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Exploring the nutraceutical elixirs of commercial fruit and vegetables and wild edible plants with ethnomedicinal importance: Review article

Sharon Jacob

Ph.D scholar, Department of Postharvest Management, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala, India
Corresponding author email: jacobsharon1930@gmail.com

Anupam Raj

PG student, Department of Postharvest Management, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala, India

Saji Gomez

Professor and Head, Department of Postharvest Management, College of Agriculture, Vellanikkara, Kerala Agricultural University, Thrissur, Kerala, India

Abstract--The increasing emphasis on preventive healthcare has sparked interest in nutraceuticals, which bridge the gap between nutrition and pharmaceuticals. Nutraceuticals, including functional foods, supplements, and herbal products, are gaining popularity for their targeted health benefits, reflecting a societal shift towards proactive health management. Defined by the Food Safety and Standards Authority of India, nutraceuticals provide health benefits beyond basic nutrition and are increasingly valued for their preventive and therapeutic properties. This review explores the nutraceutical potential of fruits, vegetables, and wild edible plants, highlighting their diverse bioactive compounds. Fruits and vegetables are rich in phytochemicals like minerals, vitamins, dietary fiber, and bioactive compounds such as flavonoids, contributing to their nutraceutical potential. Focusing on fruits like mango, pineapple, citrus, and berries like strawberry and blueberry, the discussion underscores their role in enhancing overall well-being. Studies on specific vegetables such as tomato, garlic, moringa, *etc.*, highlight their diverse health benefits, including antioxidant and anti-inflammatory properties. Research on wild edible fruits and vegetables among tribal populations in India reveals their nutritional and therapeutic significance, providing insights into their ethnomedicinal uses.

Keywords--Nutraceuticals, antioxidants, anti-inflammatory, anti-diabetic, wild edible plants.

Introduction

In recent years, there has been a notable surge in public awareness and concern towards health, driven by a growing recognition of the importance of preventive measures in maintaining overall well-being. This heightened awareness has led individuals to seek proactive approaches to enhance their health and address nutritional deficiencies. In this context, nutraceuticals have emerged as pivotal players in the intersection of health and nutrition. Defined as products that combine the benefits of both nutrition and pharmaceuticals, nutraceuticals offer a proactive and holistic approach to health management. According to the global health expenditure database of the World Health Organisation (WHO 2022), the United States and India have spent 17 per cent and 4 per cent of their gross domestic product, respectively on healthcare. As consumers increasingly prioritize self-care and wellness, nutraceuticals, which encompass a diverse range of functional foods, dietary supplements, and herbal products, have gained popularity for their potential to provide targeted health benefits. This evolving trend underscores a societal shift towards a more comprehensive and personalized approach to healthcare, where individuals actively engage in preventive practices, including the incorporation of nutraceuticals into their daily routines to optimize their health outcomes.

According to the Food Safety and Standards Authority of India (FSSAI), nutraceuticals is defined as the category of foods that consist of extracts, isolates and purified chemical compounds having physiological benefits and helps to maintain health. Nutraceutical is a term that combines "nutrition" and "pharmaceutical," referring to a food or food product that provides health benefits beyond basic nutritional functions. Nutraceuticals are often associated with the prevention and treatment of various medical conditions and are valued for their potential to promote health and well-being. These products may include dietary supplements, functional foods, herbal products, and other naturally derived substances that have demonstrated physiological benefits or provide specific health-related advantages. Unlike pharmaceuticals, nutraceuticals are typically available without a prescription and are consumed as part of a regular diet. The concept of nutraceuticals underscores the idea that certain foods and dietary supplements can have therapeutic properties, contributing to the growing interest in preventive healthcare and lifestyle management.

According to the Ministry of Food Processing Industries, the market value of nutraceuticals in 2020 was estimated as 4 billion US dollars. Similarly, growth rate of this sector is expected to be 7 % from 2019-2024. The export revenue obtained by marketing of nutraceuticals in 2018 was around 330 million US dollars and the share of India towards global nutraceuticals market is 2 %. The abovesaid figures clearly indicate the potential of nutraceuticals in the Indian scenario.

Horticulture constitutes the cultivation of a diverse group of crops that includes fruits, vegetables, flowers, medicinal plants, aromatic crops, spices, *etc.* The various nutrients present in horticultural crops like vitamins, minerals, protein, fibre, minerals *etc.* and the bioactive compounds like polyphenols, alkaloids, glycosides, terpenoids, *etc.* make these potential sources for nutraceuticals.

The increasing demand for health promoting nutritional diet is encouraging researchers to explore the potential of wild edible plants. Ethnobotanical studies play a crucial role in documenting and preserving traditional knowledge related to plants, especially those used for food and medicine in different regions. Ethnobotanical research in various regions of India focuses on studying the traditional knowledge of local communities regarding wild edible plants to understand the cultural significance, medicinal properties, and nutritional benefits of these plants. This review showcases the nutraceutical importance of major sections of horticultural crops *viz.*, fruits and vegetables, and also some of the wild edible plants consumed by tribals living in various settlements across India.

