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Ripening Characterization, Fruit Quality and Sensory Attributes of *Passiflora quarangularis* L.

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Abstract

Passiflora quadrangularis is a genus *Passiflora* species well-known for its beautiful flowers, large and aromatic fruits with edible mesocarp and pulp. Although it is cultivated substantially, scientific studies pertaining to *P. quadrangularis* fruit quality characteristics at different harvesting maturity and sensory attributes of this fruit harvested at various stages of maturity are very scanty. Therefore, the present study aims to examine the quality features of *P. quadrangularis* at different harvesting stages for optimum harvest maturity and characterize the sensory properties and preference segments for *P. quadrangularis* among local consumers. The fruits at three ripening stages were harvested and tested for their physicochemical properties. The quantitative descriptive analysis (QDA) method using trained panelist and consumers were conducted for sensory evaluation and acceptability of this fruit. Nutritional properties were determined using the standard protocol of Association of Official Analytical Chemists (AOAC). The optimum harvesting period of this fruit was 55 to 60 days after anthesis (DAA). During ripening at day 60, fruit firmness was 3.33±0.10N, with a total soluble solid of the pulp at 14.57±0.33 °Brix. Pulp and mesocarp pH also increased slightly at ripening, 3.76±0.02 and 5.14±0.02, respectively. The trained panelists used sweet, juicy, with a little sourish to describe the taste of the fully ripened fruits (60 DAA), while crunchy with mild sweetness was used to describe the taste of the fully matured fruits (50 DAA). The Internal Preference Mapping (IPM) matrix of hedonic ratings on the acceptability of *P. quadrangularis* fruits among consumers revealed that fruits harvested at full ripen (60 DAA) were suitable to be consumed as fresh, with a matrix of 70-80% for mesocarp and 60-70% for pulp. Unripe fruit had hedonic ratings of 40-50% and was suggested to be cooked as a vegetable. Notably, the pulp of the fully ripe fruit was high in carbohydrates (7.36±0.21%) and protein (2.55±0.14%), whereas the mesocarp was high in fibre (2.36±0.07%). The findings support the significant importance of harvest maturity on *P. quadrangularis* fruit quality attributes and overall consumer acceptance.

Keywords: Fruit maturity, fruit ripening, giant granadilla, non-climacteric fruit, passion fruit

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1. Introduction

Passiflora is the largest genus in the Passifloraceae family, which consists of more than 500 species [1]. It is mostly distributed in Neotropics, with only 23 native species in Southeast Asia, Australia, and Oceania [2,3]. Brazil produces 83% of the world's passion fruit [4]. Every species in this family has commercial value and worth, while cultivation is mainly for fruit production, therapeutic use, and ornamental purposes [5,6]. There are approximately 50 edible species cultivated around the world, with only two species being economically important, namely *P. edulis f. edulis* (Purple passion fruit) and *P. edulis* f. *flavicarpa* (Yellow passion fruit) [7]. In Malaysia, nine *Passiflora* species were recorded, with two well-known species of purple and yellow passion fruits. Furthermore, *P. quadrangularis*, a lesser-recognised species, has gained the attention of farmers in recent years. This species bears a larger fruit than any species within the genus *Passiflora*.

The pulp has a distinctive aroma and taste, which contributes to the tastes of drinks and desserts [6,8]. Both mesocarp and pulp have well-balanced fibre, minerals, sugars, organic acids, and phenolic compounds.

Consumers demand on specific attributes of the fruit, not only because of the sensory characteristics, *i.e.*, appearance, texture, and flavour but fruit maturity at harvest is one of the key factors influencing passion fruit quality due to the numerous physico-biochemical changes that take place during the ripening process [9]. In passion fruit, the harvest maturity may be indicated by the exocarp colour and abscission layer of the fruit pedicle. The onset of physiological maturity is marked by a change in exocarp colour from green to purple or yellow around 70-80 days after anthesis [10,11]. For the common passion fruit of *P. edulis*, the fruits fall to the ground, remarked they reached the physiological maturation point. Additionally, fruits harvested at 75% purple or yellow exocarp for local market distribution, but other factors such as genetic, environmental, and agronomical may often complicate ripeness assessment by influencing the fruit's physiology and development, resulting in variable fruit quality [12]. The fruit of *P. quadrangularis*, by nature, does not exhibit outstanding exocarp colour development upon ripening. This condition makes it difficult to identify the optimum harvesting stage (physiological maturation) perceived by pressing on the proximal and distal positions of the fruit. Unlike other purple passion fruit, *P. quadrangularis* is a non-climacteric fruit as it cannot ripen after being picked from the vine [13]. Harvesting before the physiological maturation stage to facilitate handling or long-distance transport may result in less juice content, inferior flavour, and unacceptable Brix and acidity compared to vine-ripened fruit [9,10,14].

Previous studies have evaluated the fruit quality features of common passion fruit species (*P. edulis*) with physicochemical [12,15] mainly to investigate maturity effects and sensory and consumers preference for passion fruit various juices [16,17]. Distinct regional demands for different species reflect local idiosyncrasies in consumer tastes. To date, information pertaining to *P. quadrangularis* fruit quality characteristics at different harvesting maturity and sensory attributes of this fruit harvested at various stages of maturity is very scanty. *Passiflora quadrangularis* fruit offers different tastes, textures, scents, and flavours, which promise future domestication and product derivations. Therefore, the present study aims to examine the quality features of *P. quadrangularis* at different harvesting stages for optimum harvest maturity and characterize the sensory properties and preference segments for *P. quadrangularis* among local consumers. Knowledge of this non-native species' maturity stages and sensory divers is crucial for fruit management, nutritional enrichment, and product development.

