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Nutritional and Bioactive Composition of Exotic and Indigenous Kalimantan Fruits: Case Studies of *Ramania*, *Kapul*, and *Ihau* Fruits

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Abstract

Indonesia is renowned for its rich tropical flora diversity, and Kalimantan Island stands out for its exceptional fruit variety. Three fruits, *ramania*, *kapul*, and *ihau* fruits, have drawn particular interest due to their potential health benefits and possible uses in the food and pharmaceutical industries. Nevertheless, these fruits are rarely explored comprehensively. So, this study offers a better understanding of the diverse fruits found in Kalimantan through a comparative analysis of literature data. This literature review aims to provide valuable insights into the nutritional and bioactive properties of these fruits and highlights their potential health benefits. The results from various previous studies exhibited that the exotic and indigenous fruits from Kalimantan, including *ramania*, *kapul*, and *ihau* fruits, are packed with essential nutrients like proteins, fats, carbohydrates, vitamins, and bioactive compounds that act as anti-aging, anti-bacterial, anticancer, antioxidants, and other bioactivities. Moreover, Kalimantan's exotic and indigenous fruits also have great potential as ingredients for functional food or pharmaceutical production. However, further research is necessary to fully explore their potential and innovative applications in various industries.

INTRODUCTION

Indonesia is one of the countries with the highest diversity of tropical flora in the world, including fruit diversity, with no less than 329 fruit species, both native and introduced, of which 144 species are found on Kalimantan Island (Uji, 2007). Kalimantan, part of the Indonesian island of Borneo, has a wide variety of native and exotic fruits that are not widely known, so it needs to be cultivated to utilize the swamp land there to be more productive (Susi, 2014). In addition, local fruits in Kalimantan are annual plants, and the fruiting period is too long, so local people are reluctant to grow them, and the population is decreasing. Moreover, local fruits in Kalimantan lack high economic value due to poor fruit quality, such as a sour or less sweet flavor than those from other regions (Antarlina, 2016). However, the local fruit from the Kalimantan region has a complete nutritional, bioactive composition. Also, it has distinct flavors, possibly due to health advantages.

Fruits, including local fruit, are a source of nutrients, especially vitamins such as vitamins A and C, minerals, carbohydrates, fats, proteins, and others (Antarlina, 2016; Sutrisno et al., 2019). Moreover, the fruits are also rich in bioactive or phytochemical compounds, which have health advantages (Chel-Guerrero et al., 2022; Ibrahim et al., 2023). The local fruits, like *ramania*, *kepul*, and *ihau* fruits, are widely found in various regions of Kalimantan Island (Gunawan et al., 2021; Khoo et al., 2016; Noor et al., 2015) and have long been consumed directly by local communities as "table fruit" (Susi, 2014), still their nutritional and bioactive composition information has not been comprehensively informed. Thus, this paper aims to comprehensively discuss the nutritional and bioactive composition of local Kalimantan fruits, particularly *ramania, kapul*, and *ihau* fruits, and also provide insights into their possible health properties and their further applications in food products and related products, such as pharmaceuticals in the future. This article is written based on various previous studies, which were selectively chosen from various open-access sources, including Google Scholar (https://scholar.google.com/) and other open-access sources, based on the topic under discussion (Utoro et al., 2022; Witoyo & Utoro, 2023).

The Physical Properties of Kalimantan Local Fruits

Kalimantan Island boasts a diverse array of exotic and native fruits, with over 144 species in the region (Uji, 2007). Certain fruits that are native to Kalimantan possess distinctive and exotic physical features. This subsection will explore the physical characteristics of a few selected exotic and native fruits from Kalimantan, such as *ramani*a, *kapul*, and *ihau* fruits.

