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RESEARCH ARTICLE

MEDICINAL PROPERTIES OF BIOACTIVE COMPOUNDS AND ANTIOXIDANT ACTIVITY IN *Durio zibethinus*

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ABSTRACT

Durio zibethinus, commonly known as Durian, is an exotic Southeast Asian tropical fruit. More than the pungent aroma the fruit is well-known for, it is said to be beneficial to health as it contains many antioxidants and bioactive compounds that have different potentials for positive impacts on health. However, there is scant existing literature which gives an overview on the amounts of bioactive compounds in several varieties of durian in Southeast Asia, and the relevant health benefits. This review article therefore seeks to consolidate the literature which have identified bioactive compounds and investigated antioxidant activities in durian cultivars from Malaysia, Indonesia, Thailand and China, and studies that have given insight on potential medicinal properties of durians. A literature review was conducted using databases Scopus and ScienceDirect and a total of 30 articles were reviewed. Total polyphenols and flavonoids were highest in the Mon Thong cultivar compared to other Thailand varieties, and ripe or overripe durians were found to contain the highest amounts of polyphenols and flavonoids. Durians were also found to contain medicinal properties, such as anti-inflammatory and antidiabetic potential, and protective effects on cardiac health. Further research on these bioactive compounds in the nutritious fruit with potential medicinal properties can contribute to the medicinal value of durians, as well as benefit the pharmaceutical industries.

KEYWORDS

Durian, Bioactive, Antioxidant, Medicinal.

1. INTRODUCTION

Durio zibethinus, more commonly known as Durian, is an exotic fruit from the tropical Durian fruit tree that falls under the hibiscus family, Malvaceae (Bombacaceae). There are at least 9 known edible species of durio, with Durio zibethinus being the only available species on the international market. Often dubbed as the 'King of Fruits', durio zibethinus is well-known for its pungent odour which turns many consumers away (Ketsa, 2020; Leontowicz et al., 2011). More than its distinctive aroma, durio zibethinus is said to be extremely nutritious, and to contain many antioxidants and bioactive compounds that are beneficial to health (Charoenkiatkul et al., 2016; Pasko et al., 2019).

The portion of durian that is usually eaten by consumers is the soft, pulpy part called the flesh, while the seeds, rinds and hull are usually considered as waste. The flesh is however not the only part containing compounds that could be potentially beneficial to health -- compounds in the seeds, rinds and hulls, which are usually considered as waste, have also been studied and found to contain bioactive compounds (Wang and Li, 2011). Further research on these compounds can contribute to the medicinal value of durians, as well as benefit the pharmaceutical industries. To date, studies have been done on how number of bioactive compounds found in durians varies with degree of ripening or different cultivars of durians, potential medicinal properties of durians, nutritional properties and potential as diet enhancers, as well as on anti-inflammatory, anti-cancer or antidiabetic potential (Leontowicz et al., 2007; Huang et al., 2020; Gorinstein et al., 2011; Evary and Muhammad, 2018).

There are many studies documenting the identities and amounts of bioactive compounds in durians and the corresponding antioxidant activity and antioxidant potential levels (Leontowicz et al., 2011; Charoenkiatkul et al., 2016; Pasko et al., 2019; Wang and Li, 2011; Leontowicz et al., 2007; Huang et al., 2020; Gorinstein et al., 2011; Arancibia-Avila et al., 2008; Haruenkit et al., 2010; Harunenkit et al., 2007; Toledo et al., 2009; Isabelle et al., 2010; Evary and Muhammad, 2018; Ashraf et al., 2011; Leontowicz et al., 2008). This literature review was conducted to compile information on the types of bioactive compounds found in durians and antioxidant activities from all studies that have discussed it. This review will help to provide a summary on which cultivars and compounds could be explored further for the properties its bioactive components exhibit, and can also provide information on which cultivars could be more valuable to the pharmaceutical industry and health-conscious consumers.

