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Review Article

Passion Fruit—A Potential Crop for Exploration in Malaysia: A Review

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ABSTRACT

Passion fruit is a short-term crop with a life span of up to 2 years. Nowadays, passion fruit captures increasing demand in the global market. However, passion fruit is considered an underrated fruit in Malaysia as the production has not reached commercial cultivation. Highlighting the passion fruit as the next important commodity could rejuvenate the economy by disseminating equal benefits for both small and large-scale growers. This article provides a perspective on underlining the fruit to be explored as a commercial commodity. The fruit consists of three main components: juice, seed, and peel. Each of the fruit components has unique properties that can benefit multiple industries. In addition, strategies for successful passion fruit planting are also emphasised by farm management until the processing line produces high-quality fruit that can penetrate the global market. Therefore, a comprehensive review of passion as an essential crop could benefit Malaysia's agriculture and processing industries.

Keywords: Agricultural industry, economy, fruit quality, market expansion, natural product, passion fruit

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INTRODUCTION

Passiflora edulis is a perennial vine plant belonging to the Passifloraceae family. There are 18 genera under the Passifloraceae family that consist of 530 species, where 50–60 species are edible (Ghada et al., 2020). There are two types of passion fruit involved in global cultivation which are purple passion fruit (*Passiflora edulis*

Sims) and yellow passion fruit (*Passiflora edulis* f. *flavicarpa* Degener) (Md Nor et al., 2021a). The common name of passion fruit varies according to country. In Spanish, gulupa refers to purple passion fruit, while granadilla, parcha, and maracuyá refer to yellow passion fruit. Purple passion fruit is known in Portugal as maracuja, peroba, and maracujazeiro, whilst in France, it is known as grenadille and couzou (Pineapple Research Station, 2010). There is no specific name to distinguish between the purple and yellow passion fruits in Malaysia since both are called markisa. Morphologically, both fruits are round with leathery skin and contain aromatic, juicy pulp with small black seeds (Md Nor et al., 2022). Purple and yellow passion fruits can be differentiated by the plant's growth performance and fruit properties. The purple passion fruit plant is more resistant to cold injuries, while the fruit juice is less acidic and superior in aroma and flavour, making it highly palatable as dessert fruit (Azizah, 2011). *Vice versa*, the yellow passion fruit plant is not chilling resistant to a more vigorous vine, and the fruit has more acidic juice making it utilised highly in food processing industries (Md Nor et al., 2021b). Globally, purple passion fruit is mainly cultivated in East Africa, Venezuela, Brazil, Peru, Ecuador, and Colombia, while yellow passion fruit is primarily grown in South America (Kishore et al., 2006). The growing passion fruit in Malaysia is still underrated because it is used mainly for regional cultivation and has not yet reached commercial levels.

Market Potential of Passion Fruit

The passion fruit market can be segmented into North America, Europe, Asia Pacific, South America, the Middle East, and Africa (Altendorf, 2018). In 2019, Europe became the largest market share of passion fruit, followed by South America and North America. In Europe, passion fruit is highly traded as fresh, exotic fruit (Arias et al., 2020). The import value experienced a 40% increment over the past five years, with 42 million Euros in 2019, and this has made European countries, which Germany dominates, become the biggest importers (Center for the Promotion of Imports [CBI], 2021). This value is projected to continually increase in the upcoming years since there is high demand for fruit such as desert fruit and fresh juice. Since the beginning of 2020, when the Corona Virus Disease-2019 (COVID-19) pandemic hit the global, consumers physiologists found out consumers' behaviour changed with an attempt to eat a healthy diet with plenty of fruit and vegetables (Borsellino et al., 2020). The consumers stockpile food and confer for longer shelf-life nutritious food. In the European market, one of the fruit products that grabbed high demand during the panic buying was passion fruit puree (The Insight Partners, 2020). Passion fruit puree retains its full flavour and colour of fresh fruit. It is manufactured from fully ripened fruit that has been frozen, providing cost-effective products with a longer shelf life alternative to fresh fruit (Vaillant et al., 2001). Between 2004 and 2007, fresh passion fruit's price was around US$250/metric tonne in US