Nutraceutical properties of fruits

Fruits are cherished by most of the people because of its refreshing flavour, taste and aroma. Besides being flavourful and nutritious, these serve as sources of various bioactive constituents that have nutraceutical properties. Several polyphenolic compounds found in fruits have the ability to improve human health by acting as antioxidants. Furthermore, many fruits possess anti-inflammatory, antibacterial, antifungal, and chemo-preventive properties. Besides polyphenols, other substances with health benefits include xanthenes, carotenoids, saponins, *etc.* (Dolkar et al. 2016). A brief review on the nutraceutical potential of some of the major, minor and underutilized fruit crops are dealt in the following sections.

Mango

Mango (*Mangifera indica* L.), known as the king of fruits, is rich in nutritional composition and bioactive compounds. It has good amount of minerals like calcium, magnesium and potassium, vitamins especially vitamin A and C, carotenoids, phenolic compounds, terpenoid compounds *etc.* (Ribeiro and Schieber 2010). Mangiferin, which occurs as glycoside in mango leaves, bark and fruits have potential antioxidant and anticancerous activity making it a good nutraceutical (Ahmad et al. 2012). In a study conducted by Ebeid et al. (2015), the nutraceutical potential of mango was explored and it was found that it can be used against carbon tetrachloride induced hepatocellular toxicity. The ethanolic extract of mango peel was reported to possess antidiabetic properties in a study conducted by Gondi and Rao (2015). Ripe mangoes serve as one of the richest sources of provitamin A among fruits. The major polyphenolic compounds identified in mango pulp are mangiferin, gallic acids, gallotannins, quercetin, isoquercetin, ellagic acid and β -glucogallin whereas quercetin and catechin are the main flavonoids present (Kabir et al. 2017).

Pineapple

Pineapple (*Ananas comosus* L. Merr.) is a much sought after fruit for its unique flavour properties. It is good source of vitamin C, A and B. Though it originated in Paraguay, it is now extensively cultivated in almost all tropical regions of the world. In addition to their delicious flavour, pineapples are incredibly high in potassium, calcium, vitamin C, copper, folate, glycans, fibre, and other important minerals. Pineapple is a wonderful choice for a portion of a diet that is nutritionally balanced because it contains all these elements (Hossain et al. 2015). Bhui et al. (2009) reported the anti-tumour initiating activity of the enzyme bromelain present in pineapple. Bromelain was reported to show proteolytic effect which contributes to its anti-inflammatory activity (Huang et al. 2008). According to Khan et al. (2011), bromelain has the ability to improve digestion and also it possesses antidiabetic and antioxidant properties. In another study by Dougnon et al. (2011), it was observed that the extract of pineapple could protect the life-threatening changes occurred in Wistar rats like haematological and biochemical changes induced by Doliprane drug. According to Riya et al. (2013), the fruit residue of pineapple has potential effect against diabetes. The pineapple extract was found effective against some of the oral pathogens confirming its antimicrobial activity (Ahamed et al. 2016). Prakoso et al. (2018) reported that pineapple extract showed wound healing properties on skin infected with methicillin resistant *Staphylococcus aureus*. Chabib et al. (2023) prepared pineapple extract with nano-emulsion gel as the base and it was found to possess high antioxidant and anti-acne properties.

Citrus

The refreshing flavour of citrus fruits is unparalleled and is therefore widely consumed all over the world. Besides the excellent flavour, citrus fruits are good source of vitamin C, flavonoids and terpenoids. Because of the complexity of species diversity, the classification of citrus fruits is extensively studied. The citrus flavonoids are one of the important bioactive groups that possess various nutraceutical properties. They occur majorly under three categories *viz.*, flavanone glycosides, flavone glycosides and polymethoxyflavones (Manthey and Grohmann 1998). The presence of these flavonoids at various concentrations are said to be responsible for the anti-inflammatory and anticancerous properties in citrus fruits (Manthey et al. 2001). Some of the popular cultivated species are sweet orange (*Citrus sinensis* L.), sour orange (*C. aurantium* L.), grapefruit (*C. paradisi* Macf.), lemon (*C. limon* (L.) Burm. f.) and lime (*C. aurantifolia* (Christm.) Swingle). Ancient records revealed that citron and lemon were used as antidotes against poison (Arias and Ramon-Laca 2005). Du et al. (2009) reported that naringenin can be used a potential immunomodulator against lung fibrosis and metastasis. Bertuzzi et al. (2013) reported that hesperidin and geraniol, which are present in lemon, can increase the resistance against fever and cold. Also, it was said to have antiseptic properties and the juice is good for asthma, headache and arthritis. Clinical study in mice by Li et al. (2015) demonstrated that naringenin had potential therapeutic effect in rheumatoid-arthritis. The presence of limonene in citrus species *Citrus limon* L. Burm. and *Citrus limonia* Osbeck. contributes to its anti-inflammatory effects (Amorim et al. 2016). The citrus flavonoid naringenin

also has potential anti-inflammatory effect by regulating the intracellular cytokine degradation (Jin et al. 2017).