2. Materials and Methods

2.1. Study location and plant cultivation

The experiment was conducted at a passion fruit farm, Universiti Putra Malaysia Bintulu (N 03° 12.45' and E 113° 4.68'), Sarawak. The plants were cultivated from seeds obtained from the commercial provider Trade Winds Fruit, Windsor. A vertical trellis system with 20 rows of 25 m length each was constructed. The trellis system consisted of 2.0 m tall posts set at 5 m intervals along the rows in a north-south direction. Furthermore, five-months-old seedlings were transplanted with a planting distance of 2.0 x 1.5 m. Fertilizer application was made monthly throughout the growing season with the rate of 250-50-80 kg N P_2O_5-K_2O ha^{-1}. During cultivation, early light pruning was practiced whereby the secondary shoots grew downwards kept cut 15 cm above the ground and selective pruning was carried out after the major fruit harvesting.

2.2. Fruit development

Assessments were performed from June 2019 to June 2020, in which the tagging and observation of the vegetative shoots in terms of developmental growth to the fruiting phase. The plant development phase was recorded based on the extended BBCH scale [Growth stage of plants, BBCH Monograph, 18]. The main observations taken into account were fruit development comprised of fruit initiation (1^{st} stage) and fruit expansion (2^{nd} stage). The initiation of fruits was started after 3-4 days of anthesis. Thus, the data collection was carried out from day 3 of anthesis until 65 days with every five days of interval. The parameters recorded were fruit length (cm), fruit diameter (cm), and fruit weight (g). The collected data were used to distinguish the fruit growth curve and maturity indexes for harvesting at the right time.

2.3. Fruit maturity index

The harvesting stage of *P. quadrangularis* was observed in the 3^{rd} stage of fruit development which was fruit ripening. The fruit was harvested at three ripening stages, namely 1) immature-green, harvested after 40 and 45 days after anthesis (DAA), 2) mature-green, harvested 50-55 DAA, and 3) fully ripe, 60-65 DAA. All the samples were analysed for their physicochemical properties based on the standard protocol of Association of Official Analytical Chemist [19], while the colour was determined using the colourimeter technique and Colour Reader CR10 (Konica Minolta, Tokyo, Japan) to identify the degree of material lightness (L), redness, (a), and yellowness (b) of the skin surface, mesocarp, and pulp. The fruit's firmness was measured using a penetrometer (FT011, Virginia, USA). Penetrometer readings were converted to newton (N) values. The pH was measured using a pH meter (Mettler-Toledo, Greifensee, Switzerland) (method 964.24, [19]), while the fruit firmness was determined using a sclerometer, where the total soluble solids (TSS) were analysed using a handheld refractometer (ATAGO Corp., Tokyo, Japan) (method 983.17, [19]). The total titratable acidity (TTA) was measured by titration method using a standard alkaline solution of 0.1 mol L−1 sodium hydroxide (method 942.15, [19]).

2.4. Sensory analysis

Three fresh fruits (mesocarp and pulp) of *P. quadrangularis* at two different maturity stages (50 and 60 DAA) were harvested and delivered directly from the passion fruit orchard to the laboratory. In the laboratory, the fruits were cleaned and processed to minimize any risk of contamination. Each fruit mesocarp was cut into half longitudinally and ten pieces, and the peel was removed. The pulps also were separated from the mesocarp. Each piece was cut into small cubes with approximately 1-cm thickness, and the pulp was kept at 4°C prior to serving. Therefore, the panelist received for evaluation six pieces of mesocarp per maturity with 20 g of pulp at room temperature (20°C), placed in a transparent plastic container with a lid.

2.5. Scorecard development by trained panelists

The quantitative descriptive analysis (QDA) method was used to train the sensory panels and to carry out the sensory analysis according to set sensory standards (ISO Standard 8586-2 1994). A trained panel of 15 trained judges (8 females, 7 males), ages 23-36 years were screened and selected (2 sessions) for their sensory ability and trained (4 sessions) for descriptive analysis. The training was held for 1-2 hour's sessions a week for four weeks until satisfactory discrimination, reproducibility and concept alignment were achieved. Reference standards are provided to help panelists with specific descriptors. To generate a descriptive language for passion fruit, panelists were provided with passion fruit (*P. edulis* Sims) and asked to list the sensory characteristics that they consider important to describing the samples. Terminology characterizing sensory attributes were developed from panelists' opinion. Descriptors with similar meanings were grouped, and finally, a consensus list of 18 terms was chosen to describe *P. quadrangularis*. The intensity of the attributes was rated on 5 cm scale lines (0-5 cm) labeled with not detected at 0 and extremely high at 5 cm on the end of the scale. The panels sat in individual booths and were asked to score the sensory properties of *P. quadrangularis*. For each session, the prepared samples (pulp and mesocarp at two different maturities) were given to the panels for testing. Three sessions were carried out to obtain a mean value for each sample. Panelists were provided with water to clear their palates in between samples.

2.6. Consumer tests

Three fresh fruits (mesocarp and pulp) of *P. quadrangularis* at two different maturities (50 and 60 DAA) were harvested and delivered directly from the orchard to the laboratory. Each fruit mesocarp was cut into half longitudinally and further cut into ten pieces, and the peel was removed. The pulps also were separated from the mesocarp. Each piece was cut into small cubes with approximately 1-cm thickness, and the pulp was kept at 4ºC prior to serving. All the pieces obtained were placed together in a large plastic container and thoroughly mixed. Then the samples of mesocarp pieces were distributed into a plastic container with a lid. Two pieces were served at room temperature (20ºC) to each consumer per sample. Similarly, the pulps were also combined, and then samples of the pulps with 5 g of were distributed into a plastic container with a lid. Water was provided for cleansing the palate between samples. Forty consumers were selected randomly for testing. Consumers were instructed to score the overall degree of liking of each sample, followed by a degree of liking for appearance, texture, taste, and smell on the 5-point hedonic scale from 1="dislike" to 5="like extremely".

