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Underutilised fruits: a review of phytochemistry and biological properties

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Abstract

Underutilised fruits are not only important sources of food and nutrition, but also secure household income especially for rural and farm communities. However, some of the underutilised fruits have not received much attention as compared to commercial fruits. This could be due to their lack of knowledge of their potential values. Hence, information about their health promoting properties is critical to increase the value of underutilised fruit species to enhance their preservation and sustainable use in strengthening food, nutrition, health and livelihood security. This article aims to provide a comprehensive review on the phytochemical properties and biological activities of underutilised fruit species grown in Malaysia focussing on health promoting aspects. With regard to phytochemistry, only 21 species of underutilised fruits have been identified and quantified. Phytochemical investigations of various parts of the fruits have revealed the presence of over 100 phytochemicals which are phenolics, terpenoids, carotenoids and other miscellaneous compounds. About 51 underutilised fruit species have been explored for interesting biological activities (antioxidant, antimicrobial, anticholinesterase, cytotoxicity, antiatherosclerotic, antihyperlipidemia, antidiabetic, cytoprotective, cardioprotective and antiplatelet activities) supporting their diverse traditional uses. Different parts of the fruits have been analysed mainly *in vitro* and barely *in vivo,* with pulp being the most dominant. Of all the underutilised fruits studied, *Mangifera* species and *Canarium odontophyllum* have been the major focus for researchers. The gaps obtained from this review create further research opportunities to add to the current knowledge of health promoting properties of underutilised fruits in Malaysia. More studies are needed to confirm the health significance and explain their mechanisms of action in order to fully understand the real potential of this underutilised fruit species.

Keywords: Underutilised fruits; Traditional uses; Phytochemical compounds; Biological activities.

1. Introduction

Malaysia possesses a rich diversity of underutilised fruits grown in orchards, home gardens and some can be found in the wild of Peninsular Malaysia, Sabah and Sarawak, which are located on the Borneo Island. These underutilised fruits are important sources of food and nutrition for rural and farm communities, which improve the quality of diets and sustenance of the communities. The diversity of the fruit species in the fruit orchards or home gardens is not only an important source of food and nutrition, but also probably more importantly secure household income and thus leads to the improvement of their livelihood (Salma et al., 2006). Other than being popularly consumed as a source of food, some of the underutilised fruits have also been used in folk medicine. The comprehensive list of the ethnobotanical uses of over 50 Malaysian underutilised fruits from 23 families is displayed in Table 1. This information can be the basis for further research to investigate the health and phytochemical aspects of underutilised fruit species.

Anacardaceae family which consists of one species of *Bouea macrophylla* and seven species of the genus *Mangifera,* is the most studied underutilised fruit in Malaysia. Anacardaceae fruits are mainly used as food source and only some have been reported to possess medicinal properties to treat various ailments such as *M. caesia, M. foetida, M. pajang* and *M. pentandra* (Gerten et al., 2015; Khoo et al., 2016; Mirfat et al., 2016; Mirfat et al., 2015; Salma et al., 2006). Euphorbiaceae, Guttiferae and Sapindaceae are the next commonly studied underutilised fruits in Malaysia. However, there are no reports in the literature on the ethnomedicinal properties of Euphorbiaceae (*Baccaurea angulata, B. lanceolata, B. macrocarpa, B. motleyana* and *B. polyneura*) other than being a source of food. *Nephelium ramboutan-ake* from the Sapindaceae family has been described to treat scabbies and itchiness (Gerten et al., 2015). Guttiferae which are usually used in cooking, have been reported to have medicinal potential as shown by *Garcinia atroviridis* (Gerten et al., 2015; Salma et al., 2006), *G. dulcis* (Abu Bakar et al., 2015) and *G. parvifolia* (Gerten et al., 2015; Salma et al., 2006). In addition, other underutilised fruits species such as *Parkia speciosa* and *Averrhoa bilimbi* have also been widely reported by researchers to have various traditional remedial use. *Parkia speciosa* has been used for its diuretic and relaxing properties, treatment of high blood pressure, diabetes and has antibacterial effects on kidney, ureter and urinary bladder (Ko et al., 2014; Salma et al., 2006; Voon and Kueh, 1999) . Meanwhile, *A. bilimbi* is useful in treating fever, cold, coughs, itches, boils, beriberi, biliousness, inflammation of the rectum, internal haemorrhoids, hypertension, diabetes, syphilis and rheumatism (Khoo et al., 2016; Muhamad et al., 2014; Noor & Noriham, 2014; Salma et al., 2006).

However, as these underutilised fruits are usually maintained by cultural preferences and traditional practices, some of them have been largely neglected in research and conservation. They have also not received much attention as compared to commercial fruits. This could be due to their lack of knowledge of their potential value and also promotional campaigns. Information about their health promoting properties is critical to increase the value of such neglected species to enhance the preservation and sustainable use of these underutilised fruits in strengthening food, nutrition, health and livelihood security. Therefore, this review was conducted to describe the current progress in research regarding the phytochemical properties and biological activities of underutilised fruit species in Malaysia which cover various health promoting aspects. The gaps present will further highlight existing research opportunities to enhance the current knowledge of health promoting properties of underutilised fruits in Malaysia.

2. Phytochemistry

Phytochemicals are non-nutritive bioactive compounds naturally produced by plants that can be categorized into phenolics, alkaloids, terpenes and steroids, among others (Chew et al., 2011). Table 2 summarizes the major phytochemical components of 21 species of Malaysian underutilised fruits. Over 100 phytochemicals were identified and isolated from different parts of the fruits with pulp being the mostly studied. Phenolics have been identified as the most vital phytochemical compounds that contribute to the diverse health properties reported. Of the phenolic compounds, the most important reported were gallic acid, catechin and protocatechuic acid (Abu Bakar et al., 2010; Ahmad et al., 2015; Ahmed et al., 2013; Hassan et al., 2011; Khoo et al., 2012a; Prasad et al., 2011a; 2011b; Sulaiman and Ooi, 2012; Tee et al., 2015). Among the most useful and powerful analytical instruments used to investigate these compounds are high performance liquid chromatography (HPLC), gas chromatography-mass spectrometry (GC-MS) and liquid chromatography-mass spectrometry (LC-MS).

The Anarcardiaceae family which consists of *M. caesia, M. foetida, M. odorata, M. pajang, M. pentandra* and *M. quadrifida* dominates the number of the phytochemical studies. Gallic acid, vanillic acid and mangiferin were among the compounds found especially in the pulp of the fruit species (Sulaiman and Ooi, 2012). However, *M. pajang* fruit parts were thoroughly investigated by researchers. The peel was reported to contain various classes of phenolics including pyrogallic acid, gallic acid, catechin, epicatechin, mangiferin, rutin, protocatechuic acid, chlorogenic acid, methyl gallate, 4-hydroxybenzoic acid, vanillic acid, ethyl gallate, *p*-coumaric acid, ferulic acid, ellagic acid, morin, daidzein, kaempferol, luteolin, diosmin, quercetin, naringin, hesperidin, caffeic acid, chlorogenic acid and sinapic acid (Abu Bakar et al., 2010; Ahmad et al., 2015; Hassan et al., 2011; Prasad et al., 2011b).

A broad phytochemical study was also conducted in *Canarium odontophyllum* or fondly known as *dabai*. All the fruit parts comprising pulp, peel, pulp with peel, pericarp and seed were investigated. The chemical composition differs largely according to the fruit parts. Catechin, epicatechin, epigallocatechin, epicatechin gallate, methyl gallate, ellagic acid and vanillic acid were the major phenolics reported in the pulp and peel (Khoo et al., 2012a). Another study by Khoo et al. (2013) indicated that the peel and pericarp contained cyanidin-3-glucoside, cyanidin-3-galactoside and cyanidin-3-arabinoside. These anthocyanins are one of the many classes of phenolics that are normally found in fruits. Meanwhile, all -trans-β-carotene, 13-cis-β-carotene, all-trans-lutein, 9-cis-lutein, 13-cis-lutein, di-cis-β-carotene, 15-cis-β-carotene and 9-cis-β-carotene were the carotenoids present in almost all parts of the fruits (Prasad et al., 2011a).

A phytochemical screening of various fruit parts of *Litsea garciae*, locally known as *engkala*, has resulted in the identification of viniferin, cyanidin, ferulic acid (pulp), dihydroquercetin, *p*-coumaroyl, tartaric acid, caffeoyl tartaric acid, cinnamoyl glucose (seed), ferulic acid, cinnamoyl glucose, epigallocatechin (cupule) and viniferin, elphinidin 3,5-O-diglucoside, cinnamoyl glucose (peel) (Husen, 2015). *Baccaurea angulata* peel, pulp and whole fruit were phytochemically investigated by Ahmed et al. (2013; 2015) in two different studies. Both studies confirmed the presence of catechin, ascorbic acid, vanillic acid, carnosic acid, cinnamic acid, caffeic acid and myricetin in the different parts of the fruit (Ahmed et al., 2013; Ahmed et al., 2015). The most recent study of the Malaysian underutilised fruits was reported by Abu Bakar et al. (2016). They analysed the chemical constituents of *Rubus moluccanus, R. fraxinifolius* and *R. alpestris* using a GC-MS. The results

Table 1. Ethnobotanical uses of selected Malaysian underutilised fruits

Family	Species	Local Name	Use	Reference
Anacardiaceae	*Bouea macrophylla*	Kundang	Freshly eaten as salad, processed into pickle and used as cooking ingredients (whole ripe fruit). Serves as ornamental fruit tree	Khoo et al., 2016; Rajan et al., 2014; Rajan and Bhat, 2016; Salma et al., 2006
	Mangifera caesia	Binjai	Freshly eaten (ripe flesh), processed into pickle and used as food additive. Treatment of cold, body itchiness, high blood pressure and bronchitis	Mirfat et al., 2015; Mirfat et al., 2016; Gerten et al., 2015
	Mangifera foetida	Bacang	Freshly eaten (ripe flesh), processed into pickle, used as salad and as food additives (unripe flesh). Seeds used against trichophytosis, scabies and eczema	Khoo et al., 2016; Mirfat et al., 2015; Mirfat et al., 2016; Salma et al., 2006
	Mangifera laurina	Mempelam air	Source of food. Treatment of shingles	Gerten et al., 2015; Mirfat et al., 2015; Mirfat et al., 2016
	Mangifera longipetiolata	Sepam	Source of food	Mirfat et al., 2015; Mirfat et al., 2016
	Mangifera odorata	Kuini	Freshly eaten (ripe flesh), processed into pickle and jam, used as salad and food additives (unripe flesh)	Gerten et al., 2015; Mirfat et al., 2015; Mirfat et al., 2016; Salma et al., 2006
	Mangifera pajang	Bambangan	Freshly eaten (ripe flesh), processed into pickle (flesh, peel and kernel) and used as food additives (unripe flesh). Peels are used in different fruit ingredients or incorporated in food products. Treatment of scabies, ulcer, winds, etc.	Abu Bakar and Fry, 2013; Azlan et al., 2013; Gerten et al., 2015; Hassan et al., 2011; Mirfat et al., 2015; Mirfat et al., 2016; Salma et al., 2006
	Mangifera pentandra	Mempelam bemban / Asam pauh	Freshly eaten, processed into pickle, jam, chutney and used in cooking dishes (unripe flesh and seed). Treatment of piles and gastric pain. Increase men's health	Gerten et al., 2015; Mirfat et al., 2015; Mirfat et al., 2016; Salma et al., 2006
Arecaceae	*Nypa fruticans*	Nipah	Freshly eaten (unripe fruits). Sap (obtained from the inflorescence stalk) is used to produce alcoholic drink, beverage, vinegar, sweets, sugar and syrup	Sum et al., 2013; Prasad et al., 2013
	Salacca conferta	Asam kelubi	Source of food	Ikram et al., 2009
Bombacaceae	*Durio kutejensis*	Durian nyekak	Freshly eaten (ripe flesh)	Voon and Kueh, 1999; Khoo et al., 2016
Burseraceae	*Canarium odontophyllum*	Dabai	Freshly eaten, made into jam, pickle and used as salad and cooking ingredients (ripe flesh)	Ali Hassan et al., 2013b; Azlan et al., 2010; Basri, et al., 2014a; Khoo et al., 2012b; Salma et al., 2006
	Dacryodes rostrata	Kembayau	Source of food; fruits soaked in warm water before consumption. Preserved with salt or soy sauce, and eaten as appetisers with rice or porridge	Kong et al., 2011; Salma et al., 2006; Tee et al., 2014
Euphorbiaceae	*Baccaurea angulata*	Tampoi belimbing / Belimbing dayak	Source of food	Jauhari et al., 2013; Momand, 2014
	Baccaurea lanceolata	Liposu / Limpaung	Source of food	Bakar et al., 2014
	Baccaurea macrocarpa	Tampoi putih	Freshly eaten (ripe flesh)	Abu Bakar et al., 2014; Khoo et al., 2016; Salma et al., 2006
	Baccaurea motleyana	Rambai	Freshly eaten and made into jam (ripe flesh)	Khoo et al., 2016; Mokhtar et al., 2014; Salma et al., 2006
	Baccaurea polyneura	Jentik-jentik	Freshly eaten	Salma et al., 2006
Fabaceae	*Cynometra cauliflora*	Nam-nam	Freshly eaten as salad and cooking ingredients (ripe flesh). Used as traditional medicine and ornamental purpose	Abd Aziz and Mohammad, 2013; Khoo et al., 2016; Tajudin et al., 2012
Flacourtiaceae	*Flacourtia jangomas*	Kerekup	Treatment of stomachic diarrhea, inflammation, skin disease, jaundice, tumours, nausea, dyspepsia and diabetes	Mohamed, 2012
	Flacourtia rukam	Rokam	Source of food	Salma et al., 2006
Gnetaceae	*Gnetum gnemon*	Belinjau / Melinjau	Seeds are prepared as crackers, in cooking dishes (soup) and as coffee substitute	Bhat and Yahya, 2014; Voon and Kueh, 1999