Jackfruit

The jackfruit (*Artocarpus heterophyllus* Lam.) is regarded as an abundant source of nutritional fibre, ascorbic acid, thiamine, minerals, and carboxylic acids (Lin et al. 2000). In a study conducted by Tan et al. (2013), the crude polysaccharides extracted from jackfruit pulp enhanced the immune system activity of mice under study. Biworo et al. (2015) reported that jackfruit extract contained good amount of ascorbic acid, β -carotene and lycopene which might have played a role in its antioxidant activity. The extract also showed anti-diabetic effect because of its ability to reduce or inhibit the glycation of haemoglobin. Along with carotenoids, jackfruit pulp contains varying amounts of flavonoids, volatile acid sterols, tannins etc. depending on varieties (Ranasinghe et al. 2019). The anti-diabetic properties of unripe jackfruit pulp flour were studied in a placebo-controlled group and found that it can be used as nutrition therapy by replacing equal volume of rice or wheat flour in daily meal (Rao et al. 2021).

Papaya

Papaya (*Carica papaya* Linn.) is rich in vitamins that have antioxidant properties such as vitamin A, C and E. It has also good content of vitamin B complex, minerals like potassium and magnesium and phytochemical compounds such as glutathione peroxidase, glutathione transferase, glutathione reductase, total phenols, terpenols, alkaloids, flavonoids and saponins (Aravind et al. 2013; Santana et al. 2019). Chen et al. (2010) studied the impact of a transgenic papaya line in the immune response of ovalbumin-sensitised mice and it was found that the induced allergy was not increased on administration and there was an increase in the total serum IgM (Immunoglobulin M) levels. The comparative antioxidant study of different parts of papaya by Maisarah et al. (2013) revealed that its young leaves had highest antioxidant activity followed by unripe fruit, ripe fruit and seeds. It was reported in another study that the polysaccharides extracted from unripe papaya possess anti-inflammatory effects and have potential scope in the cosmetic industry (Lin et al. 2023).

Amla

Amla or Indian gooseberry (*Emblica officinalis* Gaertn), cultivated in the arid and semi-arid regions, is a widely used in traditional treatment systems such as ayurveda. Amla fruits are rich in phytochemical components that are contributing to its various nutraceutical properties. It was said to have the ability to reduce several age-related problems such as reducing the stress-induced disorders in oxidative free radical scavenging activity (Bhattacharya et al. 2000), hyperlipidemia (Yokozawa et al. 2007) etc. Studies have shown that amla fruit has numerous biological activities that include antioxidative, hypolipidemic, hypoglycemic, antimicrobial, antitumor, and anti-inflammatory activities (Liu et al. 2008). Huang et al. (2017) studied the hepatoprotective effect of amla in rats on diet-induced non-alcoholic fatty liver disease. It was found that the fat deposition was significantly reduced when the rats were fed with amla extract,

showing its potential in treating obesity. The phenolic compounds isolated from the juice powder extract of amla were gallic acid, gallic acid derivatives, ellagic acid and its derivatives. Pedunculagin, emlicanin A, phyllaemblicin B, emblicanin B and puniguconine are the major tannin compounds present in amla and the ascorbic acid, the major vitamin present in *aonla* is in the range of 470-680 mg/100g (El-Desouky et al. 2008). The high levels of vitamin C (45-70%) along with phenolic compounds contributes to its high antioxidant activity which was estimated higher than the synthetic commercial antioxidant (Scartezzini et al. 2005; Rose et al. 2018).

Pomegranate

Pomegranate (*Punica granatum* L.) is a colourful and attractive fruit with good nutritional parameters. It is a widely reported fruit from India and cultivated in semi-arid regions and several improved varieties have been released in the country. Cultivars with soft seeds and bright red colour imparted by anthocyanin pigment are highly sought after. The pericarp of fruits contains various types of tannins like ellagitannins (Wang et al. 2004), punicalin, punicalagin (Wang et al. 2006) etc. Pomegranate is rich in flavonoid compounds like flavones, flavonols, flavon-3-ols and anthocyanidins, where the last two compounds are majorly responsible for the brilliant colour (Wang et al. 2010). Juice of this fruit was found to be rich in citric and malic acids (Neuhofer et al. 1989) whereas the pomegranate seeds are rich in unsaturated fatty acids such as punic acid, linoleic acid, oleic acid, palmitic acid, etc (Li et al. 1994). Lei et al. (2007) reported that the presence of tannins like ellagic acid along with other constituents could be responsible for the activity of lowering the lipid concentration in blood. The study on bioactive properties of pomegranate juice revealed its antioxidant potential, moderate antiproliferative and enzyme inhibiting activities (Les et al. 2015). Pomegranate fruits, either pericarp or juice were also reported to have nutraceutical properties like anti-hypertensive (Li et al. 2006), gastroprotective (Ajaikumar et al. 2005), hepatoprotective (Celik et al. 2009) and antipathogenic effects.