2.7. Sample preparation

Ten fully ripe (15 kg) fruits of *P. quadrangularis* (60 days after anthesis) were harvested randomly from a passion fruit farm. At this stage, the fruits, suitable to consume fresh, were dissected into half with the pulp separated from the mesocarp. The mesocarp and pulp were dried in an oven at 60ºC until weight loss stabilized, where the dried samples were homogenized into a fine powder using a conventional blender, followed by sample storage in airtight containers prior to analyses.

2.8. Nutritional composition

Proximate analyses of crude fibre composition, crude lipid, crude protein, ash, and moisture of the mesocarp and pulp of *P. quadrangularis* were measured through the standard approaches of the [19]. The moisture content of the fruit sample was determined by drying the sample until a constant weight was obtained. Ash value was determined by incinerating samples in a muffle furnace at 550ºC for 5-6 hours (method 930.05, [19]). The crude protein content was measured through the multiplication of the nitrogen content acquired from the samples through Kjeltec™ 2200 Auto Distillation Unit by a factor of 6.25 (Hoganas, Sweden) (method 955.04, [19]). Crude lipid was measured using the Soxtec Avanti 2055 Manual System (Hoganas, Sweden) (method 920.39, [19]), while crude fibre was calculated by acid-base digestion according to method 993.19 [19]. Estimation of the carbohydrate was performed in terms of differences through the subtraction of the overall percentage of crude protein, lipid, fibre, ash, and moisture from 100% dry weight (DW).

2.9. Statistical analysis

Data for physicochemical properties and nutritional composition were statistically analysed using SAS 9.4 Windows software (SAS Institute Inc, Cary, USA). Means were compared using single-factor analysis of variance (ANOVA). Post hoc Tukey's test ($p < 0.05$) was performed if the ANOVA result was significant. For sensory attributes and consumer acceptance of demographic data in the survey responses were analysed by simple frequency and percentages (%). Mean data on the descriptive analysis by the panelist were analysed using spider web in Excel. Principle component analysis (PCA) was carried out using XLSTAT software (Addinsoft, New York, USA) on sensory attributes and descriptive ratings to study the interrelationship among the attributes. Multiple correlation analysis was performed to determine relationships between the sensory attributes and fruit characteristics. Consumer hedonic ratings were analysed to assess differences in liking among consumers. The matrix of hedonic ratings of samples across consumers was then analysed by PCA for Internal Preference Mapping (IPM).

3. Results and Discussion

3.1. Fruit development and maturity indexes

Passion fruit (Passifloraceae) matures on vines after 60 to 75 days of flowering, while the skin colour is used as a maturity index for fresh market consumption [20]. The skin of passion fruit commonly changes from green to purple, red, yellow, or orange when ripen [12]. However, the skin of the fruit of *P. quadrangularis* does not develop any distinct pigmentation when matured. To determine the correct maturing stage and subsequently harvesting time, the data based on the skin colour changes, and the general properties of the fruit were examined. The development of the fruit began three days after anthesis. This observation was synchronised with other passion fruits plants, as reported by Nave *et al.* [21] and Ramaiya *et al.* [22]. *Passiflora quadrangularis* exhibited a growth pattern of a simple sigmoid curve (Figure 1). On day 40, the fruit showed a decline in growth rate as it entered the maturity stage. At the ripening stage, the weight of the fruit gradually increased due to the complete development of pulp, mesocarp, and seeds.

It was found that the fruits of *P. quadrangularis* required 58 to 60 days from anthesis to achieve full maturity. This duration was slightly faster, compared to the common passion fruit; *P. edulis* Sims, which requires 60 to 65 days to fully ripen [23]. The pericarp of *P. quadrangularis* fruits, which contains the arils, is formed by three distinct tissues, namely 1) an external epidermis, which is the green to yellowish peel, 2) a mesocarp, thick, juicy, and sweet flesh, with the texture and taste similar to honeydew, and 3) the endocarp, which is separated from the mesocarp by an aerenchymatous tissue and parenchymatous tissues, which is also known as the placental region. The parenchymatous tissues contain numerous funiculi directed towards the locular cavity. In other passion fruit species, the non-edible mesocarp is white and spongy parenchyma, with the thickness varying with maturity [24].

Three stages of *P. quadrangularis* fruits development were identified in this study. In stage 1, fruit initiation began at the fruit set, in which the fruit growth through cell division and cell expansion took place. Notably, both the length and diameter showed sharp increased at day 10 to 15 after anthesis, followed by development until the maximum length was reached. Following this was stage 2, which involved fruit expansion and maturation, including the expansion of the arils. Stage 2 led to the formation of a “juice sac”, which contains white juice, pulp, and seeds. The arils were oriented in four rows longitudinally at the positions of the endocarp wall. The next stage was stage 3, which involved ripening, softening, and colouring of the fruit, and the accumulation of soluble solids and acids. Moreover, the maximum size and weight of the juice sac were obtained at stage 3. When the size and volume of the juice sac increased, the foretop became roundish, while the membrane became notable slender. *Passiflora quadrangularis* produces fruit (19.80-24.10 cm x 13.00-14.80 cm) with an oblong shape and ~2.0 kg average weight.

To determine the correct harvesting stage, the index of maturity should be non-destructive and ideally factual instead of being arbitrary and giving an actual contribution to the commodity quality and post-harvest shelf-life [25]. The data on the chemical properties of *P. quadrangularis* highlighted the fruit firmness, and juice and mesocarp Brix, pH, and acidity from day 40 to 65 (Table 1). The firmness of the fruit amounted to 12.02±0.26 N on day 40, which gradually decreased to 1.89±0.14 N on day 65 when the fruit is overripened. Harvest and raw consumption of the fruit between days 40 to 50 are not recommended, as the mesocarp of the fruit is hard and unpalatable. On day 50, the fruit was suitable for cooking as a vegetable, while on day 60, it was ideal for fresh juice consumption, juice production, and raw consumption of the mesocarp. However, the fruits were overripened at 65 days after anthesis, resulting in an excessively soft fruit texture. Nevertheless, the pulp remained suitable for fresh juice production with a sweet flavour. The TSS of the pulp and mesocarp gradually increased over time ranging from 7.57±0.15 °Brix (day 40) to 15.03±0.12 °Brix (day 65) for pulp and 1.90±0.06 Brix (day 40) to 6.27±0.09 °Brix (day 65) for mesocarp. The increase in °Brix content was possibly caused by the reduction of starch during the next phase of maturation and the high rate of metabolic transformations in soluble compounds [10,26,27].