and European markets (Altendorf, 2018). The price has increased with fresh fruit and puree rated at US$400–600/metric tonne (Anonymous, 2022). The global market analysts have predicted that due to the pandemic, the demand for passion fruit puree will continue to rise until 2027 (The Insight Partners, 2020). The expanding global market price of passion fruit is remunerative and estimated to bring extra revenues to the producers. Most global passion fruit producers belong to tropical and subtropical countries (Table 1). Since Malaysia is tropical, the climate could be conducive to passion fruit cultivation.

Table 1

The different geographical features of global passion fruit producer

Country	Production (ha)/year	Type of cultivation	Climate	Light/ solar radiation (hour/ day)	Altitude (m)	Temperature (°C)	Rainfall (mm)	References
Ecuador	948,100	Plantation farming	Subtropical	12	51–479	23–25	64-2,658	Viera et al. (2020)
Brazil	150,000	Plantation farming	Subtropical	10–13	13–1,000	17–26	1,300-1,844	de Jesus et al. (2018)
Indonesia	114,600	Plantation farming	Tropical	12	195–2,000	28–32	2,600-3,000	Nadja et al. (2019)
India	78,000	Plantation farming	Subtropical	12	800–1,500	18–23	1,000-2,500	Tripathi et al. (2014)
Colombia	60,000	Plantation farming	Subtropical	5-13	0–2,200	15–28	800-1,800	Fischer et al. (2018)

Passion fruit plants grow well in regions with the temperature between 28 °C–33 °C and 60%–70% relative humidity. This environment will enable the flower's stigmas to remain hydrated and adhesive for effective pollination, thus producing fruit with a sweet juice taste and content (Fischer & Miranda, 2021). The flower is photoreceptive and only blooms after adequate sunlight. The agro-climatic conditions of Malaysia are tropical, with an average daily temperature of 27 °C–32 °C and 60%–70% relative humidity, while its annual precipitation is 2,000 mm to 2,500 mm (Malaysian Meteorological Department [MetMalaysia], 2022). In addition, Malaysia receives equal days and nights throughout the year, allowing the plant to flower and fruit optimally (Tripathi et al., 2014). The optimal ecosystem should be grasped so that Malaysia can produce the fruit on a mass scale.

Malaysia has around 310,000 acres of fruit-planting land. The output stands at 1.8 million metric tonnes (mt) with a USD127.8 million export value to Singapore, Hong Kong, and the Middle East. Malaysia continues to be a net importer of fresh and processed fruits, with fruit imports valued at around USD174 million (Salleh

& Yusof, 2006). In the late 60 and early 70s, Malaysia first positioned pineapple as a commercial commodity for export (Jaji et al., 2018). Till now, the variety of commercial fruits has grown to more than 10 fruits. In 2017 commercial fruits include banana, pineapple, durian, watermelon, and guava, with a production of around 84,288–350,493 ha/year (Figure 1).

