ellipticus* displayed antimicrobial properties (Ding et al. 2008).

Rubus niveus (Family: Rosaceae; English name: Mysore raspberry)

R. niveus is a remarkably invasive continuous bush local to India. The plant is distributed in subtropical to temperate areas of Himachal Pradesh: Mandi, Solan, Chamba, Kangra, Sirmaur, Kullu, and Shimla (Shri et al. 2018). The genus Rubus has an important action to help in diabetes remains stated to crop mixes that exert hypoglycaemic, sterile, anti-allergic, and anti-asthmatic doings (Daubeny et al. 1996; Jennings 1988). *Rubus* berries have gastroprotective, antioxidant, and nutraceutical values (Pancholi & Rana 2020).

Viburnum mullaha (Family: Viburnaceae; English name: Starry viburnum)

V. mullaha is one of the unemployed rough, comestible florae in the Indian Himalayas. *V. mullaha* is native to the Himalayas, Southeast Asia and is distributed in sub-temperate: Palampur and Dharamsala of Kangra District, Jogindernagar area of Mandi district and Dalhousie area of Chamba district to temperate parts: Mandi, Solan, Chamba, Kangra, Sirmaur, Kullu, and Shimla of the Himachal Pradesh. This plant cultivates richly in nature at an altitude of 1500–3300 m overhead sea level in Uttarakhand, Jammu and Kashmir (Shri et al. 2018). The berries of *V. mullaha* are reddish-yellow, very nourishing, delicious, and ironic in minerals and vitamins (Singh et al. 2017).

Ziziphus mauritiana (Family: Rhammnaceae; English name: Indian jujube)

Z. mauritiana is a spiny fruit tree that grows in tropical and sub-tropical regions worldwide. *Z. mauritiana* is one of the important medicinal plants found in Uttarakhand, India (Dhanik et al. 2017; Batool et al. 2018). Its fruits have various medicinal and food values. It is an ironic basis of lupine cyclopeptide alkaloids and triterpenes. Cyclopeptide macrocycles of the *Ziziphus* species exhibit stimulating biological properties, including sedative, analgesic, antibacterial, antifungal and antiplasmotic effects. The plant relieves pitta disorders, kapha, obesity, fever, burning, coughing, wounds, skin diseases, ulcers, stomatitis, diarrhoea, sexual weakness and general weakness (Upadhyay et al. 2012).

Phytochemical compositions and nutritional profile of underutilized fruits of the northern Himalayas of India

Fruits are a rich source of various phytochemical compounds, including alkaloids, phenolic compounds, terpenes and terpenoids, saponins, proteins, fats, carbohydrates, vitamins, and minerals which have comprehensive health benefits (Krishnamurthy & Sarala 2013; Ahmad et al. 2015; Joshi & Joshi 2015). Most of the underutilized fruits mentioned in Tables 2, 3 and 4 and Fig. 2 are rich sources of these compounds.

Table 2 Bioactive compounds extracted from underutilized fruits of the northern Himalayas

Scientific name and family	English name	Phytochemical present	Medicinal uses	Key reference
Artocarpus lacucha (*Moraceae*)	Monkey fruit	Tannins, terpenoids, saponins, glycosides, alkaloids, steroids, quercetin, and kaempferol	Used as astringent and purgative, treat dysentery and arthritic swelling, prevent skin diseases, and clean wounds.	(Saleem et al. 2018)
Berberis asiatiica (Berberidaceae)	Indian barberry	Alkaloids (berberine), glycosides, flavonoids, phenolic acids, resin, carbohydrates and tannins	For the management of respiratory issues, problems related to eyes, jaundice, pigmentation on skin, and tooth pain, as well as for favouring the removal of redness and puffiness, and for ulcers.	(Saklani et al. 2011)
Carissa spinarum (Apocynaceae)	Conkerberry or bush plum	Alkaloids, flavonoids, tannins, and terpenoids and carbohydrates	Used in the management of tenderness, joint pains, microbial infection, epilepsy, viral infection, cancer disease	(Ansari & Patil 2018)
Cordia dichomata (Boraginaceae)	Glue berry/ Indian Cherry	Alkaloids, phenols, flavanol (Isorhamnetin, quercetin, and kaempferol) and glycosides	For management of cough, chest pains, sour throat, treatment of animal's intestinal problems and used as gum	(Oza & Kulkarni 2017)
Corylus acquemontii (Betulaceae)	Jacquemont's Hazel	Tannins, carotenoids, and polyphenols	Antioxidative properties, ability to reduce risk of certain type of cancers, coronary heart disease, cardiovascular disease, stroke, atherosclerosis, osteoporosis, inflammation and other oxidative stress-associated ailments	(Kumar et al. 2016)
Cydonia oblonga (Rosaceae)	Beeddana	Flavonoids (quercetin, kaempferol), flavan-3-ols, phenolic acids, alkaloids, polyphenols, mainly coumaroyl-quinic acid, mono and di caffeoylquinic acids, oxalic acid, citric acid, ascorbic acid, and fumaric acids, terpenes and tannins	Used as harsh, antiseptic, hepatoprotective, cicatrising, anti-inflammatory; for management of diarrhoea, dysentery, hepatic disorders, leucorrhoea, haemoptysis, uterine haemorrhages, and wound	(Zhang et al. 2021; Hanan et al. 2020)
Elaeagnus latifolia (Elaeagnaceae)	Bastard oleaster	Terpenoids, triterpenoids, and anthraquinones	Antioxidative properties	(Panja et al. 2014; Basumatary et al. 2020)
Ficus auriculata (Moraceae)	Roxburgh Fig	Alkaloids, saponins, glycosides, tannins, diterpenes, flavonoids, and some other compounds such as betulinic acid, lupeol, stigmasterol, β-sitosterol-3-O-β-D-gluco pyranoside, myricetin and quercetin-3-O-β-D-glucopyranoside, resins, and tannins	Leaves are applied on wounds and also used as fodder. Stem and bark juice used to treat diarrhoea, wounds and small cuts.	(Mehra & Tandon 2021; Thingbaijam et al. 2012; Saklani et al. 2012)
Flacourtia indica (Salicaceae)	Aarlia of Panjali	Alkaloids, flavonoids, saponins, terpenes, tannins and glycoside	Used in the treatment of various illnesses like liver problems, joint pain, bone inflammation and treatment of gout.	(Patro et al. 2013)
Ficus palmata (Moraceae)	Wild Himalayan fig	Alkaloids, phenols, tannins, flavonoids, terpenoids and anthocyanins, ascorbic acid, cardiac glycosides. trans-psoralenoside, furanocoumarins, vanillic acid flavone, glycoside, and rutin	Source of mineral and phosphorous, also used in the treatment of lungs and bladder diseases.	(Alqasoumi et al. 2014; Chauhan et al. 2014)