Annonaceae fruits

Annonaceae family accommodates a variety of species among which six are more prevalent viz., *Annona squamosa*, *A. reticulata*, *A. muricata*, *A. cherimola*, *A. senegalensis*, and *A. atemoya* (hybrid). Screening of the extract of *A. squamosa* pulp revealed the presence of various components like fatty acids, alcohols, ketones and aldehydes whereas through phenolic estimations and antioxidant assays, it was found to have very good antioxidant properties (Bhardwaj et al. 2014). Saleem et al. (2010) reported that the extract of *A. squamosa* have shown hepatoprotective effect in albino Wistar rats. According to Barreca et al. 2011, *Annona cherimola* Mill. fruit extract showed strong antioxidant properties as well as cytoprotective effects. In a study conducted by Sarma et al. (2015), the antioxidant activity based on DPPH assay of fruits of *A. squamosa* Linn. was found as $26.21 \pm 1.34 \mu\text{g/ml}$. The flavour of *A. muricata* or soursop when ripe is similar to custard and is relished by many. Around 114 volatile compounds are responsible for its flavour properties including various esters, terpenes, alcohols, aldehydes, ketones and other aromatic compounds. It shows many therapeutic

properties like anti-tumoral, anti-cytotoxicity, anti-viral and anti-carcinogenic properties (Gajalakshmi et al. 2012).

Apple

Being a well-known and well accepted fruit, numerous works have been carried out in apple (*Malus domestica* Borkh.) in various research fields. Apple is rich in various bioactive components like phenolics, flavonoids, vitamins and minerals that have health protective effects such as antioxidant activity, anti-proliferative activity, cholesterol lowering property, etc (Boyer and Liu 2004). Huber and Rupasinghe (2009) observed the inhibition of oxidation of lipids by treating with apple peel extract revealing its antioxidant activity. Study on the soluble apple polysaccharides revealed its hepatoprotective effect in carbon tetrachloride induced hepatotoxicity in mice (Yang et al. 2013). In a study conducted by Raphaelli et al. (2019), the phenolic compounds present in Gala apple contributes to its antimicrobial activity as it was inhibiting the four common gram-positive bacteria making it a potential natural antibacterial agent. In a double-blinded pilot study by Popiolek-Kalisz et al. (2024), overweight adults were supplemented with different fruit derived nutraceutical products and it was observed that supplementation from apple and kiwi nutraceuticals induced improvement in the lipid profile of the subjects.

Strawberry

Strawberries (*Fragaria x ananassa* Duch) are considered as good sources of bioactive components like vitamin C, anthocyanin, folate and phenolic contents with high antioxidant activity (Giampieri et al. 2012) and nutrients like fat soluble vitamins, carotenoids, dietary fibre, potassium, manganese and other minerals etc. (Giampieri et al. 2013). Ji-Young et al. (2008) also reported that the strawberry extracts might possess antioxidant, anti-inflammatory and anti-proliferative activities. The activity of tannin extract from strawberry was studied on gastric inflammation by Fumagalli (2018) and was found to exhibit anti-gastritic or anti-inflammatory activities even after *in vitro* simulated gastric digestion of tannins. Study by Mazzoni et al. (2019) demonstrated the antiproliferative effect of strawberry anthocyanin extract on cancer cells and its possible pathway.

Berries

Blueberry is one of the famous fruits among the berries belonging to the genus *Vaccinium*. It is known to be rich in various bioactive compounds like phenolic acids, anthocyanin, flavonols (kaempferol, quercetin, myricetin), ascorbic acid, hydroxybenzoic acids, hydroxycinnamic acids, resveratrol, etc (Chen et al. 2010). According to the studies carried out, consumption of blueberry products might help in reducing obesity and its related problems like chronic inflammation and type 2 diabetes (Shi et al. 2017). *Rubus* is a diverse genus entailing a large group of species mainly under two sub-genera; *rubus* (consisting of blackberries) and *ideobatus* (consisting of raspberries). Frias-Moreno et al. (2021) studied various bioactive components present in few cultivars of raspberries (*Rubus* spp.) cultivated in northern Mexico and found out that they are rich in flavonoids

(catechin, quercetin-3- β -D-glucoside, quercetin-3-glucuronide), anthocyanins and polyphenols (ellagic acid, gallic acid, caffeic acid, chlorogenic acid, *etc.*) which were responsible for its antioxidant capacity. Bowen-Forbes et al. (2010) reported that some of the types of blackberry and raspberry species exhibited high antioxidant activity and showed high anti-inflammatory and anticancerous properties.