Ramania (*Bouea macrophylla* Griff) Fruit

The *ramania* fruit, or *gandaria*, is a tropical fruit resembling a mango. They are also known as plum mangoes. It is green in color and matures to an orange or yellow hue. The fruit has a sweet and sour flavor with a distinctive terpene smell (Susi, 2014). The fruit is popular in Indonesia and the Philippines as *gandaria* or *ramania*, *maprang* or *mayong* in Thailand, and *kundang* or *ramania* in Malaysia (Dechsupa et al., 2019; Lawalata, 2021; Lim, 2013; Rajan & Bhat, 2017). It is a part of the Anacardiaceae family, including mango and cashew. The tree that bears the *Ramania* fruit can grow to heights of 27 meters and belongs to the family *Anacardiaceae* (Lim, 2013). Based on exploration and characterization by Susi (2014), the *ramania* fruit had a green to yellowish-yellow outer skin, with a light-yellow color in its flesh and a sour taste. The physical appearance of the *Ramania* fruit is presented in Figure 1.

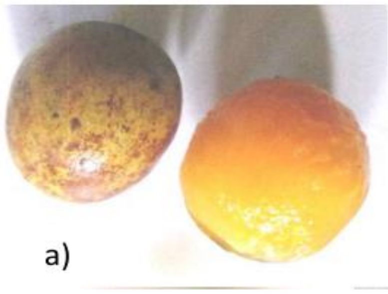

Figure 1. *Ramania* fruit (Susi, 2014)

Kapul (*Baccaurea macrocarpa)* fruit

Baccaurea macrocarpa is a tropical rainforest plant native to Southeast Asia, especially from Kalimantan Island (Borneo) (Erwin et al., 2018). It can also be found along the Peninsula of Sumatra, Malaysia, Thailand, Ambon, and Irian Jaya (Gunawan et al., 2021). This plant produces distinctive and unique fruits with different local names in different regions in Kalimantan, such as *mawuh* (Rosawanti et al., 2021), *tampoi/tampui* (Masriani & Fadly, 2022; Tirtana et al., 2013), and *kapul* fruit (Akhmadi & Sumarmiyati, 2015; Gunawan et al., 2021; Noor et al., 2015). This fruit is known as tampoi in Malaysia, while in

Thailand, it is known as *Lang-khae* (Khoo et al., 2016). This fruit is commonly and widely consumed fresh by local people in Kalimantan (Gunawan et al., 2021; Khoo et al., 2016).

Based on exploration and characterization conducted by Akhmadi & Sumarmiyati (2015), the *kapul* fruit found in Kalimantan, especially East Kalimantan, is divided into white *kapul* fruit (Figure 2 A and B), yellow *kapul* fruit, and small *kapul* fruit (Figure 2C and D). Physically, the *kapul* fruit has a round and flat shape, brown outer skin, various weights and dimensions. The fruit's flesh has a combination taste, which is sweet and sour, and different flesh colors depending on the variety. White *kapul* fruits have a white flesh color, yellow *kapul* fruits have a yellow flesh color, and small *kapul* fruits have a reddish-yellow flesh color.

Figure 2. White *kapul* fruit (A and B) and small *kapul* fruit (C and D) (Akhmadi & Sumarmiyati, 2015)

***Ihau/Mata Kucing* (*Dimocarpus longan*) fruit**

Dimocarpus longan. ssp. *Malesianus* is a tropical local fruit native to Southeast Asia found on Kalimantan Island (Borneo), Peninsular Malaysia, Sumatera, and the Philippines (Lim, 2013). In Indonesia, this fruit is found in the South Kalimantan area and is known by various local names, such as *ihau* fruit, *mata kucing* fruit (Ismuhajaroh, 2012; Susi, 2014), or *kangkus*/*lengkeng hutan* (Saryamassuka et al., 2022). In other regions, the fruit known as *book*, *Isau Bala*, *Isau Beleng*, *Jilen*, *Sau*, *Nyau Belah*, *Nyau Bong*, *Nyau lucih* (East Kalimantan), and *Medaru* (Sumatera). This fruit is known in Malaysia as *mata kucing*, *Sau, Isau, Kakus, Guring* (Sarawak), *Bauh Arut,* and *Buah Binkoi* (Sabah). This fruit consumption is the same as *kapul* fruit, which can be consumed directly (fresh fruit) or processed into products such as drinks and desserts (Lim, 2013). *Ihau* fruit (Figure 3) has a round shape with varied fruit colors, green (un-ripe fruit) (Figure 3A) and brownish-yellow (mature fruit) (Figure 3B), with white flesh (Ismuhajaroh, 2012). The flesh of the *ihau* fruit has a sweet and juicy taste with a musky or melon taste (Lim, 2013).