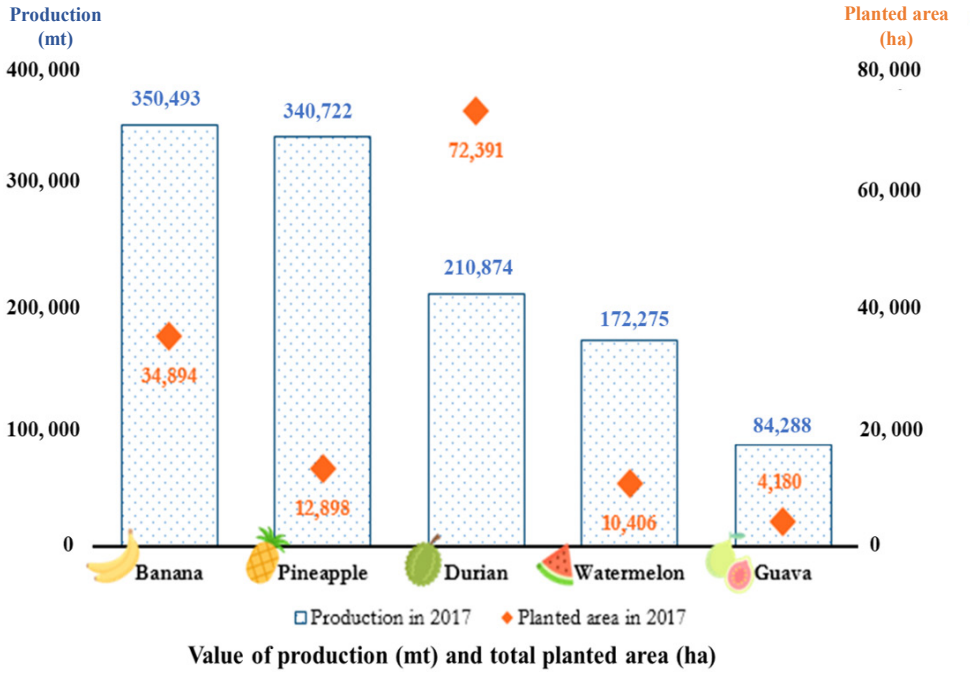

Figure 1. Different types of commercial fruits in Malaysia that were produced in 2017 [Source from Tumin and Shaharudin (2019)]

Among fruit planting areas, durian has the largest acreage with 72,391 ha. In 2019, Malaysia was only focusing on durian (*Durio zibethinus*), jackfruit (*Artocarpus heterophyllus*), papaya (*Carica papaya*), watermelon (*Citrullus lanatus*), and banana (*Musa* spp.) as export commodities (Rozhan, 2019). Nevertheless, due to inadequate information about its feasibility, passion fruit planting remains an underutilised crop in Malaysia. The fruit is not even listed as an essential commodity in Malaysia (Ministry of Agriculture and Food Industries [MAFI], 2022). Even though the passion fruit is not particularly popular in Malaysia, it has a competitive market price compared to other commercial commodities (Figure 2).

Among these fruits, durian poses the most premium market price with US$3,500–12,500/metric tonne, while papaya values US$317–333/metric tonne, watermelon at US$300-321/metric tonne, and jackfruit at US$200–300/metric tonne. An exception to durian, passion fruit has a higher export value than other fruits, priced at US$400-600/metric tonne. Although durian fruit

Commodity	Gross production value (current thousand USD)	Minimum market price (USD per tonne)	Maximum market price (USD per tonne)
Passion fruit	-	400	600
Papaya	20,575	317	333
Watermelon	43,108	300	321
Jackfruit	-	200	300
Durian	-	350	1,250

Figure 2. The commercial market price of tropical fruits in the global market in 2017–2020 [Source from Food and Agriculture Organization Corporate Statistical Database (FAOSTAT) (2022)]

could give a good return, it is a long-term crop in Malaysia. The tree takes four to eight years to bear fruit (Ketsa et al., 2020). In addition, the durian tree is tall and big, which takes up a large area of space, making crop management difficult (Radchanui & Keawvongsri, 2017). The long-term investment of time and effort makes the durian's price premium. Nevertheless, the investment cannot assure economic guarantee to the growers as there are substantial risks that can cause losses, especially when fungal diseases and floods infect the trees. Due to the intimidating likelihood, durian growers require big capital for intricate plant management and tolerate risky investments.

Venturing to passion fruit as the next enlightened crop could offer profitable investment since it is getting high demand globally. The plant is a vigorous climbing vine crop that can grow quickly. Previous research shows that the plant starts to bear fruit within six months after transplanting, and the crop's life span is up to 2 years (Md Nor & Ding, 2019). Passion fruit is a short-term cash crop that could bring a rapid return to growers, thus offering a less risky investment. Venturing into passion fruit cultivation is less capital intensive but captures a higher market price that could bring a better return (Nsubuga, 2021). Reflecting Brazil, the world's largest commercial passion fruit producer, the production is 7,613 kg/ha, which leads to a net profit of US$3,519.22, a benefit-cost ratio of 2.5, and a profitable index of 177.5% (da Silva et al., 2020). The profitable index of passion fruit is higher than bananas, valued at 141.58% (Magbalot-Fernandez &

Montifalcon, 2019). Cultivating the passion fruit in mass-scale production could bring economic growth to Malaysia as the fruit offers remunerative profit.