Table 2 (continued)

Scientific name and family	English name	Phytochemical present	Medicinal uses	Key reference
Hippophae sps. (Elaeagnaceae) *rhamnoides* (Ladakh and Himachal Pradesh) *salicifolia* (Uttarakhand) and *tibetana.*	Sea buckthorn	Polyphenols, flavonoids, tannins, terpenes, carbohydrates and carotenoids	For pain-relieving, cough suppressant, digestive tonic, and promoter of blood-flow in heart and chest pains, abdominal dysfunctions, spleen deficiency, to reduce food intake, and stasis due to injuries from falls.	(Pundir et al. 2021)
Malus sikkimensis (Rosaceae)	Crab Apple	Alkaloids, phenolics, flavonoids, saponins, tannins, chlorogenic acid, epicatechin, rutin, hyperin, and phlorizin	Used to heal and obviate constipation.	(Li et al. 2014)
Myrica esculenta (Myricaceae)	Bayberry	Alkaloids, flavonoid, saponins, tannins, gallic acid, chlorogenic acid, p-coumaric acid, glycosides, terpenes, triterpenoids, ascorbic acid, catechin, chlorogenic, caffeic acid, myricetin, L-hydroxyproline, iso-leucine, valine, L-cysteine hydroxychloride, alanine, tryptophan, glutamic acid, tyrosine, threonine, leucine, lysine monochloride, furfural, oxirane, myo-inositol, and 1-ethyl-4 methylcyclohexane	Used in the management of ulcers and numerous other illnesses.	(Kabra et al. 2019; Sood & Shri 2018; Rawat et al. 2013)
Olea ferruginea (Oleaceae)	Indian olive	Polyphenols, quinones, flavonoids, catechins, coumarins, terpenoids	Antioxidant properties	(Sharma et al. 2013)
Physalis peruviana (*Solanaceae*)	Rasbhari	Alkaloids, phenols, flavonoids, saponins, terpenes, carbohydrates, tannins and glycosides	Used as therapeutic such as anti-spasmodic, diuretic, antiseptic, sedative, and analgesic.	(Bharthi et al. 2016)
Pinus gerardiana (Pinaceae)	Pine nuts	Phenols, terpenes, flavonoids, alkaloids, and saponins	Asthma, diabetes, neurodegenerative diseases, cancer, oxidative stress related diseases, cardiovascular-related problems, liver and kidney disorders, and various pathogenic infections	(Zulfqar et al. 2020; Bhardwaj et al. 2022)
Prunus armeniaca (Rosaceae)	Wild apricot	Flavonoids, tannins, saponins, alkaloids, sorbitol, phytosterol, fatty acids, eugenol, and carotenoids	Rich in vitamin C and potassium and helps in maintaining cholesterol level	(Sharma et al. 2014; Alajil et al. 2021)
Pyracantha crenulate (Rosaceae)	Himalayan firethorn	Flavonoids, terpenoids, glycoside, anthocyanins, ascorbic acid and tannins	Used in various cardiovascular diseases, hypertension, and heavy bleeding in the menstrual cycle	(Sati 2017)
Pyrus pashia (Rosaceae)	Wild Himalayan Pear	Flavonoids, anthocyanins, ascorbic acid and polyphenols	Used to treat constipation, ailments, like dysentery, eye conditions, abdominal issues (dyspepsia), headaches, diaphoretic, hysteria, epilepsy, anaemia, sore throat, irritability, dysmenorrhea, also as astringent and has diuretic properties.	(Siddiqui et al. 2015)

Table 2 (continued)

Scientific name and family	English name	Phytochemical present	Medicinal uses	Key reference
Rubus ellipticus (Rosaceae)	Yellow Himalayan raspberry	Flavonoids, glycosides, steroids, phenols, tannins, antioxidants, anthocyanin, ascorbic acid, and resin	Provide energy for travellers or hikers.	(Saklani et al. 2012)
Rubus niveus (Rosaceae)	Mysore raspberry	Phenols, alkaloids, flavonoids, saponins, terpenes, carbohydrates and tannins	Decreases joint and bone pain, detoxifies, clear wind moist and deals with dysentery	(Pancholi & Rana 2020)
Viburnum mullaha (Viburnaceae)	Starry viburnum	Flavonoids	Possesses hypotensive, calming, antispasmodic, and anti-inflammatory properties	(Singh et al. 2017)
Ziziphus mauritiana (Rhammnaceae)	Indian jujube	Flavonoids, tannins, alkaloids and saponins.	It helps improve muscular strength and weight and acts as a sweet nutritive, aphrodisiac, and appetizer.	(Prakash et al. 2021; Cheema et al. 2017)