Table 1. Ethnobotanical uses of selected Malaysian underutilised fruits - *(continued)*

Family	Species	Local Name	Use	Reference
Guttiferae	*Garcinia atroviridis*	Asam gelugor	Normally dried (flesh) and used as food additives. Leaves used as vegetable and salad. Treatment of cough, dandruff, earache, throat irritation, high blood pressure, itchiness, post-natal treatment and metal cleaning	Al-Mansoub et al., 2014; Gerten et al., 2015; Salma et al., 2006
	Garcinia dulcis	Mundu	Freshly eaten (flesh), processed into pickle and used as cooking ingredients Treatment of lymphatitis, parotitis and goitre	Abu Bakar et al., 2015
	Garcinia hombroniana	Beruas	Freshly eaten (flesh)	Khoo et al., 2016
	Garcinia parvifolia	Kundong	Freshly eaten (ripe flesh), processed into pickle (unripe) and dried flesh used as food additives. Treatment of cough, sore throat, swelling and post-natal treatment	Gerten et al., 2015; Salma et al., 2006
	Garcinia prainiana	Cerapu	Freshly eaten (ripe flesh) and used in cooking dishes (unripe)	Salma et al., 2006
Lauraceae	*Litsea garciae*	Engkala / Pengolaban	Freshly eaten (flesh) and used in cooking dishes (seed). Treatment of boils and fever	Ali Hassan et al., 2013a; Husen, 2015; Salma et al., 2006
Leguminosae	*Parkia speciosa*	Petai	Freshly eaten (fruit or cotyledon) and used in cooking dishes. Diuretic and relaxing properties. Treatment of high blood pressure, diabetes, and has antibacterial effects on kidney, ureter and urinary bladder	Ko et al., 2014; Salma et al., 2006; Voon and Kueh, 1999
Meliaceae	*Sandoricum macropodum*	Sentol	Source of food	Ikram et al., 2009
Moraceae	*Artocarpus altilis*	Sukun	Immature or ripe fruits (flesh) are eaten after boiling, baking, roasting or frying. Used as cooking ingredient. Serves as traditional medicine, clothing and animal feed	Anupunt et al., 2003; Jalal et al., 2015; Salma et al., 2006
	Artocarpus odoratissimus	Tarap / Terap	Freshly eaten (ripe flesh) and made into crackers (seed)	Abu Bakar et al., 2009; Salma et al., 2006
Myrtaceae	*Syzygium jambos*	Jambu mawar	Freshly eaten, made into jam and served as dessert (whole ripe fruit). Ripe fruits used as a tonic for brain and liver and as a diuretic; seeds for treatment of diarrhea, dysentery and catarrh	Khoo et al., 2016
	Syzygium malaccense	Jambu bol	Freshly eaten (whole ripe fruit), as pickle and used in cooking dishes (unripe fruit). Fruit decoction as a febrifuge. Flatulent and antithirst	Khoo et al., 2016; Wetwitayaklung et al., 2012
Oxalidaceae	*Averrhoa bilimbi*	Belimbing buluh	Freshly eaten as salad, made into pickle and used in cooking dishes (whole ripe fruit). Treatment of fever, cold, coughs, pimples, itches, boils, beriberi, biliousness, inflammation of the rectum, internal haemorrhoids, hypertension, diabetes, syphilis and rheumatism	Abraham, 2016; Khoo et al., 2016; Muhamad et al., 2014; Noor and Noriham, 2014; Salma et al., 2006
Pandanaceae	*Pandanus tectorius*	Pandan laut	Source of food (keys)	Andriani et al., 2015
Phyllanthaceae	*Phyllanthus emblica*	Buah Melaka	Freshly eaten (ripe flesh), as pickle and used in cooking dishes (unripe flesh). Treat cough and asthma. Remedies for hepatic disorders	Khoo et al., 2016; Kubola et al., 2011
Rhamnaceae	*Ziziphus mauritania*	Bidara	Freshly eaten as salad or pickle, and used in cooking dishes (whole ripe fruit). Ripe fruits for treatment of sore throat and cough; seeds for treatment of diarrhea and weakness of stomach	Khoo et al., 2016
Rosaceae	*Rubus moluccanus*	Wild berry	No report	Abu Bakar et al., 2016
	Rubus fraxinifolius	Wild berry	No report	Abu Bakar et al., 2016
	Rubus alpestris	Wild berry	No report	Abu Bakar et al., 2016

Table 1. Ethnobotanical uses of selected Malaysian underutilised fruits - *(continued)*

Family	Species	Local Name	Use	Reference
Rutaceae	*Citrus hystrix*	Limau purut	Source of food	Abd Ghafar et al., 2010
	Citrus aurantifolia	Limau nipis	Source of food and food additives. Relieve body from winds and eliminate body odour	Abd Ghafar et al., 2010; Gerten et al., 2015
	Citrus microcarpa	Limau kasturi	Source of food and food additives—eliminates fishy smell of fish. Used as seasoning	Abd Ghafar et al., 2010; Cheong et al., 2012; Gerten et al., 2015
Sapotaceae	*Pouteria campechiana*	Kuning telur	Source of food	Kong et al., 2013
Sapindaceae	*Dimorcarpus longan*	Isau	Freshly eaten	Salma et al., 2006
	Lepisanthes rubiginosa	Mertajam	Source of food	Ikram et al., 2009
	Nephelium malaiense	Mata kucing	Source of food	Ikram et al., 2009
	Nephelium ramboutan-ake	Pulasan / Meritam	Freshly eaten and used as cooking ingredients. Treatment of scabbies and itchiness	Gerten et al., 2015; Salma et al., 2006
	Pometia sp	Lenggeng	Source of food	Ikram et al., 2009
Solanaceae	*Cyphomandra betacea*	Buah cinta / tamarillo	Source of food	Ali Hassan and Abu Bakar, 2013

revealed the presence of at least 12, 21, and 7 different compounds in *R. alpestris*, *R. moluccanus* and *R. fraxinifolius*, respectively.

3. Biological activities

Based on the literature search, the health promoting aspects of Malaysian underutilised fruits have not been thoroughly investigated, as shown in Tables 2, 3 and 4. Antioxidant effect has dominated the activities (63%) as it is the basis study to lead to possibilities of finding other therapeutic potentials. A few studies have been reported on antimicrobial activities (14%) of selected underutilised fruit species. Other biological activities that were documented from Malaysian underutilised fruits include anti-cholinesterase (9%), cytotoxicity (7%), cytoprotective (4%), anti-atherosclerotic (3%), anti-hyperlipidemia (1%), antidiabetic (1%), cardioprotective (1%) and anti-platelete (1%). Both *in vitro* and *in vivo* assays have been performed to evaluate antioxidant potential, while *in vitro* assays were used for antimicrobial, anticholinesterase and anticancer activities. Other *in vivo* experiments were carried out to assess antiatherosclerotic, antihyperlipidemia, antidiabetic, cytoprotective and cardioprotective effects. Pulp was the commonly used fruit part (47%) in the analyses, followed by peel (16%), whole fruit (11%), seed (9%) and others. A summary of the findings is presented below.

3.1. Antioxidant effect

All underutilised fruit species listed in were tested for their antioxidant capacity. The findings that have been documented showed that different fruit species exhibited varying degrees of antioxidant activities depending on the fruit parts, assays and extraction solvents used (Table 3). With regard to *in vitro* assays, 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging was the most widely applied. Ferric reducing antioxidant power (FRAP) ranked second, followed by 2-2′-azino-bis (3-ethylbenz-thiazoline-6-sulfonic acid (ABTS) and β-carotene bleaching activity. The *in vitro* activities were also measured using metal chelating, Trolox equivalent antioxidant capacity (TEAC), phosphatidylcholine peroxidation, phosphomolybdenum, oxygen radical absorbance capacity (ORAC), copper (II) reduction antioxidant capacity (CUPRAC), thiocyanate, superoxide radical, linoleic acid peroxidation and haemoglobin oxidation assays. With respect to extraction solvents, methanol was the most popular one followed by water and ethanol. Other solvents used were hexane, ethyl acetate, acetone, petroleum ether, chloroform, dichloromethane and phosphate buffered saline (PBS). *In vivo* assays were conducted using enzymatic and non-enzymatic antioxidant assays in both animals and humans.

Out of 51 underutilised fruit species tested for antioxidant, *C. odontophyllum* demonstrated the highest numbers of antioxidant studies. Various parts of the fruits were analysed almost by the same group of researchers which comprised pulp (Ali Hassan et al.; 2013b; Prasad et al., 2010; Shakirin et al., 2010), pulp with peel (Ali Hassan et al., 2013b; Khoo et al., 2012a; 2012b; Shakirin et al., 2010), peel (Khoo et al., 2012; 2013; 2014; Prasad et al., 2010; Shakirin et al., 2010), seed (Ali Hassan, 2013b; Khoo et al., 2012; Prasad et al., 2010), pericarp (Khoo et al., 2013; 2014), kernel (Shakirin et al., 2010) and whole fruit (Chew et al., 2011). Khoo et al. (2013) and Shakirin et al. (2010) reported that peel extracts showed the highest inhibition percentage as measured by DPPH radical scavenging activity with 60% and 78.2 ± 0.5%, respectively. Meanwhile, Prasad et al. (2010) reported that peel exhibited stronger ABTS radical scavenging activity (84.5 ± 0.9%) and higher β-carotene

Table 2. Phytochemical compounds from different parts of Malaysian underutilised fruits