(A) (B)

Figure 3. Un-ripe (A) (Lim, 2013) and ripe (B) *ihau* fruit (Susi, 2014)

Nutritional Composition of Kalimantan Local Fruits

The selected exotic and native fruits from Kalimantan, including *ramania*, *kapul*, and *ihau* fruits*,* also had a complete nutritional composition that benefits health. These compositions include proximate (macronutrients), vitamin C, and total acid. So, this section explained a further comprehensive discussion of the nutritional composition of the three local exotic fruits.

Table 1 shows that the three exotic fruits, including *ramania*, *kapul*, and *ihau* fruit, have complete nutritional content, including carbohydrates, fiber, protein, fat, moisture content, vitamin C, and total acid. Like the other fresh fruits, the three local and exotic fruits also have a high moisture content, around 61.90 to 86.03%, depending on the fruit. The high moisture content causes a relatively short storage shelf life and requires further food processing (Hou et al., 2020). It also can accelerate damage, mainly due to biological agents, such as fungi and bacteria, which result in spoilage (Bist & Bist, 2021). The fiber content in three exotic fruits ranges from 2.2 to 10.93%, as in Table 1. The high-fiber content in fruit has helped improve digestion, the immune system, and cholesterol levels of diabetes mellitus type 2 and heart health issues (Bölek, 2022; Khalil et al., 2023). Foods that contain fiber, both soluble and insoluble, have a significant impact on glycemic control, starting in the gut, and also have the potential to impact improving gut microbiota health positively (Harlan et al., 2023; Makki et al., 2018; Reynolds et al., 2019). Moreover, the three local and exotic fruits had crude fat of 0.52 to 3.83%, crude protein of 0.44 to 11.20%, and ash content of 0.12 to 0.9%, depending on fruit type (Table 1). According to Hanum (2016), the fats in the human body's metabolism serve multiple functions, including supporting and protecting vital organs and regulating body temperature. Fat also plays a role in dissolving and aiding the absorption of fat-soluble vitamins, such as A, D, E, and K. Moreover, it serves as an energy reserve alongside carbohydrates and proteins. Additionally, protein is an essential nutrient that plays a critical role in cell growth and repair mechanisms in the human body (Fărcaș et al., 2022). The carbohydrate content in the three exotic and native fruits of Kalimantan ranges from 6.48 to 34.60%, as listed in Table 1. Fruit typically contains many carbohydrates, primarily sugar, such as sucrose, fructose, and glucose.(Jia et al., 2020; Li et al., 2020)

Ramania fruit contains vitamin C of 172.14 mg/100 g (Susi, 2014). Meanwhile, *kapul* and *ihau* fruits also range from 0.317 – 1500 mg/100 g (Salusu et al., 2020; Susi, 2014; Tirtana et al., 2013), and 66.9 mg/100 g (Susi, 2014) in sequence. In the body's metabolism, vitamin C has various physiological roles, such as the prevention of mouth ulcers, playing a role in wound closure, strengthening immunity against infection by pathogenic microorganisms, aiding iron absorption, and sharpening consciousness. Furthermore, vitamin C is required to synthesize collagen and carnitine and acts as an antioxidant to reduce free radicals in humans (Moore & Khanna, 2023; Wijayanti, 2017). The recommended daily vitamin C intake is 100 mg for adults, 140 mg for lactating women, and 40 mg for infants aged 0-5 years (Wijayanti, 2017).