Table 3 Nutritional profile of underutilized fruits of the Northern Himalayas

Scientific name	Moisture (%)	Protein (g/100 g)	Fat (g/100 g)	Carbohydrate (g/100 g)	Calcium (g/100 g)	Phosphorus (g/100 g)	Iron (g/100 g)	Key reference
Artocarpus lacucha	90	2	1	–	0.067	0.025	–	(Vanajakshi et al. 2016)
Berberis asiatiica	65.20	3.30	0.80	24.98	0.065	0.079	0.012	(Saklani et al. 2011)
Carissa spinarum	58.62–62.1	1.24–1.42	4.94–5.33	25.92–28.42	0.0836–0.118	0.02802–0.03812	0.0015–0.0030	(Siyum & Meresa 2021)
Cordia dichotoma	60.04	35	37	18	0.06	0.28	0.006	(Jamkhande et al. 2013; Aimey et al. 2020)
Cydonia oblonga	80.36 -84.27	0.60	0.24–2.29	9.10	0.066	0.025	0.001	(Al-Snafi 2016; Rasheed et al. 2018; Gani et al. 2018)
Elaeagnus latifolia	87.31	7.8	0.52	74.06	1.47	–	0.18	Kumar & Said 2018
Ficus auriculata	87.1	0.59	–	Total sugar 60.15, Reducing sugar 6.12	0.04,	0.04	0.003	(Chandran & Ravikumar 2017)
Flacourtia indica	–	0.5	0.6	24.2	0.033	0.17	0.0007	(Saklani et al. 2011)
Ficus palmata	80.5	1.7	–	Total sugar 6	0.071	0.034	0.004	(Joshi et al. 2014)
Hippophae sps. *rhamnoides* (Ladakh and Himachal pradesh) *salicifolia* (Uttarakhand) and *tibetana.*	74.58	2.64	1.54	20.56	0.383	0.02	0.01	(Dwivedi & Ahmed 2006)
Malus sikkimensis	77.43	1.79	0.36 ± 0.15	29.50	–	0.16	–	(Saha et al. 2014)
Myrica esculenta	72.33	9.62	4.93	78.03	4.63	0.24 ± 0.25	0.404	(Sood & Shri 2018)
Olea ferruginea	7.79-9.01	9.12-19.62	13-15	4.09-5.31	–	–	–	(Bugti et al. 2022)
Physalis peruviana	79.80–85.90	01.50–01.90	00.50–3.16	11-17.30	0.01055–0.028	0.027–0.038	0.00009–0.0012	(Joshi & Joshi 2015)
Pinus gerardiana	7.5	15.9	49.9	21.6	–	–	–	(Kumar et al. 2013)
Prunus armeniaca	4.39	3.01	1.53	–	–	74.91-162.56	2.69–6.97	(Alajil et al. 2021; Sharif et al. 2015)
Pyracantha crenulate	75	0.60–0.29	–	5.90–0.96	3.08–0.021	–	–	(Singh et al. 2018)
Pyrus pashia	84.97	3.29	0.45	17.93	0.061	0.026	0.006	(Saha et al. 2014)
Rubus ellipticus	66.36–80.6	4–4.37	7.10	72.7–86.4	450.10	1.26	4.25	(Ahmad et al. 2015)
Rubus niveus	78.56	3.28	1.10	85.35	–	–	3.26	(Pancholi & Rana 2020)
Viburnum mullaha	–	113	184	18.4 g/100 g	7.86	5.62	0.68	(Maikhuri et al. 2012)
Ziziphus mauritiana	81.06	0.8	0.07	17	0.026	0.027	0.00076–0.0018	(Prakash et al. 2021)

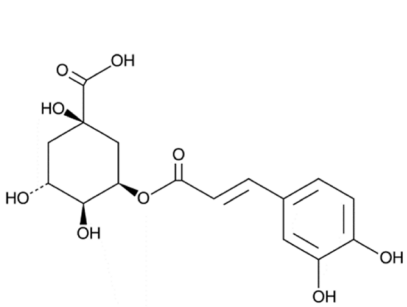
Table 4 Phytochemical profile of underutilized fruits of the Northern Himalayas