2. MATERIALS AND METHODS

Relevant studies were sourced on databases Scopus, PubMed and ScienceDirect for this literature review. This review focuses on the bioactive compounds and antioxidant activities in durians. Key terms "Durian", "Durio", "Bioactive", "Bioactivity", "Pharmaceutical", "Health", "Antioxidant" and "Medicinal" were included in the search strategy. Relevance of the results from the searches was first assessed through reviewing each title and its abstract. A total of 17, 10 and 15 relevant articles were found on Scopus, ScienceDirect and PubMed respectively. Relevant articles were also hand-searched from the bibliographies of

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articles for discussion. Only English articles in the two databases were shortlisted. With the English language filter applied, there was no change to the number of articles. A total of 8 results, which were duplicates on more than one of the above databases, were removed.

2.1 Inclusion Criteria

Articles discussing bioactive compounds and antioxidant activity or properties in durians were shortlisted for review. A total of 30 articles were considered for final review (Abbas et al., 2016; Khorshidi et al., 2018; Loke et al., 2008; Javadi et al., 2016; Lu et al., 2015; Egert et al., 2009; Serban et al., 2016; Bondonno et al., 2016; Yang et al., 2017; Kent et al., 2015; Zhang et al., 2015; Mezzomo and Ferreira, 2016; Power et al., 2018; Renzi-Hammond et al., 2017; Bumrungpert et al., 2018; Ferk et al., 2018; Leontowicz et al., 2006; Shui and Leong, 2005; Fitrianingsih et al., 2019; Feng et al., 2018).

2.2 Exclusion Criteria

Articles discussing bioactivity in other fruits, volatile compounds in durians, durian fruit preservation, were not considered for this literature review.

3. RESULTS

3.1 Bioactive compounds and their amounts found in ripe durians

11 papers were sourced and consolidated in Table 1 to summarise the bioactive compounds that were found in ripe durians from places around the world such as Malaysia and Thailand.

3.2 Durians with The Highest Amount of Bioactive Compounds

In a study, the Mon Thong cultivar was found to contain higher total phenolics than other cultivars (Cha-ni, Kra-dum and Kob-ta-kam), while Kob-ta-kam had higher carotenoid levels than other varieties (Charoenkiatkul et al., 2016). Similarly, in other study, total polyphenols and flavonoids were highest in the Mon Thong in comparison with the other cultivars, Cha-ni and Kan Yao (Leontowicz et al., 2008). Again, in a study, the highest amount of bioactive substances was found in the Mon Thong and Cha-ni cultivars, while the lowest amount was in Kan Yao and Kra-dum (Toledo et al., 2009). Anthocyanins and flavanols were significantly higher in Mon Thong than in Kradum and Kan Yao. Hence, generally across all studies the Mon Thong variety had the highest number of bioactive compounds compared to other varieties.

Many studies had also compared durian bioactivity at different stages of ripening (i.e immature, young, mature, ripe, overripe) (Haruenkit et al., 2010; Arancibia-Avila et al., 2008; Pasko et al., 2019; Leontowicz et al., 2011). A study found that overripe durians showed notably higher levels of polyphenols, flavonoids, flavanols, tannins and ascorbic acid than immature durians (Pasko et al., 2019).

This was also seen in other study which found that overripe and ripe durian fruits, respectively, had the highest level of polyphenols and flavonoids concentrations (Haruenkit et al., 2010). A study however found that in ripe durians, sum polyphenols and flavonoids were much higher compared to mature and overripe durians (Arancibia et al., 2008). Anthocyanins and flavanols were found to be in significantly higher amounts in ripe durian than in mature and overripe durians, respectively.

Polyphenols and flavonoids were remarkably higher in overripe durians, while quercetin, ascorbic acid and anthocyanins were higher in ripe durians, and tannins more abundant in mature durians, compared to young durians in study (Leontowicz et al., 2011). The general trend observed across these studies is that ripe durians contain higher levels of bioactive compounds than immature or young durians.

3.3 Antioxidant Activity Levels in Ripe Durians

9 papers were sourced and found to contain information about antioxidant activity levels in different cultivars of ripe durians using a range of antioxidant assays. The antioxidant activity levels were collated in Table 2.

