REVIEW ARTICLE

Bioactive and Functional Properties of Selected Underutilized Blue/Purple Colour Fruits Available in Sri Lanka: A Review

W. M. D. Rangana[*] and H. D. Delpachithra

Highlights

- Anthocyanins are the main pigments responsible for the colour of the blue/purple fruits.
- Blue/purple fruits grow in Sri Lanka are mostly underutilized, seasonal and found in rural areas.
- Blue/purple fruits have many functional properties and rich in bioactive compounds such as polyphenols, flavonoids and organic acids.
- The Locally available blue/ purple colour cultivars are often consumed as raw, but have the potential to be used in the value added product development with functional ingredients.

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Bioactive and Functional Properties of Selected Underutilized Blue/Purple Colour Fruits Available in Sri Lanka: A Review

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Abstract: Climatic changes and human activities have brought global food security to an unbalanced stage where poor-income communities face challenges in fulfilling their dietary requirements and healthy well-being. Functional foods play a key role in these situations and their popularity increases among communities. Blue/purple colour fruits hold a unique position due to their phytochemical profile and few species are available in Sri Lanka though many are underutilized despite their both nutritional and functional benefits. Many of these fruits are rarely seen in the market and are limited to rural areas and/or forests. The review aims to summarize the available data related to bioactive compounds and functional properties of *Dovyalis hebecarpa, Carissa Spinarum, Syzygium caryophyllatum* L*, Antidesma alexiteria, Polyalthia suberosa,* and *Ziziphus oenoplia,* which are underutilized blue/purple fruits available in Sri Lankan soil. These fruits are evidenced to have many functional properties, which include antioxidant, anti-inflammatory, anticancer, antibacterial, etc. As main bioactive compounds, Anthocyanin Phenolic compounds, Flavonoids, carotenoids and ascorbic acids are evidenced in majority of the fruits and many other important compounds are found through studies. The facts highlight these fruits can use to ensure certain nutritional requirements and well-being of the local communities while adding positive feedback to food sustainability. The studies related to many blue/purple colour fruits are highly limited and suggest further studies in the fields of nutritional composition, health benefits, and genetic traits.

Keywords**:** Blue/purple; Fruits; Underutilized; Bioactive-compounds; Functional properties

INTRODUCTION

Fruits and vegetables are dietary sources providing nutritional compounds for both humans and animals. From a botanical point of view, the fruit is the ripened ovary of the plant and the structure, which bears its seeds. Even though fruits are important as a food source, their importance go beyond and provides functional and economical values. The composition of the fruit varies among species, surrounding a spectrum of essential nutrients and phytochemicals including, pigments, tannins, essential oils, phenolic compounds, and organic acids (Lozano, 2006). These phytochemicals play pivotal roles in promoting health, and contribute to the flavour and colour profiles of the fruits. However, it is noteworthy that some of these compounds might exhibit anti-nutritional properties upon consumption as well (Mwamatope et al., 2023).

Global food security faces challenges due to a range of biotic and abiotic factors, including climatic changes and human conflicts (FAO, 2024). Sri Lanka, as a South Asian country, also experiences food insecurities intensified by climate-induced phenomena such as prolonged droughts and high rainfall on agricultural lands that pose threat on nutrition of locals (WFP, 2025). However, indigenous wild fruit plants have shown resilience to local climatic conditions, in contrast to exotic fruit plants, which are cultivated for commercial purposes. Despite their nutritional and functional importance, wild fruits often face limited acceptance and accessibility within communities, primarily due to their restricted availability in wild habitats, which might lead them as underutilized foods (Bvenura & Sivakumar, 2017). The term underutilize is defined by many authors in various ways though simply these are not cultivated commercially and/or large scale nor widely traded. Underutilized or neglected crop plants also easily grow, are hardy in nature, and produce crops under adverse environmental conditions. Underutilized fruits create alternative food sources thus providing key nutrients and phytochemicals. Furthermore, these fruits can be used to produce medicines, oils, and stimulants. Therefore studying crops with such potential is important in fulfilling the dietary requirements of the rural community and their well-being (Mayes et al., 2012; Murthy & Bapat, 2020; Saikia et al., 2024).

The adult daily intake of fruits in Sri Lanka, the value is found to be 0.43 servings per day. However, as per the WHO recommendations, at least two servings of fruits per day for adults are recommended (Jayawardena et al., 2012). Therefore, it is important to utilize available resources to fill the gaps.

