Bioactive Compounds of Plum mango (*Bouea macrophylla* Griffith)

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Abstract

The fruit of *Bouea macrophylla* referred as Plum mango or Gandaria is a popular seasonal fruit, which is widely consumed in the Malay subcontinent. There is ample of traditional knowledge available among the locals on the use of leaves, bark, fruits and seeds of this plant. However, very limited research information and scientific report is available on their composition, phytochemicals or on the bioactive compounds. In the present chapter, we have aimed towards comprehensively providing information on nutritional value, functional qualities, health promoting bioactive compounds and volatile constituents of this underutilized fruit.

Keywords Antioxidant compounds ·Functional properties · Nutraceutical value ·Plum mango ·Volatiles

1 Introduction

Fruits consumption has gained significant status in the normal diet, and this is attributed to their high nutritional value and vital health benefits provided. Ample amounts of beneficial phytochemicals in the fruits and their bioavailability plays a vital role in determining the beneficial effects to humans [1-3]. As of today, there are countless reports available in the scientific database on the composition, nutritional values and health benefits of consuming fresh fruits. Tropical regions of South-East Asia, has a wide diversity of underutilized plant resources, which possess rich nutraceutical values. Among these are the underexploited and underutilized fruits, which are popular among locals, especially among the rural population and farming communities. Besides, on many occasions these fruit are encountered in the wild too. These fruits embrace their own distinctive and characteristic taste and aroma. Some examples of the popular exotic fruits in Southeast Asia include Plum mango, Durian, Rambutan, Longan, Maprang or Ma Yong, Ee-quee, and Nangka. In majority of the Southeast

Asian countries, especially in rural households and personnel involved in the farming sectors, these underutilized fruits play a vital role as a part of the daily diet, providing essential daily nutrients. In certain instances, these underutilized fruits form a part of folk or the traditional medicine system. Some of the underutilized fruits have been opined to provide household income and ensure food security in rural households [4].

2 Botanical Classification of Genus *Bouea*

There are specifically two plants species belonging to genus *Bouea*: *Bouea macrophylla* Griffith (also known as *Bouea gandaria* Blume ex Miq. and *Tropidopetalum javanicum* Turcz.) and *Bouea oppositifolia* (Roxb.) Meisn (also known as *Bouea angustifolia* Bl., *Bouea burmanica* Griff.,*Bouea microphylla* Griff., *Bouea diversifolia* Miq.) [5].

Bouea macrophylla Griffith belong to the family Anacardiaceae and is commonly referred as Plum mango, Gandaria and Marian plum. This tropical fruit tree is native to Southeast Asia especially in Malaysia, Indonesia, Thailand, Burma, Philippines and is widely cultivated for shade, as ornamental plant and also for the fruits [5]. A wide range of vernacular names are there for this fruit in different regions (Table 1).

Bouea macrophylla are small trees, which are evergreen, robust and perennial grow up to 27 m tall, and luxuriantly in light and lush soil. They are of hot and humid tropics species and found located mainly in the lowland rainforests (below 300 m elevation); however, some cultivated species are reported to grow up to elevation of 850 m height [5].

3 General Uses

Plum mango tree are common in home gardens as an ornamental fruit bearing shade tree [6,7]. Apart from this, the timber of plum mango is used in making handicrafts, casings for 'kris' (Malay dagger), and are used for small-scale construction purpose[5].All of the plant parts viz. stem, leaves, unripe and ripe fruits and their seeds are edible. Unripe fruits are used as ingredient in preparation of many dishes. Both of the 'matured' unripe and ripe fruits are sub-globose drupes (3-5 cm × 3−5 cm in size). The ripe fruits are orange coloured [Fig.1 (b)] encompasses orange to yellowish pulp, which are highly juicy with mild sweet to sourness. Regularly in Malaysia and other regions, ripe fruits usein jam, refreshing drinks, syrups, stews. Whereas, unripe fruit with green skin [Fig. 1 (a)] are sour in taste and finds their use in salads. These unripe fruits are used in preparing ‘rojak’,a traditional dishin Malaysia and Indonesia [Fig. 1 (c)].. Unripe fruits are also used in preparing ‘asinan’ (pickles) [Fig. 1 (d)]. Just like the raw and unripe mangoes, young unripe fruits of Plum mango are used to prepare 'chilli-based' condiments and pickles in Thailand [6, 7].

