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Review

A review on underutilized indigenous bambangan (*Mangifera pajang*) fruit as a potential novel source for functional food and medicine

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***Mangifera pajang* Konsterman, popularly known as 'Bambangan' is a plant endemic to Borneo Island. This seasonal tree produces edible fruit that can be eaten fresh. It is also used in cooking, and in making juice and pickles. The fruit is nutritious and contains various phytochemicals such as phenolics, flavonoids and carotenoids. Recent studies have demonstrated that selected fractions of the fruit extract displayed high antioxidant properties and have the ability to inhibit the proliferation of selected cancer cell lines. However, the efficacy of the plant extracts to treat diseases, their long-term safety and their toxicity evaluation have not been pursued. The main objective of this review is to provide information on the research work undertaken to date, and to provide basic information for future commercialization as functional food and medicine.**

Key words: *Mangifera pajang*, phytochemicals, antioxidant, anticancer, functional food, medicine.

INTRODUCTION

Fruit production is expected to rise due to the high demands worldwide. One reason for this high demand is the health benefits ascribed to fruits and their products. The major tropical fruits account for approximately 75% of global fresh tropical fruit production, and developing countries account for about 98% of the total production of tropical fruits (FAO, 2010). Mango (*Mangifera indica*) is the dominant tropical fruit variety produced worldwide, followed by pineapple, papaya and avocado. The production of mango is expected to grow by 3.4% each year (FAO, 2010).

Southeast Asia possesses a rich diversity of commercial fruits such as mango, durian, rambutan, papaya and banana. However, there are also fruits that are sold locally but remain underutilized. There are about 200 species of edible fruits in Borneo Island, many of which are beneficial to health but not fully commercialized and utilized (Wong et al., 2007; Abu Bakar et al., 2009). Most of the fruits grow naturally in the natural environment such as forest and jungle. This lack of commercialization and utilization might be due to the lack of promotion, minimal planting area, and not being fully explored, but still having economic potential (Chai et al., 2008). Research and development of rare and underutilized fruits species is becoming economically important for developing countries to promote a new generation of 'superfruits' which can be commercialized worldwide. The fruits of Acai (*Euterpe oleracea*) and camu-camu (*Myrciaria dubia*) are examples of underutilized fruits of Amazon which have been a global

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phenomenon as nutraceutical and functional foods (Mertens-Talcott et al., 2008; Akter et al., 2011).

The *Mangifera* genus comprises about 40 species, of which at least 26 are known to produce edible fruits (Verheij and Coronel, 1991). The most common species in this genus is common mango, known scientifically as *M. indica,* which has many attributes, being cultivated and sold worldwide. Other types of edible endemic *Mangifera* species which are underutilized and have the potential for commercialization are *Mangifera caesia, Mangifera foetida, Mangifera odorata* and *Mangifera pajang*. *M. pajang* Kostermans is a species of plant which is believed to originate from Borneo Island (Malaysia–Sabah and Sarawak, Brunei and Indonesia-Kalimantan). The tree is scattered throughout the Borneo Rainforest. Areas of wild distribution are found mostly in Kota Belud, Sipitang, Beauford, Sandakan in Sabah; Kapit, Ulu Dapoi, Long Silat in Sarawak and Sangkaruling and West Kutei in Kalimantan (Lim, 2012). The superior variety which is usually characterized by sweet and less-fibrous flesh is currently being cultivated in domestic backyards and also in small-scale orchards, including the so-called "forest gardens" (*simpukng*) in East Kalimantan (Mulyoutami et al., 2009). This tree has many names, based on locality. In Sabah, this tree is usually called 'bambangan'. In Sarawak and Brunei, besides bambangan, this tree is also called 'mawang', 'embang', 'buah pangin' and 'membangan'. In Kalimantan, this tree has been called by many local names such as 'limun', 'asam pajang', 'pangin', 'lempayang' and also 'bambangan'. The most common local name is 'bambangan' (Abu Bakar et al., 2009; Aman, 1999; Wong and Siew, 1994).

BOTANICAL DESCRIPTION OF *MANGIFERA PAJANG* KONSTERMAN

The tree of *M. pajang* (Class: Magnoliopsida, Order: Sapindales, Family: Anacardiaceae) can grow well in tropical weather with high humidity and a shaded location such as lowland dipterocarp forest (Lim, 2012). This species can grow in many types of soil including highland soil with pH between 5 and 7 (Lim, 2012), and can grow up to 35 m tall and bear up to hundreds of fruits during fruiting season (October to February each year).