The major nutraceutical properties of other minor or underexploited fruits are given below in the Table 1.

Table 1: Major nutraceutical properties of other fruit crops

Sl no.	Crop	Properties	References
1.	Litchi (<i>Litchi chinensis</i>)	Anticancer, Neuroprotective, Antioxidant, Anti-viral, Antimicrobial, Hepatoprotective, Lipid lowering	Punia and Kumar 2021
2.	Avocado (<i>Persea americana</i>)	Antioxidant and Antiproliferative activity	Velderrain-Rodríguez et al. 2021
3.	Mulberry (<i>Morus nigra</i> ; <i>Morus alba</i>)	Antioxidant and Anti-inflammatory activity	Negro et al. 2019
4.	Karonda (<i>Carissa carandas</i> L.)	Antioxidant activity Antibacterial activity	Shamina et al. 2016; Joshi et al. 2018
5.	Mexico black cherry (<i>Prunus serotina</i>)	Antioxidant capacity, Vasorelaxant effect, and Antihypertensive effect	Luna-Vázquez et al. 2013
6.	Loquat (<i>Eriobotrya japonica</i> Lindl.)	Antioxidant activity, and Antiproliferative activity	Gentile et al. 2016.
7.	Durian (<i>Durio zibethinus</i> murr.)	Antioxidant and Anti-inflammatory activity	Chingsuwanrote et al. 2016
8.	Persimmon (<i>Diospyros kaki</i> L.)	Antioxidant, Antibacterial and antifungal activity	Lee et al. 2012; Gea-Botella et al. 2021
9.	Apricots (<i>Prunus armeniaca</i> L.)	Antioxidant activity	Alajil et al. 2021
10.	Passion Fruit (<i>Passiflora edulis</i> Sims)	Antihaemolytic, Antimicrobial, Antifungal activities and Cytotoxicity against cervical carcinoma	Ghada et al. 2020

Nutraceutical properties of vegetables

Vegetables are considered as protective foods, just as fruit crops, because of the presence of various nutrients and phytochemical compounds with nutraceutical properties. The major phytochemical compounds present in vegetables that could contribute to the nutraceutical potential are minerals, vitamins, dietary fibre, organosulphur compounds and flavonoids (Singh and Devi 2015). Karuna and Prasad (2015) reviewed the potential of vegetable oils as sources of nutraceuticals. Presence of triglycerides, fatty acids, tocopherols and tocotrienols, lecithin, *etc.* in vegetable oil makes it a promising ingredient in the nutraceutical industry. A brief review on the nutraceutical potential of some of the major, minor and underutilized vegetable crops are dealt in the following sections.

Tomato

Friedman et al. (2009) worked on the green tomato (*Solanum lycopersicum* L.) extracts and found that those containing glycoalkaloids, especially tomatine, have the beneficial effect against cancerous cell lines of breast, colon, gastric and hepatoma. According to Mohamadain et al. (2012), the lycopene content, another important phytoconstituent of tomato, can reduce the oxidative stress and have protective effect against isoproterenol induced cardiotoxicity in rats. Lycopene was also found to have growth inhibiting properties against hepatocarcinogenesis induced by N-nitrosodiethylamine (Gupta et al. 2013). The immunomodulatory properties of lycopene were reported by many researchers. Huang et al. (2013) reported the anti-angiogenic effects of lycopene through immunomodulatory changes in the secretion of cytokine. The antimicrobial property of tomato juice was reported by Kwon et al. (2024) on the typhoid causing organism *Salmonella typhi*. The specific peptides in the tomato juice resulted in damaging the membranes of bacteria, thus destroying them. Lycopene, tocopherols, vitamin C, γ -aminobutyric acid, phenols, and flavonoids are abundant in tomatoes (Kang et al. 2022).

Brinjal

The fruits of brinjal (*Solanum melongena* L.) contain good amounts of ascorbic acid and total phenolic content, which are potent antioxidants (Vinson et al. 1998). Somawathi et al. (2014) estimated the phenolic content and antioxidant activity of different coloured varieties of brinjal and found that dark purple brinjal possess high antioxidant activity and total phenolic content. In another study Somawathi et al. (2016) observed that the coloured varieties of brinjal showed DNA protective activity against AAPH (2,2-azobis (2-amidinopropane) dihydrochloride) induced radical damage. Purple coloured brinjals are rich in anthocyanin content which are said to have properties like anti-inflammatory, antiulcer, antioxidant and antimutagenic properties in humans (Kumari et al. 2018). Shi et al. (2023) reported that the eggplant fruits contained compounds that possess anti-inflammatory and antioxidant properties *viz.*, fatty acids, flavonoids, alkaloids, phenolic acids, saponins and lignans, and hence could be used externally to relieve the symptoms of chilblains (inflammation and swelling of skin against cold). The main phenolic constituents in brinjal include total

phenols, flavonols, ortho-dihydroxyphenols, quinones and tannin (Sharma et al. 2019).