The leaves find usage in preparing salads or are eaten raw (in Java region of Indonesia). The endosperm of seeds is purpled colour [Fig.1 (e and f)], bitter and edible [5,8]. Its use had well documented in traditional folk medicines for treating headaches, and juice as a natural antibiotic gargle to treat oral thrush [5].Recently, moisturizing anti-photo-aging effects of the fruits extract in hairless mice exposed to UV-B irradiation is reported [9].

Table 1 Commonvernacular names of *Boueamacrophylla* Griffith

Country	Vernacular name
Malaysia	Kundang, Setar, Asam Suku, Kondongan, Kedungan Hutan, Serapok, Pako, Kundangan
Thailand	Somprang, Mayong
Indonesia	Gandaria, Pao Gandaria, Kundangan, Gandoriah, Barania, Buwa Gunarjah
Philippines	Gandaria
Spanish	Gandaria
German	Pflaumen mango

Source:[5,10].

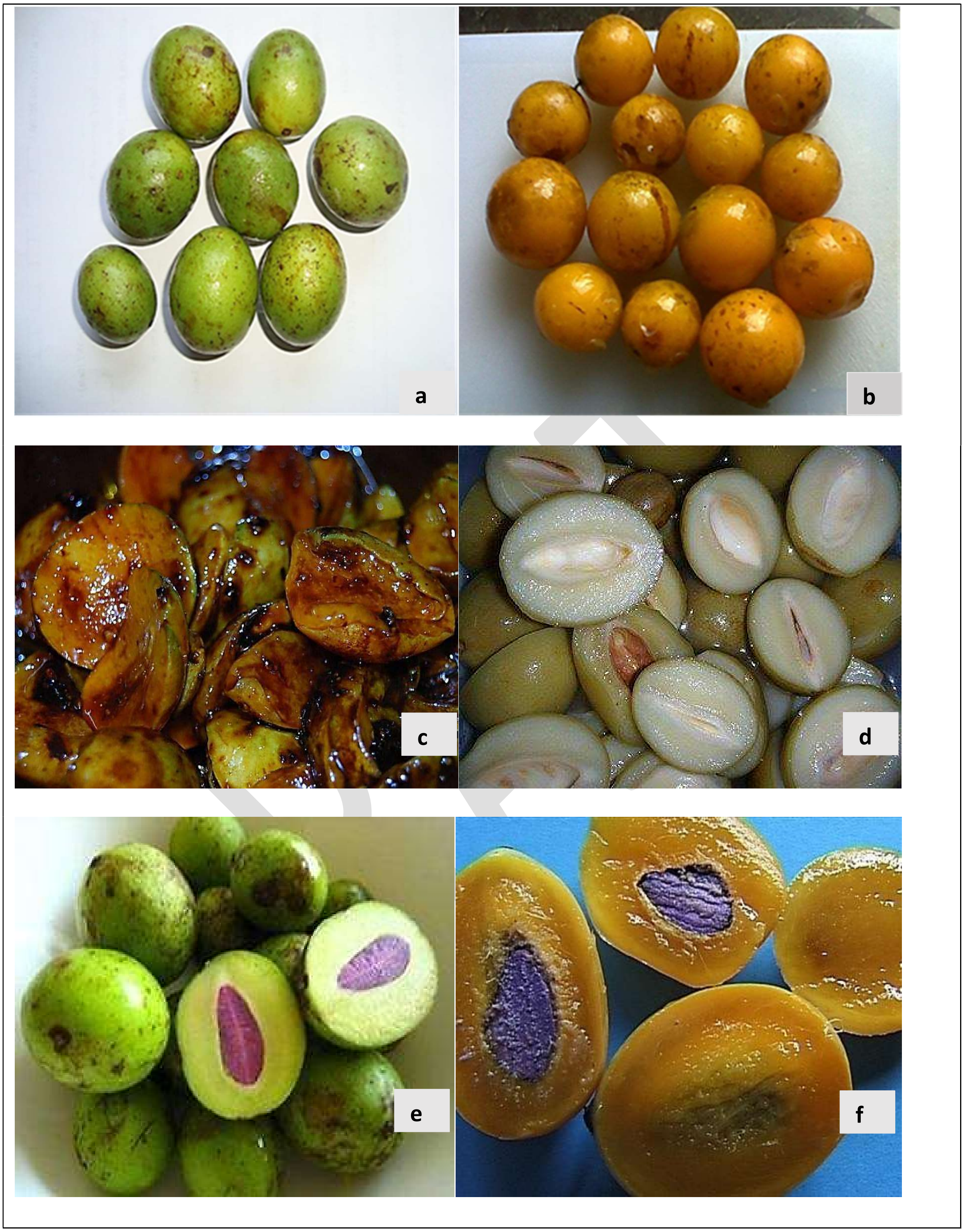

Fig.1. (a) Unripe fruits **(b)** ripe fruits **(c)** Rojak (traditional fruit and vegetable salad dish) **(d)** Pickles (Asinan) **(e)** Purple coloured seeds in unripe fruit **(f)** Purple coloured seeds in ripe fruit Source:Rajan[10].

4 Nutritional Compositions

The nutritional composition of edible portion of ripe fruits (peel and pulp portions) is reported. However, very limited information is available on the nutritional composition of different cultivars of this fruits from different regions.

Recently, the nutritional composition (as proximate composition, amino acids, minerals, and heavy metals) of both unripe and ripe fruits has been reported [11] (Table 2). Fruits are rich source of ash, fiber, protein and lipid. Amino acid contents in unripe fruits were much higher than ripe fruits, and this was