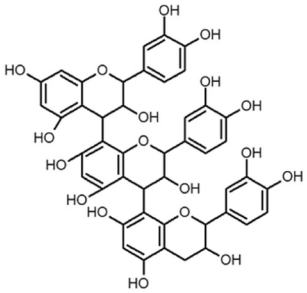
Scientific name and family	Alkaloids (HPLC, mg RE/g)	Total Phenols (HPLC, mg GAE/g)	Saponins (TLC)	Terpenes (TLC)	Carbohydrate (%)	Tannins (HPLC, mg CE/g)	Flavonoids (mg QE/g)	Glycosides (TLC)	Key reference
Artocarpus lacucha (Moraceae)	7-37 mg/g	0.59-1.50 mg/g	+	+	–	0.16-0.23 mg/g	0.41-1.28 mg/g	+	(Krishnamurthy & Sarala 2013)
Berberis asiatiica (Berberidaceae)	–	670 mg/100 g	–	–	24.98 mg/100 g	0.64 mg/100 g	190.40 mg/100 g	+	(Chandra et al. 2011)
Carissa spinarum (Apocynaceae)	+	+	–	+	+	+	+	–	(Ansari & Patil 2018)
Cordia dichomata (Boraginaceae)	+	+	–	–	+	–	+	–	(Oza & Kulkarni 2017)
Corylus acquemontii (Betulaceae)	–	4449 mg/g	–	–	–	–	–	–	(Kumar et al. 2016)
Cydonia oblonga (Rosaceae)	–	37-47 mg/g	–	+	–	0.80 mg/g	+	–	(Ashraf et al. 2016)
Elaeagnus latifolia (Elaeagnaceae)	–	6.77-7.31 mg/g	–	+	10.88-11.04 mg/g	0.17-.23 mg/g	5.28-.5.60 mg/g	–	(Panja et al. 2014)
Ficus auriculata (Moraceae)	0.15 mg/g	1.03 mg/g	–	–	–	+	0.64 mg/g	+	(Kumar, Saurabh, et al. 2021)
Flacourtia indica (Salicaceae)	+	+	+	+	+	+	+		(Santhosh 2021)
Ficus palmata (Moraceae)	+	7.91 mg/g	–	+	–	+	8.42 mg/g	+	(Saklani et al. 2011)
Hippophae sps. (Elaeagnaceae)	–	65.89 mg/100 g	–	+	+	23.55 mg/100 g	54.68 mg/100 g	–	(Thakur et al. 2015)
Malus sikkimensis (Rosaceae)	+	+	+	–	–	+	+	–	(Oyinlade 2014)
Myrica esculenta (Myricaceae)	+	7.12 mg/100 g extract	+	+	+	+	5.23 mg/100 g extract	+	(Anjum & Tripathi 2021)
Physalis peruviana (Solanaceae)	+	26.24 mg/100 g	+	–	+	1.74 mg/100 g	1.48 mg/100 g	+	(Bharthi et al. 2016; Muñoz et al. 2021)
Prunus armeniaca (Rosaceae)	+	25.31-89.95 mg/100 g	+	–	+	0.10%	5-15.46 mg/100 g	+	(Alajil et al. 2021)
Pyracantha crenulate (Rosaceae)	–	6.59 mg/g	–	+	–	+	7.46 mg/g	+	(Saklani et al. 2011)
Pyrus pashia (Rosaceae)	–	4.92 mg/g	–	–	–	–	4.94 mg/g	–	(Saklani et al. 2011)
Rubus ellipticus (Rosaceae)	–	83.33 mg/100 g	–	–	–	+	200.05 mg /100 g	+	(Karuppusamy et al. 2011)
Rubus niveus (Rosaceae)	+	3.21 mg/g	+	+	+	+	4.91 mg/g	–	(Pancholi & Rana 2020)
Viburnum mullaha (Viburnaceae)	–	1257 mg/100 g	–	–	–	–	3503 mg 100/g	–	(Singh et al. 2017)
Ziziphus mauritiana (Rhammnaceae)	+	+	+	+	–	+	+	+	(Kushwaha et al. 2019; Mbahi et al. 2018)

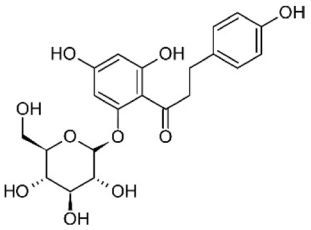
Key note: + shows the presence, − shows the absence of phytochemicals, *HPLC* High pressure liquid chromatography, *TLC* Thin liquid chromatography, *CE* Catechin equivalent, *GAE* Garlic acid equivalent, *QE* Quercetin equivalent, *RE* Rutin equivalent

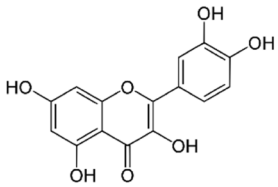
Phenolic compounds

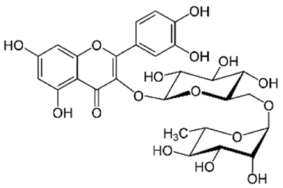
The fruits with phenolic compounds such as phenolic acids, flavonoids, and tannins showed antioxidant, anti-carcinogenic, anti-mutagenic, and anti-inflammatory properties, which induce apoptosis by arresting the cell cycle (Sharma et al. 2013; Zhang et al. 2021). They

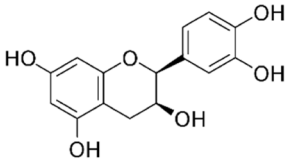

5-O-cafeoylquinic acid

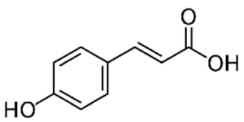

Procyanidin C2

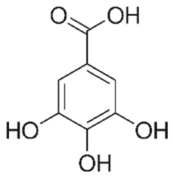

Phlorizin

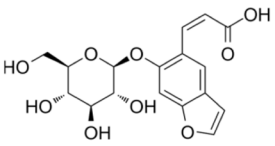

Quercetin

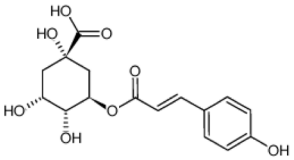

Rutin

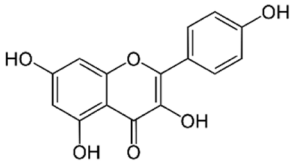

Epicatechin

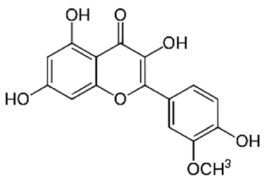

p-Coumaric acid

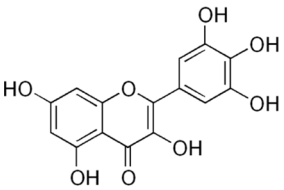

Gallic acid

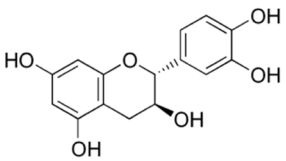

Psoralenoside

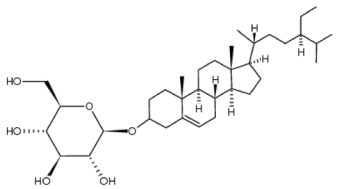

3-p-Coumaroylquinic acid

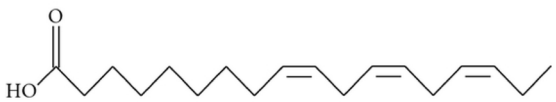

kaempferol


Isorhamnetin


Myricetin


Catechin


β-sitosterol-3-O-Beta- D- glucopyranoside


9,12,15-octadecatrienoic acid (linolenic acid)