3.3.1 Sources of antioxidant activity in durians

Generally, across the studies that discussed antioxidant activity in durians, phenolic content was found to be the main contributor to high antioxidant activity in durians (Charoenkiatkul et al., 2016; Arancibia-Avila et al., 2008; Toledo et al., 2009). A study found that the main contributor to antioxidant capacity in durians was the total phenolic content (Charoenkiatkul et al., 2015). In a study, the antioxidant capacity was mainly derived from the antioxidants that were soluble in alcohol, and the antioxidant capacity also had a high correlation coefficient with polyphenols, suggesting that the polyphenols had contributed most to antioxidant activity (Arancibia-Avila et al., 2008).

In a study, caffeic acid and quercetin constituted the main bioactive substances in Mon Thong cultivar, with total polyphenols contributing the most to the total antioxidant capacity of the durians (Toledo et al., 2009). Phenols were found to display a strong antioxidant activity in one study, and flavonoids and flavanols were likely contributors to high antioxidant activity in the fruits investigated in another study (Leontowicz et al., 2006; Shui and Leong, 2005).

3.3.2 Durians with the highest antioxidant activity

Among the studies discussed ripe and overripe durians generally had higher antioxidant activity than immature durians (Leontowicz et al., 2011; Leontowicz et al., 2007; Haruenkit et al., 2007; Toledo et al., 2009). Mon Thong durian cultivar was found to have the highest antioxidant activity compared to other cultivars like Cha-ni, Kan Yao and Kra-dum in the studies discussed (Toledo et al., 2009; Leontowicz et al., 2008). Highest antioxidant capacity and bioactive compounds were found in ripe durians study, and highest antioxidant capacity found in other study, as compared to overripe and mature durians in both studies (Arancibia-Avila et al., 2008; Leontowicz et al., 2007).

A study found that methanol extract of overripe durians showed the highest antioxidant activity, compared to immature, mature and ripe durians (Haruenkit et al., 2010). Similarly, in other study, it was found that overripe durians generally had the highest antioxidant potential (Leontowicz et al., 2011)9.

In comparing antioxidant capacity in different cultivars of durians, some researchers study found that the antioxidant activity of Mon Thong cultivar was significantly higher than in Kradum and in Kan Yao (Toledo et al., 2009). The DPPH, β-carotene and Folin–Ciocalteu assays showed a significant increase in the antioxidant capacities and in the content of total polyphenols in Mon Thong and Chani samples in Leontowicz et al's 2008 study (Leontowicz et al., 2008).

4. DISCUSSION

4.1 Other relevant literature

Several other literature reviews have been done on the nutritional value, bioactivity, and potential health benefits of durian in general on human health. A group researcher had summarised briefly the bioactive contents of a few durian varieties, and found that the Kob-ta-kam variety had the highest carotenoids and beta-carotene levels (Mohd et al., 2020).

In a study, the durian pulp across various varieties was found to contain linoleic acid, myristic acid, oleic acid, 10-octadecenoic acid, palmitoleic acid, palmitic acid, and stearic acid, with alpha-carotene and beta-carotene in durian pulp of, in particular, the Chani and Monthong varieties (Mohd et al., 2020).

The total carotenoid content was found to be higher in the Chani variety compared to the Monthong variety, which aligns with what our paper has found as well.

Some of researchers found three main flavonoids: flavanones, which include hesperetin and hesperidin; flavonols, which include morin, quercetin, rutin, kaempferol, myricetin; and flavones, which include luteolin and apigenin (Aziz and Jalil, 2019).

The main flavonol in the Monthong variety was found to be quercetin while the main flavones in durians in general were found to be luteolin and apigenin. The phenolic acids found in durians were hydroxycinnamic acid derivatives, including caffeic, p-coumaric, ferulic, p-anisic acid; and hydroxybenzoic acid, including gallic and vanillic acid, with the main hydroxybenzoic acid in Monthong, Chani and Pung Manee varieties being gallic acid.

Total carotenoid content was higher in Thailand varieties of durian, compared with Malaysian varieties. All in all, these findings largely corroborate with what our paper has found.