Species	Part	Compound	Classification	Reference
Artocarpus odoratissimus	Pulp	Quercetin, caffeic acid, *p*-coumaric acid, naringin	Phenolics	Abu Bakar et al., 2010
	Seed	Kaempferol, ferulic acid, diosmin, caffeic acid, *p*-coumaric acid, chlorogenic acid, hesperidin, naringin	Phenolics	
Baccaurea angulata	Peel	Catechin, ,ascorbic acid, vanillic acid, carnosic acid, cinnamic acid, caffeic acid, myricetin	Phenolics	Ahmed et al., 2013; Ahmed et al., 2015
	Pulp	Catechin, ,ascorbic acid, vanillic acid, carnosic acid, cinnamic acid, caffeic acid, myricetin	Phenolics	Ahmed et al., 2013; Ahmed et al., 2015
	Whole fruit	Catechin, ,ascorbic acid, vanillic acid, carnosic acid, cinnamic acid, caffeic acid, myricetin	Phenolics	Ahmed et al., 2013; Ahmed et al., 2015
Baccaurea motleyana	Pulp	Citric acid, tartaric acid, malic acid, oxalic acid	Organic acids	Mokhtar et al., 2014
Bouea macrophylla	Pulp	Alpha-cadinol, delta-cadinene, tumerone, alpha-muurolene, alpha-terpineol, candin-4-en-10-ol, 1,10-di-epi-cubenol, (e,e)-alpha-farnesene, alpha-muurolol, (E)-beta-ionone, delta-cadinene, 5,6-decanedione, acetophenone and acetyl valery Hexanedioic acid, bis (2-ethyl) ester Pentanoic acid, 2-propanoic acid, trimethylacetic anhydride, N-hexadecanoic acid, dodecanoic acid, oleic acid α-terpineol, β-terpineol, thymol, myristic acid, eugenol, octanal, non-anal	Terpenes Ketones Esters Acids	Rajan et al., 2014
Canarium odontophyllum	Pulp	Catechin, epicatechin, epigallocatechin, epicatechin gallate, methyl gallate, ellagic acid, vanillic acid, protocatechuic acid	Phenolics	Khoo et al., 2012a
		All-trans-β-carotene, 13-cis-β-carotene, all-trans-lutein, 9-cis-lutein, 13-cis-lutein, di-cis-β-carotene, 15-cis-β-carotene, 9-cis-β-carotene	Carotenoids	Prasad et al., 2011a
	Peel	Catechin, epicatechin, epigallocatechin, epicatechin gallate, methyl gallate, ellagic acid, vanillic acid, apigenin, protocatechuic acid, delphinidin, cyanidin, pelargonidin, cyanidin-3-glucoside, cyanidin-3-galactoside , cyanidin-3-arabinoside, pelargonidin-3-glucoside, malvidin-3-glucoside, peonidin-3-glucoside	Phenolics	Khoo et al., 2012a; Khoo et al., 2013
		All-trans-β-carotene, 13-cis-β-carotene, all-trans-lutein, 9-cis-lutein, 13-cis-lutein, di-cis-β-carotene, 15-cis-β-carotene, 9-cis-β-carotene	Carotenoids	Prasad et al., 2011a
	Pulp with peel	Catechin, epicatechin, epicatechin gallate, epigallocatechin, methyl gallate, ethyl gallate, ellagic acid, vanillic acid, apigenin, protocatechuic acid, delphinidin, cyanidin, pelargonidin	Phenolics	Khoo et al., 2012a
	Pericarp	Cyanidin-3-glucoside, cyanidin-3-galactoside , cyanidin-3-arabinoside	Phenolics	Khoo et al., 2013
	Seed	All-trans-β-carotene, 13-cis-β-carotene, all-trans-lutein, 9-cis-lutein, 13-cis-lutein, di-cis-β-carotene, 15-cis-β-carotene, 9-cis-β-carotene	Carotenoids	Prasad et al., 2011a
Dacryodes rostrata	Seed	Gallic acid, epigallocatechin, chlorogenic acid, apigenin 7-(4″-Z-p-coumarylglucoside), 1-caffeoyl-4-deoxyquinic acid, 5-O-caffeoylshikimic acid, (±)-catechin, syringic acid, ellagic acid, (-)-epicatechin 3-O-gallate	Phenolics	Tee et al., 2015
Garcinia dulcis	Pulp	5-hydroxymethylfurfural, 2,5-furandione, 3-methyl, furfural, 1-butanol, 2-methyl-, propanoate (CAS) 2-methylbutyl propionate, catechol, 2,5-furandione, dihydro-3-methylene-, 4H-pyran-4-one, 2,3-dihydro-3,5-dihydroxy-6-methyl-, furyl hydroxymethyl ketone, D-allose, 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, 1,6-anhydro-alpha-d-galactofuranose, 5,5′-oxy-dimethylene-bis(2-furaldehyde), 1,4-dioxadiene, 1,3,5-triazine-2,4,6-triamine, n-hexadecanoic acid, 1,3,5-triazine-2,4,6-triamine, octadecanoic acid, heptadecene-(8)-carbonic acid-(1), 2-furanmethanol	Terpenoids	Abu Bakar et al., 2015

Table 2. Phytochemical compounds from different parts of Malaysian underutilised fruits - *(continued)*

Species	Part	Compound	Classification	Reference
Litsea garciae	Pulp	Viniferin, cyanidin, ferulic acid	Phenolics	Husen, 2015
	Seed	Dihydroquercetin, *p*-coumaroyl tartaric acid, caffeoyl tartaric acid, cinnamoyl glucose	Phenolics	
	Cupule	Ferulic acid, cinnamoyl glucose, epigallocatechin	Phenolics	
	Peel	Viniferin, elphinidin 3,5-O-diglucoside, cinnamoyl glucose	Phenolics	
Mangifera caesia	Pulp	Gallic acid, vanillic acid, mangiferin	Phenolics	Sulaiman and Ooi, 2012
Mangifera foetida	Pulp	Mangiferin, gallic acid, protocatechuic acid, vanillic acid	Phenolics	Sulaiman and Ooi, 2012
Mangifera odorata	Pulp	Mangiferin, gallic acid, vanillic acid	Phenolics	Sulaiman and Ooi, 2012
Mangifera pajang	Peel	Pyrogallic acid, gallic acid, catechin, epicatechin, mangiferin, rutin, protocatechuic acid, chlorogenic acid, methyl gallate, 4-hydroxy- benzoic acid, vanillic acid, ethyl gallate, *p*-coumaric acid, ferulic acid, ellagic acid, morin, daidzein, kaempferol, luteolin, diosmin, quercetin, naringin, hesperidin, caffeic acid, chlorogenic acid, sinapic acid	Phenolics	Abu Bakar et al., 2010; Ahmad et al., 2015; Hassan et al., 2011; Prasad et al., 2011b
	Pulp	Luteolin, kaempferol, quercetin, naringin, hesperidin, caffeic acid, *p*-coumaric acid, chlorogenic acid	Phenolics	Abu Bakar et al., 2010
	Kernel	Methyl gallate and a mixture of benzaldehyde and benzyl alcohol together with β-sitosterol	Phenolic esters	Abu Bakar et al., 2010;
		Diosmin, rutin, mangiferonic acid, ferulic acid, gallic acid, *p*-coumaric acid, caffeic acid, sinapic acid, chlorogenic acid, naringin, hesperidin	Phenolics	Ahmad et al., 2015
Mangifera pentandra	Pulp	Mangiferin, gallic acid, *p*-hydroxybenzoic acid, protocatechuic acid	Phenolics	Sulaiman and Ooi, 2012
Mangifera quadrifida	Pulp	Mangiferin, gallic acid, protocatechuic acid, *p*-hydroxybenzoic acid, vanillic acid	Phenolics	Sulaiman and Ooi, 2012
Nypa fruticans	Endosperm	Chlorogenic acid, protocatechuic acid, kaempferol, rutin, quercetin, cinnamic acid, hydroxybenzoic acid and gallic acid	Phenolics	Prasad et al., 2013
Parkia speciosa	Empty pod	Gallic acid, ellagic acid, catechin, quercetin, epicatechin, vanillic acid, kaempferol, chlorogenic acid, caffeic acid, cinnamic acid, hydroxybenzoic acid, ferulic acid and *p*-coumaric acid	Phenolics	Ko et al., 2014
Rubus moluccanus	Whole fruit	2-propenoic acid, 2-propenyl ester, pyruvate, furfural, 1,3-butadiene-1-carboxylic acid, propenoic acid, 2-methyl-, methyl ester, dl-glyceraldehyde dimer, 2(1H)-pyridinone, 6-hydroxy-2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, pentanoic acid, 4-oxo-, 2-hydroxy-3-methyl-4-pyrone, isopropylmethylnitrosamine, 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, hydroxymethyl furfural, 1,1,2-triacetoxyethane, butanedioic acid, 2-hydroxy-2-methyl, (S)-, benzeneacetic acid, 4-hydroxy-,methyl ester, succinic acid, 3-methylbutyl pentyl ester, β-D-glucopyranoside,methyl, quinic acid, β-tocopherol, δ-sitosterol	Terpenoids	Abu Bakar et al., 2016
Rubus fraxinifolius	Whole fruit	2-propenoic acid, 2-propenyl ester, furfural, 1,3-butadiene-1-carboxylic acid, 2(1H)-pyridinone, 6-hydroxy-, 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, 1,1,2-triacetoxyethane, 3-deoxy-d-mannoic lactone	Terpenoids	Abu Bakar et al., 2016
Rubus alpestris	Whole fruit	Furfural, 2(1H)-pyridinone, 6-hydroxy-, 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, furaneol, 1H-imidazole-4-carboxylic acid, methyl ester, 2,4-dihydroxy-2,5-dimethyl-3(2H)-furan-3-one, 5-hydroxymethylfurfural, butane, 1,1′-1 (isopentyloxy) methoxy]-3-methylbutane, rhamnose, 5,5′-oxy-dimethylene-bis (2-furaldehyde), β-tocopherol, stigmast-5-en-3-ol	Terpenoids	Abu Bakar et al., 2016
Syzigium jambos	Pulp	3-phenylpropan-1-ol, (E)-cinnamyl alcohol, (Z)-hex-3-en-l-ol, hexanol, hexanal, (Z)-hex-3-enal, linalool, myrcene, geraniol, citronellol, nerol, α-terpineol, cis-rose oxide, geranial, limonene, (E)-β-ocimene, trans-rose oxide, α-cubebene, δ-cadinene	Terpenoids	Wong and Lai, 1996
Syzigium malaccense	Pulp	Limonene, linalool, geraniol, nerol, δ-cadinene, α-selinene, humulene	Terpenoids	Wong and Lai, 1996

Table 3. Biological activities of Malaysian underutilised fruits

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
Antioxidant	*Artocarpus altilis*	Whole fruit, pulp, peel	Hexane, dichloromethane and methanol	DPPH radical scavenging assay β-carotene linoleic acid model system Folin-Ciocalteau method Aluminium chloride colorimetric method	Methanol pulp extract showed the highest scavenging activity (IC_{50}: 55 ± 5.89 µg/ml), β-carotene bleaching (88.34 ± 1.31%) compared to Trolox (90.02 ± 1.51 %), total phenolic content (TPC) (781 ± 52.97 mg gallic acid equivalent (GAE)/g of dry sample) and total flavonoid content (TFC) (6,213.33 ± 142.22 mg quercetin equivalent (QE)/g)	Jalal et al., 2015
	Artocarpus odoratissimus	Pulp, seed	80% methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method	Seed extract showed higher antioxidant activity; TPC (14.67 mg GAE/g) and TFC (3.65 ± 0.04 mg GAE/g). Pulp extract contained higher total antioxidant capacity (11.02 ± 0.38 mg c-3-gE/100g)	Abu Bakar et al., 2009
	Averrhoa bilimbi	Whole fruit	Water	Folin-Ciocalteau method Aluminium chloride colorimetric method DPPH radical scavenging assay FRAP assay β-carotene linoleate bleaching assay	*Averrhoa bilimbi* L. extract showed higher TPC (41.00 ± 2.75 mg GAE/g) and TFC (23.32 ± 3.50 mg/QE g) than *A. bilimbi* cv. *Averrhoa bilimbi* cv. showed higher FRAP (1.76 ± 0.87 mmol TE/g), scavenging activity and β-carotene linoleate bleaching: (87.65 ± 3.12%)	Noor and Noriham, 2014
		Pulp	80% methanol	Folin-Ciocalteau method β-carotene linoleate bleaching assay	TPC: 1,261.63 31.41 mg GAE/100g. Antioxidant activity: 91.89 ± 0.00%	Ikram et al., 2009
	Baccaurea angulata	Whole fruit, pulp, peel	Methanol, phosphate buffered saline (PBS)	Folin-Ciocalteau method Aluminium chloride colorimetric method Total carotene method DPPH radical scavenging assay Linoleic acid peroxidation assay Phosphatidylcholine peroxidation assay	Methanol pulp extract showed the highest TPC (15,357.77 ± 150.72 µg GAE/g), TFC (37.32 ± 0.55 mg QE/g) and total carotene content (TCC) (6,571.43 ± 185.86 µg beta-carotene equivalent (BC)/100g). Methanol peel extract showed the highest scavenging activity (96.80 ± 0.53%), while methanol whole fruit showed the highest linoleic acid peroxidation (96.60 ± 0.29 %) and phosphatidylcholine peroxidation (78.48 ± 0.85%)	Ahmed et al., 2015
		Whole fruit, peel, pulp	Distilled water (juice)	In Vivo Method Lipid peroxidation assay Enzymatic antioxidant assays High cholesterol-induced rabbits	Plasma malon-aldehyde (MDA) levels were highest in cholesterol + peel juice group (671.04 %). Catalase was highest in cholesterol + whole fruit juice group (12.66 %) compared to simvastatin control (9.13 %). TAC was also highest in whole fruit group (309.08 ± 35.59 mM)	Mikail et al., 2015