The fruit of *M. pajang* weigh about 0.5 to 1.0 kg or more each and is among the largest fruit of *Mangifera* spp. The fruit is ovoid in shape, with a rough brown skin that distinguishes it from other *Mangifera* spp. which are usually characterized by smooth green, red and yellow skin. The edible portion of the fruit, the flesh or the pulp which represents 50 to 67% of the total weight of the fruit, is usually characterized by a bright yellow colour, sweet-sour taste, and juicy, although rather fibrous, texture, with a somewhat strong aromatic mango-ish smell (Wong and Siew, 1994). Photographs of *M. pajang* whole fruit, skinned fruit and cut fruit are shown in Figures 1 to 3, respectively.

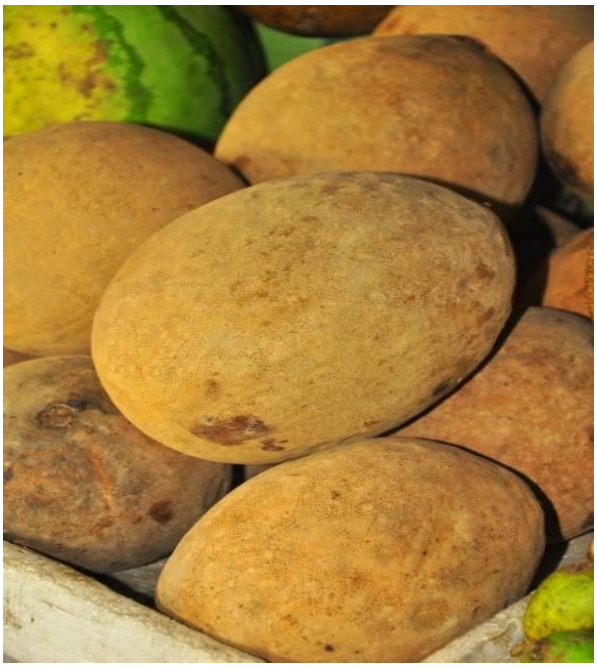

Figure 1. Whole fruit of *M. pajang*.

Figure 2. Fruit of *M. pajang* without skin/peel.

CULINARY USES OF *M. PAJANG*

The flesh is usually eaten fresh, whilst the peel and kernel, which represent about 40 to 50% of the total weight, are usually discarded. However, the peel, which

Figure 3. Cross-sectional picture of *M. pajang* fruit.

possesses an aromatic smell, is sometimes used in cooking of local dishes. The thick skin is added in curry to give mango-ish aroma, and can also be eaten after being pickled. In addition, the kernel or the seed is sometimes used with the flesh for making pickle. *M. pajang* pickle is easy to make and is widely sold locally. Basically, the fruit is de-skinned and the flesh cut into small pieces. The grated kernel of *M. pajang* is added to the cut flesh together with some salt and mixed thoroughly, hot and spicy 'bird eye chili' sometimes being added to the pickle. This pickle can be kept for almost one year. The pickle of *M. pajang* is usually eaten with plain rice together with other types of side dishes. Since *M. pajang* is a seasonal fruit, the pickling process makes the product of *M. pajang* available throughout the year.

NUTRITIONAL COMPOSITION

The proximate nutrient composition of the flesh of *M. pajang* per 100 g of edible portion based on analyses of samples from Sarawak, Malaysia was reported by Ibrahim et al. (2010) and is presented in Table 1. The relatively higher content of protein, ash (total mineral) and total fiber as compared to common mango (*M. indica*) is associated with various potential beneficial health properties (Ibrahim et al., 2010; Ramulu and Rao, 2003). Al-Sheraji et al. (2011) also reported that *M. pajang* flesh contained a rich amount of dietary fiber which can be beneficial for human health.

Table 1. Proximate nutrient composition of the flesh of *M. pajang* (Taken from Ibrahim et al., 2010).

Variable	Presence (% of edible portion)
Protein	1.13
Fat	1.98
Carbohydrate	21.02
Ash	0.43
Total fiber	5.26
Insoluble fiber	4.84
Soluble fiber	0.42

The vitamin content of the flesh of *M. pajang* was also determined by Ibrahim et al. (2010), with vitamins A (β-carotene) and C (ascorbic acid) being identified at levels of 42.21 and 46.31 mg/100 g of edible portion, respectively. The vitamin C content in the flesh of *M. pajang* was comparable to that of common mango (*M. indica*) (Ibrahim et al., 2010). Intake of vitamin C plays vital roles in human health and functions to treat colds, assist in wound healing, reducing the formation of atherosclerosis plaque and acting as antioxidant agent associated with prevention of the incidence of some degenerative diseases such as cancer (Naidu, 2003). The high level of β-carotene in *M. pajang* flesh (about 2 times higher as compared to the flesh or pulp of common mango) indicated that the flesh has a potential as a functional food and drink, as high intake of β-carotene

has been associated with the prevention of stroke, heart diseases, cataract and cancer (Mayne, 1996).