The colour of fruits plays an important role in consumer perception, with various hues like red, pink, yellow, green, orange, and blue/purple being prevalent worldwide (Paakki et al., 2015). Compared to the red and black, blue colour fruits are rare in nature. The Colour play a role in attracting frugivores, with blue fruits typically being dispersed by non-avian frugivores (Duan et al., 2014). The blue/purple colour fruits are distinguished by their richness in anthocyanidins, which contribute mainly to the colour of the fruit and are associated with many functional properties

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including health benefits (Khoo et al., 2017; Blumfield et al., 2022). Anthocyanins, a class of flavonoids, represent plant secondary metabolites found in flowers, leaves, and fruits. They are water-soluble pigments that contribute to the different shades of orange, red, blue, and purple in various plant tissues. Functionally, anthocyanins serve as naturally occurring bioactive compounds, which is proven through scientific studies (Horbowicz et al., 2008 and Sirijan et al., 2020).

Sri Lanka, being a tropical country, is home to more than 237 species of fruits, though over 60 varieties are classified as underutilized fruit crops (Ratnayake et al., 2019). As blue/purple colour fruits *Ardisia elliptica Thunb (*Coralberry)*, Antidesma buinis (L.) Spreng* (Queensland Cherry, Bignay)*, Carissa carandas L* (Ceylon Damson), *Dianella ensifolia* (L.) (Umbrella dracaena), *Elaeocarpus granitrus Roxb* (Blue olive), *Syzygium cumini* (L.) Skeels-Java plum, and *Solanum nigrum L* (Black Nightshade) can be identified which are available in Sri Lanka (Uddin & Hassan, 2009; Sumanarathne et al., 2020; Kapesa et al., 2021; Bhowmick et al., 2023; Wathon et al., 2023; Nethmini et al., 2024;). This review aims to highlight the significance of selected underutilized blue/purple fruits (*Antidesma alexiteria L* - Ceylon Bignay, *Carissa Spinarum* L.- Conkerberry, *Dovyalis hebecarpa*- Ceylon gooseberry, *Polyalthia suberosa*- Corky Debbar, *Syzygium caryophyllatum* (L.)- South Indian plum, Indian blackberry, and *Ziziphus oenoplia* (L.)- Jakal Jujube) predominantly found in Sri Lanka by analyzing the bioactive compounds they contain and examining their potential functional properties through a comprehensive review of the existing literature.

METHODOLOGY

The searching and reviewing of the literature was initially conducted between May and October 2024 and second stage was conducted in March 2025. As the blue/ purple colour fruits, *Dovyalis hebecarpa (Gardner) Warb, Carissa Spinarum L., Syzygium caryophyllatum* (L.) Alsoton, *Antidesma alexiteria L.*, *Polyalthia suberosa Roxb*, and *Ziziphus oenoplia* (L.) Mill were selected for the study. As the inclusion criteria, journals, eBooks, book chapters conference or symposium abstracts are selected as the main source for referencing. The publications were searched on databases such as Google scholar, ResearchGate and Pubmed. The publications with addressing fruit with only with common name (no scientific name) were excluded due to uncertainty of fruit identification. Commercial websites and blogs with no traceability to scientific data were not taken but websites that use to market the product of selected fruits were referred only to identify available commercial products.

As the key words, scientific name of the fruit, nutritional and functional properties, bioactive compounds were used in the initial stage. The current scientific name of the fruit is taken from “Plants of the World Online” database. In latter stage of the review, individual properties such as antibacterial, antidiabetic etc. were used to filter the search process.

Dovyalis hebecarpa – Ceylon Gooseberry

D. hebecarpa, locally known as Ketembilla, is native to Sri Lanka and India, yet it has been found in regions such as Brazil, Cuba, and Hawaii. This shrub typically reaches a height ranging from 4 to 6 meters and the trees are dioecious, featuring apetalous flowers in shades of green to yellow. The fruit is globular in shape with a diameter of around 2.5 cm and possesses a velvety pubescent surface. As the fruit matures, it undergoes a colour transformation from green to brown-orange and finally changes to red-purple when fully matured. Notably, the fruits have a sour and astringent taste. However, upon the removal of the peel (exocarp), they are utilized in the preparation of jams, jellies, and juices. About 86% of the fresh weight of the mature fruit is accounted by moisture, while protein and fat constitute 1.05% and 0.22%, respectively (Lim, 2013; Ekanayake & Fernando, 2021).

The anthocyanin content of gooseberry fruit’s peel and pulp show variations with harvesting conditions, during winter harvest, the pulp contains 78 mg Cyanadin-3-glucoside equivalent (C3GE)/100g, while the peel has a higher content of 535 mg C3GE/100g anthocyanins. Notably, a peak anthocyanin content of 646 mg C3GE/100g is observed in the peel harvested in the autumn season. Qualitative analysis reveals that delphinidin-3-rutinoside and cyanidin-3-rutinoside are the main compounds, making 80% of the total anthocyanin profile (Bochi et al., 2015a). Many researchers have demonstrated the health-promoting qualities of anthocyanins, including antioxidant, anti-inflammatory, anti-cancer, and antiviral properties. Notably, these compounds manifest an anti-obesity effect by increasing energy expenditure (Salehi et al., 2020). Furthermore, their health benefits extend to anti-diabetic effects, protection against peroxynitrite-mediated disorders in epithelial cells, and effects against atherogenic and neoplastic conditions. Anthocyanins are pH-dependent pigments and the highly acidic nature of Ceylon gooseberry, may stabilize the anthocyanin structure under its natural form. However, there is a risk of losing its functional properties during food processing (Stintzing & Carle, 2004; Dini et al., 2019).