The pH of the pulp slightly decreased from day 40 to 65 from 3.98±0.01 to 3.74±0.04. The mesocarp was less acidic than the pulp, with a gradual decrease from 5.55±0.03 to 5.13±0.01 over time. This was followed by a decrease in the total titratable acidity (TTA) of the pulp and mesocarp from day 40 to day 65. Furthermore, °Brix/acid ratio was identified as the ideal objective measurement indicating the consumer’s acceptability and could be employed as a useful instrument to determine the ideal harvesting phase of passion fruit. The harvesting stage from day 55 to day 65 fulfilled the standard of Brazilian legislation (e.g., glucose < 18.00 g 100 g^{-1}, 11 ºBrix, and pH values ranging from 2.7 to 3.8, which met the standard of *Passiflora* fruit pulp [28].

Fruit skin colour is one of the indicators determining the maturity of passion fruit. Based on the differences between the fruit colouration (L^* a^* b^* values) shown in Table 2, a negative value was observed for the skin of the fruit on days 45 to 55, which amounted -5.63 to -0.33. The negative value for a^* implies a reduced quality of the chlorophyll and pigmentation synthesis of deep green and light green from day 40 to day 45. At this point, the green pigmentation started to deplete, while the light green and light-yellow pigmentation developed on day 50. Light yellow, yellow, and light green pigmentation could be observed when the fruit matured on day 60.

For the fruit skin, it was observed that the lightness (L^*) decreased upon the fading of the deep green colouration. While the pulp developed orange pigmentation on day 55 and formed deep orange colour on day 60 showed increased trend in the L^* values. The changes in the ripening and maturity of *P. quadrangularis* were contradictory to the ripening and maturity of other *Passiflora* species. According to Patel *et al.* [29], *P. edulis* f. *flavicarpa* showed a transition from green until day 20 after anthesis to dark green around day 48, followed by bright green, greenish-yellow, and bright yellow at 62, 69, and 83 days after anthesis, respectively.

3.2. Sensory characteristics of Passiflora quadrangularis at two maturity stages by trained panelists

Quantitative descriptive analysis (QDA) was used to evaluate the sensory profile of the *Passiflora quadrangularis* at two different maturity stages. The general terms include appearance, taste, aroma, and texture preference by the panelist are presented in Figure 2. Sweet, juicy with a little sourish were used to describe the taste of the mesocarp of the fully ripened fruits (day 60), while crunchy with mild sweetness used to explain the taste of the mesocarp of the fully matured fruits (day 50) (Figure 2a). Besides, the pulp of fully matured fruits has the attractive colour of orange and has a sweet with sourish taste. In contrast, unripe fruits’ pulp is white in colour and highly sourish (Figure 2b).

The relationship between the physicochemical properties and the sensory profiling was explained in PCA biplots (Figure 3). The first two PC’s accounted for 90.39% of the total variance. PC1 explained the higher percentage of the total variance, which was 52.75%, compared to PC2, which was 37.64%. The studied samples were clustered into four main groups. Group 1 consisted of the mesocarp of the fruit harvested at day 60, which was highly associated with its uneven surface colour, with a fibrous, juicy, and sweet taste. This shows the mesocarp is suitable to be consumed fresh.