Okra

An *in vitro* study by Olorunnipa et al. (2013) revealed anti-helicobacter pylori activity of okra. *Helicobacter pylori* was reported to be a causative agent of chronic gastritis, peptic ulcer disease, adenocarcinoma and lymphoma. Xia et al. (2015) reported that okra (*Abelmoschus esculentus* L.), commonly called as lady's finger, have antioxidant and anti-fatigue properties especially in okra seeds which might be due to the presence of polyphenols and flavonoids. The polysaccharides extracted from okra was reported to have potential effect on immunomodulatory activities in both *in vitro* cell studies and *in vivo* studies on mice (Chen et al. 2016). Mairuae et al. (2017) examined the okra extract's anti-neuroinflammatory characteristics and its ability to block the generation of pro-inflammatory cytokines and reactive oxygen species in lipopolysaccharide-stimulated BV2 microglia. An antidiabetic nutraceutical formulation (against *diabetes mellitus*) was developed by Muhammad et al. (2018) from okra and based on the evaluation of functional properties of different dose combination ratios of seed and peel revealed the best combination for formulation as 10 : 90 percent ratio of seeds and peels respectively. A study by Sipahi et al. (2022) showcased the wound healing property of ethanolic extract of okra which can be based on its anti-inflammatory, antioxidant and antimicrobial properties. Okra primarily contains flavonoids as its major polyphenolic compounds. These include quercetin-3-gentiobioside (Q3G), quercetin-3-sambubioside (Q3S), rutin, quercetin-7-glucoside (Q7G), isoquercitrin (ISO), and quercetin-3-malonylglucoside (Q3M) (Yang et al. 2022).

Cruciferous species

The effect of red cabbage (*Brassica oleracea* L.) on diabetic rats was investigated by Kataya and Hamza (2008) and revealed its potential antihyperglycemic properties. Ahmed and Ali (2013) reported the predominant phenolic components of raw cauliflower such as protocatechuic acid, quercetin, pyrogallol, vanillic acid, coumaric acid and kaempferol. A meta-analysis was conducted by Hu et al. (2015) on the consumption of cruciferous vegetables and the risk of ovarian cancer which showed that it might reduce the risk of cancer. The presence of phenols and flavonoid components in cruciferous vegetables like cabbage, cauliflower, broccoli *etc.* indicates their potential to act as antioxidants (Upadhyay et al. 2016). The antiproliferative activities of kale (*Brassica oleracea* var. *acephala* DC.) and wild cabbage (*Brassica incana* Ten.) was reported by Lucic et al. (2023). Li et al. (2018) identified 74 phenolic compounds in cruciferous vegetables, including 16 hydroxycinnamic acids and derivatives, and 58 flavonoids and derivatives. The main flavonoids detected were glycosylated quercetin, kaempferol, and isorhamnetin, while the major hydroxycinnamic acids included ferulic, sinapic, caffeic, and p-coumaric acids.

Carrot

Dacus carota L.(carrot) is a nutritional as well as medicinal plant mentioned in the traditional Persian medicine (Bahrami et al. 2018). The extract of carrot was reported to significantly reduce the carbon tetrachloride-induced hepatocellular injury (Bishayee et al. 1995). The effect of different bioactive compounds from carrot on human lymphoid leukaemia cells were studied by Rana et al. (2012) and reported that rather than beta carotene and lutein, polyacetylene compounds showed significant results by inducing apoptosis and arresting the cell cycle. The antidepressant activity of carrot extract was observed in mice by Babu et al. (2014) and the activity was comparable to the standard drugs. Jiin et al. (2014) reported the gastroprotective effect of carrot juice in experimental rats. Likewise, carrot is known to possess many therapeutic properties such as antioxidant, analgesic, anti-inflammatory, antimicrobial, antifungal, diuretic, lithontriptic, emmenagogue, intra ocular hypotensive, gastroprotective, hepatoprotective, aphrodisiac, nephroprotective, antispasmodic, anticancer, antiestrogenic, cardioprotective, and wound healing activities (Bahrami et al. 2018). Carrots are abundant in bioactive compounds such as pectins, vitamin C, and polyphenolic compounds. The primary sugar in carrots is sucrose, and the most prevalent organic acid is isocitric acid (Yusuf et al. 2021).