attributed to higher protein content in unripe fruits. In unripe fruits, cysteine was the main amino acid (13.59 g/100 g N), with methionine present in lower level (1.26 g/100 g N). In ripe fruits, alanine was the major amino acid (7.52% N), with tyrosine being the lowest (1.37% N).It was reported that both unripe and ripe fruits are rich in essential minerals especially potassium (7801.5 and 10087.5 mg/kg) with the trace amount of heavy metals (< 5.0 mg/kg) (cadmium, nickel, mercury, lead and arsenic). Further, chromium, selenium and boron were also detected in low amounts (<2.5 mg/kg). Unripe and ripe fruits encompassed significant amounts of insoluble dietary fibre (16.62 and 10.18%) [11].

Table 2 Nutrient composition of edible portion of ripe plum mango fruit per 100 g [Source:[11]

Components	**Tee et al.** [33]	**Fruit from Honduras, Morton** [34]	**Rajan et al.** [11] **(Malaysia)**	
			Unripe fruit	**Ripe fruit**
Energy	49 kcl			
Water/moisture	87.5 g	85 g	7.16 mg	6.0 mg
Protein	0.6 g	112 mg	0.64 mg	0.47 mg
Fat	1.2 g	40 mg	2.14 mg	1.89
Carbohydrate	9.0 g		88.62 (NFE)	91.81 (NFE)
Fibre	1.4 g	600 mg	6.39 mg	3.64 mg
Ash	0.3 g	230 mg	2.22 mg	2.19 mg
Ca	5 mg	6 mg	931.6 mg/kg	561.4 mg/kg
P	10 mg	10.8 mg	1200 mg/kg	800 mg/kg
Fe	0.2 mg	0.31 mg	35.5 mg/kg	22.9 mg/kg
Na	2 mg		101.9 mg/kg	90.5 mg/kg
K	84.0 mg		7801mg/kg	10087.5 mg/kg
Vitamin A	55 µg RE			
Vitamin B1	0.03 mg			
Vitamin B2	0.03 mg			
Vitamin C	20 mg	75 mg		
Niacin	0.1 mg	0.286 mg		
Lutein	457 mg			
Thiamine		0.031		
Riboflavin		0.025 mg		
Crytoxanthin	155 µg			
Carotene	331 µg			
α-carotene				
β-carotene	301 mg			
γ-carotene	52 mg			
Other carotenoids	514 mg			
Total carotenoids	67 mg RE			