Besides vitamin C, *ihau* fruit is also rich in other vitamins such as thiamin (B_1) of 0.031 mg/100 g, riboflavin (B_2) of 0.14 mg/100g, and niacin (B_3) of 0.3 mg/100g (Shahrajabian et al., 2019). Thiamine, or Vitamin B1, is a vital vitamin supporting healthy cell function. This nutrient plays a crucial role in the body as a coenzyme, assisting with metabolizing carbohydrates, fats, and proteins. Additionally, it is involved in cellular respiration and fatty acid oxidation and contributes to the proper functioning of the central and peripheral nervous systems. Thiamine also aids neurotransmitter synthesis, which is essential for optimal neurological health (Mrowicka et al., 2023). Remembering the recommended daily intake of thiamine for different age groups is essential. For infants aged 0-6 months, the recommended intake is 0.3 mg/day, while for infants aged 7-11 months, it goes up to 0.4 mg/day. For children aged 1-3, the recommended intake is 0.7 mg/day, and for adults, pregnant women, and lactating mothers of 1.4 mg/day. Following these guidelines can help ensure you and your loved ones get the necessary amount of thiamine for optimal health (Wijayanti, 2017).

Vitamin B2, or riboflavin, is essential to the body's metabolic processes. It is responsible for developing steroid molecules, red blood cells, and glycogen and supporting the growth of various body parts such as skin, hair, and nails. To maintain optimal health, it is recommended that infants aged 0-6 months consume 0.3 mg/day, infants aged 7-11 months consume 0.4 mg/day, children aged 1-3 consume 0.7 mg/day, adults consume 1.6 mg/day, pregnant women consume 1.7 mg/day, and lactating mothers consume 1.8 mg/day. Similarly, vitamin B3, known as niacin, is vital in carbohydrate metabolism, energy production, fat metabolism, and protein synthesis. It also helps maintain blood sugar levels, lower cholesterol and plasma triglyceride, and reduce high blood pressure. Daily consumption recommendations vary based on age and gender, with infants aged 0-6 months advised to consume 2 mg/day, infants aged 7-11 months advised to consume 4 mg/day, children aged 1-3 advised to consume 6 mg/day, adults advised to consume 15 mg/day, pregnant women advised to consume 16 mg/day, and lactating mothers advised to consume 15 mg/day (Wijayanti, 2017).

Regarding total acid parameters, the *ramania*, *kapul*, and *ihau* fruits have 84.71 mg/g, 32.53 mg/g, and 11.67 mg/g, respectively (Susi, 2014). According to Rahman et al. (2023), Titratable acidity measures and represents the concentration of acid in food products, which can decrease due to changes in pH, temperature, and chemical presence during food storage. So, the high titratable acidity in fruit samples means the fruit is also high in organic acids therein, and vice versa. Commonly, tartaric acid, quinic acid, malic acid, shikimic acid, citric acid, and fumaric acid are abundantly in fruit and fruits derived, and the composition depends on the fruit and fruit-derived type (Jia et al., 2020; Li et al., 2020). Moreover, *ihau* fruit is rich in organic acids such as citric acid, malic acid, fumaric acid, and shikimic acid (Yang et al., 2021).

Table 1. The nutritional composition of the exotic and native fruit from Kalimantan

Nutritional composition	*Ramania* Fruit[1]	*Kapul* Fruit [2]	*Kapul* Fruit [3]	*Kapul* Fruit [1]	*Ihau* Fruit[1]
Moisture content	75.85% db	77.56±8.21%	61.9%	77.25% wb	76.75% wb
Fiber Content	10.93%	7.91±2.31%	2.2%	10.93% wb	10.80% wb
Carbohydrate Content	6.48%	21.09±3.33%	34.6%	8.73% wb	27.27% wb
Protein Content	2.80%	0.44±0.51%	1.5%	11.20% wb	1.75% wb
Fat Content	0.52%	0.59±0.02%	1.1%	2.59% wb	3.83% wb
Ash content	0.22%	0.32±0.03%	0.90%	0.84% wb	0.12% wb

Source: [1]Susi (2014), [2]Masriani & Fadly (2022), and [3]Tirtana et al. (2013). Wb: wet basis and d.b: dry basis