PHYTOCHEMICAL COMPOSITION

Research on the phytochemical components present in the fruit of *M. pajang* has increased rapidly over the past few years. The first report on the volatile components of the fruit of *M. pajang* was that of Wong and Siew (1994). The essential oil of the fruit was extracted using vacuum distillation and analyzed using gas-chromatography and gas-chromatography-mass spectroscopy. Fifty volatile components were identified in *M. pajang*; monoterpene hydrocarbons (91.3%) and esters (7.6%) predominated with α-pinene (67.2%) and α-phellandrene (11.0%) constituting the two most abundant components.

Abu Bakar et al. (2009) reported that the kernel of *M. pajang* contained the highest total phenolics content, followed by the peel and flesh, with values of 103.30 ± 0.63, 22.93 ± 0.36 and 5.96 ± 0.34 mg gallic acid equivalents/gram of freeze dried sample, respectively. The same trend of total flavonoids contents was also observed with the values of 10.98 ± 0.10, 7.50 ± 0.09 and 0.07 ± 0.00 mg rutin equivalent/gram of freeze dried sample. Subsequently, Abu Bakar et al. (2010a) investigated the polyphenol composition in the kernel, peel and flesh of *M. pajang*. The kernel of *M. pajang* contained a wide range of polyphenols, with phenolic acids (caffeic acid, p-coumaric acid, ferulic acid, sinapic acid, gallic acid) constituting the most abundant components. The kernel also contained flavanones (naringin, hesperidin), flavonols (rutin) and flavones (sinensetin, diosmin). Besides the presence of phenolic acids, the peel of *M. pajang* also contained various flavonols (quercetin, kaempferol, rutin), flavones (luteolin and diosmin), and flavanones (naringin and hesperidin). This finding was confirmed by Hassan et al. (2011a) who also identified mangiferin, daidzein and ellagic acid in the peel. However, only minor amounts of polyphenols were present in the flesh of *M. pajang*. Since the content of polyphenols was low in the flesh and peel of *M. pajang*, other researchers focused on the diversity of carotenoids which might be present in the flesh and peel. The carotenoids content in the flesh and peel of *M. pajang* were studied by Khoo et al. (2010). The flesh of *M. pajang* fruit contained higher α- and β-carotene contents (7.96 ± 1.53 and 20.04 ± 1.01 mg/100 g) than the peel (4.2 ± 0.14 and 13.09 ± 0.28 mg/100 g). The cryptoxanthin content of *M. pajang* flesh was higher (1.18 mg/100 g) as compared to the peel (0.60 mg/100 g). The flesh of *M. pajang* also contained isoflavones such as daidzein and genistein, with the levels of 8.49 ± 5.16 and 0.53 ± 0.74 mg/100 g sample (Khoo and Ismail, 2008). The presence of these phytochemicals in different parts of the *M. pajang* fruit suggests a potential use as a food or drink with health-promoting properties.

ANTIOXIDANT PROPERTIES

Abu Bakar et al. (2009) investigated the antioxidant properties of flesh, kernel and peel of *M. pajang*. The results showed that the kernel of *M. pajang* displayed superior antioxidant properties as compared to the peel and flesh, as assessed using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical scavenging and ferric reducing antioxidant power (FRAP) assays. The anti-oxidant activity of the fruit extracts was significantly correlated with the total phenolic and total flavonoid content, but not with the total anthocyanin content. This result suggested the use of the non-edible parts of the fruit (that is, kernel and peel) as antioxidant-rich phytopharmaceutical and nutraceutical products. Later, Ibrahim et al. (2010) reported the comparison of the antioxidant properties of *M. pajang* juice powder and *M. pajang* pulp powder. The results showed that the juice powder displayed the highest free radical scavenging activity and significantly correlated with ascorbic acid and β-carotene content, but not the phenolic content. Khoo et al. (2010) reported that *M. pajang* peel and flesh showed protective effects against hemoglobin and low-density lipoproteins (LDL) oxidation at concentration of 1 part per million, whilst Zabidah et al. (2011) demonstrated high antioxidant capacity in bambangan juice when tested in a variety of chemical antioxidant assays. Al-Sheraji et al. (2012a) further isolated potent antioxidant acidic polysaccharides and their fractions from the fibrous pulp of *M. pajang* and these also should be considered as prospective antioxidants.

More intensive study of the cell-based-antioxidant or cytoprotection potential of *M. pajang* extracts was conducted by Abu Bakar et al. (2013). Cytoprotective potential of the extracts was studied against oxidative damage caused by *tert*-butyl hydroperoxide in human hepatocellular HepG2 cell line. The results showed that the kernel displayed good cytoprotective activity, comparable to that of quercetin. Glutathione reductase and methionine sulfoxide reductase A were shown to be involved in the cytoprotective activity of *M. pajang* kernel extract.