5 Functional Properties

In a food system, functional properties are generally characterized and dependent on the physico-chemical properties of protein. Studying these properties is vital as they can affect the behaviour of foods during formulation, processing, and storage [12,13].Determination of functional properties in the development of food product or as an added ingredient is crucial as they provide information on various types of processing applications to bead opted, preparation styles, enhancing the food quality and consumer acceptance of particular food product aimed to be developed. Generally, functional properties are determined for cereal or legumes based flours (wheat, rice, legumes), however in this case fruit powders (freeze-dried) properties were determined as they can find wide applications during food fortification while developing new food products [10].

5.1 Water and Oil Absorption Capacity(WAC and OAC)

WAC of the unripe fruit flour/powder was recorded to be appreciably higher than ripe fruit powder (Table3). This is credited to high fibre content in unripe fruits than in ripe fruits. The hydroxyl groups (in the structure of fibre) cause hydration process to occur by permitting higher level of water binding through the hydrogen bonding. As unripe fruit contained higher soluble fibre content than the ripe fruit, the soluble fiber will have higher hydration capability to form viscous solution in the unripe fruit. This renders unripe fruits to have a better water absorption capacity [14,15].Further, this observation was attributed to the higher hydrophilic sub-units structure of protein in unripe fruits that can bind more water molecules[16].As indicated in the Table 3, it was observed that oil absorption capacity(OAC) of unripe fruit powder to be significantly higher than the ripe fruit powder. The attraction of non-polar protein side chains for lipids and physical entrapment of oil by food components is opined to be the basic operating system for the OAC[17].

The capability of protein to absorb and retain water and/or oil is an important factor in determining texture of food products and for the mouthfeel. As per Bhat and Sridhar [18]food commodities with higher WAC are beneficial for maintaining freshness of foods and for easy handling of products like sausages, bread, soup and gravies. In addition, food products with good WAC are beneficial in semi-liquid and liquid foods as can perform the role of thickeners [19].Besides, foods with higher OAC can be a better flavour retainer and can contribute towards enhancement of shelf-life[12, 20].

5.2 Emulsion Activity and Emulsion Stability

Emulsion is influenced by protein surface activities [21]. Emulsion capacity is the maximal volume of oil, which are emulsified via dispersion of protein. Whereas, emulsion activity is a reflection of the interfacial area happening between oil and water, and that is stabilized per unit weight of protein. On the other hand, emulsion stability indicates stability of the emulsion, which forms or remains unaltered for a specified time. This shows protein strength that resists changes to stability of interfacial area formed [22,23]. As indicated in the Table 3, emulsion activity of the unripe fruit powder was significantly high than the ripe fruit. So also, emulsion stability of unripe fruit powder was higher than ripe fruit powder, but were not significantly different. The ripe fruit had a lower EA and ES than the unripe fruit, attributed to the lower protein content in the ripe fruit.

5.3 Foaming Capacity (FC)

Foaming capacity (FC) of unripe fruit powder/flour was high when compared with ripe fruit powder. Improved foaming capability can be influenced via high protein content and solubility [24]. Besides, the capability of flour to foam can get affected by flexible protein molecules, which can have characteristics to reduce surface tension of water. Food components with good foaming capacity and stability are vital in bakery products, cakes, confectionary, sausages, frozen desserts, soup, salad dressing [25].

5.4 pH and Least Gelation Capacity (LGC)

The pH values in both unripe and ripe freeze dried fruit flour are represented in Table 3. The unripe fruits were more acidic (pH 2.58) than the ripe fruit (pH 3.09).LGC was determined for the concentrations of 2 % to 16%. During a food formulation, specifically like that of semi-solid food products, LGC can be a good binder[26]. The unripe fruit powder had high LGC when compared with ripe fruit powder (16 % and 12 % respectively). LGC is an important indicator of gelling capacity and is termed as the least or lowest concentration required to form a self-supporting gel inside a food system. Gelation includes enlargement of starch and protein molecules in flour during heating. Various components of protein, lipids and carbohydrates can also influence the LGC in food flours. Higher protein level in flour enables better gelation property, owed to improved interactions between the binding forces. According to Sathe et al. [27], different flours have different LGC and this is influenced by relative ratios of various components such as lipid, protein and carbohydrates. The higher the protein contents in the flour, better is the gelation properties, owing to improved interactions among binding forces.