About 97% of smallholders in Malaysia lack capital investment and limited land size (Arshad, 2016). Large-scale growers are usually established by large-scale organisations that are professionally managed and have a substantial amount of capital capable of in investing both short and long-term crops (Ng, 2016). Nonetheless, the small-scale farmers grab a small chance to invest a substantial amount of money in a long-term commodity like durian. Offering the passion fruit in commercial planting could provide a better opportunity for small-scale growers to improve their socio-economy (da Silva et al., 2020). This strategy may help the Malaysian agricultural industry to build resilience in rural communities and improve the socio-economy. The small-scale farmers have significantly impacted the Malaysian economy, contributing 23% of total export earnings and 7.2% of gross domestic product (GDP) (Ng, 2016). In 2020, Malaysia's economy had contracted by 5.6% due to the pandemic crisis. Therefore, for the Twelfth Malaysia Plan (12MP) (2022) from 2021–2025, the government has outlined an agenda for holistically restoring economic stability. The agriculture sector is being highlighted for the next five years to rejuvenate the Malaysian economy, which includes the production of vegetables and fruits. Positioning the passion fruit for commercial cultivation in Malaysia could positively impact the agricultural sector, restoring its economic stability.

Passion Fruit as Multifunction Fruit for Industrial Usage

Botanically, passion fruit belongs to pepo, a type of berry. Upon pollination, the flower ovule is developed into a seed while the walls of the ovary are transformed to peel (Md Nor et al., 2021b). Morphologically, the tissues can be segregated into pericarp (peel) and endocarp (seed and juice) (Figure 3).

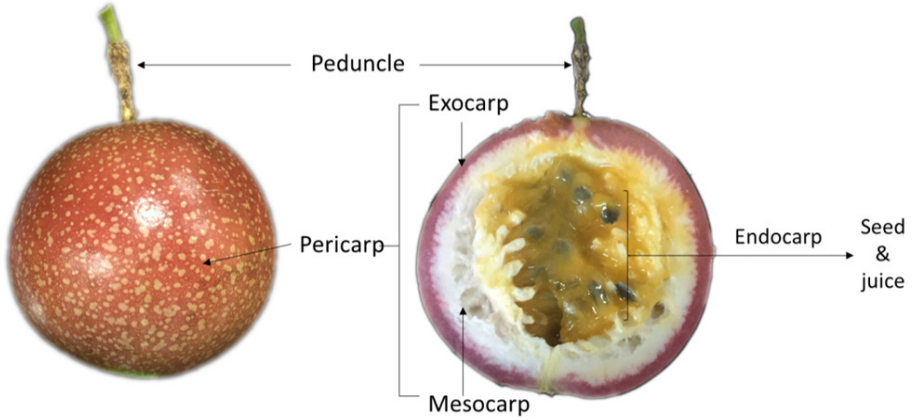

Figure 3. Morphological organisation of a passion fruit tissue. Pericarp refers to the peel composed of exocarp (outer layer with purple colour) and mesocarp (white spongy layer). Endocarp refers to the flesh that is composed of seed and juice

In the fresh fruit industry, only the seed and juice are edible, while the peel is normally discarded. Nonetheless, due to the unique benefits of each tissue, the whole fruit compartment can be fully utilised for diverse industrial products (Table 2). Passion fruit juice has a distinct sweet-sour and fruity flavour with notable amounts of potassium, copper, phosphorus, iron, and vitamins A, B, and C (He et al., 2020). Passion fruit juice extracts show a wide range of potential health effects and biological activities: antioxidant, anti-hypertensive, antidiabetic, anti-tumour, and hypolipidemic (Guimarães et al., 2020). Besides, it is considered a low-calorie fruit, making its consumption suitable for those on a diet (He et al., 2020). Daily consumption of fresh passion fruit juice was also reported to be non-toxic. This opportunity makes the passion fruits economically important worldwide as they have a great demand to be marketed for fresh consumption, food, and beverages.