The study on phenolic compounds, and other bioactive groups, of Ceylon gooseberry fruit, identified the presence of 30 compounds in the flesh and 29 in the peel. Among these compounds, flavonols, hydroxybenzoic acid derivatives, and flavan-3-ols were among the identified groups (Bochi et al., 2015b). In comparison, locally grown gooseberries depict a considerably higher total phenolic content (TPC)- 677 mg Gallic acid equivalent (GAE)/100g in contrast to those cultivated in Brazil (ranging from 43 to 239 mg GAE/100g) and Ecuador (31 mg/g dry weight – moisture content of 85.1%) (Bochi et al., 2015a; Da Silva et al., 2022; Perera et al., 2022; Coyago-Cruz et al., 2023). In the case of the total flavonoid content (TFC) of locally grown fruits, it is valued as 20.5 mg Quercetin equivalent (QE)/100g by fresh weight. (Abeysuriya et al., 2021).

The Ellagitannin is a polyphenol, which shows anti-diabetic effects by inhibition of α-amylase enzyme activity. Ceylon gooseberries evidenced to have Ellagitannin polyphenol thus might have antidiabetic effects. However further research are required to prove the anti-diabetic potential of the fruit (Solayman et al., 2016).

The assessment of the antioxidant capacity of Ceylon gooseberries cultivated in the Brazilian region, as determined by the Oxygen Radical Absorbance Capacity (ORAC) assay, revealed a value of 51.9 µmol GAE/g in fresh fruit. Notably, these values exhibited significant variations with respect to the harvesting season, and the highest value is observed in the winter season (Bochi et al., 2015a). In a Sri Lankan study, antioxidant capacity of the fruit was determined using both FRAP and DPPH assays. The results show a good antioxidant capacity as FRAP and DPPH- IC50 assays 121.7 µmol $FeSO_4$/g and 9.5 mg/mL respectively (Abeysuriya et al., 2021).

Vitamin C is an important nutrient in human nutrition, known for its various health benefits, and causes scurvy under deficiency conditions. The synergistic antioxidant effects of vitamins E and C are studied, showing efficient interaction between the two when present together. In the Ceylon gooseberry fruits cultivated in Brazil, both the pulp and peel are rich sources of ascorbic acid, with concentrations of 142 mg/100g and 33 mg/100g, respectively. The fruit is recognized as a significant source of vitamin C. However, it is noteworthy that previous studies indicate a considerable reduction in ascorbic acid content during the jam processing stages, which highlights necessary actions are required to preserve the ascorbic acids (Niki, 2010; Da Silva et al., 2022). Lazzari et al., (2024), studied adding fruit residue to beer thus modifying its functional and sensory properties. The outcomes showed phenolic compounds, anthocyanin, and antioxidant capacity are increased with improved sensory properties in taste and colour.

The carotenoid compound analysis of *D. hebecarpa* evidenced the presence of Lutein and Zeinoxanthin. The results of total carotenoid content in fruit pulp and peel resulted in 29 mg/100g and 14mg/100g respectively (Da Silva et al., 2022; Coyago-Cruz et al., 2023).

Vanillin is a flavoring agent widely employed in the food industry and possesses significant bioactive properties that proved to have several health benefits. These include antioxidant, anticancer, anti-depressant, neuroprotective, antimicrobial, antibiotic potentiation, and relaxing activities. Notably, locally available Ceylon gooseberries have been found to contain 1.35 mg/kg of vanillin within the fruit (Arya et al., 2021; Perera et al., 2022).

Even though Ceylon gooseberries are considered as an underutilized fruit locally, scientists have developed a hybrid fruit plant with improved qualities and commercial value using *D. hebecarpa* species due to their good bioactive potential. The fruits of the hybrid variety possess a good anthocyanin profile with 10 identified compounds, and delphinidin-3-rutinoside as the major anthocyanin compound. Furthermore, 26 carotenoids have been identified with beta-cryptoxanthin as the major carotenoid and also stated as hybrid fruit, that is a good source of vitamin C (De Rosso & Mercadante, 2007).

Carissa spinarum – Conkerberry

Carissa spinarum, an evergreen shrub of the Apocynaceae family, grows to a height ranging from 2 to 3 m. It was formerly classified as *Carissa edulis* (syn.), and locally named as Heen Karamba. This species is found in many different regions of the world, such as Australia, Bangladesh, India, Ethiopia, Myanmar, Malaysia, and Pakistan. The fruits are seasonal, ovoid-globular in shape, and appear in clusters of groups of 3 to 10 fruits in each. The young immature fruits display a greenish colour, turning to a red shade, and ultimately into a reddish-purple upon full ripening (Fatima et al., 2013; Chauhan et al., 2015; Mamoona et al., 2023).