Table 2. Bioactive compounds of the exotic and native fruit from Kalimantan

Sample	Total Phenolic Content	Total Flavonoid	Total Anthocyanin	Total Carotenoids	Gallic acid content	Ellagic acid	Corilagin	Reference
Ramania (B. macrophylla) ethyl acetate fraction (BPEA)	76.75±0.09 mg GAE/g extract	31.95±0.10 mg QE/g extract	n.i.	n.i.	n.i.	n.i.	n.i.	Maneechai et al. (2023)
Ramania (B. macrophylla) hydroethanolic extract (BPHE)	80.25±0.01 mg GAE/g extract	6.04±0.01 mg QE/g extract	n.i.	n.i.	n.i.	n.i.	n.i.	
Ramania (B. macrophylla) ethanolic fraction (BPEE)	78.50±0.09 mg GAE/g extract	6.63±0.01 mg QE/g extract	n.i.	n.i.	n.i.	n.i.	n.i.	
Ramania (B. macrophylla) crude ethanolic extract (BPE)	87.35±0.09 mg GAE/g extract	6.63 ± 0.01 mg QE/g extract	n.i.	n.i.	n.i.	n.i.	n.i.	
Kapul fruit flesh	4.60 mg GAE/g	1.51 mg CE/g	0.01 mg cyanidin-3-glucoside/g	0.69 mg BCE/g	n.i.	n.i.	n.i.	Bakar et al. (2014)
Yellow *kapul (tampoi)* fruits hexane fraction	n.i.	n.i.	n.i.	13.71 mg/100 g	n.i.	n.i.	n.i.	Khoo & Ismail (2009)
White *kapul (tampoi)* fruits in hexane fraction	n.i.	n.i.	n.i.	1.47 mg/100 g	n.i.	n.i.	n.i.	
Ihau (Dimocarpus longan) fresh fruit extract	n.i.	n.i.	n.i.	n.i.	9.75 mg/g DW	9.24 mg/g DW	3.01 mg/g DW	Rangkadilok et al. (2007)

Note: n.i. : no information, GAE: Gallic Acid Equivalent, QE: Quercetin Equivalent, CE: Catechin Equivalent, DW: Dry weight

Bioactive Composition of Kalimantan Local Fruits

Alongside complete nutritional composition, the *ramania, kapul,* and *ihau* fruits from Kalimantan are rich in bioactive compounds, including total phenolic, total flavonoid, and another bioactive compound listed in Table 2. The extract and fractions of B. *macrophylla peel* contain various bioactive compounds such as phenolics, saponin, tannin, and phytosterol. Moreover, the quantification of the extract and fractions of B. *macrophylla peel* showed a diverse range of the total phenolic and flavonoid content, as presented in Table 2. The total phenolic ranged from 76.75 to 87.35 mg GAE/g extract, and the total flavonoid ranged from 6.33 to 31.95 mg QE/g extract (Maneechai et al., 2023). Furthermore, *kapul* fruit also contains essential phytochemical compounds such as alkaloids, terpenoids, flavonoids, and saponins (Sofiyanti et al., 2022; Tirtana et al., 2013). *Kapul* fruit flesh has total phenolic content of 4.60 mg GAE/g, total flavonoid content of 1.51 mg CE/g, total anthocyanins of 0.01 mg cyanidin-3-glucoside/g, and total carotenoids of 0.69 mg BCE/g (Bakar et al., 2014). Khoo & Ismail (2009) reported that carotenoid levels of yellow and white *tampoi* fruits in hexane fraction were 13.71 mg/100 g and 1.47 mg/100 g respectively.