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
		Whole fruit, pulp, peel	Methanol, PBS	Folin-Ciocalteau method Aluminium chloride colorimetric method Total carotene method DPPH radical scavenging assay Lipid peroxidation assay	Methanol pulp extract showed the highest TPC (11,308.59 ± 12.54 µg catechin equivalent (CAT)/g crude extracts), TFC (37.32 ± 0.55 mg QE/ g crude extracts) and total carotene content (TCC) (6,571.43 ± 185.86 µg BC/100g crude extracts). Methanol peel extract showed the highest scavenging activity (96.80 ± 0.53%) and methanol whole fruit extract showed the highest LPO (78.48 ± 0.85%)	Ahmed et al., 2013
		Whole fruit, peel, berry	80% methanol	DPPH radical scavenging assay FRAP assay TEAC/ABTS scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method	Peel extract exhibited the highest antioxidant properties ($p < 0.05$); FRAP (50.86 ± 4.24 mm trolox equivalent (TE)/g), DPPH (78.54 ± 2.08 mg ascorbic acid (AA)/100g), TEAC (492.79 ± 53.77 mm TE/100g), TPC (8.62 ± 0.01 mg/g), TFC (19.12 ± 0.11 mg QE/g) and total anthocyanin content (TAC) (0.96 ± 0.19 mg cyanidin-3-glucoside (c-3-g)/100g). Antioxidant activities were significantly correlated ($p < 0.05$) with TPC and TFC but not to TAC	Jauhari et al., 2013
	Baccaurea lanceolata	Pericarp, pulp, seed	80% methanol	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method Total carotene method DPPH radical scavenging assay ABTS scavenging assay FRAP assay	Pulp extract showed the highest TPC (4.81 ± 0.14 mg GAE/g dry sample), TFC (4.73 ± 0.27 mg catechin equivalent (CE)/g dry sample), DPPH activity (94.36 ± 0.02 mg ascorbic acid equivalent antioxidant capacity (AEAC)/g dry sample) and FRAP activity (2.81 ± 0.23 mM/g dry sample). Pericarp extract showed the highest TAC (0.50 ± 0.13 (mg c-3-gE/100g dry sample) and TCC (0.75 ± 0.00 mg BCE/g dry sample). Seed showed the highest ABTS activity (3.03 ± 0.11 AEAC/g dry sample)	Abu Bakar et al., 2014
	Baccaurea macrocarpa	Pericarp, pulp, seed	80% methanol	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method Total carotene method DPPH radical scavenging assay ABTS scavenging assay FRAP assay	Pericarp contained the highest amount of TPC, TFC, TAC and TCC with the values of 60.04 ± 0.53 mg GAE/g, 44.68 ± 0.67 mg CE/g, 1.23 ± 0.20 mg c-3-gE/100g and 0.81 ± 0.14 mg BCE/g. Results from DPPH, ABTS and FRAP assays also showed that pericarp extract displayed the highest antioxidant capacity	Abu Bakar et al., 2014

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
		Pulp	80% methanol	Folin-Ciocalteau method β-carotene linoleate bleaching assay	TPC: 1,064.68 ± 19.40 mg GAE/100g and antioxidant activity: 76.58 ± 1.56 %	Ikram et al., 2009
	Baccaurea motleyana	Pulp (young, mature, ripe)	80 % aqueous methanol	Folin-Ciocalteau method DPPH radical scavenging assay	TPC and antioxidant activity of young fruit extract were the highest with 97.23 mg/100g and 13.10%, respectively	Kin et al., 2011; Mokhtar et al., 2014
		Pulp	80% methanol	Folin-Ciocalteau method β-carotene linoleate bleaching assay	TPC: 1,160.14 ± 20.56 mg GAE/100g and antioxidant activity: 71.17 ± 5.63 %	Ikram et al., 2009
	Baccaurea polyneura	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 81.98 ± 312% TPC: 1,064.68 ± 19.40 mg GAE/100g	Ikram et al., 2009
	Canarium odontophyllum	Pericarp, peel	80% methanol	In Vitro and *In Vivo* Method Cell culture assays MTT assay NAD^+ assay CD36 ELISA assay LDL-oxidation method in rats	Peel extract (1.0 mg/ml) showed protective effect against oxidative stress and lipid peroxidation. The extract was not cytotoxic to normal liver cells. IC_{50} concentration (0.153 mg/ml) is good for inhibition of oxidized LDL binding to CD36 receptor.	Khoo et al., 2014
		Pulp, peel, pulp with peel	80% methanol, distilled water	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method TCC method DPPH radical scavenging assay FRAP assay ABTS scavenging assay	Methanol pulp extracts showed the highest potential in all tests; TPC (11.96 ± 0.05 mg GAE/g), TFC (10.11 ± 1.54 mg rutin equivalent (RE)/g), TAC (12.75 ± 0.28 c-3-gE/100g), TCC (2.84 ± 0.11 mg BA/100g), DPPH (88.14 ± 1.42%), FRAP (30.52 ± 0.54 mM Fe^{2+}/l) and ABTS (46.71 ± 0.98 mg AEAC/g)	Ali Hassan et al., 2013b
		Pericarp, peel	80% methanol	DPPH radical scavenging assay CUPRAC assay	Peel crude extract showed the highest antioxidant capacity; DPPH (60%), CUPRAC (1.75 mM) as compared to pericarp and extract fractions	Khoo et al., 2013
		Pulp with peel, peel	Methanol, water	Folin-Ciocalteau method pH differential method TEAC assay	Pulp-peel crude extracts had the most significant antioxidant properties compared to the methanolic and water fractions	Khoo et al., 2012a
		Pulp with peel, seed	Methanol, ethanol, ethyl acetate, acetone, water	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method	Methanol peel extracts showed the highest TPC, TFC, TAC and antioxidant activities	Khoo et al., 2012b

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
		Whole fruit (purple, red)	70% ethanol	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method TEAC assay FRAP assay DPPH radical scavenging assay	Purple fruits had higher TPC (33.21 ± 6.11 mg GAE/g dry weight), TFC (103.92 ± 24.60 mg RE/g dry weight), TE (0.68 ± 0.09 mmol TE/g dry weight) and FRAP (1.74 ± 0.32 mmol Fe^{2+}/g dry weight) than red fruits	Chew et al., 2011
		Peel, pulp, seed	Hexane:acetone: ethanol (70:15:15)	Beta-carotene bleaching assay ABTS scavenging assay DPPH radical scavenging assay Hemoglobin oxidation assay	Pulp exhibited excellent antioxidant activity coefficient of 2,611 ± 12.7 and the highest DPPH activity (30.5 ± 1%). Peel exhibited highest ABTS activity (84.5 ± 0.9%) and higher than beta carotene (74.6 ± 0.4%). Hemoglobin oxidation was highest in seed fraction (59.7 ± 0.03%)	Prasad et al., 2010
		Pulp, peel, pulp with peel, kernel	80% methanol	Folin-Ciocalteau method Beta-carotene bleaching assay DPPH radical scavenging assay FRAP assay	Peel showed the highest TPC (25.68 ± 1.02 mg GAE/g), beta-carotene bleaching (63.23 ± 1.59%), FRAP (1,744 ± 0.32 mM Fe^{2+}/g) and DPPH (78.2 ± 0.5%)	Shakirin et al., 2010
	Citrus hystrix	Pulp	Water (juice)	Folin-Ciocalteau method Aluminium chloride colorimetric method DPPH radical scavenging assay FRAP assay	TPC: 490.74 ± 1.75 mg GAE/ml TFC: 22.25 ± 0.20 mg GAE/ml Scavenging activity: IC_{50} 35 mg/100 ml FRAP activity: 89.0 ± 5.88 µmol Fe^{2+}/100 ml	Ghafar et al., 2010
	Citrus aurantifolia	Pulp	Water (juice)	Folin-Ciocalteau method Aluminium chloride colorimetric method DPPH radical scavenging assay FRAP assay	TPC: 211.70 ± 0.0 mg GAE/ml TFC: 10.67 ± 0.27 mg GAE/ml Scavenging activity: IC_{50} 79 mg/100 ml FRAP activity: 78 µmol Fe^{2+}/100 ml	Ghafar et al., 2010
	Citrus microcarpa	Pulp	Water (juice)	Folin-Ciocalteau method Aluminium chloride colorimetric method DPPH radical scavenging assay FRAP assay	TPC: 105.0 ± 3.0 mg GAE/100 ml TFC: 8.70 ± 0.13 mg GAE/ml Scavenging activity: IC_{50} 125 mg/100 ml FRAP activity: 48.18 ± 3.34 µmol Fe^{2+}/100 ml	Ghafar et al., 2010
	Cynometra cauliflora	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 45.95 ± 2.70% TPC: 1,868.94 ± 11.68 mg GAE/100g	Ikram et al., 2009

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Cyphomandra betacea	Pulp, peel	80% methanol, distilled water	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method Total carotene method DPPH free radical scavenging assay ABTS assay FRAP assay	Methanol peel extract showed higher FRAP (9.33 ± 0.54 mM Fe^{2+}/g) and ABTS activity (40.14 ± 1.76 AEAC/g), while pulp showed higher DPPH activity (31.82 ± 1.29%). TPC and TFC were higher in peel with 4.89 ± 0.04 mg GAE/g and 3.36 ± 0.01 mg RE/g, respectively. TAC and TCC were higher in pulp with 4.15 ± 0.04 mg/100g and 25.13 ± 0.35 mg/100g	Ali Hassan & Abu Bakar, 2013
	Dacryodes rostrata	Pulp, peel, seed	50% ethanol	Folin-Ciocalteau method Aluminium chloride colorimetric method Phosphomolybdenum method FRAP assay DPPH radical scavenging assay	Seed exhibited the highest TPC (1,007.96 mg GAE/g dry weight), TFC (2,550.90 mg QE/g dry weight), scavenging activity, FRAP and phosphomolybdenum analysis over butylated hydroxyl toluene (BHT) and ascorbic acid	Tee et al., 2015
		Pulp, peel, seed	70% ethanol	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method TEAC assay FRAP assay DPPH free radical scavenging assay	Seed extract exhibited the highest potential in all tests except TAC, with TPC (8,211.21–8,629.92 g GAE/100g), TFC (22,210.30–28,022.28 mg RE/100g), TEAC (51.39–74.59 mmol TE/100g), FRAP (530.05–556.98 mmol Fe^{2+}/100g) and DPPH (92.18–92.19%)	Kin et al., 2011
	Dimorcarpus longan	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 52.25 ± 3.12% TPC: 203.92 ± 14.35 mg GAE/100g	Ikram et al., 2009
	Durio kutejensis	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 54.05 ± 2.07% TPC: 183.07 ± 6.23 mg GAE/100g	Ikram et al., 2009
	Flacourtia jangomas	Pulp	70% ethanol, distilled water	Folin-ciocalteau reagent method DPPH radical scavenging assay FRAP assay. AOAC method	Ethanol extracts gave the highest TPC (2,507.41 mg GAE/100g). DPPH activity was highly correlated with TPC (r = 1.000) and FRAP (r = 0.968). Ascorbic acid content (AAC) was 89.39 mg/100g	Mohamed, 2012
	Flacourtia rukam	Pulp	80% methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method	Scavenging activity: 78.09 ± 3.09% FRAP activity: 2.09 ± 0.13 mM Fe^{2+} TPC: 40.0 ± 0.2 mg GAE/100g	Ikram et al., 2009