Table 1: Bioactive Compounds Found In Durians from Various Studies

Bioactive compounds found in ripe durians and their amounts if available	Authors, year, species of durians and country
Carotenoids (µg/100 g dry matter) Lutein Mon Thong: 136; Cha-ni: 129; Kra-dum:130; Kob-ta-kam: 225 Alpha-carotene Mon Thong: 13; Cha-ni: 279; Kra-dum:126; Kob-ta-kam: 821 Beta-carotene Mon Thong: 117; Cha-ni: 421; Kra-dum: 600; Kob-ta-kam: 1202 **Fatty acids** Lauric acid C12:0, Myristic acid C14:0, Palmitic acid C16:0, Palmitoleic acid C16:1, Stearic acid C18:0, Oleic acid C18:1 n9, Linoleic acid C18:2 n6, γ-Linolenic acid C18:3 n6	Charoenkiatkul et al., 2016 Mon-thong, Chani, Kradum and Kob-ta-kam Thailand
Polyphenols 4 mg GAE/g DW Flavanols 113.9 µg CE/g DW Flavonoids 2.06 mg CE/g DW Tannins 0.88 mg CE/g DW Ascorbic acid 1.46 mgAsc/g DW	Paśko et al., 2019 Mon Thong Thailand
Polyphenols 2.58 mg GAE Flavonoids 1.523 CE Flavanols 67.05µg CE Anthocyanins 17.12 mg C3GE Vitamin C (ascorbic acid) 5.65mg Tannin 1.37mg CE Beta-carotenoids 4.94µg/g	Gorinstein et al., 2011 Mon Thong Thailand
Total polyphenols 374.4mg GAE Total flavonoids 97.9mg CE Anthocyanins 442.7µg C3GE Flavanols 177.1µg CE **Phenolic acids/Flavonoids** Vanillic acid, Caffeic acid, p-Coumaric acid, Cinnamic acid, Morin, Quercetin, Myricetin, Apigenin, Campherol	Arancibia-Avila et al., 2008 Mon Thong Thailand
Polyphenols 3.3mg GAE/g Flavonoids 2.2mg CE /g Flavanols 101.0µg CE/g Tannins 0.8mg CE/g **Fatty acids** Capric acid (C10:0), Palmitic acid (C16:0), Stearic acid (C18:0), Arachidic acid (C20:0), Oleic acid (C18:1), Linoleic acid (C18:2)	Haruenkit et al., 2010 Mon Thong Thailand
Polyphenols 2.14 mg GAE Flavonoids 311.2µg CE Quercetin 68.9mg	Leontowicz et al., 2011 Mon Thong Thailand

Flavanols 16.61µg CE Tannins 1.52mg CE Ascorbic acid 2.33mg Anthocyanins 1.43mg	
Total polyphenols 309.7mg GAE/100g FW Free polyphenols 37.1 mg GAE/100g of FW Total flavonoids 85.1mg CE/100g FW Free flavonoids 21.2mg CE/100g FW **Phenolic acids** Caffeic, p-coumaric, cinnamic vanilic **Flavonoids** Quercetin, Morin, Myricetin, Apigenin, Campherol	Haruenkit et al., 2011 Mon Thong Thailand
Total polyphenols (mg GAE/100g FW) Mon Thong: 361.4; Cha-ni: 321.1; Pung Manee: 310.5; Kra-dum: 271.5; Kan Yao: 283.2 Total flavonoids (mg CE/100g FW) Mon Thong: 93.9; Cha-ni: 81.6; Pung Manee: 78.8; Kra-dum: 69.2; Kan Yao: 72.1 Anthocyanins (µg C3GE/100 g FW) Mon Thong: 427.3; Cha-ni: 379.1; Pung Manee:367.3; Kra-dum:320.2; Kan Yao: 335.3 Flavanols(µg CE/100 g FW) Mon Thong: 177.4; Cha-ni: 152.2; Pung Manee:147.1; Kra-dum:128.6; Kan Yao: 134.4	Toledo et al., 2009 Mon Thong, Cha-ni, Pung Manee, Kra-dum, Kan Yao Thailand
Lipophilic antioxidants Lutein, Zeaxanthin, beta-cryptoxanthin, Lycopene, Carotene, Tocopherol, Tocotrienol	Isabelle et al., 2010 Unknown durian cultivar from Malaysia
Total polyphenols Hexane extract: 19.55 mg/g GAE Ethyl acetate extract: 90.62 mg/g GAE Ethanol extract: 102.92mg/g GAE Total flavonoid content Ethyl acetate extract: 1.004 mg/g QE, ethanol extracts: 1.88mg/g QE	Evary and Nur, 2018 Unknown durian cultivar from Indonesia
Total phenolic contents (mg/L GAE) Chaer Phoy: 690.62 Ang Jin: 998.29 D11: 730.46 Yah Kang:825.37 Total flavonoid contents (mg/L CE) Chaer Phoy:219.27 Ang Jin: 220.34 D11: 211.36 Yah Kang: 216.61 Total carotenoids contents (mg/L beta carotene equivalent) Chaer Phoy: 0.07 Ang Jin: 0.06 D11: 0.08 Yah Kang: 0.05 Vitamin C contents (mg/L) Chaer Phoy: ~24 Ang Jin: 18.87 D11: 25.13 Yah Kang: ~22	M. A Ashraf et al., 2011 Chaer Phoy, D11, Yah Kang, Ang Jin Malaysia