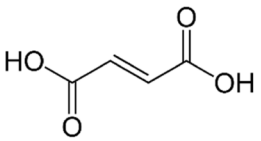

Fumaric acids

Fig. 2 Important phytochemicals present in under-utilized, fruits of the northern Himalayas

also help in regulating carcinogen metabolism, ontogenesis expressions, inhibiting DNA binding and cell adhesion, migration, proliferation or differentiation and blocking signal pathways, for example, *Carissa spinarum*, *Corylus acquemontii*, *Ficus auriculata*, *Flacourtia indica*, *Hippophae* spp., *Physalis peruviana*, *Prunus armeniaca*, *Pyracantha crenulate*, *Pyrus pashia*, *Rubus ellipticus*, *Rubus niveus*, *Viburnum mullahaa*, and *Ziziphus Mauritia* (Huang et al. 2009; Kumar et al. 2016), whereas as fruits of *Cydonia oblonga*, *Ficus auriculata*, and *Myrica esculenta* are rich in phenolic acids and in vitro tests showed antioxidant, antidiabetic, antimicrobial, anticancer and anti-inflammatory properties (Kumar & Goel 2019).

Fruits of *Berberis asiatiica*, *Carissa spinarum*, *Ficus auriculata*, *Ficus palmata*, *Myrica esculenta*, *Physalis peruviana*, *Pyracantha crenulate*, *Rubus ellipticus*, *and Ziziphus mauritiana* showed astringent, and styptic properties hence help in conditions like tonsillitis, pharyngitis, haemorrhoids, and skin eruptions because of the presence of tannins. Tannins are also used as an antidote for metallic poison (Shri et al. 2018). Flavonoids reported from fruits of underutilized plant species possess potent antioxidant activity and help regulate cellular activity and reduce oxidative stress in the body by fighting off free radicals and assist the body in efficient functioning by protecting it from everyday toxins and stressors (Saklani et al. 2011; Panja et al. 2014). Some in vitro tests of anthocyanins obtained from underutilized fruits also showed significant activity in treating diseases like cancer, Alzheimer's, and atherosclerosis (Castañeda-Ovando et al. 2009). Flavonoids (Quercetin and kaempferol) ranges from 0.41-1.28 mg/g and tannins ranges from 0.16-0.23 mg/g are found in abundance in fruits of *Artocarpus lacucha* (Saleem et al. 2018; Krishnamurthy & Sarala 2013). Fruits of *Berberis asiatiica* were also reported to have flavonoids (190.40 mg/100 g), phenols (670 mg/100 g), and tannins (0.64 mg/100 g) (Saklani et al. 2011; Chandra et al. 2011).

Flavonoids, tannins, and phenolic acids were reported from the *Carissa spinarum* fruits (Ansari & Patil 2018). Phenols and flavanol (Isorhamnetin, quercetin, and kaempferol) were determined as the main chemical constituents of the fruits of *Cordia dichomata* (Oza et al. 2017). Flavonoids (quercetin and kaempferol), flavan-3-ols, phenolic acids, tannins (0.80 mg/g), and polyphenols, mainly coumaroyl-quinic acid, mono- and dicaffeoylquinic acids (37-47 mg/g) were the principal phytochemical compounds that reported from *Cydonia oblonga* fruits (Ashraf et al. 2016; Hanan et al. 2020; Zhang et al. 2021). Secondary metabolites such as tannins and flavonoids including myricetin and quercetin-3-O-β-D-glucopyranoside (0.64 mg/g) were isolated from the fruits of *Ficus auriculata* (Saklani et al. 2012; Thingbaijam et al. 2012; Mehra & Tandon 2021; Raja et al. 2021).

Phytochemicals such as phenolic acids, flavonoids, and tannins were also found in *Flacourtia indica* fruits as the main chemical components (Patro et al. 2013; Santhosh 2021). *Ficus palmata* fruits are a rich source of flavonoids (8.42 mg/g), anthocyanins (0.39 mg/100 g, and flavone (Saklani et al. 2011; Alqasoumi et al. 2014; Chauhan et al. 2014). Polyphenols (65.89 mg/100 g extract), flavonoids (54.68 mg/100 g), and tannins (23.55 mg/100 g extract) were usually found in fruits of different species of *Hippophae* using colorimetric determination technique (Pundir et al. 2021; Thakur et al. 2015). Flavonoids (epicatechin, rutin, and hyperin), phlorizin, and tannins are also present in *Malus sikkimensis* fruits (Li et al. 2014; Oyinlade 2014). *Myrica esculenta* fruits are also a rich source of phytochemicals such as flavonoids (5.23 mg/100 g), tannins, catechin, chlorogenic acid, and myricetin, (Rawat et al. 2013; Sood & Shri 2018; Kabra et al. 2019; Anjum & Tripathi 2021). Flavonoids (1.48 mg/100 g) and tannins (1.74 mg/100 g) were reported from fruits of *Physalis peruviana* (Bharthi et al. 2016; Muñoz et al. 2021). Total phenolics (25.31-89.95 mg/100 g) were determined from the fruit extract of *Prunus armeniaca* (Sharma et al. 2014; Alajil et al. 2021).