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Garcinia atroviridis	Fruit with seed, fruit rind (ripe, unripe)	Methanol, water	Folin-Ciocalteau method Aluminium chloride colorimetric method ABTS assay DPPH radical scavenging assay FRAP assay	Methanol unripe fruit extract showed the highest TPC (10.50 ± 0.39 mg GAE/g), TFC (4.37 ± 0.06 mg QE/g) and aqueous unripe fruit extract had the highest FRAP (17.57 ± 0.26 nmol Fe^{2+}/g). Aqueous ripe and unripe fruit rind showed the highest DPPH (EC_{50}: 943.08 ± 11.46 µg/ml) and ABTS (148.69 ± 4.54 µg/ml), respectively	Al-Mansoub et al., 2014
		Whole fruit	Methanol	Folin-Ciocalteau method TBARS Assay	TPC: 4.4 ± 1.7 mg GAE/g LDL oxidation: 53.0 ± 0.5% at 1,000 µg/ml	Jantan et al., 2011
		Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 72.97 ± 2.70% TPC: 68.41 ± 0.95 mg GAE/100g	Ikram et al., 2009
	Garcinia hombroniana	Whole fruit	Methanol	Folin-Ciocalteu method TBARS Assay	TPC: 20.7 ± 3.8 mg GAE/g LDL oxidation at 1,000 µg/ml: 86.0 ± 7.1%	Jantan et al., 2011
	Garcinia parvifolia	Pulp, peel	80% methanol, distilled water	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method TCC method DPPH radical scavenging assay FRAP assay ABTS assay	Methanol pulp extract had the highest antioxidant properties; TPC: 7.2 ± 0.3 mg GAE/g, TFC: 5.9 ± 0.1 mg RE/g, DPPH: 85.4 ± 1.3%, FRAP: 16.6 ± 3.8 mM Fe^{2+}/g and ABTS: 32.7 ± 8.5 mg AEAC/g. Peel showed the highest TAC: 4.4 ± 0.2 mg c-3-gE/100g and TCC: 17.0 ± 0.2 mg BC/100g	Ali Hassan et al., 2013c
		Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 79.28 ± 7.80% TPC: 95.84 ± 3.43 mg GAE/100g	Ikram et al., 2009
	Garcinia prainiana	Whole fruit Pulp	Methanol 80% methanol	Folin-Ciocalteau method TBARS Assay β-carotene linoleate bleaching assay Folin-Ciocalteau method	TPC: 33.6 ± 6.0 mg GAE/g LDL oxidation at 1,000 µg/ml: 69.5 ± 0.7% β-carotene bleaching: 91.90 ± 0.00% TPC: 1,868.94 ± 11.68 mg GAE/100g	Jantan et al., 2011 Ikram et al., 2009
	Gnetum gnemon	Seed	Ethanol, water	Folin-Ciocalteau method Aluminium chloride colorimetric method FRAP assay DPPH radical scavenging assay	Ethanol extract showed higher antioxidant properties except for FRAP assay. TPC: (15.1 ± 2.19 mg GAE/100g), tannins (35.6 ± 3.81 mg CE/100g), TFC (709 ± 79.9 mg CE/100g) and scavenging activity (48.9 ± 38.9%)	Bhat and Yahya, 2014
	Lepisanthes rubiginosa	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching ranged from 54.05 ± 2.70 to 50.45 ± 5.63%. TPC ranged from 1,110.21 ± 38.99 to 1,308.26 ± 79.94 mg GAE/100g	Ikram et al., 2009

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Litsea garciae	Pulp, cap, seed	80% ethanol	Folin-Ciocalteau method Aluminium chloride colorimetric method DPPH radical scavenging assay ORAC scavenging assay	Freeze-dried seed extract showed the highest TPC (3,405.09 mg GAE/100g), TFC (534.94 mg RE/100g), DPPH (IC_{50}: 0.22 mg/ml) and ORAC (120,675 µmol TE/100g). Other fruit extracts had higher TPC and TFC when superheated steam dried	Husen, 2015
		Pulp, stem cap, seed	50% methanol, distilled water	DPPH radical scavenging assay FRAP assay ABTS scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method	Methanol extracts of stem cap displayed the highest antioxidant; DPPH (IC_{50}: 16.7 ± 0.6 µg/ ml), FRAP (2,050.0 ± 28.5 µM Fe^{2+}/g) and ABTS (25.05 ± 1.7 mg AEAC/g). The extract also showed the highest TPC (08.29 ± 0.70 mg GAE/g) and TFC (6.90 ± 0.61 mg RE/g)	Ali Hassan et al., 2013a
	Mangifera caesia	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 8.14 ± 0.17 mg/ml, TPC: 2,637.35 ± 178.92 mg/100g, TFC 550.67 ± 19.78 mg/100g and AAC 270.22 ± 12.79 mg/100g	Mirfat et al., 2015
		Pulp (mature-green, ripe)	Water	AOAC method Folin-Ciocalteau method Metal chelating FRAP assay DPPH radical scavenging assay	Mature-green extract showed higher AAC (142.41 ± 2.98 µg AAE/g), TPC (122.82 ± 2.45 µg GAE/g), scavenging activity (303.71 ± 21.11 µg TE/g), FRAP activity (868.29 ± 2.71 µg TE/g) and metal chelating (6.09 ± .2.21%)	Sulaiman and Ooi, 2012
	Mangifera foetida	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 43.22 ± 0.29 mg/ml, TPC: 2,917.92 ± 155.35 mg/100g, TFC 282.88 ± 71.75 mg/100g and AAC 122.13 ± 32.84 mg/100g	Mirfat et al., 2015
		Pulp (mature-green, ripe)	Water	AOAC method Folin-Ciocalteau method Metal chelating FRAP assay DPPH radical scavenging assay	Ripe extract showed higher TPC (72.91 ± 0.44 µg GAE/g), scavenging activity (291.48 ± 25.21 µg TE/g) and FRAP activity (101.79 ± 3.84 µg TE/g)	Sulaiman and Ooi, 2012
	Mangifera laurina	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 13.32 ± 0.11 mg/ml, TPC: 144.33 ± 23.88 mg/100g, TFC 176.71 ± 25.78 mg/100g and AAC 135.74 ± 30.33 mg/100g	Mirfat et al., 2015

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Mangifera longipetiolata	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 8.33 ± 0.08 mg/ml, TPC: 263.31 ± 35.53 mg/100g, TFC 129.11 ± 56.39 mg/100g and AAC 322.75 ± 32.55 mg/100g	Mirfat et al., 2015
	Mangifera odorata	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 20.16 ± 1.31 mg/ml, TPC: 257.17 ± 27.72 mg/100g, TFC 202.33 ± 32.19 mg/100g and AAC 47.32 ± 9.73 mg/100g	Mirfat et al., 2015
		Pulp (mature-green, ripe)	Water	AOAC method Folin-Ciocalteau method Metal chelating FRAP assay DPPH radical scavenging assay	Ripe extract showed higher TPC (42.10 ± 3.27 µg GAE/g), scavenging activity (114.74 ± 3.56 µg TE/g) and metal chelating (48.88 ± 0.61%)	Sulaiman and Ooi, 2012
		Pulp	80% methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method	Scavenging activity: 45.68 ± 11.09% FRAP activity: 0.28 ± 0.10 mM Fe^{2+} TPC: 8.0 ± 0.0 mg GAE/100g	Ikram et al., 2009
	Mangifera pajang	Kernel	Petroleum ether, chloroform, ethyl acetate and methanol	DPPH radical scavenging assay	Ethyl acetate and methanol kernel extracts showed strong radical scavenging activity with IC_{50} values of 7.28 ± 0.30 and 8.84 ± 1.04 µg/ml	Ahmad et al., 2015
		Peel	Water (juice)	In Vivo Method Enzymatic and non-enzymatic antioxidants and plasma antioxidant status in humans	Plasma total antioxidant status, plasma β-carotene and ascorbic acid were increased by 18, 45 and 28% compared to baseline level and placebo, but liver and kidney functions were unaffected	Ibrahim et al., 2013
		Pulp, kernel, peel	80% methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method	Kernel extract displayed the highest DPPH activity (23.23 mg AEAC/g), FRAP activity (3,130.00 ± 35.47 µM Fe^{2+}/g), TPC (103.30 ± 0.63.mg GAE/g) and TFC (10.98 ± 0.16 mg GAE/g)	Abu Bakar et al., 2009; Abu Bakar et al., 2011
		Peel	Methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method	TPC: 9.8 ± 0.12 mg GAE/g Scavenging activity: 44.5 ± 0.24 µg/ml FRAP activity: 1,248 µg/ml higher than ascorbic acid (1,318 µg/ml)	Hassan et al., 2011
		Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 37.94 ± 1.29 mg/ml, TPC: 7,055.65 ± 101.89 mg/100g, TFC 256.42 ± 17.52 mg/100g and AAC 403.21 ± 46.83 mg/100g	Mirfat et al., 2015

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
		Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching ranged from 68.47 ± 1.56 to 48.65 ± 2.70% TPC ranged from 221.47 ± 10.71 to 339.97 ± 20.58 mg GAE/100g	Ikram et al., 2009
	Mangifera pentandra	Pulp	70% methanol	DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method AOAC method	IC_{50} : 13.27 ± 0.81 mg/ml, TPC: 676.24 ± 40.13 mg/100g, TFC 118.82 ± 24.83 mg/100g and AAC 400.94 ± 71.74 mg/100g	Mirfat et al., 2015
		Pulp (mature-green, ripe)	Water	AOAC method Folin-Ciocalteau method Metal chelating FRAP assay DPPH radical scavenging assay	Ripe extract showed higher AAC (175.07 ± 4.89 µg AAE/g), scavenging activity (100.46 ± 2.27 µg TE/g), FRAP activity (80.47 ± 2.08 µg TE/g) and metal chelating (88.94 ± 1.43%)	Sulaiman and Ooi, 2012
	Mangifera quadrifida	Pulp (mature-green, ripe)	Water	AOAC method Folin-Ciocalteau method Metal chelating FRAP assay DPPH radical scavenging assay	Mature-green extract showed higher AAC (123.51 ± 7.88 µg AAE/g), TPC (51.88 ± 1.00 µg GAE/g), scavenging activity (200.58 ± 13.75 µg TE/g) and FRAP activity (78.82 ± 7.86 µg TE/g)	Sulaiman and Ooi, 2012
	Nephelium malaiense	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 97.30 ± 0.00% TPC: 894.61 ± 81.19 mg GAE/100g	Ikram et al., 2009
	Nephelium ramboutan-ake	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 72.07 ± 4.13% TPC: 240.67 ± 18.50 mg GAE/100g	Ikram et al., 2009
	Nypa fruticans	Endosperm (ripe and unripe)	50% ethanol	Folin-Ciocalteau method Aluminium chloride colorimetric method ABTS assay FRAP assay DPPH radical scavenging assay Phosphomolybdenum method	Unripe extract exhibited the highest TPC (135.6 ± 4.5 mg GAE/g), TFC (68.6 ± 3.1 RE/g) and antioxidant capacity; ABTS activity (78 ± 1.2%), DPPH activity (85 ± 2.6%), antioxidant excellent coefficient (2,550 ± 123), phosphomolybdenum activity (0.9) and FRAP activity (819 ± 4.3 mmol Fe^{2+}/100g)	Prasad et al., 2013
	Pandanus tectorius	Keys, core	Hexane, ethyl acetate, methanol	DPPH radical scavenging assay Folin-Ciocalteau method	Ethyl acetate core extract showed the highest antioxidant capacity (IC_{50}: 0.8 ± 0.20 mg/ml) and TPC (180 µ GAE/g).	Andriani et al., 2015

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Parkia speciosa	Empty pod	Water, 95% ethanol	Thiocyanate method Superoxide radical scavenging assay DPPH radical scavenging assay ABTS radical scavenging assay Metal chelating FRAP assay Folin-Ciocalteau method Aluminium chloride colorimetric method	Ethanol extract showed stronger antioxidant activities with IC_{50}: DPPH (64.2 ± 3.46 µg/ml), ABTS radical scavenging (19.6 ± 0.44), anti-lipid peroxidation (5.02 ± 1.06), metal chelating (319 ± 26.3) and reducing power (274 ± 16.1) and contained higher TPC and TFC	Ko et al., 2014
	Phyllanthus emblica	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 81.98 ± 5.63% TPC: 2,664.97 ± 115.40 mg GAE/100g	Ikram et al., 2009
	Pometia sp	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 97.30 ± 0.00% TPC: 894.61 ± 81.19 mg GAE/100g	Ikram et al., 2009
	Pouteria campechiana	Seed, pulp, peel	Distilled water, 70% methanol, 70% ethanol	ABTS assay FRAP assay DPPH radical scavenging assay Folin-Ciocalteau method Aluminium chloride colorimetric method	Antioxidant activities of ethanolic and methanolic extracts did not differ significantly. 70% ethanol showed the highest TPC and TFC for all the fruit parts. Seed contained the highest TPC (2,304.7 mg GAE/100g), pulp contained the highest TFC (6,414 mg RE/g)	Kong et al., 2013
		Pulp	80% methanol	DPPH radical scavenging assay FRAP assay Folin-Ciocalteau method	Scavenging activity: 73.32 ± 0.72% FRAP activity: 0.43 ± 0.09 mM Fe^{2+} TPC: 21.0 ± 0.1 mg GAE/100g	Ikram et al., 2009
	Rubus moluccanus	Whole fruit	80% methanol	Folin-Ciocalteau method Aluminium chloride colorimetric method pH differential method Total carotene method DPPH radical scavenging assay FRAP assay ABTS scavenging assay	TPC: 20.76 ± 0.24 mg GAE/g, TFC: 18.17 ± 0.20 mg CE/g, TAC: 36.96 ± 0.39 mg c-3-gE/g, TCC: 9.69 ± 0.58 mg BC/g Scavenging activity: 38.00 ± 1.63 µg/ml FRAP activity: 0.73 ± 0.03 mM Fe^{2+}/g ABTS activity: 50.37 ± 5.28 mg AEAC/g	Abu Bakar et al., 2016
	Rubus fraxinifolius				TPC: 11.09 ± 0.10 mg GAE/g, TFC: 5.82 ± 0.02 mg CE/g, TAC: 23.82 ± 0.77 mg c-3-gE/g, TCC: 10.49 ± 1.01 mg BC/g Scavenging activity: 86.00 ± 3.65 µg/ml FRAP activity: 0.75 ± 0.03 mM Fe^{2+}/g ABTS activity: 26.34 ± 4.79 mg AEAC/g	Abu Bakar et al., 2016