Table 2

Summary of passion fruit's functional properties and its potential industrial applications

Compartment	Functional properties	Industrial applications	References
Juice	Nutritious and lucrative taste	Fresh consumption, food, beverages, and confectionaries products	Zhu et al. (2017)
Seed	Rich in essential fatty acid	Premium edible oil	He et al. (2020)
	Excellent source of fibre	Natural food fibre ingredient	Liu et al. (2008)
	Rich in phenolic and flavonoid	Food supplements	He et al. (2020)
	Source of stilbenes	Medicine for cancer and diabetic	Yamamoto et al. (2019)
	Tyrosinase inhibitory effects	Cosmetic	Yepes et al. (2021)
Peel	Rich in fibre content	Thickener and gelling agent	Lima et al. (2016)
	Excellent rheological property	Flour with medicinal function	Lima et al. (2016)
	Good antioxidant property with antimicrobial activity	Natural food preservatives	Ramli et al. (2020)

Passion fruit juice is wholly used in the food and beverages industry. The passion fruit juice is normally extracted from the pulpy seed and processed as clarified juice or juice concentrates. Production of clarified juice involves extraction from the pulpy seed. Then, the clarification process is conducted by treating the juice with pectinase and afterward being filtered, pH adjusted, sweetened, packed, and sterilised (Zhu et al., 2017). A similar processing step is conducted for juice concentrates but with additional steps in which 50% of water content will be removed (Vaillant et al., 2001). Concentrates are not intended for direct consumption as they can be reconstituted and incorporated in the desert, carbonated drinks, ice pop, ice cream, dessert, and multiple confectionery products. Passion fruit juice concentrates are now even available in powdered form, allowing for greater applications and extended shelf-life (Borrmann et al., 2013). The functionality of passion fruit juice in the food industry is still expanding as food technologists actively develop innovative products. Recent research shows that the juice can be fabricated into passion fruit juice-enriched set yogurt (Ning et al., 2021), nutritious jelly drinks (Agnes et al., 2021), and probiotic drinks (Guedes et al., 2021).

The passion fruit seed is equipped with high sodium contents, followed by magnesium, phosphorus, potassium, and calcium (He et al., 2020; Lourith & Kanlayavattanakul, 2013). Around 20% of oil can be extracted from the seed, mainly comprised of 70% linoleic acid, followed by oleic acid, palmitic acid, and a trace amount of linolenic acid (Liu et al., 2008). This compound makes the seed a great source of essential fatty acids that can function in the food industry. Furthermore, premium edible oil can be extracted from passion fruit seed as it is predominantly constituted of unsaturated fatty acid, where linoleic acid exceeds 60% (Liu et al., 2008). Apart from that, the seed is also an excellent source of fibre. A study by Chau and Huang (2004) has proven that passion fruit is rich in insoluble dietary fibre (99.96%) composed of pectin, cellulose, and hemicellulose with the capability of absorbing glucose and retarding the amylase activity. The findings also suggest that the seed fibre can enrich the formulation of healthy dietary snacks.

The passion fruit seed is also rich in antioxidants with high phenolic and flavonoid contents that work as active compounds where it can be formulated as food supplements for healing life-threatening diseases such as cancer, immunodeficiency disorders, and cardiac disorders (He et al., 2020). Passion fruit's seed extract is rich in stilbene, such as piceatannol and scripusin, which have various physiological effects where these compounds can provide a novel anticancer strategy for preventing and treating diseases (Yamamoto et al., 2019). The piceatannol from the seed improved insulin sensitivity in obese patients and potentially reduced type 2 diabetes (Kitada et al., 2017). The oral intake supplement made by passion fruit seed extract, which is rich in piceatannol, improves dry skin, and reduces fatigue among women, who suffer

from these problems (Maruki-Uchida et al., 2018). In addition, the tyrosinase inhibitory effects of the seed extract can be beneficial for developing skin-lightening cream, sunscreen, and anti-ageing cream (Yepes et al., 2021).