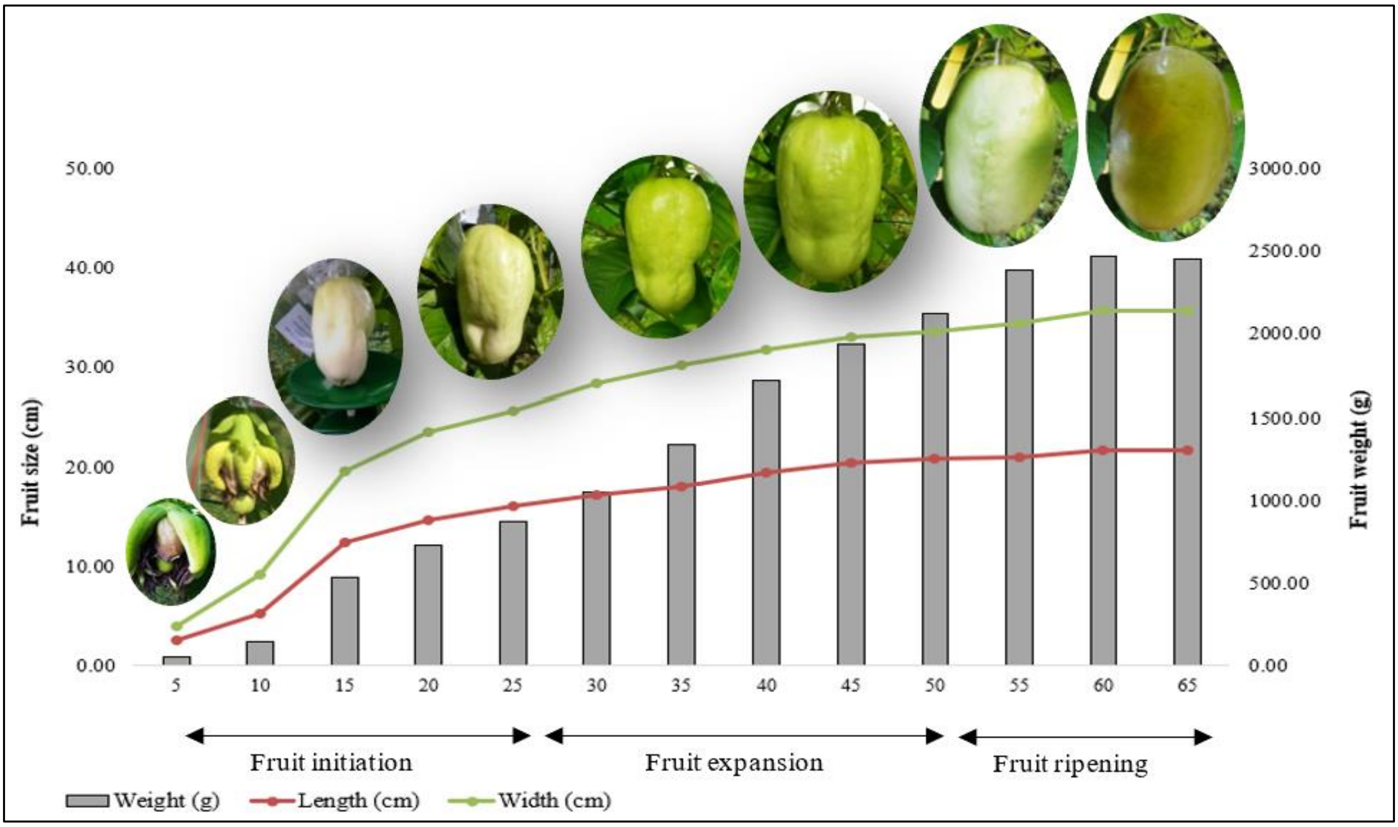

Figure 1. Fruit development of *P. quadrangularis* fruit based on their weight, length, and width

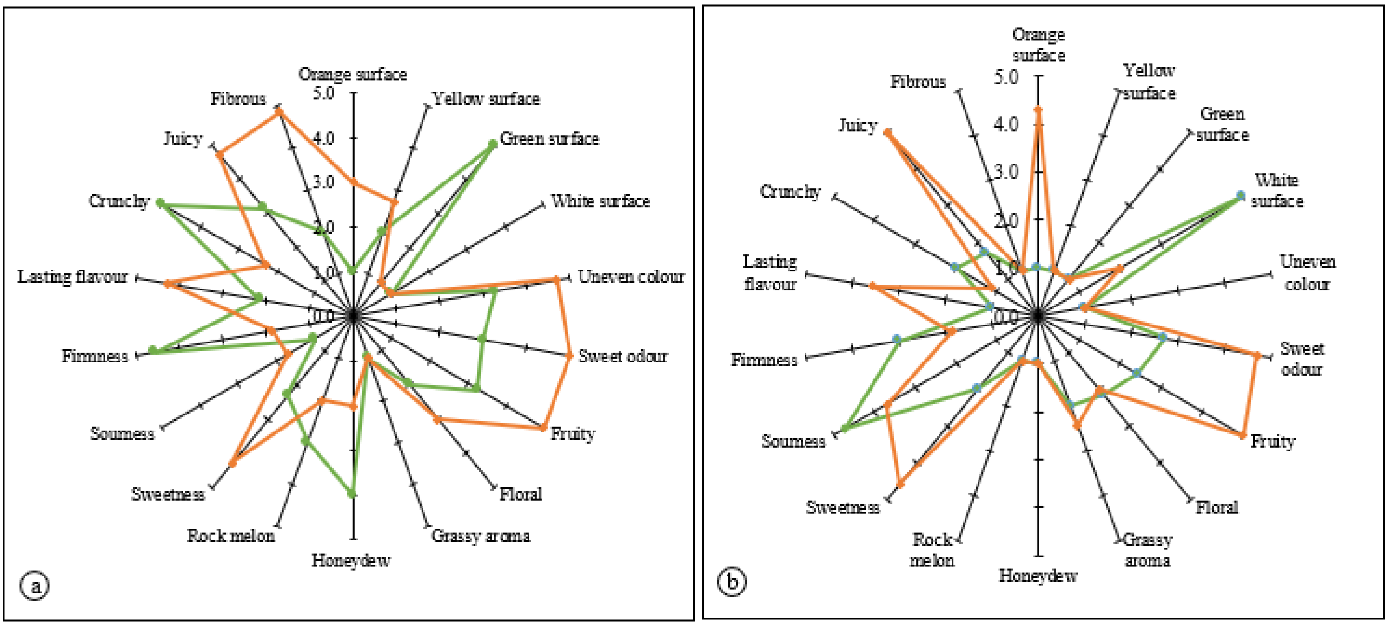

Figure 2. Comparison of sensory profiles composed of average scores of 18 attributes identified in *Passiflora quadrangularis* (a) mesocarp and (b) pulp at two different maturity stages; green line-harvested at day 50 and orange line-harvested at day 60 after anthesis

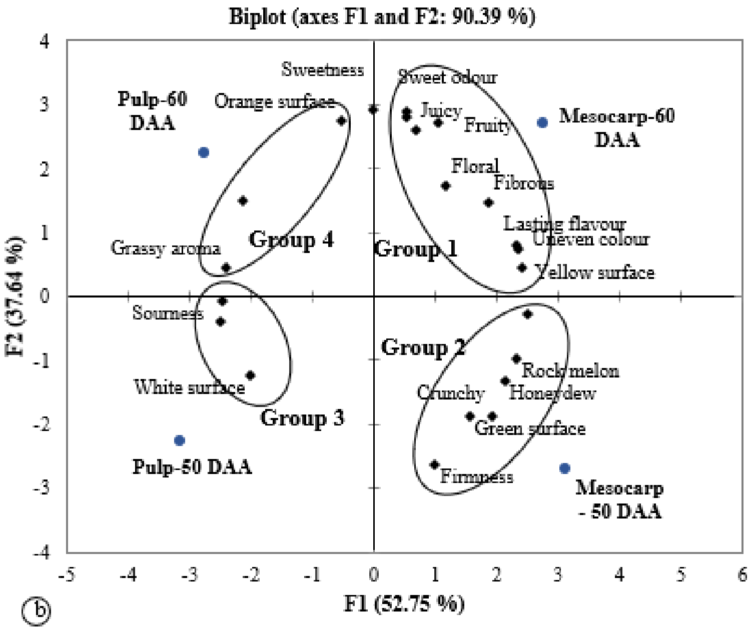

Figure 3. Plot of sensory profiling properties of *Passiflora quadrangularis.* Position of PC score of *Passiflora quadrangularis* according to PC1 and PC2