The proximate composition analysis of *C. spinarum* fruit in the Indian context reveals a predominant moisture content of 81%, accompanied by carbohydrate (19%), protein (2%) and fat (1.3%) (Chauhan et al., 2015). However, in the Ethiopian variety, notable variations are seen, showing reduced moisture levels (59% - 62%) alongside elevated fat (5%) and carbohydrate (26% - 28%) content (Siyum & Meresa, 2021).

The antioxidant capacity of *C. spinarum* fruits found in Indian and African regions was assessed through various assays. In an Indian study, it was determined to be 1013 mg Ascorbic acid equivalent (AEAC)/100g of dry weight using the DPPH assay and 2118 µM AEAC/g in the FRAP assay (Nayak & Basak, 2015). However, when examining the African region, the values differed, ranging from 20-18 mmol Trolox equivalent (TE)/g. Furthermore, it was observed that the antioxidant capacity decreased with fruit maturity, highlighting the significance of harvesting the fruits at the right time (Makumbele et al., 2019). The IC50 values of the fruit extracts ranged from 4.69 to 4.88 mg/mL in the DPPH assay and 35.67 mg/mL in the FRAP assay. Additionally, the research revealed significant variations in antioxidant capacity between ripe and unripe fruits, with higher values found in unripe fruits (Fowsiya & Madhumitha, 2017; Nazareth et al., 2021).

Compared to the unripe fruit, the ripe fruit has a much higher TPC value, ranging from 273 to 1880 mg GAE/100g (fresh weight). This pattern persists with the TFC, resulting highest value at 454 mg QE/100g. The qualitative analysis reveals the presence of various polyphenols in the ripe fruit of *C. spinarum*, including Protocatechuic acid, Gentisic acid, Chlorogenic acid, Vanillic acid, Epicatechin, Syringic acid, p-Coumaric acid, Sinapinic acid, Myricetin, Quercetin, Luteolin, Cinnamic acid, Apigenin, and Resveratrol. Notably, Quercetin, Luteolin, Apigenin, and Resveratrol are not detected in the unripe fruit. Among the identified polyphenolics, Resveratrol (8.2 mg/100g) and Syringic acid (21 mg/100g) were identified as the major compounds in the fruit (Ojerinde et al., 2021; Nazareth et al., 2021). These compounds are important because several phenolic compounds exhibit diverse functional properties such as anticancer, antidiabetic, anti-inflammatory, anti-obesity effects, etc. (Rasouli et al., 2017).

The anthocyanin content of fresh fruit is 50 mg C3GE/L and upon drying, the values are reduced to a significant level probably due to low stability. The reduction was seen in the TPC and TFC values as well; and therefore necessary actions are required to preserve the bioactive compounds (Rafique et al., 2023).

As stated previously, *C. spinarum* has a considerable amount of resveratrol, which is primarily found in grapes (20-366 µg/g). In the pharmaceutical industry, this compound functions as an antiaging and anticancer agent (Wang et al., 2013; Hasan & Bae, 2017). Moreover, research evidence supports the potential therapeutic benefits of resveratrol in treating disorders including obesity, diabetes, hypertension, cardiovascular diseases, and kidney diseases, and it demonstrates antiplatelet properties (Kuršvietienė et al., 2016; Singh et al., 2019).

The ripe fruits of *C. spinarum* are used in the production of jams, jellies, juices, ice cream, pudding, and cakes. In addition, unripe fruits can be found in the production of chutneys, candies, and pickles (Patel, 2015; Dhatwalia et al., 2021). However, Ahuja et al. (2024) state in their review, unripe fruit can cause poisonous effects based on an Australian website. Due to the exclusion criteria of the current review website data is not taken into account and research related to negative effect was not evidenced as well.

Given their seasonal availability and limited shelf life, researchers have explored the feasibility of producing wines from these fruits. Studies have revealed that the sensory attributes of the developed product are satisfactory, showing significant level of antioxidant activity, total phenolic content, and flavonoid content (Mundaragi & Thangadurai, 2017). Mamoona et al. (2023) formulated a functional beverage containing 40% *C. spinarum* fruit extract. However, findings suggest that prolonged storage of such beverages may not suitable due to the degradation of bioactive components such as anthocyanins, vitamin C, and flavonoids over time.

Both ripe and unripe fruits have been documented for their utilization in traditional medicinal practices for certain minor illnesses. Ripe fruits are prescribed for conditions such as diarrhea, anorexia, hyperdipsia, hematemesis, and intermittent fever, whereas unripe fruits are used for the treatment of fever, mouth ulcers, sore throats, and dermatological afflictions such as scabies (Lim, 2012). Nevertheless, despite extensive review, the precise bioactive compound/s responsible for these therapeutic properties remains unknown or not evidenced during the review.