Like the passion fruit's seed, the peel composed of high fibre makes up 60%–80% of the fruit's total weight (He et al., 2020). Pectin is well known as a functional food ingredient that grabbed high commercial value by its technological properties. The pectin can be used as a thickener, gelling agent, and stabiliser in formulating foams and emulsions (Elizabeth et al., 2019). Due to this technical quality, pectin extracted from the passion fruit can be used to prepare jellies, jams, fruit juice, and formulation of concentrated dairy products such as yogurt (Elizabeth et al., 2019). Furthermore, passion fruit pectin is safer for human health because it is a natural element that can improve digestive system function and boost satiety (Freitas et al., 2016). Ingesting the passion fruit pectin leads to gel formation in the gastrointestinal tract. Due to high flavonoid contents, the gel later inhibits the gastric absorption of sugar and amino acids in the small intestine, reducing postprandial blood glucose in controlling diabetes response (Espinal-Ruiz et al., 2016).

Passion fruit's peel can be processed directly as flour. Technically, the passion fruit's peel flour can replace the commercial hydrocolloids. The flour can be processed with a low-cost procedure but obtain similar technological characteristics to commercial hydrocolloids in stabilising, emulsifying, thickening, and gelling power (Lima et al., 2016). Therefore, passion fruit peel flour can be considered a high nutritional ingredient. Study shows that the intake of passion fruit peel flour can effectively lower cholesterol and triacylglycerides levels in HIV patients (Marques et al., 2016). Furthermore, *in vivo* study shows that direct intake of passion fruit peel flour can improve short-chain fatty acids production, ameliorate antioxidant status, modulate the microbiota, and improve insulin sensitivity (Lima et al., 2016). In addition, the extract obtained from passion fruit peel has great potential application in the meat industry as it can be developed as a natural additive to control oxidation and spoilage microorganisms due to its antioxidant and antibacterial properties (Ramli et al., 2020).

Strategies for Successful Passion Fruit Planting

It is critical to assist growers in producing high-quality fruit that can penetrate the global market. Strategies are needed to promote this fruit among Malaysian growers so that growers are willing to invest in planting passion fruit. The first strategy is determining the optimal stages to cater to different distances of markets (Md Nor & Ding, 2020). Estimating the fruit harvesting stage is vital for ensuring the fruit quality is optimal when it reaches consumers. The harvesting stage significantly impacts fruit eating quality and the post-harvest life of manufactured products (Camargo et al., 2017; Mohammad & Ding, 2019; Tee et al., 2012). For a fruit grown in tropical

regions with a uniform climate throughout the year, calendar dates that depend on days from flowering to fruit set can be used as a reliable guide to predicting its optimal harvesting stage. The flowering duration can predict the relative growth period of fruit to maturity (Camargo et al., 2017). This method is applicable since the time of flowering, and fruiting greatly depends on temperature, humidity, precipitation, and radiation. The uniform climate makes the harvesting stage relies on calendar dates to become successful, as applied in a few countries such as Malaysia, Vietnam, and Thailand to predict fruits' maturity (Uda et al., 2020).

Ensuring fruit is harvested at its optimal harvesting stage, it should achieve its minimal level of acceptability during harvesting. The grading requirement that outlines the minimal acceptability of fruit for trading is known as maturity indices. The maturity indices are maturity declaration to avoid selling immature or overmature fruit, undermining consumer confidence (Yadav et al., 2014). The common maturity indices for fruit are summarised in Table 3. The physical characteristics (size, colour, texture), chemical (soluble solids concentration, organic acid, and sugar content), and physiology (ethylene and respiration) were found to have good correlations with the stage of fruit development (Mohammad & Ding, 2019).