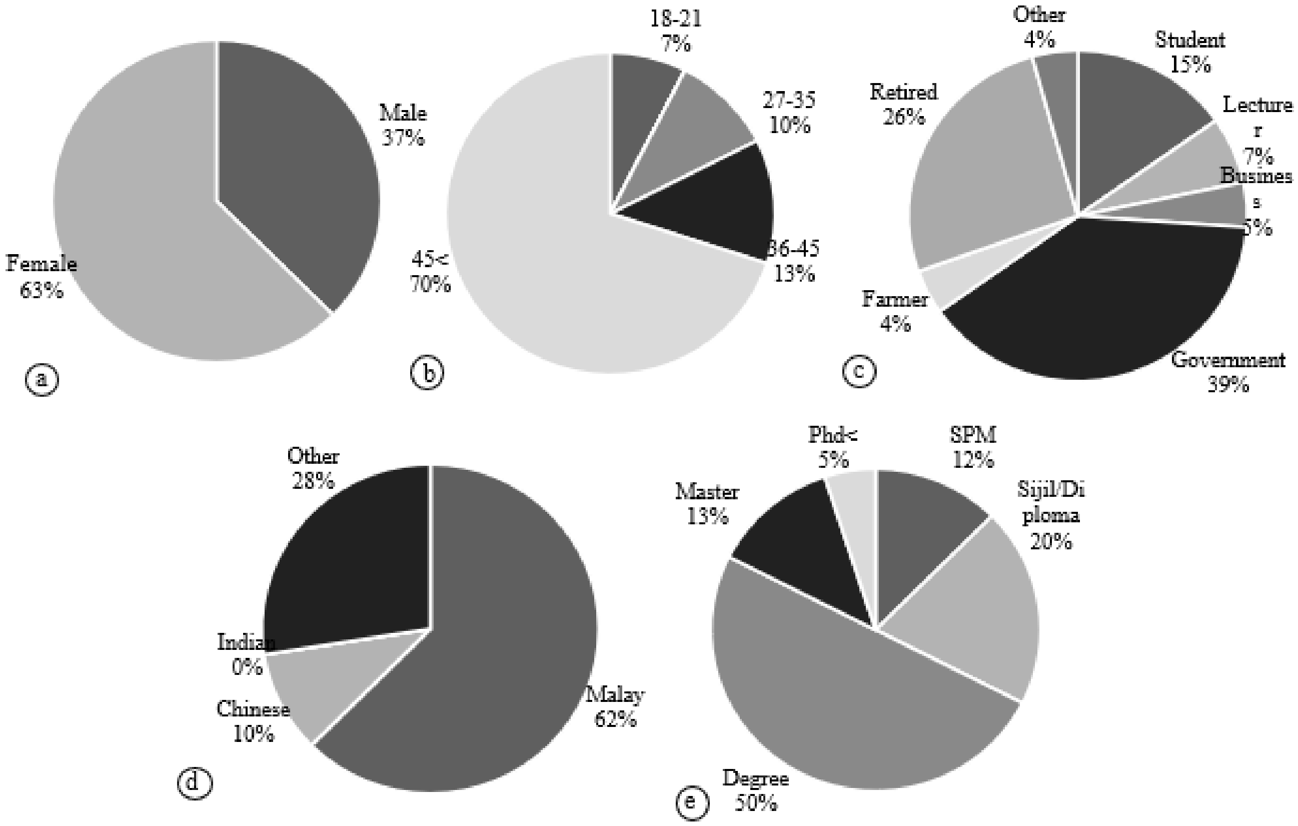

Figure 4. Demographic information of the 40 respondents; (a) gender, (b) age, (c) occupation, (d) ethic, and (e) education level