Beetroot

Beetroot (*Beta vulgaris* L.) contains betalains, betaxanthins and betacyanins which contributes to its antioxidant activity (Tomasz et al. 2016). Mi-Ran et al. (2017) discovered the possible anti-inflammatory qualities of beetroot fraction by examining its inhibitory influence on pro-inflammatory mediators. In another study by Ahmadi et al. (2020), the betanins from beetroot extract inhibited the lipopolysaccharide activated microglial cell functions like production of free radicals, reactive oxygen species etc. According to Aliahmadi et al. (2021), consuming raw red beetroot led to a significant improvement in total antioxidant capacity and cognitive function tests, and a significant decrease in metabolic markers of type-II diabetes like homocysteine, glycosylated haemoglobin, fasting blood sugar etc. Similarly, a different study conducted in by Al-Harbi et al. (2021) found that methanolic extract of beetroot inhibits insulin-sensitive liver damage and hepatic steatosis in type II *diabetes mellitus* rats by upregulating peroxisome proliferator-activated receptor-alpha (PPAR α) and producing hypoglycemic effects. Ali and Bilal (2023) reported that administration of beetroot extract in iron deficient anaemic rats could improve the haemoglobin content, red blood cells and iron serum. The bioactive compounds found in beetroot include betalains, anthocyanins, polyphenols, vitamins, organic acids, and minerals (Kovarovič et al. 2017).

Garlic and Onion

The organosulphur compounds in both onion and garlic and onion (*Allium cepa* L. and *Allium sativum* L.) have the property of scavenging oxidizing agents which contributes to its various health protecting properties like antioxidant, anti-inflammatory and antibacterial activities (Wilson and Demmig-Adams 2007). Curcic et al. (2012) studied different constituents of fragrant yellow onion and

reported to contain good amount of total phenolics and flavonoid content which might be responsible for its antioxidant, antibacterial and anti-proliferative properties. Oboh et al. (2018) reported anti-diabetic and cardioprotective effects (hypertension) of garlic, purple onion and white onion. The aforementioned characteristics stem from the suppression of α -amylase and α -glucosidase enzymes, ACE (Angiotensin converting enzymes) activities, and safeguarding of pancreatic and cardiac tissue from oxidative harm. Besides these properties, onion bulbs were reported to possess analgesic property in a study conducted by Dimitry et al. (2021). Garlic and onion contain bioactive organosulfur compounds such as alliin, allicin, and ACSOs (S-alk(en)yl-L-cysteine sulfoxides) *viz.*, isoalliin, methiin, and cycloalliin (Kim et al. 2018).

Moringa

Moringa (*Moringa oleifera* Lam.) is a rich source of phenolic compounds and minerals such as calcium, iron, copper, and potassium, with high bioaccessibility. This plant has the potential to increase iron levels in breastfeeding mothers, which could help combat iron deficiency and prevent various diseases like osteoporosis and cardiovascular disorders (Peñalver et al. 2022). Research by Castillo-Lopez et al. (2017) has highlighted the antioxidant properties of moringa leaves. Chelliah et al. (2016) found that moringa leaves contain high levels of total polyphenols and exhibit strong antimicrobial effects against dysentery-causing pathogens. Cuellar-Nuñez et al. (2018) suggested that the bioactive components found in moringa leaves, including total dietary fiber and phenolic compounds, may possess chemopreventive properties. Oladeji et al. (2017) reported that moringa leaves and seeds have a low amount of phosphate as phytate, indicating a high bioavailability of phosphate. The most prevalent amino acids in moringa were found to be glutamic acid, arginine, and aspartic acid. The fatty acids present in the highest amounts were linolenic acid, palmitic acid, linoleic acid, and oleic acid (Sánchez-Machado et al. 2010).

The major nutraceutical properties of other minor or underexploited vegetables are given below in the Table 2.

Table 2: Major nutraceutical properties of other vegetables

Sl no.	Crop	Properties	References
1.	Dolichos bean (<i>Lablab purpureus</i> L.)	Pheromone activity, Sleep-inducing activity, Signaling activity, Neuroactive and Analgesic activity	Das et al. 2023
2.	Cluster bean (<i>Cyamopsis tetragonoloba</i> L.)	Antioxidant, Antidiabetic, Antimicrobial, and Cytotoxic potential	Riaz et al. 2022
3.	Asparagus (<i>Asparagus Officinalis</i> L.)	Antimicrobial	Vora et al. 2017
4.	Mint (<i>Mentha spicata</i> L.)	Antioxidant activity	Bajaj et al. 2016
5.	Chinese cabbage (<i>Brassica rapa</i> L. subsp. <i>Pekinensis</i>)	Antioxidant activity	Seong et al. 2016
6.	Basella (<i>B. alba</i> L. and <i>B.</i>	Anti-proliferative, Anti-	Kumar et al. 2018