Abbreviations: GAE: gallic acid equivalent; TE: Trolox equivalent; QE: quercetin equivalent; C3GE: cyanidin-3-glucoside equivalent; FW: fresh weight; DW: dry weight

Table 2: Antioxidant Activity In Durians

Authors, year, species of durian, country	Assays	Antioxidant activity in ripe durian fruits
Charoenkiatkul et al., 2016 Mon-thong, Chani, Kradum and Kob-ta-kam Thailand	DPPH	Mon Thong: 8µmole TE/g dry matter
		Cha-ni: 4 µmol TE/g dry matter
		Kra-dum: 6 µmol TE/g dry matter
		Kob-ta-kam: 6 µmol TE/g dry matter
	FRAP	Mon Thong: 16µmol TE/g dry matter
		Cha-ni: 11µmole TE/g dry matter
		Kra-dum: 16µmol TE/g dry matter
		Kob-ta-kam: 16µmol TE/g dry matter
	ORAC	Mon Thong: 62µmol TE/g dry matter
		Cha-ni: 72µmol TE/g dry matter
		Kra-dum: 67µmol TE/g dry matter
		Kob-ta-kam: 73µmol TE/g dry matter
Paśko et al., 2019 Mon Thong Thailand	DPPH	7.48µmol TE/g dry matter
	CUPRAC	25.8µmol TE/g dry matter
	FRAP	15.8 µmol TE/g dry matter
	$ABTS^{\cdot+}$	32.7µmol TE/g dry matter
Arancibia-Avila et al., 2008 Mon Thong Thailand	FRAP	270.4µmol TE
	CUPRAC	1112.7µmol TE
	Beta-carotene inhibition	76.8% inhibition
Haruenkit et al., 2010 Mon Thong Thailand	CUPRAC	26.1µmol TE/g
	DPPH	6.1µmol TE/g
	$ABTS^{\cdot+}$	31.3µmol TE/g
	FRAP	14.9µmol TE/g
Leontowicz et al., 2011 Mon Thong Thailand	$ABTS^{\cdot+}$	11.06µmol TE/g
	FRAP	5.87µmol TE/g
	CUPRAC	2.21µmol TE/g
	DPPH	1.12µmol TE/g
Haruenkit et al., 2010 Mon Thong Thailand	TDPPH	228.2 mmol TE/100g FW
	FDPPH	35.3 mmol TE/100g FW
	TABTS	2016.3 mmol TE/100g FW
	FABTS	321.2 mmol TE/100g FW
Toledo et al., 2009 Mon Thong, Cha-ni, Pung Manee, Kra-dum, Kan Yao Thailand	FRAP	Mon Thong: 260.8µmol TE/100 g FW
		Cha-ni: 232.1µmol TE/100 g FW
		Pung Manee:224.9µmol TE/100 g FW
		Kra-dum:197.4µmol TE/100 g FW