In fruits of *Pyracantha crenulate*, flavonoids (7.46 mg/g), phenolics (6.59 mg/g), anthocyanins (0.62 mg/100 g), and tannins are present in the significant amount (Saklani et al. 2011; Sati 2017). The phytochemicals present in fruits of *Pyrus pashia* are flavonoids (4.94 mg/g), anthocyanins (0.47 mg/100 g), and polyphenols (Saklani et al. 2011; Siddiqui et al. 2015). Flavonoids (200.05 mg/100 g), phenols (83.33 mg/100 g), tannins, and anthocyanins were also reported from fruits of *Rubus ellipticus* (Saklani et al. 2012; Karuppusamy et al. 2011). Pancholi and Rana (2020) reported the presence of phenols, flavonoids, and tannins in fruits of *Rubus niveus.* Fruits of *Viburnum mullaha* are also a rich source of flavonoid contents (3503 mg 100/g) (Singh et al. 2017). The presence of phenols, flavonoids, and tannins was reported in fruits of *Ziziphus mauritiana* (Cheema et al. 2017; Mbahi et al. 2018; Kushwaha et al. 2019; Prakash et al. 2021). Pereda et al. (2019) reported that bioactive compounds, including tannins obtained from the fruits of *Physalis peruviana*, demonstrated strong antioxidant activity.

Alkaloids

Alkaloids (ranges 7-37 mg/g) were found in fruits of *Artocarpus lacucha* (Krishnamurthy & Sarala 2013; Saleem et al. 2018). Fruits of *Berberis asiatiica* were

also reported to contain alkaloids, mainly Berberine (1.08 mg/100 g) (Chandra et al. 2011; Saklani et al. 2011). Alkaloids were also found in the fruits of *Carissa spinarum* and *Cordia dichomata* as the dominant phytochemical compounds (Oza & Kulkarni 2017; Ansari & Patil 2018). Phytochemical profile screening of fruits of *Cydonia oblonga* showed abundant alkaloids in the extracts (Ashraf et al. 2016; Hanan et al. 2020; Zhang et al. 2021).

The fruits of *Ficus auriculata* also demonstrated principally alkaloids as 0.15 mg/g (Saklani et al. 2012; Thingbaijam et al. 2012; Mehra & Tandon 2021; Raja et al. 2021). The extracts of fruits of *Flacourtia indica* and *Ficus palmata* were reported to contain alkaloids (Saklani et al. 2011; Patro et al. 2013; Alqasoumi et al. 2014; Chauhan et al. 2014; Santhosh 2021). Fruits of *Malus sikkimensis* and *Myrica esculenta* were also reported to be a rich source of alkaloids (Rawat et al. 2013; Li et al. 2014; Oyinlade 2014; Sood & Shri 2018; Kabra et al. 2019; Anjum & Tripathi 2021). Alkaloids were determined from the fruits of *Physalis peruviana* and *Prunus armeniaca* (Sharma et al. 2014; Bharthi et al. 2016; Alajil et al. 2021; Muñoz et al. 2021). In the fruits of *Rubus niveus*, *Viburnum mullaha*, and *Ziziphus mauritiana*, alkaloids were identified as one of class of chemical components (Cheema et al. 2017; Singh et al. 2017; Mbahi et al. 2018; Kushwaha et al. 2019; Pancholi & Rana 2020; Prakash et al. 2021).

Saponins and steroids

Sterol or triterpenoid saponins were reported for their potential biological activities. For example, saponins in fruits are used to decrease blood lipids, lower cancer risks, and lower blood glucose response (Karuppusamy et al. 2011). Fruits of *Physalis peruviana*, and *Prunus armeniaca* plant species are promising sources of saponins (Moghimipour & Handali 2015). Secondary metabolites including saponins obtained from the *Ficus auriculata* were reported as potential phytoconstituents of the fruits extract (Saklani et al. 2012; Thingbaijam et al. 2012; Mehra & Tandon 2021; Raja et al. 2021). The study of phytochemical profile demonstrated steroids (ranges 0.16-0.23 mg/g) and saponins were also found in excess in the fruits of *Artocarpus lacucha* (Krishnamurthy & Sarala 2013; Saleem et al. 2018).

Steroids were also reported from the fruits of *Rubus ellipticus* (Saklani et al. 2012). The extracts of fruits of *Flacourtia indica* exhibited saponins as one of the main chemical constituents (Patro et al. 2013; Santhosh 2021). Saponins were also isolated from the fruits of *Malus sikkimensis* and *Myrica esculenta* (Rawat et al. 2013; Li et al. 2014; Oyinlade 2014; Sood & Shri 2018; Kabra et al. 2019; Anjum & Tripathi 2021). Saponins were identified from the fruits of *Physalis peruviana* and *Prunus armeniaca* (Sharma et al. 2014; Bharthi et al. 2016; Alajil et al. 2021; Muñoz et al. 2021). Pancholi and Rana (2020) also reported the presence of saponins in fruits of *Rubus niveus*. The presence of saponins were reported from the fruits of *Ziziphus mauritiana* as the main phytochemical compounds (Prakash et al. 2021; Cheema et al. 2017; Mbahi et al. 2018; Kushwaha et al. 2019).