Table 3

Criteria in ascertaining the fruit maturity indices (Paltrinieri, 2014)

Criteria	Fruits
Physical properties	
Development of abscission layer	Some melons, apples, and feijoa
Surface morphology and structure	Grapes and tomatoes (cuticle formation) Some melons (netting formation) Some fruits (glossiness)
Size	All fruits
Specific gravity	Cherries, watermelons, and potatoes
Shape	Banana (fingers angularity) Mangoes (full cheeks)
Textural properties - Firmness - Tenderness	 Apples, pears, stone fruits Peas
External colour	All fruits
Internal colour and structure	Tomato (surface with a jelly-like colour) Some fruits (flesh colour)
Cellular structure	
Angularity of cell and cell size at mesocarp layer	Banana and karanda fruit

Table 3 *(Continue)*

Biochemical properties	
Starch content	Apples and pears
Sugar content	Apples, pears, stone fruits, and grapes
Acid content, sugar/acid ratio	Pomegranates, citrus, papaya, Melons and kiwifruit
Juice content	Citrus fruits and avocados
Astringency (tannin content)	Persimmons dates
Physiological properties	
Internal ethylene concentration	Apples and pears
Mean heat units during development	Peas, apples, and sweet corn

The indices cover fruits' physical, cellular, biochemical, and physiological properties. Ideally, fruit maturity indices involve non-destructive measurement, simple to measure by producers, handlers, and quality control personnel, which are readily performed in the field with non-sophisticated instruments (Lina et al., 2014). Specific criteria have been outlined for passion fruit maturity indices released by commercial producers such as America, Brazil, and Kenya (Ghosh et al., 2017). The indices are simplified in Table 4. These indices can be inferred as guidelines for establishing the optimal harvesting stage of passion fruit in Malaysia. The primary step for establishing maturity indices is to study the physicochemical properties of fruit during growth and development (Camargo et al., 2017; Mohammad & Ding, 2019; Tee et al., 2012). Nevertheless, this study is still lacking in Malaysia; therefore, it is crucial to ratify it first.

Table 4

Maturity indices of passion fruit in global trading (Codex Alimentarius, 2014)

Indices	Descriptions
Size (Diameter)	Small (5 cm) Medium (6.5 cm) Large (8 cm)
Peel colour	Green—not ripen 50% purple colour—acceptable for market 75% purple colour—acceptable for market 100% purple colour—highly desirable
Soluble solids concentration	13–18 °Brix

The second strategy for commercial planting passion fruit is to control the pests and diseases of the plant. Fungal infestation is a major threat to the commercial cultivation of passion fruit. Fungal infestations such as *Fusarium oxysporum*, *Phytophthora cinnanomi*, *Phytophthora nicotinae*, and *Colletotrichum gloeosporioides* can cause various diseases such as fusarium wilt, collar rot, anthracnose, and crown rot on passion fruit (Melo et al., 2019). Pale-green leaves, mild dieback, chlorosis, leaf drop, plant wilting, and death are common signs of diseases too. In 1960, the passion fruit plant was once cultivated on a commercial scale in Malaysia. However, the project was unsuccessful due to the fungal disease outbreak (Chai, 1979). Nevertheless, research in agriculture has undergone tremendous advancement in this era. The use of chemical and bio-fungicide was proven effective in controlling bacterial and fungal diseases in plants (C. Wang et al., 2021; Ons et al., 2020). Therefore, the historic failure of commercial passion fruit planting in Malaysia cannot be interpreted as a hurdle for the current implementation. Therefore, a pilot-scale study on passion fruit cultivation must be executed to evaluate the project's feasibility before the implementation of full-scale production.

The third strategy for commercial planting passion fruit is efficient post-harvest management. An effective management system can ensure the harvested product meets the market/consumer expectations in terms of volume, quality, and other transaction features, such as nutrition and product safety (Md Nor & Ding, 2020). Passion fruit is a climacteric fruit. The beauty of climacteric fruit is that the fruit can be harvested at early maturity and ripened during transportation and distribution (Wang & Sugar, 2015). The application of 1-methylcyclopropene (1-MCP) is a standard method to prolong the post-harvest life of passion fruit in a commercial by inhibiting the production of endogenous ethylene in the fruit (Yumbya et al., 2014). Nevertheless, the tricky part of applying 1-MCP is that it must be applied when the fruit's endogenous ethylene is neither too low nor too high to allow appropriate fruit ripening. Therefore, before applying this technique, the physiological feature of passion fruit needs to be understood to allow effective treatment that can produce optimal fruit quality.