Ojerinde et al. (2021) conducted a study on the antidiabetic effects of Conkerberries by identifying compounds exhibiting anti-alpha glucosidase activity. The results showed the existence of substances with notable anti-diabetic properties. The fruit also showed anticancer, antimalarial, and antimicrobial activities against bacterial strains such as *B.subtilis, S. aureus, E.coli, Streptococcus faecalis,* and *Salmonella typhimurium* (Arif et al., 2019).

***Syzygium caryophyllatum* – South Indian plum**

Syzygium caryophyllatum, another native plant found in Sri Lanka and India, is an endangered species belonging to the family Myrtaceae (Wathsara et al., 2020). This medium-sized tree typically reaches a height of 2 to 6 m (Shareef & Kumar 2022). The fruits are seasonal, appearing from April to June, globular in shape, and turning dark purple when fully ripened. They are considered as an underutilized fruit possibly due to limited availability and low amount of edible parts. Additionally, the fruits are acidic and exhibit a taste profile of sweet-astringent-sour, with a relatively low pH value of 4.04 (Shilpa & Krishnakumar, 2015; Kasunmala et al., 2021)

The fruit has a high moisture content of 61-63% and value is increased with full maturation. The proximate composition of these plums revealed crude fat- 0.95%, protein- 3.37%, crude fiber - 4.12%, and carbohydrates constituting 90% (dry basis). Furthermore, the total sugar content resulted as 38g/ 100g on a dry weight basis (Shilpa & Krishnakumar, 2015; Abdussalam et al., 2024).

The anthocyanins, a prominent group of compounds responsible for the colour of the plum, have been quantified at 79 mg C3GE/g of dry weight, and in a separate study, it is mentioned as 240 mg/L (Shilpa & Krishnakumar, 2015; Mallawaarachchi et al, 2021). These values account for the monomeric forms of anthocyanins, although it is noted that around 43% of the anthocyanins present in black plums are in polymerized forms. Therefore, the total anthocyanin content can be expected in much higher value. The studies were also conducted beyond the quantification and found the principal anthocyanin compounds contributing to the fruit's colour are derivatives of Malvidin and Petunidin (Shetty et al., 2019).

The flavonoid content of black plums grown in Sri Lanka is approximately 2 mg QE/g. In comparison to Indian fruits, which have a content of 2.5 mg Rutin equivalents (RE)/g on a dry weight basis, the values observed in Sri Lankan black plums are slightly lower (Stalin & Sudhakar, 2018; Wathsara et al., 2020). The flavonoid compounds Liquiritegenin, Quercetin, Kaempferol, Isoquercetin, Dihydroxyflavan, Kaempferide, Quercemeritrin, Hydroxyflavan, and Quercetin methyl ester were identified in fruits grown in Kerala-India (Kala et al., 2016).

It is noteworthy that the values reported by Shilpa & Krishnakumar (2015) appeared to be significantly higher than the recent studies. In comparison to the Indian type, which is rated at 8 mg/g (dry basis), Sri Lankan grown black plums have a significantly greater TPC, ranging from 8 to 61 mg GAE/g (dry weight basis), which defies the trend TFC. (Stalin & Sudhakar, 2018; Kasunmala et al., 2020; Mallawaarachchi et al., 2021).

A Sri Lankan study conducted to investigate the antioxidant properties of black plum, important findings were reported, including a FRAP assay result of 63 TE/g, EC50 value of 946 µg/mL in the DPPH assay, and the ORAC assay value of 119 mg TE/g (Wathsara et al., 2020).

Coumarins were detected in the *S. caryophyllatum* fruits (seed and pulp) and Xanthotoxin, Xanthatoxin, Xanthatoxol, Xanthotoxol, Scopoletin and Wedelolactone are among the identified compounds (Kala et al., 2016).

Tannins are bioactive compounds known for their diverse range of health-promoting properties, including antioxidant, antimicrobial, antidiabetic, anti-obesity, anticancer, cardioprotective, histamine release inhibition, and cytotoxic activities. However, tannins can also exhibit negative effects such as forming complexes with proteins, starches, and metal ions, thereby reducing bioavailability. Additionally, tannins contribute to the astringency and bitter taste of foods (Sieniawska & Baj, 2017; Soares et al., 2020). In the case of black plum fruits' tannin content, it is reported as 1.04 mg/g (dry weight), which is significantly lower compared to the content found in the leaves (Stalin & Sudhakar, 2018). A different study indicated tannin content as 207mg Tannic Acid Equivalent/ g of extract. It is difficult to compare the values as protocols used in analysis are different (Sathyanarayanan et al., 2017). Moreover, based on study in Indian cultivar the fruits also contain Oxalate, Phytate and saponins (Abdussalam et al., 2024).