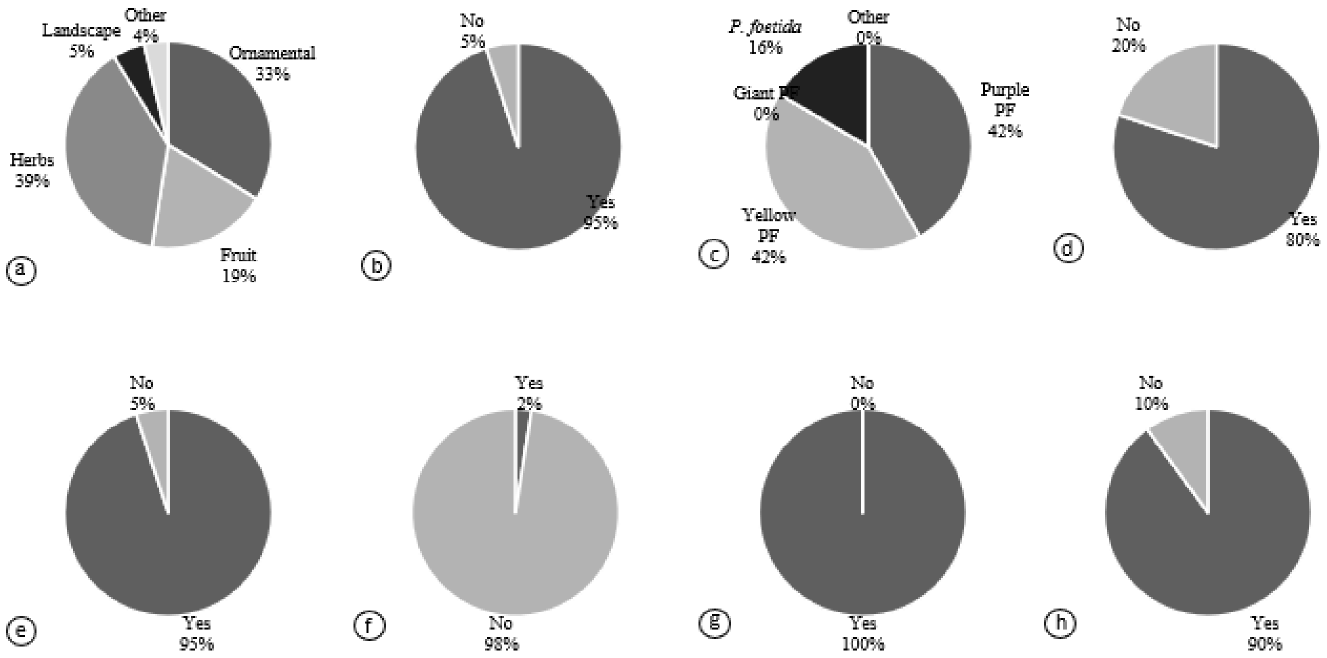

Figure 5. Perception and acceptance of passion fruit among the respondents; (a) uses of passion fruit, (b) know about passion fruit, (c) passion fruit species that respondents familiar with, (d) have consume passion fruit, (e) acceptability of the taste of the *P. quadrangularis*, (f) *P. quadrangularis* have potential to be commercialised in Malaysia, (g) this fruit is suitable to be make products, and (h) interest in cultivating the *P. quadrangularis*

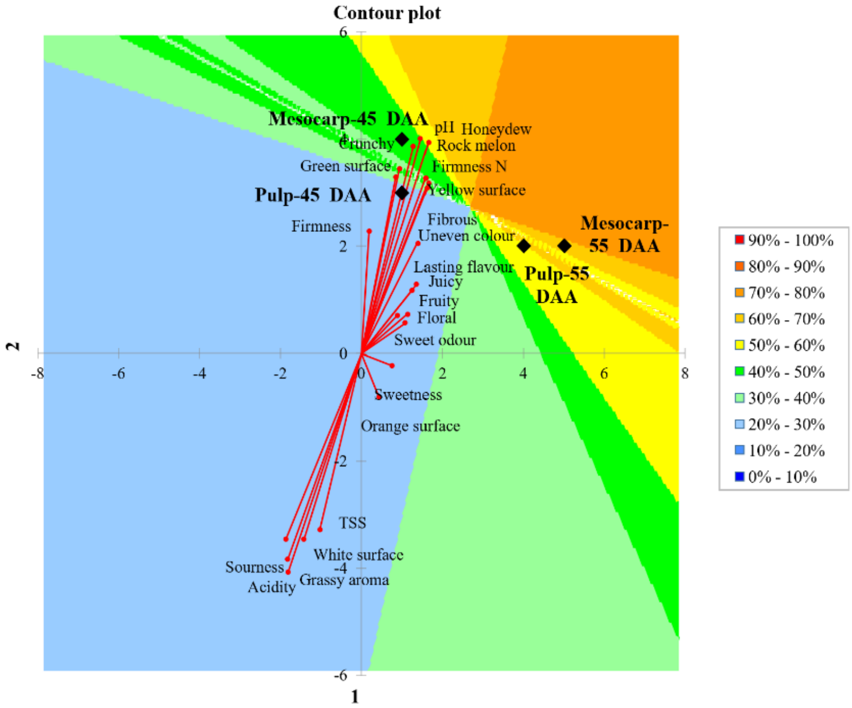

Figure 6. Matrix of hedonic ratings on the acceptability of *Passiflora quadrangularis* fruits parts among the consumers at different maturity

Table 1. Physicochemical characteristics of the fruits of *P. quadrangularis* based on different days of maturation

Variables	**40**	**45**	**50**	**55**	**60**	**65**
Firmness (N)	12.02±0.26^{a}	10.25±0.61^{b}	9.49±0.16^{bc}	7.58±0.28^{c}	4.33±0.10^{d}	1.89±0.14^{d}
TSS-pulp (°Brix)	7.57±0.15^{d}	8.17±0.03^{d}	10.40±0.21^{c}	12.90±0.26^{b}	14.57±0.33^{d}	15.03±0.12^{a}
TSS-mesocarp (°Brix)	1.90±0.06^{d}	2.03±0.03^{d}	3.57±0.30^{c}	5.47±0.18^{b}	5.93±0.09^{a}	6.27±0.09^{a}
pH-pulp	3.98±0.01^{a}	3.97±0.01^{a}	3.89±0.06^{b}	3.84±0.02^{b}	3.76±0.02^{c}	3.74±0.04^{c}
pH-mesocarp	5.55±0.03^{a}	5.34±0.05^{b}	5.28±0.01^{bc}	5.19±0.02^{cd}	5.14±0.02^{d}	5.13±0.01^{d}
TTA-pulp (%)	2.04±0.02^{a}	1.41±0.04^{b}	1.15±0.01^{c}	1.09±0.01^{c}	1.04±0.04^{c}	0.82±0.04^{d}
TTA-mesocarp (%)	0.06±0.01^{a}	0.05±0.003^{ab}	0.05±0.01^{abc}	0.03±0.01^{c}	0.04±0.01^{bc}	0.03±0.01^{c}
Brix/acid (pulp)	3.71	5.79	9.04	11.83	14.42	18.32
Brix/acid (mesocarp)	31.66	40.60	71.40	182.33	148.25	209.00

Different superscript letters in the same row indicate significant differences ($p < 0.05$, ANOVA, Tukey's test). TSS-Total soluble solids; TTA- Total titratable acidity