Table 3 The functional properties of unripe and ripe fruit of plum mango

Functional Properties	**Unripe**	**Ripe**
Water absorption capacity (WAC) (%)	3.36 ± 0.0 [b]	2.83 ± 0.1 [a]
Oil absorption capacity (OAC) (%)	2.64 ± 0.0 [b]	2.51 ± 0.1 [a]
Emulsifying Activity (EA) (%)	39.00 ± 0.9 [b]	30.31 ± 2.9 [a]
Emulsion Stability (ES) (%)	28.23 ± 2.4 [a]	25.44 ± 2.2 [a]
Foaming capacity (FC) (%)	60.13 ± 1.1 [b]	19.14 ± 1.1 [a]
pH	2.58 ± 0.0 [a]	3.09 ± 0.0 [b]
Least gelation concentration (LGC) (%)	16.00	12.00

n = 3 (mean ± SD). Values in the same row with different superscript letter are significantly different from each other ($p < 0.05$). All the results reported are on dry weight basis.

Source: Rajan [10]

6 Sugar Compositions

Rajan [10] evaluated the composition of sugars (in freeze dried fruit powder) like glucose, fructose and sucrose in unripe and ripe fruits (Fig 2.1 A, B and C). Ripe fruit powder to contain higher sugar levels than unripe fruit. Ripe fruit, which was extracted in methanol, had high sucrose content, followed by fructose in ripe fruits extracted with distilled water. It was observed that independently, in each sugar type, ripe fruits extracted in distilled water to have highest glucose and fructose content; however, sucrose concentration was recorded to be highest in methanol extracts of ripe fruit. The ripe fruit extracted in distilled water (541.63 mg/g) followed the total sugar content in ripe fruit extracted with methanol. The level recorded was highest sugar concentration (546.78 mg/g) and this can be attributed to the simple sugars and oligosaccharides that can readily dissolve in methanol and water during extraction process [28].Table 4 depicts glucose, fructose and sucrose concentration of unripe and ripe fruits.