In addition to the aforementioned bioactive compounds, the fruit contains beta-carotene (112 µg/g), crocetin, lycopene (23 µg/g), and ascorbic acid (8 µg/g).(Kala et al., 2016; Kumari & Gunathilake, 2020). Abdussalam et al. (2024) also studied on total carotenoid content but the article is lack of information such as units of the resulted values, which give contradictions on the results.

The antibacterial properties of the fruit extract were assessed through an in vitro study using strains of *E. coli*, *Bacillus subtilis*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Proteus vulgaris*, and *Pseudomonas aeruginosa* bacteria. The findings demonstrated a significant level of antibacterial activity against these tested strains (Shilpa & Krishnakumar, 2015). In a separate study, the extract's anti-glycation and anti-amylase activities were investigated, which revealed positive effects. However, the specific compounds responsible for these properties were not investigated (Wathsara et al., 2020).

Stalin & Sudhakar, (2018), investigated the inhibitory potential of α-amylase and α-glucosidase of methanolic extract of *S. caryophyllatum* fruit. The results showed positive inhibition of the enzymes; however, the inhibition activity is dependent with the concentration of the extract. The IC50 values of the study are 292 µg/mL (α-amylase) and 62 µg/mL (α-glucosidase).

Antidesma alexiteria – Ceylon Bignay

Antidesma alexiteria, a shrub of the Euphorbiaceae family, is indigenous to Sri Lanka and India. It is locally referred to as Heen-ambilla, and its leaves and bark are utilized in traditional medicine. The fruit, which grows in clusters and takes an ovoid form, transitions to a dark purple hue upon full ripening. It is edible and can be consumed either raw or after processing into juice (George et al., 2021). However, comprehensive data regarding the fruit's proximate composition and many other functional information are unavailable in literature except for the moisture content (76.7%) (Nethmini et al., 2024).

The reported highest TFC of Ceylon bignay is 207 mg QE/100g (by fresh weight), while the TPC values ranged from 3 to 7 mg GAE/ g. The antioxidant properties, as per the FRAP assay is 877.5 mg TE/100g and, its potency in scavenging free radicals, assessed through the DPPH assay, indicates an IC50 value ranging from 1.3 to 5 mg/mL. Additionally, the fruit contains a significant quantity of vitamin C, known for its antioxidant properties, resulting at 46 mg/100g (fresh weight) (Narayana et al., 2019; Abeysuriya et al., 2021; Nethmini et al., 2024). The antioxidant property of the fruit is experimented through ability to stabilize oxidative rancidity process of selected oils. The results indicated fruit extract is an excellent source of antioxidant that can use to control the oxidation of edible oils such as sunflower and virgin coconut oil (Nanayakkara et al., 2019).

The monomeric anthocyanin content of the fruit was found to be in the range of 68 to 130 mg/L. Given its significant anthocyanin concentration, researchers have conducted experiments suggesting its potential utilization as a natural food colourant source (Narayana et al., 2019). The antidiabetic efficacy of the fruit extract has been examined, revealing its capacity to inhibit alpha-amylase activity (Karunarathne & Weerasiri, 2023).

The *A. bunius*, another species having purple fruits with wider distribution across the world, is used to prepare Jam, Juice, Juice concentrate, cider, and wine. Therefore, the Heen embilla might also have possibilities to produce such products though further research is required (Jorjong et al., 2015; Marchellia et al., 2020). However, scarcity of the fruits and highly limited distribution of the plant may affect its economic importance. Moreover, toxic effects of the *A. bunius* fruit were conducted using mice by giving ethanolic extracts of the fruits. The study indicated that orally given extracts of 2000mg/kg of body weight showed no adverse effects and acute toxic conditions and stated fruit is safe to eat (Muñoz et al., 2021).

Polyalthia suberosa – Corky Debbar

Polyalthia suberosa, a small shrub reaching heights of 2-4 meters, distributed in the regions of India, China, Bangladesh, Vietnam, Thailand, Myanmar, Philippines, and Malaysia. The plant is commonly termed Corky debbar and named locally as Kalatiya. The fruiting is seasonal and available in February and March. The fruit is edible, globular in shape, fleshy texture, purple in colour, and grows as clusters. Analysis of its proximate composition reveals a moisture content of 65%, with carbohydrate content 4.25%, protein 1.96%, and total sugars measuring at 4.3%. (Mahapatra et al., 2012; Yasmen et al., 2018; Islam et al., 2019).

The TPC of the fruit extract is (135 mg GAE/g) higher than that of the bark and leaf part, but TFC is (61 mg QE/g) is lower than the bark and leaf extracts (Labu et al., 2013). Uddin et al. (2011), studied on antioxidant activity of the fruits extract through DPPH assay and resulted with an IC50 value of 102 µg/mL. Additionally, the fruit contains 15.7 mg/100g of ascorbic acid content (Mahapatra et al., 2012).