		Kan Yao:204.7μmol TE/100 g FW
	CUPRAC	Mon Thong:1075.6μmol TE/100 g FW
		Cha-ni: 955.4μmol TE/100 g FW
		Pung Manee: 924.9μmol TE/100 g FW
		Kra-dum: 806.5μmol TE/100 g FW
		Kan Yao:845.5μmol TE/100 g FW
	ABTS	Mon Thong: 2352.7μmol TE/100 g FW
		Cha-ni: 2091.4μmol TE/100 g FW
		Pung Manee:2020.4μmol TE/100 g FW
		Kra-dum:1773.2μmol TE/100 g FW
		Kan Yao:1843.6μmol TE/100 g FW
Evary and Nur, 2018 Unknown durian cultivar from Indonesia	DPPH	Hexane extracts: IC50 of 541.28μg/ml
		Ethyl acetate extracts: IC50 of 83.95 μg/ml
		Ethanol extracts: IC50 of 11.24 μg/ml
	β-carotene-linoleic acid	Hexane extracts: IC50 of 273.58μg/ml
		Ethyl acetate extracts: IC50 of 139.53 μg/ml
		Ethanol extracts: IC50 of 166.83 μg/ml
	α-Glucosidase	Hexane extracts: IC50 of 3.346μg/ml
		Ethyl acetate extracts: IC50 of 23.693 μg/ml
		Ethanol extracts: IC50 of 119.84 μg/ml
Wang and Li, 2011 Unknown durian cultivar from Guangdong, China	Reducing power (Fe^{3+})	MEDS IC50: 280.79 μg/mL
	Reducing power (Cu^{2+})	MEDS IC50: 154.67μg/mL
	•OH	MEDS IC50: 324.63μg/mL
	O_2•$^-$	MEDS IC50:770.52μg/mL
	Anti-lipid peroxidation	MEDS IC50: 4.45μg/mL
	DPPH	MEDS IC50: 102.37μg/mL
	ABTS	MEDS IC50: 19.50μg/mL
	Chelating power	MEDS IC50: 63.95μg/mL

Abbreviations:
DPPH: 1,1-Diphenyl-2-picrylhydrazyl; CUPRAC: Cupric reducing antioxidant capacity; FRAP: Ferric-reducing/antioxidant power; ABTS·+: 2,2-Azino-bis(3-ethyl-benzothiazoline-6-sulphonic acid) diammonium salt; ORAC: Oxygen radical absorbance capacity; MEDS: Methanol extract of durian shell; *TDPPH: 1,1-diphenyl-2-picrylhydrazyl determined in the fruit extracts of total polyphenols; FDPPH: 1,1-diphenyl-2-picrylhydrazyl determined in the extracts of free polyphenols; TABTS: 2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) in the fruit extracts of total polyphenols; FABTS: 2,2'-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) in the fruit extracts of free polyphenols*

4.2 Potential Benefits of Bioactive Compounds in Durians on Human Health

Polyphenols are a bioactive class of compounds abundant in durians as seen from the studies in Table 1. Examples of classes of polyphenols include flavonoids and phenolic acids, while an example of a class of flavonoids includes flavanols and anthocyanins (Abbas et al., 2016). Taking quercetin supplements had decreased resistin levels in plasma of women with polycystic ovary syndrome, as well as its gene expression, which suggested a correlation with antidiabetic potential of quercetin, in these women (Khorshidi et al., 2018).-Quercetin has also been shown to improve endothelial functioning and hence contribute to cardiovascular health by regulating concentrations of vasoactive nitric oxide products and endothelin-1 in the blood circulation (Loke et al., 2008). In another study, supplementation of five hundred milligrams a day of quercetin for 8 weeks resulted in notable improvements in clinical symptoms and disease activity in women with rheumatoid arthritis (Javadi et al., 2016).