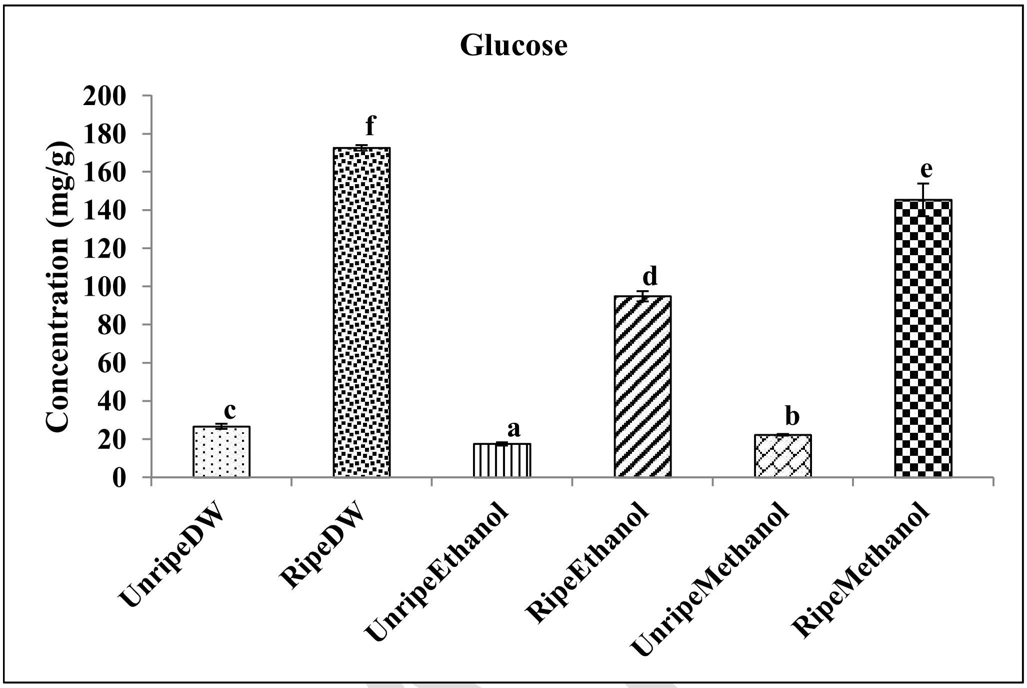

Figure 2 (A) Concentration (mg/g) of glucose in unripe and ripe *Bouea macrophylla* fruits of three solvents (distilled water, ethanol and methanol), (n = 3, mean ± S.D.)

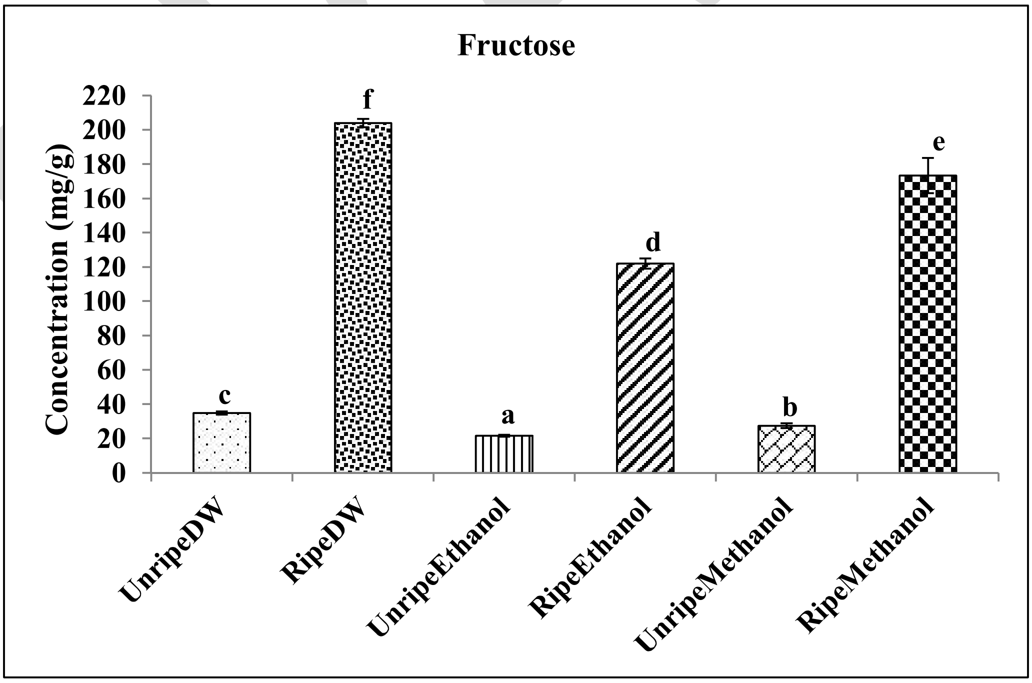

Figure 2 (B) Concentration (mg/g) of fructose in unripe and ripe *Bouea macrophylla* fruits of three solvents (distilled water, ethanol and methanol), (n = 3, mean ± S.D.)