Terpenes and terpenoids

Terpenoids were reported as abundant phytochemicals in the fruits of *Artocarpus lacucha* (Krishnamurthy & Sarala 2013; Saleem et al. 2018). The fruits of *Carissa spinarum* were reported to contain terpenoid compounds (Ansari & Patil 2018). Phytochemical screening of the fruits of *Cydonia oblonga* and *Flacourtia indica* demonstrated terpenes constituents in their extracts (Patro et al. 2013; Ashraf et al. 2016; Hanan et al. 2020; Santhosh 2021; Zhang et al. 2021). Phytochemical investigation of extracts of fruits of *Myrica esculenta* also depicted the presence of triterpenoids (Rawat et al. 2013; Sood & Shri 2018; Kabra et al. 2019; Anjum & Tripathi 2021). In fruits of *Pyracantha crenulate*, terpenoids are present in significant amount (Saklani et al. 2011; Sati 2017). Terpenes are usually found in fruits of different species of *Hippophae* using colorimetric determination technique (Thakur et al. 2015; Pundir et al. 2021). Terpenes were also reported from the fruits of *Physalis peruviana* (Bharthi et al. 2016; Muñoz et al. 2021). The presence of terpenes were isolated from the extracts of fruits of *Rubus niveus* and *Ziziphus mauritiana* (Cheema et al. 2017; Mbahi et al. 2018; Kushwaha et al. 2019; Pancholi & Rana 2020; Prakash et al. 2021).

Carbohydrates, proteins, and fatty acids

Underutilized fruits provide carbohydrates, proteins and fatty acids to the body (Blaak et al. 2021). Moisture content was found to be the highest in *Artocarpus lacucha*, which is around 90% and ranges from 4.39 to 87.10% in other fruits, while *Rubus niveus* constitutes the highest carbohydrate content 85.35 g/100 g (Pancholi & Rana 2020) ranging 5.90 g/100 g to 78.03 g/100 g (Vanajakshi et al. 2016). Fruits of *Berberis asiatiica* were reported to possess carbohydrate (24.98 mg/100 g) and glycosides (Chandra et al. 2011; Saklani et al. 2011). Glycosides were also found in abundant form in the fruits of *Artocarpus lacucha* (Krishnamurthy & Sarala 2013; Saleem et al. 2018). Some studies also showed that carbohydrates were reported from the fruits of *Carissa spinarum* and *Cordia dichomata* (Oza & Kulkarni 2017; Ansari & Patil 2018). Similarly, the presence of glycosides such as cucurbitane, cyanogens, and pelargonidin in fruits of *Berberis asiatiica*, *Ficus auriculata*, *Flacourtia indica*,

Ficus palmata, *Myrica esculenta Pyracantha crenulate*, and *Rubus ellipticus* was determined for their antioxidant, anti-inflammatory, anti-hypertensive, and antidiabetic properties (Bernal et al. 2011).

Several studies demonstrated carbohydrate and other compounds such as sorbitol, phytosterol, and fatty acids were also reported from fruits of *Physalis peruviana*, *Prunus armeniaca*, *Pyracantha crenulated*, and *Rubus niveus* (Saklani et al. 2011; Sharma et al. 2014; Bharthi et al. 2016; Sati 2017; Pancholi & Rana 2020; Alajil et al. 2021; Muñoz et al. 2021). Various reports also demonstrated that glycosides are the potential nutritional components of fruits of *Ficus auriculata* and *Ficus palmata* (Saklani et al. 2011; Thingbaijam et al. 2012; Saklani et al. 2012; Alqasoumi et al. 2014; Chauhan et al. 2014; Mehra & Tandon 2021; Raja et al. 2021). The presence of glycosides was also reported in the fruits of *Rubus ellipticus* and *Ziziphus mauritiana* (Karuppusamy et al. 2011; Saklani et al. 2012; Cheema et al. 2017; Mbahi et al. 2018; Kushwaha et al. 2019; Prakash et al. 2021).

Carbohydrates are usually found in the fruits of different species of *Hippophae* using colorimetric detection method (Thakur et al. 2015; Pundir et al. 2021). *Viburnum mullaha* is a rich source of protein (11.30 g/100 g) compared to other fruits which range from 0.50 g/100 g to 9.80 g/100 g. Amino acids act as a building block of muscles, help maintain muscle mass, promote muscle growth, lower blood pressure, and help in the growth, and maintenance of tissues, boost metabolism, and help burn fat (Monirujjaman & Ferdouse 2014). *Myrica esculenta* fruits are also a rich source of phytochemicals such as *L*-hydroxyproline, iso-leucine, valine, *L*-cysteine hydroxy-chloride, alanine, tryptophan, glutamic acid, tyrosine, threonine, leucine, and lysine monochloride (Rawat et al. 2013; Sood & Shri 2018; Kabra et al. 2019; Anjum & Tripathi 2021).