Quercetin was also found to exhibit potential for antiviral activity in some hepatitis C patients, and supplementation of quercetin also significantly reduced systolic blood pressure and low-density lipoprotein cholesterol levels in overweight test subjects, thus suggesting that quercetin could provide protection against cardiovascular disease (Lu et al., 2015; Egert et al., 2009). In another similar trial carried out using quercetin supplements, it was observed that systolic and diastolic blood pressure was notably lowered, especially at doses greater than 500mg/day (Serban et al., 2016). Another study however found that using lower concentrations of isolated

quercetin resulted in no notable effect on general cardiometabolic health, blood pressure or endothelial function.-Purified anthocyanins were found to favorably affect glycemic control and lipid profile of Chinese adults with prediabetes or early untreated diabetes (Bondonno et al., 2016; Yang et al., 2017). Daily consumption of anthocyanin-rich cherry juice was found to have improved short- and long-term memory and verbal fluency in older adults with dementia, and also lowered blood pressure in general (Kent et al., 2015).

In another study [27], a 12-week supplement of purified anthocyanin was found to benefit the health of non-alcoholic fatty liver disease patients by improving insulin resistance and indicators of liver injury (Zhang et al., 2015). -Carotenoids are also found to have beneficial anti-inflammatory properties. Examples of carotenoids are lutein and zeaxanthin (Mezzomo and Ferreira, 2016). One study demonstrated a memory-enhancing effect of daily supplementation with lutein, zeaxanthin, and meso-zeaxanthin in healthy subjects with low macular pigment at baseline via their antioxidant and anti-inflammatory properties (Power et al., 2018). Supplementation with lutein and zeaxanthin was also found to improve central nervous system xanthophyll levels and cognitive function among healthy young adults (Renzi-Hammond et al., 2017). Phenolic acids are another beneficial group of bioactive compounds in durians. Ferulic acid supplementation was found to have potential to improve lipid profiles and oxidative stress, as well as inflammation in hyperlipidemic subjects, and hence, ferulic acid has potential to reduce risk factors associated with cardiovascular disease (Bumrungpert et al., 2018). Small amounts of gallic acid were found to prevent oxidative DNA damage and reduce indicators that reflect inflammation and heightened risks of cancer and cardiovascular diseases (Ferk et al., 2018).

4.3 Potential Medicinal Properties of Durians on Human Health

Several studies have been done, discussing the potential medicinal properties of Durio zibethinus.

4.3.1 Durian rinds and anti-inflammatory or antibacterial effects

Rinds of durian were shown to have potential as an antibacterial agent against *Propionibacterium acne* bacterias, which cause skin acne. One study also found that durian shells could serve as anti-inflammatory agents for medicinal use. Propacin isolated from durian peels had an anti-inflammatory effect on lipopolysaccharide-induced RAW264.7 cells, suggesting that propacin may have the potential to be developed as a therapeutic agent for inflammatory-related diseases.

4.3.2 Durians and anti-diabetic or heart-protective effects

Root extracts of durians in ethanol were shown to have high ability to inhibit the α-glucosidase enzyme, and hence have high potential as antidiabetic agents. Ripe Mon Thong durian had a positive effect on plasma lipid profile and plasma antioxidant activity in rats fed cholesterol-containing diets and did not raise the plasma glucose level, suggesting that ripe Mon Thong durian could be beneficial to patients suffering from hypercholesterolemia and diabetes mellitus. Ripe durians were also found to have liver and heart-protective effects in cholesterol-fed rats. In general, ripe durians can be said to have good antioxidant capacities and health-protective activity.

5. Conclusion

In conclusion, durians of different cultivars contain many bioactive compounds and exhibit high levels of antioxidant activity. They have been found to contain medicinal properties, such as anti-inflammatory and antidiabetic potential. This review has consolidated the durian varieties and bioactive compounds or antioxidants that have been found in them. As current literature on the potential health benefits of durians is based on experiments on animals, the effect on humans might not be exactly as postulated. Further future research on the medicinal properties of different cultivars of durians could be carried out in greater detail to investigate and find more links between durians and their direct health benefits in humans.

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