Like two fruits, *ihau* fruit contains various bioactive compounds such as polyphenols, flavonoids, saponins, and alkaloids (Chel-Guerrero et al., 2022). Polyphenolic compounds found in the skin and flesh of *ihau* fruit (*Dimocarpus longan*) are gallic acid, ellagic acid, and corilagin (Rangkadilok et al., 2005). According to Zhu et al. (2019), pericarp from the fruit *Dimocarpus longan* Lour contains various bioactive compounds such as gallic acid, corilagin, (-)-epicatechin, ellagic acid and its isomers, quercetin, flavone glycosides, 4-O-methylgallic acid, quercetin glycosides and kaempferol, protocatechuic acid, and brevifolin. *Dimocarpus longan* fresh fruit extract has a gallic acid content of 9.75 mg/g DW, ellagic acid of 9.24 mg/g DW, and corilagin of 3.01 mg/g DW (Rangkadilok et al., 2005).

Bioactivity of Kalimantan Local Fruits

This subsection will explain the bioactivity properties of the exotic and native fruits from Kalimantan, including *ramania*, *kapul*, and *ihau* fruit and their extracts. These properties include anti-aging, anti-bacterial, anticancer, and antioxidant activity, making them highly valuable in various applications.

Anti-aging

Haryono et al. (2021) reported that *kapul* fruit extract has the potential to be a gel preparation in making masks as an agent to delay the premature aging process of the skin. The chemical compounds responsible for anti-aging in *Kapul* fruit extract were phenolic and flavonoids, which have an efficient antioxidant capacity to prevent oxidative reactions by suppressing free radicals and help avert aging-related skin damage.

Anti-Bacterial

A study conducted by Norhayati et al. (2019) found that the ethanolic extract derived from *kapul* peel demonstrated the ability to inhibit the bacterial growth of *Streptococcus sanguis* in *in-vitro* studies. Moreover, the extract exhibited bacterial inhibitory activity comparable to the positive control, chlorhexidine, when administered at a concentration of 100%. Notably, concentrations ranging from 40-100% effectively inhibited bacterial growth. According to Yunus et al. (2014), the alkaloids, polyphenols, and flavonoids were active chemical compounds found in *kapul* peel extract, with different bacterial inhibition modes. Commonly, the phenolic and triterpenoid targeted the cytoplasmic membrane bacteria, although easy to partition to the lipid bilayer in bacteria cells to inhibit the growth of bacteria. The cytoplasmic membrane was chosen because it had hydrophobic properties (Hanizar & Sari, 2018). In addition, alkaloid compounds inhibit bacterial activity by disrupting the constituent components of peptidoglycan, so the bacterial cell wall layer is not formed intact, causing cell death (Minarni, 2023; Soulissa et al., 2021). Meanwhile, flavonoid compounds have various mechanisms to inhibit bacterial activity, such as membrane disruption, biofilm formation, inhibition of cell envelope synthesis, inhibition of nucleic acid synthesis, or inhibition of electron transport chain and ATP (Górniak et al., 2019). In other studies, ethanolic extracts of *ihau* fruit at concentrations of 70, 80, 90, and 100 mg/ml can inhibit bacterial growth of *S. aureus* during *in vitro* studies, which are the flavonoids compounds as responsible as anti-bacterial agents (Rahmawati et al., 2022). The mechanism of flavonoid compounds in *ihau* fruit extracts in inhibited bacteria might be similar to that in *kapul* peel extracts, as explained previously.