Vitamins and minerals

Fruits are usually a good source of many vitamins and minerals (Blaak et al. 2021). For example, some of the underutilized fruits of *Carissa spinarum*, *Ficus auriculata*, *Prunus armeniaca*, *Physalis peruviana*, *Pyracantha crenulate*, *Rubus ellipticus*, *Ziziphus mauritiana* contain potential vitamins and minerals, both in fresh and dry mass (Shri et al. 2018). *Cydonia oblonga* fruits were reported as a natural source of ascorbic acid and fumaric acid (Ashraf et al. 2016; Hanan et al. 2020; Zhang et al. 2021). Fruits of *Ficus palmate*, *Pyracantha crenulate* and *Pyrus pashia* exhibited the content of ascorbic acid as 2.93 mg/100 g, 5.30 mg/100 g, and 4.59 mg/100 g, respectively (Saklani et al. 2011; Alqasoumi et al. 2014; Chauhan et al. 2014; Siddiqui et al. 2015; Sati 2017). *Viburnum mullaha* is rich source calcium (7.86 g/100 g) compared to other fruits in which calcium ranges from 0.01 g/100 g to 4.63 g/100 g. Calcium keeps bones and teeth healthy, helps in the functioning of nerves and muscle tissues, regulates heart functioning, blood clotting, and enzyme functioning, and helps transmit nervous system messages (Brzezicha-Cirocka et al. 2016). Phosphorous helps to make energy, move muscles, keep bones and teeth strong, reduce muscle pain, help filter waste, repair tissue and cells, and manage how the body stores and uses energy. It maintains a regular heartbeat, acts as a genetic building block, and produces DNA and RNA; it also helps in the balance and use of other vitamins (B and D) and minerals (I, Mg, and Zn) (Monirujjaman & Ferdouse 2014). Phosphorous and iron concentration ranges from 0.02 g/100 g to 5.62 g/100 g and 0.09 g/100 g to 3.26 g/100 g, respectively. *Prunus armenica* is an excellent source of phosphorous (74.91 g/100 g), while *Rubus ellipticus* is a promising source of iron 4.25 g/100 g, (Table 3). The body needs iron for growth and development to make hemoglobin. Iron carries oxygen to muscles and the brain, which helps in improving energy levels. It enhances athletic performance, boosts the immune system, improves cognitive function, and promotes peaceful sleep (Gupta 2014). A detail of mineral content of some underutilized fruits is given in Table 3.

Toxicological properties of underutilized fruits of northern Himalayas

Although the underutilized fruits of the Himalayas are safe to eat, some toxicity studies were also reported (Raj et al. 2012). *Artocarpus lakoocha* refers to anti-helmintic, anti-herpetic, and skin-whitening retailers in medical terms. Besides the antioxidant activity of fruits of *Artocarpus lakoocha*, toxicity is also reported (Singhatong et al. 2010). For instance, consuming underutilized fruits such as apricot kernels or Laetrile TM (an alternative cancer medicine sold in Mexico and elsewhere outside the United States, derived from amygdalin) is not recommended by prenatal or in women who are feeding milk to children due to the possible danger of birth defects. Apricot fruit is reported to contain Amygdalin, a natural cyanogenic glycoside. It has anticancer activity but is a controversial compound. It can be toxic via enzymatic degradation and production of hydrogen cyanide (Bolarinwa et al. 2014; Jaszczak-Wilke et al. 2021).

Commercial utilization of underutilized fruits of the northern Himalayas

Even though most fruits of the Northern Himalayas have been underutilized, people are currently starting to use a few for commercial purposes due to their health benefits and other applications. For example, the fruits of *Ficus auriculata* are used to make jams and curries (Chandran

& Ravikumar 2017). *Artocarpus lakoocha* fruit is usually a sweet flesh that is eaten fresh but is most often made into curry. Pickles and a delicious sauce are made from various parts of these fruits and the thorns of male flowers (Hossain et al. 2016). The delicate fruit of *Cordia dichotoma* is used for pickling (Slathia et al. 2017). The plant is used in herbal medicine and is reaped industrially in forest areas to produce various medicines such as dried fruit infusions, liquid extracts, and tinctures (Singh et al. 2012). Private sellers already prepare a nutritious drink of *Hippophae* fruit, and products are freely obtainable in the Indian market. The procedure of preparing other food goods, such as jams, pickles, purees, mixed/flavoured drinks, and wine has also been developed, and patenting and commercializing procedures are underway (Dwivedi & Ahmed 2006).

Myrica esculenta fruits are also used to make jams, syrups, soft drinks, and pickles (Makdoh et al. 2014; Kabra et al. 2019), and to make Ayurvedic preparations such as chwayanprash and Brahma Rasayana that improve digestion, reminiscence, intellect, awareness and physical power. The herbal drink hridayamrit, made from its fruit, is nourishing, stimulating, and energizing. It is ironic in vitamins, reserves, proteins, and antioxidants (Sood & Shri 2018). In addition to being operative for hypertensive disorders, this drink is instantly energizing and has stimulating belongings that are appreciated by the general public. No synthetic colors or flavours are cast off as the fruit flesh has its normal colour and flavours (Singh et al. 2018).

Conclusions and future prospects

Fruits are an essential part of the human diet. Therefore, their demand is increasing due to the increasing number of consumers of fruits with nutritional and medicinal values. Northern Himalayas is the home of many wild/underutilized fruits that local people consume. These underutilized fruits are a potential source of food supplements, different phytochemical compounds, and micronutrients. Their natural constituents widely act as antioxidants, antimicrobial, antidiabetic, and anti-inflammatory agents. Underutilized fruits are also a potential source of fat, carbohydrate, vitamins, and fibre. The nutritional compositions of these fruits are sometimes better than their exotic and indigenous variety. Currently, only limited research works are reported for their utilization in food processing, such as jam, jelly, juice, squash, and sauce. If these fruits will be utilized by industry, a bulk quantity of them is required, which is an obstacle/challenge in their use. The need for extensive research on the toxicity profiling of the underutilized edible fruits is also the challenge for using these crops as dietary supplements. Key future strategies for domestication and more comprehensive cultivation of underutilized edible fruit species include strengthening botanical information, germplasm collection, improvement, production, and processing technologies, increasing the supply of improved planting materials, and promoting on-farm cultivation of wild edible fruit-based agroforestry systems are required. Additionally, wide research activities on their nutritional profiling, phytochemicals study, and toxicology assays are required on the underutilized edible fruits of Himalaya's region plants. The government or non-governmental organization is also urged to support such research activities through funding.

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AB and D have drafted the review. YHG revised the manuscript. AS and MZ prepared different tables and figures required for the manuscript. RKB and AH offered crucial advice, examined every step of writing. All authors read and approved the final version of the manuscript.

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