ANTI-CANCER PROPERTIES

Abu Bakar et al. (2010a) reported the cytotoxic properties of different parts of *M. pajang* fruit extracts (that is, kernel, peel and flesh) against ovarian, liver and colon cancer cell lines *in vitro*. The results showed that only ethanolic extracts of peel and kernel of *M. pajang* displayed cytotoxic effects against these cancer lines. Kernel and peel extracts of *M. pajang* inhibited the proliferation of liver and ovarian cancer lines with IC_{50} (effective concentration which can kill 50% of total cancer cell population) values ranging from 34.5 to 92.0 µg/ml. Meanwhile, the proliferation of colon cancer cell lines was

inhibited by only the kernel extract (but not the peel and flesh extract). A prominent anti-cancer effect was observed in two types of breast cancer cell lines (Abu Bakar et al., 2010b). *M. pajang* kernel extract induced cytotoxic effects in MCF-7 (hormone-dependent breast cancer cell) and MDA-MB-231 (non-hormone dependent breast cancer cell) with IC_{50} values of 23 and 30.5 µg/ml, respectively. The crude extract of *M. pajang* kernel exhibited this anti-cancer effect via different mechanisms in the types of breast cancer cell. In MCF-7 cells, *M. pajang* kernel crude extract induced cell cycle arrest at sub-G1 (apoptosis) phase of the cell cycle, whereas the kernel crude extract induced G2/M arrest (inhibition of cell proliferation) in MDA-MB-231 cells, this resulting in the induction of apoptosis (cell death). Caspase-2 and -3 were shown to be involved in the apoptosis mechanism. These results clearly show the potential of *M. pajang* (especially the kernel extract) as anti-cancer agent.

SAFETY ISSUES

In regard to human safety, it is pertinent that the fresh fruit of *M. pajang* has been consumed by local people regularly during the fruit season, with no published reports of adverse effects or toxicity. The observation that the kernel of *M. pajang* is eaten with the flesh as a pickle by the indigenous community with no recorded adverse effects is a re-assuring sign of low systemic toxicity, although it is not known if the process of making 'pickle' might modify the phytochemicals in the kernel.

Results from animal studies are also reassuring. Thus, the findings of a multi-generation study in rats fed a diet containing 10% mango kernel oil indicated a lack of adverse effects or toxicity (Rukmini and Vijayaraghavan, 1984). The findings that addition of up to 20% mango kernel to the diet of chickens for up to four weeks was also without effect on weight gain, mortality and a variety of blood parameters (Amao and Siyabola, 2013) are similarly suggestive of a lack of significant systemic toxicity of extracts of seed kernel from *Mangifera* spp. However, possible toxicity effects of bambangan kernel extracts at high dose and/or long-term exposure should be considered.

DEVELOPMENT OF FUNCTIONAL FOOD AND MEDICINE

Pharmaceutical and nutraceutical companies are continuously searching for more active and sustainable resources and ingredients for food and medicine. This paper reviewed the potential of *M. pajang* as a sustainable resource for the development of health products. In order to fully utilize the fruit of *M. pajang*, considerable research has been conducted to investigate the potential health benefits of the fruit. Basically, the fruit can be divided into the edible part (flesh) and the inedible parts (kernel and peel). The flesh of *M. pajang* has been used traditionally as food, whilst the kernel and peel are regarded as waste by-products of fruit use. Recent study has shown that the flesh contained high nutritional properties. In addition to that, the flesh also contained various phytochemicals such as carotenoids and ascorbic acid and displayed high antioxidant properties. Juice and functional drink have been developed using the flesh of the fruit (Ibrahim et al., 2010). A dried form of the flesh of *M. pajang* contained high content of dietary fiber (including mannose, arabinose, xylose, fucose), making it suitable as an ingredient in functional foods (that is, low-calorie high-fiber food product) (Al-Sheraji et al., 2011). *M. pajang* fiber and its polysaccharides have also been shown to have a potential as prebiotics since they possessed strong fermentation and non-digestibility properties (Al-Sheraji et al., 2012b).

The peel of *M. pajang* contained various phyto-chemicals and displayed high antioxidant and active anti-cancer properties (Abu Bakar et al., 2009, 2010a, b). The powder of the peel of *M. pajang* also contained a high content of dietary fiber which makes it suitable as an added ingredient in many types of food products to improve their nutraceutical properties (Hassan et al., 2011b). Also, the peel can be used as a gelling, thickening and water-binding agent. These properties make the peel a suitable candidate in bakery products and snacks. The peel and kernel can also be extracted for their phytochemicals, especially phenolic acids, flavonoids and carotenoids. These results clearly demonstrate the potential of all parts of *M. pajang* fruit for the development of antioxidant-rich-drinks, high-fiber food products as well as potent antioxidant and anti-cancer agents. Further investigation on the toxicity of *M. pajang* fruit, and development of nutraceutical and efficacy studies (pre-clinical and clinical) are suggested for assessment of human benefits.

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