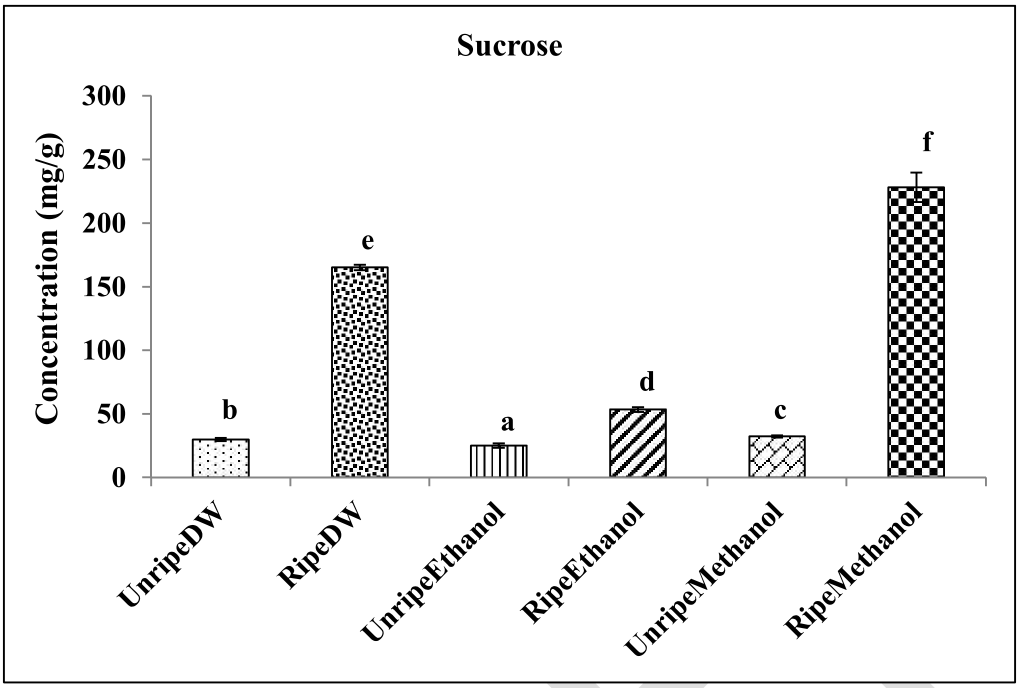

Figure 2 (C) Concentration (mg/g) of sucrose in unripe and ripe *Bouea macrophylla* fruits of three solvents (distilled water, ethanol and methanol), (n = 3, mean ± S.D.)

Table 4 The concentration of glucose, fructose and sucrose of unripe and ripe fruits of plum mango expressed in mg 100g^{-1}, mg g^{-}1, g 100g^{-1} and g kg^{-1} of three solvents (distilled water/DW, ethanol and methanol). All the values expressed on dry weight basis

Sugar Sample	**Concentration**			
	mg 100 g^{-1}	**mg g^{-1}**	**g 100 g^{-1}**	**g kg^{-1}**
Glucose				
Unripe DW	2661.94	26.62	2.66	26.62
Ripe DW	17259.38	172.59	17.26	172.59
Unripe Ethanol	1751.07	17.51	1.75	17.51
Ripe Ethanol	9483.47	94.83	9.48	94.83
Unripe Methanol	2221.52	22.22	2.22	22.22
Ripe Methanol	14534.03	145.34	14.53	145.34
Fructose				
Unripe DW	3473.86	34.74	3.47	34.74
Ripe DW	20390.13	203.90	20.39	203.90
Unripe Ethanol	2157.34	21.57	2.16	21.57
Ripe Ethanol	12196.32	121.96	12.20	121.96
Unripe Methanol	2737.49	27.37	2.74	27.37
Ripe Methanol	17336.35	173.36	17.34	173.36
Sucrose				
Unripe DW	2961.142	29.61	2.96	29.61
Ripe DW	16513.61	165.14	16.51	165.14
Unripe Ethanol	2498.04	24.98	2.50	24.98
Ripe Ethanol	5346.20	53.46	5.35	53.46
Unripe Methanol	3216.64	32.17	3.22	32.17
Ripe Methanol	22808.05	228.08	22.81	228.08

7Antioxidant Compounds and Activity

Majority of the fruits possess rich antioxidant activities owed to the presence of natural antioxidant compounds like polyphenols, tannins, flavonols, flavonoids, anthocyanin, carotenoids, vitamin C. These antioxidant compounds are well established to scavenge free radicals and provide health-promoting effects in humans.