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Rubus alpestris				TPC: 24.25 ± 0.12 mg GAE/g, TFC: 8.88 ± 0.53 mg CE/g, TAC: 33.62 ± 1.39 mg c-3-gE/g, TCC: 21.86 ± 0.63 mg BC/g Scavenging activity: 29.00 ± 3.07 µg/ml FRAP activity: 0.79 ± 0.05 mM Fe^{2+}/g ABTS activity: 70.93 ± 6.26 mg AEAC/g	Abu Bakar et al., 2016
	Salacca conferta	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 84.68 ± 8.69% TPC: 1,455.29 ± 62.14 mg GAE/100g	Ikram et al., 2009
	Sandoricum macropodum	Pulp	80% methanol	β-carotene linoleate bleaching assay Folin-Ciocalteau method	β-carotene bleaching: 74.77 ± 3.12% TPC: 3,185.05 ± 59.00 mg GAE/100g	Ikram et al., 2009
	Syzygium jambos	Pulp	Hexane	β-carotene linoleate bleaching assay Folin-Ciocalteau method TCC	β-carotene bleaching: 90.09 ± 3.12% TPC: 555.57 ± 28.33 mg GAE/100g edible portion TCC: 1.41 mg/100g	Ikram et al., 2009; Khoo et al., 2008
	Syzigium malaccense	Pulp	Hexane	FRAP assay DPPH radical scavenging assay Folin-Ciocalteau method Total carotene content	FRAP activity: 0.22 ± 0.03 mM Fe^{2+} Scavenging activity: 17.01 ± 0.32% TPC: 6.0 ± 0.0 mg GAE/100g TCC: 3.35 mg/100g	Ikram et al., 2009;Khoo et al., 2008
	Ziziphus mauritiania	Pulp	80% methanol	FRAP assay DPPH radical scavenging assay β-carotene linoleate bleaching assay Folin-Ciocalteau method	FRAP activity: 0.46 ± 0.07 mM Fe^{2+} Scavenging activity: 74.96 ± 0.44% β-carotene bleaching: 57.66 ± 8.26% TPC: 1,321.98 ± 4.14 mg GAE/100g	Ikram et al., 2009
Antimicrobial	*Artocarpus altilis*	Whole fruit, pulp, peel	Hexane,	Disc diffusion method Microdilution method	Methanol pulp extract showed the highest zone of inhibition (14.83 ± 0.28 to 20.50 ± 0.76 mm) against all Gram-positive and Gram-negative bacteria tested. MIC and MBC/MFC for the extracts ranged from 4,000 to 63 µg/ml. MBC/MFC values varied from 250 to 4,000 µg/ml	Jalal et al., 2015
	Averhhoa bilimbi	Whole fruit	Water (juice)	Disc diffusion method	Fruit juice significantly ($p < 0.05$) reduced aerobic bacteria (APC) (0.40–0.70 log cfu/g), *Listeria monocytogenes* (0.84–1.58 log cfu/g) and *Salmonella typhimurium* (1.03–2.00 log cfu/g)	Wan Norhana et al., 2009
	Baccaurea angulata	Whole fruit, peel, berry	Methanol, ethanol, water	Agar well diffusion method Microdilution method	Ethanol peel extract had the highest antimicrobial activity (37 ± 1.0 mm) against *Streptococcus pneumoniae* at concentration of 1,000 µg/ml. *Klebsiella pneumoniae* showed the highest bacteriostatic and bactericidal activity	Momand, 2014

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Canarium odontophyllum	Pulp	Methanol, acetone, hexane, distilled water	Agar well diffusion method	All extracts were not active against the bacteria, acetone extract displayed moderate activity against *Candida glabrata* (8.0 ± 0.00 mm) and hexane extract was active against *C. glabrata* only at 100 mg/ml	Basri et al., 2014a
		Seed	Ethyl acetate, acetone, methanol	Agar well diffusion method	Ethyl acetate extract was active against *Bacillus cereus* with inhibition zone ranging from 9.6 ± 0.1 to 14.6 ± 0.1 mm, whereas the acetone extract inhibited *Proteus mirabilis* and *Acinetobacter baumannii* at 9.6 ± 0.0 to 14.0 ± 0.0 mm and 7.0 ± 0.1 to 13.0 ± 0.1 mm, respectively. MIC and MBC values of ethyl acetate and acetone extract were the same against *B. cereus* and *A. baumannii* at 6.25 mg/ml and 1.563 mg/ml, respectively	Basri et al., 2014b
	Garcinia parvifolia	Whole fruit		Well diffusion method	Isolate 56 GP from fruit part identified as *Fusarium equiseti* possessed the most antibacterial activities against *Staphylococcus aureus* (9 mm), *Agromyces lapidis* (6 mm), *Listeria monocytogenes* (7 mm), *Bacillus megaterium* (5 mm) and *B. subtilis* (5 mm)	Sim et al., 2010
	Mangifera pajang	Kernel	Petroleum ether, chloroform, ethyl acetate, methanol	Disc diffusion method	All extracts showed no significant inhibition activity towards methicillin resistant *S. aureus* MRSA, *Pseudomonas aeruginosa, Salmonella choleraesuis* and *B. subtilis.* Only isolated compound methyl gallate demonstrated strong antibacterial activity towards MRSA (21.5 mm). None of extracts and isolated compounds showed activity against *Candida albican, Aspergillus ochraceaus* and *Sacchoromyces cerevisiae*	Ahmad et al., 2015
	Pandanus tectorius	Keys, core	Hexane, ethyl acetate, methanol	Disc diffusion method	Ethyl acetate keys extract demonstrated the highest activity against *Escherichia coli, Pseudomonas aeruginosa, S. aureus* and *B. subtilis* with the range of inhibition zone of 10–15 mm	Andriani et al., 2015
	Rubus moluccanus	Whole fruit	80% methanol	Disc diffusion method	Effective against Gram-positive and Gram-negative bacteria. Mild inhibition towards *B. subtilis, S. aureus, E. coli* and *Salmonella enteritidis*	Abu Bakar et al., 2016

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Rubus fraxinifolius				No inhibition towards *B. subtilis*	Abu Bakar et al., 2016
	Rubus alpestris				The highest activity against *S. enteritidis* (8.50 ± 1.80 mm) followed by *B. subtilis* (7.83 ± 1.26 mm)	Abu Bakar et al., 2016
Anti-cholinesterase	*Canarium odontophyllum*	Pulp+peel, seed	80% methanol, distilled water	Anti-cholinesterase inhibition assay	Only 80% methanol extracts displayed anti-cholinesterase activity when tested at 0-100 µg/ml. Activity was highest in the seed (22.4%)	Ali Hassan, 2013b
	Cyphomandra betacea	Pulp, peel	80% methanol, distilled water	Anti-cholinesterase inhibition assay	Only 80% methanol extracts displayed anti-cholinesterase activity when tested at 50–250 µg/ml. Activity was highest in the peel	Ali Hassan and Abu Bakar, 2013
	Garcinia parvifolia	Pulp, peel	80% methanol, distilled water	Anti-cholinesterase inhibition assay	Only 80% methanol extracts displayed anti-cholinesterase activity when tested at 50–250 µg/ml. Activity was highest in the pulp (14.3%). The activity was much smaller than positive control, galanthamine	Ali Hassan et al., 2013c
	Rubus moluccanus	Whole fruit	80% methanol	Anti-cholinesterase inhibition assay	The highest activity was 26.42 ± 1.41%. Donepenzil (positive control) showed complete acetylcholinesterase inhibition activity (100%)	Abu Bakar et al., 2016
	Rubus fraxinifolius				The highest activity was 23.06 ± 1.12%. Donepenzil (positive control) showed complete acetylcholinesterase inhibition activity (100%)	Abu Bakar et al., 2016
	Rubus alpestris				The highest activity was 25.30 ± 1.56%. Donepenzil (positive control) showed complete acetylcholinesterase inhibition activity (100%)	Abu Bakar et al., 2016
Cytotoxicity	*Artocarpus odoratissimus*	Peel, seed	Ethanol	MTT assay	No cytotoxic activity shown by all extracts in the cancer cell lines tested; human liver cancer cell (HepG2), human colon cancer cell (HT-29) and human ovarian cancer cell (Caov3)	Abu Bakar et al., 2010
	Cynometra cauliflora	Whole fruit	Methanol	MTT assay	Extract was very cytotoxic towards human promyelocytic leukemia HL-60 cells (CD_{50} 0.9 µg/ml) and inhibited the cells into apoptotic cell death mode. However, it was less cytotoxic towards normal mouse fibroblast cell line 3T3/NIH cells	Tajudin et al., 2012

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
	Garcinia dulcis	Peel, pulp, seed	80% methanol	MTT assay Cell cycle analysis Caspase-3 colorimetric assay	Seed extract induced the lowest cytotoxicity against human liver HepG2 cancer cell line with IC_{50} value of 7.5 ± 2.52 µg/ml. Pulp extract induced cell cycle arrest at sub- G1 (apoptosis) phase. The cell population underwent apoptosis after exposure of the HepG2 cell line to pulp extract. Caspase-3 was activated which led to the death of HepG2 cell	Abu Bakar et al., 2015
	Mangifera pajang	Kernel	Petroleum ether, chloroform, ethyl acetate, methanol	MTT assay	Ethyl acetate and methanol extracts showed strong cytotoxic activity towards MCF-7 (human breast) and HeLa (human cervical) cancer cell lines with IC_{50} values less than 10 µg/ml, and displayed strong to moderate activities towards HT-29 (human colon cancer)	Ahmad et al., 2015
		Kernel, peel, pulp	Ethanol	MTT assay	Kernel extract induced strong cytotoxic activity against human liver (HepG2), colon (HT-29), ovary (Caov3), and breast (MCF-7 and MDA-MB-231) cancer cell lines tested, especially MCF-7 (IC_{50} 23.0 mg/ml) and MDA-MB-231 (IC_{50} 30.5 mg/ml)	Abu Bakar et al., 2011
		Kernel	Ethanol	Flow cytometric analysis Caspase colorimetric protease assay	For MCF-7 cells, a significant arrest at G0/G1 was observed at 24 h treatment. Proportion of cells undergoing apoptosis increased significantly up to 30.7% and 51.8% compared to controls (2.9% and 5.2%). For MDA-MB-231, the proportion of cells in the G2-M phase increased significantly following 24 and 48 h. Apoptosis was dependent on caspase-2 and -3 in MCF-7 cells, and on caspase-2, -3 and -9 in MDA-MB-231 cells.	Abu Bakar et al., 2010
		Kernel, peel, pulp	Ethanol	MTT assay	Kernel and peel extracts displayed cytotoxic activity in HepG2 and Caov3 with IC_{50} values ranging from 34.5 to 92.0 mg/ml. Kernel extract inhibited the proliferation of colon cancer cell line with IC_{50} 63.0 mg/ml	Abu Bakar et al., 2010
	Pandanus tectorius	Keys, core	Hexane, ethyl acetate, methanol	MTT assay	Keys and core extracts were no cytotoxic against normal (L-6 and RAW) and cancer (MCF-7, HeLa, and HepG2) cell lines. IC_{50} values of all extracts towards RAW were more than 30 µg/ml	Andriani et al., 2015