The carotenoid content of the fruits recorded around 129 mg/g (Mahapatra et al., 2012). Carotenoids exhibit antioxidant, anti-inflammatory, and anti-angiogenic properties, as evidenced by scientific research. Moreover, numerous studies have established their potential in preventing and managing certain cancers, cardiovascular diseases, reducing the risk of non-alcoholic fatty liver disease, promoting bone health, and alleviating symptoms associated with COVID-19 (Gebregziabher et al., 2023).

The antibacterial properties of the fruit against human and fish pathogenic bacteria were examined using strains of *E. coli*, *S. aureus*, *B. subtilis, B. licheniformis, B. mycoides, P. aeruginosa, P. fluorescens*, *P. putida* and 4 species of *Aeromonas* genus. The results indicated the fruit extract is effective against selected strains (Das et al., 2023).

Labu et al., (2013) tested the analgesic activity of the methanolic extract of the fruit via Acetic acid-induced writhing model and tail immersion method on an albino mice sample. The extract showed the capability of inhibiting both mechanisms and they suggest fruit extract may act as a narcotic analgesic. The antidiarrheal activity of the fruits is experimented with using an in-vivo model, with two protocols, which are castor oil induced diarrhea and MgSO4 induced diarrhea. The mice used for the study showed around 63% - 65%% Inhibition of defaecation which supported the claim of its potential efficacy in preventing diarrhea (Labu et al., 2013). Moreover, local communities in Bangladesh use ripe fruits due to their purported diuretic, soporific, and sedative properties (Islam et al., 2019; Amin et al., 2022).

***Ziziphus oenoplia*, - Jakal Jujube**

Ziziphus oenoplia, commonly known as Jakal Jujube, is a shrub belonging to the family Rhamnaceae that is distributed across Sri Lanka, Malaysia, India, Pakistan, China, and Australia. The fruit is a small drupe, ovoid in shape, dark purple-black in colour, and possesses a sweet acidic taste (Thirugnanasampandan et al., 2017; Samarasinghe et al., 2023). The recent studies of the fruit chemical composition evidenced moisture content in the range around 78%-83%, The chemical composition of the fruit evidenced as moisture content around 57%, carbohydrates 17%, and protein content is 0.7% (Mahapatra et al., 2012; Meena et al., 2023).

The TPC of the fruits was found to be 256 mg GAE/g of fruit, with quercetin and quinic acid identified as the major phenolic compounds. The highest TFC was evidenced to be 69 mg catechin equivalent/g. However, these findings are based on the studies conducted in Indian regions and local studies were not found (Thirugnanasampandan et al., 2017; Meena et al., 2023). The study by Soorya et al. (2015) gave contradictory findings as the qualitative study indicated absence of flavonoids though they have mentioned a value for TFC.

The fruits are utilized in traditional Indian medicine for the treatment of diabetes and Goyal et al. (2021) investigated this effect by examining the fruit extract's inhibitory potential on alpha-amylase and alpha-glucosidase enzymes. The study employed different concentrations of the fruit extract and found a positive correlation with the inhibition of both enzyme activities. The study is further supported by Vadivu et al. (2024) which showed through an in-vitro study using alpha-amylase and alpha-glucosidase inhibition assays. They further state the inhibitory activity of alpha amylase (IC50 329 ug/mL) and alpha glucosidase (IC50 337 ug/mL) is by bioactive compounds present in the alcoholic extract Heneicosane, Quinic acid, 9-Octadecenoic acid methyl ester, and Linoleic acid ethyl ester.

The antioxidant potential of *Ziziphus oenoplia* was evaluated by measuring the IC50 values using the DPPH and FRAP assays. The results of these assays indicated IC50 values of 160 µg/mL for DPPH and 220 µg/mL for FRAP, suggesting that the fruits possess significant antioxidant activity (Thirugnanasampandan et al., 2017).

The antibacterial and antifungal activities of the fruits is available against *E. coli* and *Fusarium* sp. through *in vitro* studies. The results showed fruit has more inhibitory action compared to bark and leaf extracts though more studies are required against different microbial species (Mishra et al., 2025).

Kuppast & Kumar (2012) investigated the wound-healing properties of fruit extracts using 5% w/v ointment of fruit extract application on rats. They tested on both aqueous and alcoholic extracts, which showed reduced epithelialization time, increased tissue tensile strength, and granuloma tensile strength in both extracts. The authors of this study assumed the property is due to the flavonoid profile of the fruit but further studies are required to test the assumption.

The study by Vadivu et al (2024) indicated the presence of Terpenoids, Glycosides, Steroids, Anthraquinones, Quinones, and Alkaloids, Coumarins, were absent in the fruit extracts. However, Thenmozhi et al. (2021) identified alkaloids in the fruit at the level around 0.75 mg/g of hexane fruit extract. The variation of the analytical method used might be a reason behind the contradiction of the results.