Rajan and Bhat [29] have reported on the antioxidant activity and composition of both unripe and ripe fruits. Freeze dried fruit samples were extracted with various types of solvents (methanol, ethanol and water) to evaluate the effects of solvents on activity and extractability of antioxidant compounds. Results showed that except for anthocyanin, unripe fruits to contain higher amounts of antioxidant compounds compare to ripe fruits. Antioxidant compounds extracted depended on the solvent types used. Accordingly, methanol and ethanol were best solvents to extract antioxidant compounds. Methanol extracts of unripe fruits showed 77.69% of DPPH free radicals inhibition with 99.76% $ABTS^{+}$ radical scavenging activity. These extract also exhibited high antioxidant capacity (16,290.91 μM Fe (II) 100/g), compared with other extracts/samples. Besides, in unripe fruits, methanol extracts showed higher levels of polyphenols, tannin and ascorbic acid, while flavonols and flavonoids were higher in ethanolic extracts. However, overall, anthocyanin level was recorded to be highest in ripe fruits extracted with ethanol.

Sukalingam [30] undertook phytochemical analysis of leaves, ripe and unripe fruit extracts ofMalaysian plum mango via use of different solvents (ethanol, methanol, water and hexane). Their results revealed that the presence of alkaloids, saponins, sterols, triterpenes, phenols, flavonoids, tannins, and vitamin C (qualitative analysis). Overall, ripe, unripe fruits and leaves showed high amounts of phytochemical constituents in methanol and aqueous extracts with high amount of vitamin C. Besides, leaves, unripe and ripe fruits extracted with water and methanol exhibited a significant radical scavenging activity (higher DPPH ·radical scavenging activity was recorded in aqueous extracts of ripe fruit, 83%, unripe fruit, 82% and leaves, 76% respectively).

8 Volatile Constituents

Wong and Loi [31] identified 40 Volatile constituents in ripe fruits, which were mainly monoterpenes and sesquiterpene hydrocarbons. Further, Rajan and Bhat [32] reported the volatiles via steam hydro-distillation method and by employing gas chromatography-massspectrometry (GCMS) identified volatile constituents (essential oils) in unripe and ripe fruits. They identified approximately 82 and 121 compounds in unripe and ripe fruits, respectively. Their results revealed that ripe fruits more aromatic with higher number of volatile compounds than in unripe fruits. In addition, ripe fruits had high levels of oxygenated compounds, terpene hydrocarbons (29.28%), ketones (27.27%) and esters (20.73%), acetophenone (12.31%) and acetylvaleryl (10.99%) were the major compounds identified. While in unripe fruits, terpene hydrocarbons (32.89%) and their sub-class like alpha-cadinol (4.94%), alpha-muurolene (1.14%), delta-cadinene (4.80%), and tumerone (3.65%) and acids (29.72%) were dominant. In addition, aromatic compounds like eugenol (0.12%), myristic acid (0.34%), α and β-terpineol (4.41 and 0.09%), thymol (0.55%), octanal (0.10%), were present in ripe fruits. Further, in unripe fruits ketones like acetophenone (2.59%) and 5,6-decanedione (13.99%) were also identified.

9 Conclusions and Outlook

Plum mango fruits possess rich nutraceutical value and encompass good amount of bioactive compounds. Unripe fruits possess better nutritional values and functional qualities compared to the ripe fruits. In broader sense, both the unripe and ripe fruits are rich in antioxidant compounds and activities. Antioxidant potential of unripe fruits was significantly higher than the ripe fruits and the activities dependent on the solvents used for extraction purpose. In Plum mango fruits, wide range of volatile compounds has been identified, with ripe fruits containing more volatiles than the unripe fruits, thus contributing to the pleasant aroma and flavour. As there are many gaps in scientific information pertaining to plum mango fruits, further research needs to be initiated to screen for new varieties and cultivars. There is need to evaluate their composition and health promoting potential of Plum mango, especially those originating from different geographical origin. Though compositional data is available from different growing regions [11, 33-34], the data is insufficient. Research works needs to be instigated to evaluate the effects of extraction time, solvent concentration and temperature to evaluate extractability and status of antioxidant compounds. Processing of fruits to value added food products like pickles, jams and juices by subjecting to modern food processing techniques (such as UV, Ozone, Pulse electric field, High Hydrostatic Pressure) is another arena to be explored. Even novel functional food products can be developed from unripe and ripe fruits of Plum mango.

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