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
Cytoprotective	*Baccaurea angulata*	Whole fruit, peel, pulp	Distilled water	In Vivo Method Lipid peroxidation assay Enzymatic antioxidant assays High cholesterol-induced rabbits	MDA levels were highest in cholesterol + peel juice group (671.04 %). Catalase was highest in cholesterol + whole fruit juice group (12.66 %) compared to simvastatin control (9.13 %). TAC was also highest in whole fruit group (309.08 ± 35.59 mM)	Mikail et al., 2015
	Canarium odontophyllum	Pericarp, peel	80% methanol	In Vitro & *In Vivo* Method Cell culture assays MTT assay NAD^+ assay CD36 ELISA assay LDL-oxidation method in rats	Peel extract (1.0 mg/ml) showed protective effect against oxidative stress and lipid peroxidation. The extract was not cytotoxic to normal liver cell. IC_{50} concentration (0.153 mg/ml)	Khoo et al., 2014
		Pulp	Chloroform-methanol	In Vivo Method Rabbit fed oil	Pulp oil increased high-density lipoprotein (HDL)-C, reduced low-density lipoprotein (LDL)-C, triglycerides, TBARS levels with enhancement of SOD, GPx, and plasma total antixodant status (TAS) levels. Kernel oil increased SOD and TAS levels	Shakirin et al., 2012a
	Mangifera pajang	Pulp, kernel, peel	Ethanol	Cell culture	Kernel extract and quercetin showed cytoprotective activity in HepG2 cells, with EC_{50} values of 1.2 and 5.3 µg/ml, respectively	Abu Bakar et al., 2013
Anti-atheroschlerotic	*Baccaurea angulata*	Fruit	Water (juice)	In Vivo Method Cholesterol-induced rabbits	Juice reduced plaque formation in rabbits' aorta. In the high-cholesterol diet (group CH), high cholesterol diet with juice treatments (C1, C2 and C3) and standard chow diet (group N), 96, 55, 49, 22 and 0%, respectively, of the entire aorta were covered with plaque	Mikail et al., 2014
	Canarium odontophyllum	Pulp	Oil	In Vivo Method Cholesterol-induced rabbits	Hypercholesterolemic diet + 5% defatted pulp (HD) group exhibited the greatest reduction in atherosclerotic plaque formation by nearly 80%, induced by a significant reduction in total cholesterol (96.3%) and LDL-c (26.5%) and lipid peroxidation levels	Nurulhuda et al., 2013
		Pulp, kernel	Chloroform, methanol	In Vivo Method Cholesterol-induced rabbits	HD group (treated with defatted pulp) exhibited the greatest reduction in atherosclerotic plaque formation by nearly 80%	Shakirin et al., 2012b

Table 3. Biological activities of Malaysian underutilised fruits - *(continued)*

Biological Activity	Species	Part	Extract	Experimental Method	Description	Reference
Anti-hyperlipidemia	*Garcinia atroviridis*	Whole fruit, fruit rind	Methanol, distilled water	In Vivo Method Poloxamer 407-induced acute hyperlipidemic rats	Aqueous extract of ripe fruit showed the highest antihyperlipidemic activity, compared to atorvastatin. It significantly reduced the total cholesterol ($P < 0.05$), triglycerides ($P < 0.01$), low-density lipoprotein ($P < 0.01$), very-low-density lipoprotein ($P < 0.01$) and atherogenic index ($P < 0.01$)	Al-Mansoub et al., 2014
Antidiabetic	*Canarium odontophyllum*	Pulp with peel	Ethanol	In Vivo Method Obese-diabetic-induced rats	Extract at a concentration of 600 mg/kg body weight reduced the plasma glucose level by 30%. The result was strongly correlated with the reduction of plasma glucose at 60 to 90 min in the OGTT and a lower AUC value	Mokiran et al., 2014
Cardioprotective	*Canarium odontophyllum*	Peel, pericarp	53% methanol, 80% methanol	In Vivo Method Hypercholesterolemic-induced rabbits	Defatted peel had the highest amount of anthocyanin C3G (55.12 ± 0.82 mg/g). C3G-rich extract inhibited MDA production in the hypercholesterolemic rabbits and elevated cellular antioxidant enzymes (SOD and GPx)	Khoo et al., 2013
Anti-platelet	*Garcinia atroviridis*	Whole fruit	Methanol	In Vivo Method Electrical impedance method	Anti-platelet at 100 µg/ml: 72.0 ± 0.03% (ADP)	Jantan et al., 2011
	Garcinia hombroniana				Anti-platelet at 100 µg/ml: 50.0 ± 0.1% (AA), 50.0 ± 0.9% (ADP), 41 ± 0.1% (collagen)	Jantan et al., 2011
	Garcinia prainiana				Anti-platelet at 100 µg/ml: 36.0 ± 0.1% (AA), 33 ± 0.1% (ADP), 37 ± 0.1% (collagen)	Jantan et al., 2011

Table 4. Summary of biological activities and phytochemistry of Malaysian underutilised fruit species

Family	Biological Activity																				Phytochemical Identification
	Antioxidant		Antimicrobial		Anti-cholinesterase		Cytotoxicity		Cytoprotective		Anti-atherosclerotic		Anti-hyperlipidemia		Antidiabetic		Cardioprotective		Antiplatelet		
	In vitro	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	*In vitro*	*In vivo*	
Anacardiaceae	√	√	√				√			√											√
Arecaceae	√																				√
Bombacaceae	√																				
Burseraceae	√	√	√		√					√		√				√		√			√
Euphorbiaceae	√	√	√							√		√									√
Fabaceae	√						√														
Flacourtiaceae	√																				
Gnetaceae	√																				
Guttiferae	√	√	√		√		√							√						√	√
Lauraceae	√																				√
Leguminosae	√																				√
Meliaceae	√																				
Moraceae	√		√				√														
Myrtaceae	√																				√
Oxalidaceae	√		√																		
Pandanaceae	√		√				√														
Phyllanthaceae	√																				
Rhamnaceae	√																				
Rosaceae	√		√		√																√
Rutaceae	√																				
Sapotaceae	√																				
Sapindaceae	√																				
Solanaceae	√				√																

activity (74.6 ± 0.4%) than DPPH scavenging activity. Ali Hassan et al. (2013b) found that pulp extracts showed higher DPPH radical scavenging activity (88.14 ± 1.42%) and FRAP activity (30.52 ± 0.54 mM Fe^{2+}/l). However, the FRAP activity of peel extracts as reported by Shakirin et al. (2010) was remarkably higher (1744 ± 0.32 mM Fe^{2+}/g). In *in vivo* study, it was observed that both peel and pericarp extracts of *C. odontophyllum* had significantly reduced lipid peroxidation effect as compared to the anthocyanin standard, cyanidin-3-glucoside. Thiobarbiturate reactive substance (TBARS) values among defatted peel, pericarp and cyanidin-3- glucoside showed no significant differences for hemoglobin and low density lipoprotein (LDL) oxidation assays (Khoo et al, 2014).

Meanwhile, among the abundant species of Anarcadiaceae family which have been tested for antioxidant activities, *M. pajang* or *bambangan* was the centre of attention. The findings of pulp (Abu Bakar et al., 2009; Abu Bakar et al., 2011; Ikram et al., 2009; Mirfat et al., 2015), peel (Abu Bakar et al., 2009; 2011; Ahmad et al., 2015; Hassan et al., 2011) and kernel (Abu Bakar et al., 2009; 2011; Ibrahim et al., 2013) were reported by six different research groups. Abu Bakar et al. (2009; 2011) described that methanolic kernel extract displayed the highest DPPH scavenging effect (23.23 mg ascorbic acid equivalent capacity (AEAC)/g) and FRAP reducing activity (3,130.00 ± 35.47 µM Fe^{2+}/g). Meanwhile, other researchers reported that ethyl acetate and methanolic kernel extracts were strong DPPH radical scavengers with IC_{50} values of 7.28 ± 0.30 and 8.84 ± 1.04 µg/ml (Ibrahim et al., 2013). Pulp was tested for β-carotene bleaching activity which ranged from 68.47 ± 1.56 48.65 ± 2.70% (Ikram et al., 2009) and DPPH radical scavenging activity with IC_{50} of 37.94 ± 1.29 mg/ml (Mirfat et al., 2015). Peel was the only fruit part that was reported for *in vivo* study in human subjects. After administration of the peel juice extract, plasma total antioxidant status, plasma β-carotene and ascorbic acid were increased by 18, 45 and 28% as compared to the baseline level and placebo, but liver and kidney functions were unaffected (Ahmad et al., 2015).

Both *in vitro* and *in vivo* assays were also performed in *Baccaurea angulate*, known as *belimbing dayak*. Based on the literature, four studies investigated the same whole fruit, pulp and peel parts (Ahmed et al., 2013; Ahmed et al., 2015; Jauhari et al., 2013; Mikail et al., 2014; 2015;). All researchers reported the same results that methanolic peel extracts displayed the highest DPPH radical scavenging activity with 96.80 ± 0.53% (Ahmed et al., 2013; 2015) and 78.54 ± 2.08 mg AA/100g (Jauhari et al., 2013). Jauhari et al. (2013) also reported that methanolic peel extract showed the highest FRAP activity (50.86 ± 4.24 mm TE/g) and TEAC activity (492.79 ± 53.77 mm TE/100g). Mikail et al. (2015) studied the *in vivo* antioxidant effect of *B. angulata* fruits in rabbits. Plasma malondialdehyde (MDA) levels in high cholesterol-induce rabbits were the greatest in peel juice treated group (671.04 %), while whole fruit juice group demonstrated the highest level of catalase activity (12.66 %) and total antioxidant capacity (309.08 ± 35.59 mM) (Mikail et al., 2015).

3.2. Antimicrobial effect

Ten species of underutilised fruits in Malaysia have been recorded for their antimicrobial activities which comprise A. altilis, A. bilimbi, B. angulata, C. odontophyllum, G. parvifolia, M. pajang, P. tectorius, R. moluccanus, R. fraxinifolius and R. alpestris (Table 3). Similar to antioxidant activities, these fruit species also exhibited varying degrees of antimicrobial activity depending on the fruit part, methods employed and extraction solvents used. The methods that were reported to assess antimicrobial activities were in the order of disc diffusion > well diffusion > microdilution. Few of the fruit species were further evaluated for minimal inhibitory concentration (MIC) and minimum bactericidal concentration (MBC)/minimum fungicidal concentration (MFC). Several polar and non-polar extraction solvents were used which was again dominated by methanol, and the extracts were tested against common pathogenic microbes; bacteria, fungi and yeasts.

Canarium odontophyllum fruits, again, were the main focus of the researchers. This is evident by the studies reported by Basri et al. (2014a; 2014b). They found that methanol, acetone, hexane and distilled water extracts of pulp were not active against all the Gram-negative and Gram-positive bacteria tested at concentrations of 25–100 mg/ml. However, acetone extract displayed moderate activity against Candida glabrata (8.0 ± 0.00 mm) and hexane extract was active against C. glabrata only at 100 mg/ml (Basri et al., 2014a). With regard to C. odontophyllum seed, Basri et al. (2014b) demonstrated that ethyl acetate extract was active against B. cereus (9.6 ± 0.1 mm to 14.6 ± 0.1 mm), whereas the acetone extract was capable of inhibiting Proteus mirabilis and Acinetobacter baumannii at 9.6 ± 0.0 to 14.0 ± 0.0 mm and 7.0 ± 0.1 to 13.0 ± 0.1 mm, respectively. MIC and MBC values of ethyl acetate and acetone extract were the same against Bacillus cereus and A. baumannii at 6.25 and 1.563 mg/ml, respectively.

However, many other researchers claim stronger inhibitory activities against the tested microbes. For instance, Momand (2014) revealed that ethanolic extract of B. angulata peel was an effective inhibitor (37 ± 1.0 mm) against S. pneumoniae at a concentration of 1,000 µg/ml. Methanolic extract of A. altilis (sukun) pulp exhibited pronounced activity with inhibition zones ranging from 14.83 ± 0.28 to 20.50 ± 0.76 mm against all Gram-positive and Gram-negative bacteria tested (Jalal et al., 2015). Meanwhile, only isolated compound methyl gallate of M. pajang demonstrated strong antibacterial effect towards methicillin resistant Staphylococcus aureus (MRSA) (21.5 mm) (Ahmad et al., 2015). There was one study that isolated bacteria from G. parvifolia (kundong) fruits which was identified as Fusarium equiseti. The isolate (56 GP) possessed the most antibacterial activity against S. aureus (9 mm), Agromyces lapidis (6 mm), Listeria monocytogenes (7 mm), Bacillus megaterium (5 mm) and B. subtilis (5 mm) (Sim et al., 2010).

3.3. Anti-cholinesterase effect

Alzheimer's disease is a form of dementia characterized by loss of central cholinergic neurons associated with a marked reduction in content of acetylcholinesterase (AChE), the enzyme responsible for the termination of nerve impulse transmission at cholinergic synapses (Ali Hassan et al., 2013b). Therefore, anticholinesterase activities that have been documented for Malaysian underutilised fruits serve as an important information for further possibilities to develop anticholinesterase drugs as one of the important approaches in the management of Alzheimer's disease. Six underutilised fruit species which consists of *C. odontophyllum*, *C. betacea* and *G. parvifolia, R. moluccanus, R. fraxinifolius* and *R. alpestris* have been investigated for their anticholinesterase activities (Table 3).