Besides, optimal keeping temperature for passion fruit needs to be adapted too. The passion fruit is known to be chilling and sensitive. Storing the Malaysian grown passion fruit at 5 °C causes the fruit to develop chilling injuries (Md. Nor et al., 2021a). On the other hand, the yellow passion fruit was found to tolerate well with 10 °C as the fruit achieves extension in post-harvest life for 21 days (Md Nor et al., 2021a). Modified atmosphere (MA) packaging can also become an effective way to lengthen the fruit's post-harvest life. Packing passion fruit in the MA environment will allow the fruit to gain at least 14 days of shelf-life extension (Yumbya et al., 2014). Other than that, the application of biopolymer coating may also be effective

in extending the post-harvest life of passion fruit. Currently, limited research is available for passion fruit coating (Md Nor & Ding, 2020). Therefore, venturing into coating formulation specifically for passion fruit can become a good research niche in preparing the Malaysian passion fruit for commercial cultivation.

Passion fruit cultivation can also be oriented to expand beyond the fresh fruit as well as the food and beverages industry. It is because fruit can be the principal source of medicine for new drug development in addition to agrochemicals, cosmetics, and food ingredients (He et al., 2020). Nevertheless, this process needs integration between the farm production and natural product industries. The natural product industry is an important sector in the economic growth of a country. The sector covers the production of cosmetics, herbal medicine, pharmaceutical products, and natural food ingredients (Atanasov et al., 2021). According to the study made by BCC research company, the global plant-derived natural products were valued at US$ 22.1 billion in 2012, and sales are expected to expand to US$ 26.6 billion by 2017 at a compound ground rate (CAGR) of 3.8% (Krause & Tobin, 2013). For instance, the European country (EU) has become the world's leading producer of sugar beets, with a cultivation area of 1.74 million hectares targeting the fruit for fresh consumption, sugar production, and natural dye production (Haß, 2022; Popescu et al., 2021). In America, Solanaceae *Datura stramonium* are planted commercially to produce tropane alkaloids, which function as starting material in the production of different pharmaceuticals products (Moreno-Pedraza et al., 2019). *Morinda citrifolia* are planted commercially in India as a dietary supplement instead of being processed as juices, powder, flavouring, and colouring agents for food and drinks (Thorat et al., 2017).

As discussed in previous sections, passion fruit has multifunction usage in pharmaceutical, functional food ingredients, and cosmetic industries. Extended passion fruit products, such as passion fruit peel flour, pectin, seed essential oil, and flavonoid passion fruit extract, have been commercialised primarily in America and China (Anonymous, 2022; He et al., 2020). Production of extended passion fruit products could offer remunerative income for the country since the product segmentation fit various technological industries willing to pay for exclusive prices (Lang & Rodrigues, 2022). The natural product industry will benefit good return on investment as raw materials will become cheaper if Malaysia starts to implement commercial cultivation. Symbiotic interaction between the farm production and natural product industry is essential to be inaugurated. Consequently, the Malaysian economy will gain dual revenue from both industries.

CONCLUSION

Commercial passion fruit cultivation in Malaysia is a propitious plan of action. The rising global demand for fruit should be viewed as an opportunity to boost

the economy. The commodity can be endeavoured by small- and large-scale growers. The fruit can be classified as multifunction, which can be exploited beyond the orthodox food and beverages industry. With the advancement of technology, juice, seed, and peel can be converted to various extended passion fruit products. A commercial planting strategy includes effective management, which begins with producing high-quality fruit. After harvest, proper post-harvest handling should be applied to ensure the fruit maintains its quality until it reaches the consumer. Integration between farm production and the natural product industry needs to be established to penetrate passion fruit as extended passion fruit products.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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