Sl no.	Crop	Properties	References
	<i>rubra</i> L.)	angiogenic and Antioxidant activity	
7.	Curry Leaf (<i>Murraya koenigii</i> L.)	Anticarcinogenic and Antioxidant activity	Ghasemzadeh et al. 2014
8.	Winged bean (<i>Psophocarpus tetragonolobus</i> L.)	Antioxidant activity	Calvindi et al. 2020
9.	Bitter melon (<i>Momordica charantia</i> L.)	Anti-inflammatory, Antitumor, Antimicrobial and Antioxidant activity	Svobodova et al. 2017
10.	Sweet potato (<i>Ipomoea batatas</i> L.)	Antioxidant activity	Dinu et al. 2021

Wild edible fruits and vegetables consumed by tribals in India

Wild edible plants serve as a nutritional and therapeutic outreach especially for tribals and to some extent, for rural households. A lot of wild edible plants are there with various nutraceutical properties. These are rich in nutritional content, phytochemicals and bioactive components. Various studies are being done about the nutraceutical potential of wild edible fruits and vegetables present in various parts of the world. Most of these studies are conducted in tribal populations because of their intense knowledge about wild plants passed on from generation after generations (Binu 2010).

There are around eighty-three types of wild edible plants that the tribes of Parambikulam Wildlife Sanctuary (Palakkad district, Kerala, India) which are used as wild fruits, vegetables, and other preparations (Yesodharan and Sujana 2007). The majority of these come from wild vegetables, which are made up of various plant components such as roots, tubers, tender leaves, buds, inflorescences, fruits, and seeds. The species that the tribal people in this region consume the most are *Molluga pentaphylla* L., *Euphorbia hirta* L., *Amaranthus spinosus* L., *Centella asiatica* L. Urban, and *Oxalis corniculata* L. Hazarika et al. (2012) reported the ethno-medicinal importance of some wild edible fruits among Mizo tribes in Aizawl district, Mizoram, India. The major medicinal disorders reported for which these fruits were utilized are gastrointestinal disorders, dermatological problems, respiratory problems, cardiovascular compliance, ENT diseases, mental problems, muscular illness, bone diseases, gynaecological problem, cancers, snakebite, allergy and malaria. The most popular leafy vegetable in Kerala, (India) amaranthus, was compared with the nutritional value of wild leafy vegetables by Pradeepkumar et al. (2013). They observed that the leaves of *Cassia tora* L. had lower levels of antinutritional factors like nitrate and oxalate and higher levels of protein, fibre, and vitamin C than amaranthus. Bhatt et al. (2016) studied the nutraceutical potential of some of the wild edible fruits in the Indian Himalayan regions. They found that some of the fruits have good amount of total phenolic content (*Terminalia chebula*, *Phyllanthus emblica* and *Myrica esculenta*), total flavonoids (*Pyaracantha crenulata*, *Terminalia chebula* and *Berberis asiatica*), ascorbic acid and anthocyanin (*Phyllanthus emblica*, *Morus alba* and *Ficus palmata*). Kumar and Jena (2016) have given some elaborate insights about the nutraceutical potential of tubers under *Dioscorea* species

which are abundantly found in the Similipal Biosphere reserve Forest in Odisha, India. The tribal groups inhabiting these forest regions utilize various species of *Dioscorea* for different kinds of ailments such as tuberculosis, poor appetite, syphilis, skin infections, birth control, cooling agent, labour pain, gastric problems *etc.* The nutritional potential of some of the wild edible plants consumed by the tribals of Arunachal Pradesh in India were studied by Seal et al. (2017). According to this study, fruits of *Melodinus khasianus*, leaves of *Solanum nigrum*, *Phytolacca acinosa*, *Piper pedicellatum* and *Pouzolzia hirta* were good sources of protein, carbohydrates, dietary fibre and minerals and the estimated quantities were comparable with that of commercial vegetables.

Conclusion

Owing to the presence of high levels of bioactive compounds including antioxidants, regular consumption of fruits and vegetables could keep many diseases at bay. Besides providing health protective constituents, they also contribute to variety and diversity to diet. Research on health protective properties of fruits and vegetables has been a never-ending aspect, owing to the presence of several nutraceutical compounds like phenolic substances, ascorbic acid, carotenoids and minerals like zinc, selenium *etc.*, which are well-known antioxidants. These compounds along with the dietary fibre present in fruits and vegetables can contribute immensely to physical well-being and overall health of individuals. Experimental studies on health protective properties of fruits and vegetables in animals and further, clinical studies in humans have conclusively proved the disease-fighting functions of fruits like Indian gooseberry (*aonla*), pomegranate, citrus fruits, Indian blackberry (*jamun*), berry fruits *etc.* and vegetables like broccoli, leguminous vegetables, tomato, carrot, beetroot, kale spinach, lettuce *etc.*

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