More studies explored the health benefits of the fruit, revealing apoptotic, hepatoprotective, and cytotoxic activities in the extracts. Additionally, the fruit is used in traditional medicine for blood purification, alleviating stomach pain, as a febrifuge, and as a laxative. However, the review did not find scientific evidence supporting these traditional uses (Thirugnanasampandan et al., 2017).

The studies also conducted to evaluate the negative side of the Jakal Jujube by investigating its' anti-nutrients. Despite of result of Soorya et al., 2015 indicating absence of Tannins and Thenmozhi et al. (2021) as absence of Saponin in the fruits extract, other findings of various researchers mentioned presence of Tannins (0.062 g/g Tannic acid equivalents), Oxalate (3.59 mg/g), Phytate (5.15 mg/g) and Saponin (0.07 g/g) by dry weight. The seasonal and methodological variations in the studies may have effect on the findings. These phytochemicals possess anti-nutritional properties, which can potentially interfere with nutrient absorption and metabolism (Rout & Basak, 2014; Vadivu et al., 2024).

It is essential to acknowledge that determining the antioxidant potential of plant extracts is challenging with a single assay due to its complex mode of action and readers may come across few assays while going through the review. Simply the antioxidant capacity determining assays are categorized as either hydrogen transfer-based assays or single electron transfer reaction-based assays.

In hydrogen transfer assay, the antioxidant's scavenging activity of free radicals by donating hydrogen is measured while in electron transfer assay mode its ability to reduce radicals and other compounds (redox active metal ions) is measured as compounds' antioxidant capacity. The DPPH assay primarily based on the electron transfer assay method and antioxidant function through the hydrogen transfer mechanism also shows activity. In the case of the FRAP assay, it measured primarily antioxidants acting through electron transfer mode and showed little relationship with antioxidants with the hydrogen transfer method. The ORAC assay acts through hydrogen transfer-based assay reactions and is broadly used in the food industry. However, not suitable for samples with lipophilic antioxidants (Huang et al., 2005; Shalaby & Shanab, 2022). Therefore, researchers employ multiple assays to assess and predict its antioxidant activity comprehensively.

Comparatively with existing data of commonly utilized fruits in Sri Lanka; banana, pineapple, wood apple, papaya, lime, and avocado, bluish/purple colour fruits have total phenolic content and total flavonoid content in higher levels. The antioxidant capacity (based on DPPH and FRAP assays) of these underutilized fruits was also revealed to be at good levels thus providing a competitive advantage to the consumers (Abeysuriya et al., 2020).

The bioactive compounds in plants varies with both internal and external factors. Even within the same species, genetic profile, light, temperature, growing site can affect its profile (Cirak & Radusiene 2019). The article highlights how these factors affect bioactive profile and functional properties with available data, which benefits the industry on selection of raw material for processing, import/exports and identifying important genetic traits. Most importantly, this indirectly indicates that climatic changes could affect the bioactive compounds of plant fruits and its functional properties thus regional changes can expect with time.

CONCLUSIONS

Blue/purple colour fruits are significantly important due to their bioactive compounds and functional properties. Sri Lanka houses blue/purple fruits, which are seasonal, underutilized and rarely found that gives a major drawback when continuing a stable production system. All the fruits pose good TPC and TFC values with significant level of antioxidant properties. The fruits of *C. spinarum, S. caryophyllatum and Z. oenoplia* showed antidiabetic properties through in-vitro studies and *S. caryophyllatum, P. suberosa and Z. oenoplia* evidenced to have antimicrobial effects against certain microflora. In addition, their bioactive compounds evidenced to have more health benefits and economical values. Both in-vivo and in-vitro studies have supported certain health claims though data related to these fruits are highly scarce in the local context and more studies are required to highlight the importance. The knowledge gap related to *A. alexiteria* and ***P.** suberosa* are scarce compared to other fruits and suggest further scientific research in these fruits. Moreover, authors like to suggest studies on evaluating their genetic profile as it will aid in developing hybrid varieties with improved traits such as Dovyalis hybrid fruits.

Even though value added products such as wine, jam etc. of some fruits are available in international market; locals are used to consume them as in raw form. Since the evidence suggest, locally available cultivars are high in functional ingredients, developing sustainable products and/or planning to cultivate these fruits in large scale, may bring economic benefits to local farmers. However, controlling the anti-nutrient compounds and preserving the bioactive ingredients when developing value added products in order to sustain the functional properties of the fruit is crucial. Furthermore, utilizing these fruits may provide food security to the people in rural areas through sustaining food supply with quality food with nutrients and bioactive compounds, which address the nutrition deficiency-associated illnesses and disorders of the local communities.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare no conflicts of interest

AUTHOR CONTRIBUTION

All authors have accepted responsibility for the content of the manuscript, reviewed the content of the manuscript, and approved the final version; Conceptualization, writing and reviewing manuscript: **W.M.D.;** Writing, editing and reviewing manuscript: **H.D**

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