Anti-Cancer

The hydroethanolic extract of *B. macrophylla* (BPHE) shows promising potential as an anti-cancer agent. Results from in vitro cytotoxicity testing on human fibroblast cells revealed that neither BPHE nor ellagic acid caused any harm at any of the tested doses, with cell viability percentages ranging between 95.95% and 110.85% for BPHE-treated cells and 90.85% to 111.90% for ellagic acid-treated cells. In contrast, the positive control for cytotoxicity, sodium lauryl sulfate (SLS), showed toxicity against human fibroblast cells at concentrations of 0.1 and 1 mg/ml, with cell viability percentages of 46.32± 3.44% and 24.06±1.61%, respectively, with the saponin, tannin, and phenolics responsible as an anti-cancer agent in general. However, further examination by HPLC found that gallic acid and ellagic acid were potent as an anti-cancer agent (Maneechai et al., 2023). The anticancer activity of gallic acid was related to the apoptosis induction via different mechanisms, such as regulation of apoptotic and anti-apoptotic proteins, cell cycle arrest, inhibition of matrix metalloproteinases (MMPs), suppression and promotion of oncogenes, and generation of ROS (reactive oxygen species) (Subramanian et al., 2015). Moreover, ellagic acid demonstrates anticancer activity through various molecular mechanisms like metastasis, apoptosis, cell cycle, and angiogenesis in breast cancer (BC) (Golmohammadi et al., 2023). Furthermore, Rahmawati et al. (2023) reported that water and ethanolic extracts of *ihau* fruit have anticancer potential in MCF-7 breast cancer cells despite being very low cytotoxic, with the IC_{50} value of 1,197.7 ppm in water extract and 1,148 ppm in ethanolic extract, with flavonoids compounds was responsible for it. The mechanism of flavonoids as an anti-cancer through many different mechanisms, including the modulation of enzyme activities that scavenge reactive oxygen species (ROS), cell cycle arrest, induction of apoptosis and autophagy, and suppression of cancer cell proliferation and invasiveness (Kopustinskiene et al., 2020).

Antioxidant Activity

Researchers have found that *gandaria* or *ramania* fruit juice contains phytochemical components, such as saponin and phenolic, that exhibit significant potential as antioxidants, with an IC_{50} value of 36.4 mg/ml (Lolaen et al., 2013). Another study reported that *ramania* fruit juice has weak potential as an antioxidant, with an IC_{50} value of 564.271 ppm (~0.56 mg/ml) (Effendi et al., 2022). Besides, another study reported that *kapul* fruit has high antioxidant activity, with an EC_{50} value of 33.11 µg/ml, and can reduce DPPH radicals by 33.71% at a concentration of 20 ppm (Tirtana et al., 2013). Bakar et al. (2014) also reported that *kapul* fruit flesh had antioxidant activity using DPPH, ABTS, and FRAP assays. The antioxidant activity in *kapul* fruit and its flesh was the presence of phytochemical compounds such as saponin, alkaloids, phenolics, and flavonoids (Bakar et al., 2014; Tirtana et al., 2013). Lastly, the water and ethanolic extracts of *ihau* fruit have deficient antioxidant activity, with values of 681.05 µg/ml and 698.3 µg/ml, respectively (Rahmawati et al., 2023). The bioactive compounds found rich in *ihau* fruit, as reported by Zhu et al. (2019), were explained in previous sections. The mechanism of antioxidants of each phytochemical compound found in *ramania*, *kapul*, and *ihau* fruit was explained as follows: The flavonoid compounds act as antioxidants through various mechanisms like activation of antioxidant defenses, inhibition of reactive oxygen species (ROS) formation through the chelation of trace elements, inhibition of the enzymes that participate in the generation of free radicals, and direct scavenging of ROS (Dias et al., 2021). Meanwhile, phenolic compounds as antioxidants can be used through many mechanisms, such as the transfer of hydrogen atoms, single electron transfers, sequential proton loss electron transfers, and transition metal chelation (Zeb et al., 2020). Moreover, saponin acts as an antioxidant by helping to neutralize ROS and oxidative stress in the body (Timilsena et al., 2023). Saponins also act to form hydroperoxides as secondary antioxidants to inhibit the formation of lipid peroxides (Khan et al., 2023). Additionally, the mechanism of alkaloids as antioxidants is by donating H atoms to ROS (Maryuni et al., 2022). Furthermore, alkaloids also can act as H_2O_2 scavengers by donating their proton or electron to convert H_2O_2 into H_2O (Senhaji et al., 2022).

CONCLUSION

In conclusion, exotic and indigenous Kalimantan fruits like *ramania*, *kapul*, and *ihau* are excellent sources of nutritional and bioactive compounds that favorably impact health. Their rich nutritional and bioactive compounds demonstrate their promise as functional foods or raw materials of pharmaceutical products. Innovative applications in food products and related fields, such as pharmaceuticals, warrant further investigation.

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