Ali Hassan et al. (2013b) discovered that both edible (pulp with peel) and inedible (seed) extracts of *C. odontophyllum* showed anticholinesterase activity when tested at 0–100 µg/ml. However, the highest activity was seen in the seed (22.4%). In addition, Ali Hassan and Abu Bakar (2013) also suggested that *Cyphomandra betacea* (*buah cinta*) extracts displayed anticholinesterase activity at higher concentrations (50–250 µg/ml), with the highest activity in the peel. Eighty percent methanolic extracts of *G. parvifolia* also exhibited anticholinesterase activity at the same concentrations of

C. betacea. In particular, the highest activity of *G. parvifolia* was observed in the pulp at 14.3%. However, the activity was much lower than that of the positive control, galanthamine (Ali Hassan et al., 2013c). A recent study by Abu Bakar et al. (2016) revealed that all methanolic extracts of *R. moluccanus*, *R. alpestris* and *R. fraxinifolius* had weak anticholinesterase activities with 26.42 ± 1.41, 25.30 ± 1.56 and 23.06 ± 1.12%, respectively, even when tested at the highest concentration (5 mg/ml). This is in comparison with Donepenzil (positive control) which showed complete inhibition activity (100%) when tested at 1 mg/ml.

3.4. Cytotoxicity effect

Five species of underutilised fruits in Malaysia have been studied for cytotoxicity; these include *A. odoratissimus, C. cauliflora, G. dulcis, P. tectorius* and the popular, *M. pajang* (Table 3). MTT ([3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide]) assay is commonly used by researchers to investigate the cytotoxicity of the fruit species. Out of the underutilised species, only *A. odoratissimus* was not cytotoxic towards all the cancer cell lines tested; human liver (HepG2), human colon (HT-29) and human ovarian (Caov3) (Abu Bakar et al. 2010).

Cynometra cauliflora, locally known as *nam-nam*, has traditionally been used in folk medicine (Tajudin et al., 2012); it exhibited a very strong cytotoxic activity towards human promyelocytic leukemia HL-60 cells (CD_{50} 0.9 µg/ml) and inhibited the cells into apoptotic cell death mode. However, it was less cytotoxic towards normal mouse fibroblast cell line 3T3/NIH cells. The authors stated that extracts which demonstrated CD_{50} value of 10–25 µg/ml were considered to be weak in cytotoxicity, while extracts with CD_{50} value of less than 5.0 µg/ml were considered very active (Tajudin et al., 2012). Another strong cytotoxic effect was demonstrated by *G. dulcis* (*mundu*) from the Guttiferae family (Abu Bakar et al., 2015). The seed extract induced the lowest cytotoxicity against HepG2 cancer cell line with IC_{50} value of 7.5 ± 2.52 µg/ml. Meanwhile, pulp extract induced cell cycle arrest at sub-G1 (apoptosis) phase in a time-dependent manner. The cell population underwent apoptosis after 72 hours of exposure of the HepG2 cell line to pulp extract. Caspase-3 was activated which led to the death of HepG2 cell (Abu Bakar et al., 2015). Another study revealed that ethyl acetate and methanol extracts from *M. pajang* kernel showed strong cytotoxic activity towards human breast (MCF-7) and cervical (HeLa) cancer cell lines (Ahmad et al., 2015). The remarkable effect was demonstrated in a dose-dependent manner with IC_{50} value of less than 10 µg/ml. The extracts also displayed strong to moderate activities towards HT-29. This recent study was in agreement with the earlier study conducted by Abu Bakar et al. (2011). They reported that *M. pajang* methanolic kernel extract induced strong cytotoxic activities against HT-29, HepG2, Caov3, and especially breast (MCF-7 and MDA-MB-231) cancer cell lines tested. However, the IC_{50} of MCF-7 and MDA-MB-231 were much higher than 10 µg/ml with 23.0 and 30.5 mg/ml, respectively. In a previous study by Abu Bakar et al. (2010), *M. pajang* ethanolic kernel extract was found to arrest the growth of proliferating cells from MCF-7 and MDA-MB-231 cancer cell lines, which was associated with induction of apoptosis as measured by cell cycle profiling, extrusion of phosphatidylserine to the outer surface of the plasma membrane, and induction of caspase activity.

3.5. Cytoprotective effect

Cytoprotective is strongly correlated with antioxidant as antioxidants protect biological structures from oxidative damage caused by free radicals. Of the all underutilised fruit species identified, *B. angulata, C. odontophyllum* and *M. pajang* were reported for their cytoprotective activity using *in vitro* and *in vivo* systems (Table 3).

Mikail et al. (2015) investigated the effects of *B. angulata* juice on plasma MDA levels, as well as the activities of antioxidant enzymes and total antioxidant capacity in rabbits. They showed that *B. angulata* fruit significantly ($p < 0.05$) decreased the plasma level of MDA and increased the activities of superoxide dismutase (SOD), glutathione peroxidase (GPx) and catalase (CAT) in rabbits fed a high-cholesterol diet. The ability of *B. angulata* to protect low-density lipoprotein (LDL) from oxidative modification may be attributed to phenolic compounds known to act as powerful chain-breaking antioxidants and free radical scavengers. In another *in vivo* study, Shakirin et al. (2012a) suggested that the supplementation of pulp and kernel oils of *C. odontophyllum* in healthy rabbits might offer some protective effects against generation of free radicals, thus reducing the oxidative stress by enhancing the conversion of superoxide radicals to hydrogen peroxide (H_2O_2), followed by deactivation of H_2O_2 by GPx. Meanwhile, *in vitro* cytoprotective study of pericarp and peel extracts of *C. odontophyllum* was evaluated using Chang liver cells (human normal) and HUVEC (human umbilical vein endothelial) cell lines (Khoo et al., 2014). Both extracts were found to exhibit cytoprotective effects in *tert*-butyl hydroperoxide (t-BHP) and 40% methanol-induced cell death. They also showed no toxic effect to Chang liver cell line. However, using CD36 ELISA, NAD+ and LDL inhibition assays, inhibition of oxidative stress was found to be higher in the peel extract. IC_{50} concentration of the peel extract was greatly lower than the pericarp (0.153 mg/ml) indicating that peel extract had a stronger protective effect against oxidative damage compared to the pericarp extract. *Mangifera pajang* was also investigated for its potential in the protection against oxidative damage. Abu Bakar et al. (2013) reported that among pulp, kernel and peel extracts of *M. pajang,* kernel extract protected HepG2 cells against t-BHP induced-cell death. The extract gave a higher cytoprotection index than quercetin, with an EC_{50} value of 1.21 ± 0.13 µg/ml.

3.6. Anti-atherosclerotic effect

Although many species of underutilised fruits have been discovered in Malaysia, only *B. angulata* and *C. odontophyllum* fruit species were studied for their antiatherosclerotic properties (Table 3). Atherosclerosis is characterized by the accumulation of cholesterol deposits in the macrophages of arteries which if uncontrolled, may result in coronary artery heart disease (Shakirin et al., 2012b).

Baccaurea angulata was found to reduce atherosclerosis progression (Mikail et al., 2014). They described that the supplementation of *B. angulata* juice showed plaque-reducing activity in cholesterol-induced rabbits in a dose-dependent manner. In the high-cholesterol diet, high cholesterol diet with juice treatments (0.5, 1 and 1.5 ml/kg) and standard chow diet, plaque formation at the entire aorta were 96, 55, 49, 22 and 0%, respectively. In another study, Nurulhuda et al. (2013) reported that high cholesterol animal group supplemented with defatted pulp powder exhibited the greatest reduction in atherosclerotic plaque formation by 79.4%, induced by a significant reduction in total cholesterol (96.3%) and LDL-c (26.5%) and lipid peroxidation levels.

3.7. Anti-hyperlipidemia effect

Hyperlipidemia is a metabolic condition that can be due to an

increase in blood lipid levels, which include cholesterol and triglycerides (Al-Mansoub et al., 2014). Only one antihyperlipidemia study was recorded from Malaysian underutilised fruit, *G. atroviridis* or locally known as *asam gelugor* (Table 3). This fruit species has demonstrated notable ethnomedicinal properties as reported by Gerten et al. (2015), Al-Mansoub et al. (2014) and Salma et al. (2006) (Table 1). With respect to scientific research, Al-Mansoub et al. (2014) demonstrated that aqueous extract of the ripe fruit showed the most potent antihyperlipidemic activity, comparable to that of commercial drug, atorvastatin. It also significantly reduced the total cholesterol, triglycerides, low-density lipoprotein, very-low-density lipoprotein and atherogenic index at $P < 0.01$.

3.8. Antidiabetic effect

Canarium odontophyllum has been screened by researchers to see their hyperglycemic effect against obese-diabetic-induced rats (Table 3). Mokiran et al. (2014) investigated the potential of the ethanolic pulp extracts in two different concentrations. They found that after a 4-week treatment period, the administration of the higher extract concentration (600 mg DE/kg bw) reduced the plasma glucose level by 30%, but this reduction was not statistically significant. However, the result was strongly correlated with the reduction of plasma glucose at 60 to 90 min in the oral glucose tolerance test (OGTT) and a lower area under the curve (AUC) value. The high concentration extracts also failed to increase the insulin level but increased its sensitivity and reduced insulin resistance (HOMA-IR) only at the end of the experiment. This was the only study of antidiabetic effect ever reported of Malaysian underutilised fruits.

3.9. Cardioprotective effect

The cardioprotective effect of *C. odontophyllum* was conducted against hypercholesterolemic-induced rabbits using lipid peroxidation marker (plasma MDA) and antioxidant enzymes (SOD and GPx) as biomarkers (Khoo et al., 2013) (Table 3). These markers are useful in provision of information and confirmation of inhibition of oxidative stress and cardioprotective effect. It was reported that the methanolic defatted peel extract had the highest amount of anthocyanin, cyanidin-3-glucoside (C3G) with 55.12 ± 0.82 mg/g. This C3G-rich extract inhibited MDA production in the hypercholesterolemic rabbits and elevated cellular antioxidant enzymes (SOD and GPx). In particular, a significantly low increment (0.19 mol/l) of plasma MDA was observed for the treatment group after supplementation of C3G-rich extracts for 8 weeks as compared to control group. However, no significant change of GPx activity was found.

3.10. Anti-platelet activity effect

The study of the antiplatelet activity of Malaysian underutilised fruits was reported from *Garcinia* spp which comprised *G. atroviridis, G. hombroniana* and *G. prainiana* (Table 3). Platelets have been implicated in the pathogenesis of artherothrombotic conditions and play a key role in acute arterial thrombosis. Platelet aggregation was measured using electrical impedance method to assess the action of endogenous agonists such as arachidonic acid (AA), adenosine diphosphate (ADP), platelet activating factor (PAF), thrombin and collagen. Jantan et al. (2011) indicated that methanolic whole fruit extracts of *G. atroviridis* had pronounced inhibition of platelet in human subjects at 100 µg/ml with 72.0 ± 0.03% (ADP). *Garcinia hombroniana* and *G. prainiana* demonstrated anti-platelet activities of 50.0 ± 0.1% (AA), 50.0 ± 0.9% (ADP), 41 ± 0.1% (collagen) and 36.0 ± 0.1% (AA), 33 ± 0.1% (ADP), 37 ± 0.1% (collagen), respectively. The study was performed in human subjects.

4. Conclusion

Underutilised fruits grown in tropical countries like Malaysia are not only an important source of food and nutrition for the rural population, but some of them have also been used in traditional medicine. This information is the basis to lead to a wide range of scientific studies. With regard to phytochemistry, only 21 underutilised fruit species have had their compounds identified and quantified. Phytochemical investigations of various parts of the fruits have revealed the presence of over 100 phytochemicals which comprise phenolics, terpenoids, carotenoids and other miscellaneous compounds. Meanwhile, about 51 underutilised fruit species have been identified and explored for various health promoting properties. Different parts of the fruits have been analysed mainly *in vitro* and barely *in vivo.* Research have shown that these underutilised fruits exhibit varying degrees of antioxidant, antimicrobial, anticholinesterase, cytotoxicity, antiatherosclerotic, antihyperlipidemia, antidiabetic, cytoprotective, cardioprotective and antiplatelet activity, although most of the studies are still not thorough. In addition, some species that have been used traditionally to treat many types of ailments have not been comprehensively investigated for their biological activities. Several fruit species for example, *Mangifera* species and *Canarium odontophyllum* have stolen the limelight that the remainder have been neglected by researchers. In a nutshell, this review has revealed that they are still gaps and inadequate information in some areas that open interesting doors for further research opportunities. More studies are needed to confirm the health significance and explain their mechanisms of action in order to fully understand the real potential of these underutilised fruit species.

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