Table 2. Changes on the *L* a* b** values on the skin, mesocarp and pulp of *P. quadrangularis*

Variables		**40**	**45**	**50**	**55**	**60**	**65**
Skin	*L**	76.20	68.73	65.10	55.10	50.78	46.90
	*a**	0.50	-5.63	-1.27	-0.33	10.17	15.77
	*b**	7.57	27.93	30.87	33.3	39.85	45.5
	Visual	DG + LG	DG + LG	LG	LG	LY + LG	LY + Y
Mesocarp	*L**	69.7	61.43	58.7	54.57	60.85	65.27
	*a**	3.33	2.36	0.8	0.8	0.7	0.63
	*b**	29.5	11.43	9.90	7.97	6.45	5.17
	Visual	W	W	W + LY	W + LY	W + LY	W + LY
Pulp	*L**	48.63	49.07	49.97	54.23	55.11	55.43
	*a**	0.40	0.47	0.90	1.73	2.04	2.23
	*b**	0.40	0.83	1.17	2.23	2.84	3.06
	Visual	W	W	LO	O	DO	DO
Pulp colour							
Skin colour							

*L**-lightness, *a**-redness, *b**-yellowness, DG-deep green, LG-light green, LY-light yellow, Y-yellow, W-whitish, LO-light orange, O-orange and DO-deep orange

Table 3. Proximate composition (% per 100 g of DW) of ripen *P. quadrangularis* fruit

Parts	Pulp	Mesocarp	Seeds
Moisture	85.77±0.33[a]	86.55±0.46[a]	11.21±0.39[b]
Ash	1.63±0.15[b]	1.08±0.04[c]	5.45±0.10[a]
Protein	2.55±0.14[b]	0.93±0.05[c]	12.17±0.21[a]
Fibre	2.36±0.07[c]	7.63±0.20[b]	22.39±0.30[a]
Fat	0.33±0.01[b]	0.22±0.02[b]	16.62±1.96[a]
Carbohydrate	7.36±0.21[b]	3.59±0.57[b]	32.17±1.89[a]
Trend	M > C > P > Fi > A > F	M > Fi > C > A > P > F	C > Fi > F > P > M > A

Different superscript letters in the same row indicate significant differences ($p < 0.05$, ANOVA, Tukey's test). M-moisture, A-ash, P-protein, F-fat, Fi-fibre and C-carbohydrate

Group 2 consisted of mesocarp harvested at day 50, where the fruit was still firmed and had a crunchy texture. Therefore, the panels suggested that fruit at this stage is suitable to be cooked as other melons. The pulp of the fruit harvested on day 45 is the only member of Group 3 that possessed higher sourness and less attractiveness. This pulp can be cooked with its unripe mesocarp in making the dishes like salad. While Group 4 comprised the pulp from fruit harvest at day 60 (fully ripen), which an attractive appearance and possesses a sweet and grassy aroma, suitable to be consumed as fresh juice or making products.

3.3. Consumer preference of Passiflora quadrangularis

Figure 4 presents the demographic data of the 40 respondents. The respondents were 62.50% female and 37.50%, male. The consumers in our study were mostly adults (70%) with an age group of more than 45 years old, and 12.5% of them were from 36 to 45 years old. Majority of the respondents were Malay (62.50%), followed by the Chinese, about 10%. Most respondents were interested in planting ornamental plants (67.50%) and herbs (77.50%) for their self-consumption. Based on the survey conducted (Figure 5), 95% of the respondents were very well known about the presence of popular passion fruits, *i.e.,* purple passion fruit (42.00%), yellow passion fruit (42.00%) and *P. foetida* (16.00%). However, none of the respondents were aware of the presence of the studied species. Generally, 95.00% ever tasted the purple passion fruit, and 80% preferred the taste of the fruit.

According to most respondents (75.00%), the ripened mesocarp of *P. quadrangularis* tastes like honeydew and has an excellent taste to be consumed. 92.50% responded that *P. quadrangularis* fruits were attractive and would buy them from supermarkets. The fruit of *P. quadrangularis* is used to treat stomach aches, prevent scurvy, alleviate asthma, relieve insomnia and anxiety, and sedative [30]. This shows that efforts should be made through publicity to make this fruit popular. Besides, they agreed if the fruit upgraded into a product either as a food or health supplement. Eventually, all the respondents agreed that these species hold great market potential. The matrix of hedonic ratings on the acceptability of *P. quadrangularis* fruits among the consumers was analysed by PCA and presented in Internal Preference Mapping (IPM) (Figure 6). The IPM showed that consumers highly preferred the mesocarp of fully ripened fruits with 70-80%, while the pulp is also highly accepted with the matrix of 60-70%. However, the hedonic ratings for unripen mesocarp and pulp were within the range of 20-30% and 40-50%, respectively, therefore, it is suggested to be cooked as a vegetable.

3.4. Nutrient composition of ripened fruit

The fruit of *P. quadrangularis* is an important edible part of the plant due to its potential health benefits [31]. There has been an increasing interest in the fruit composition over the past few years. Researchers highlighted that the nutrients found in fruit have increased capabilities besides preventing deficiency diseases. Therefore, the maturity level or stage of harvested commodities can impact the shelf-life and quality of the fruit [32,33]. The results of the proximate composition of *P. quadrangularis* fruit parts are presented in Table 3. The proximate composition in the pulp, mesocarp, and seed of *P. quadrangularis* was statistically different ($p<0.05$) and expressed in percentage (%). Furthermore, the proximate content of pulp was presented as moisture > carbohydrate > protein > fibre > ash > fat, while the mesocarp was illustrated as moisture > fibre > carbohydrate > ash > protein > fat. The trend for the seed is presented as carbohydrate > fibre > fat > protein > moisture > ash.

Higher moisture content was recorded for mesocarp and pulp, with 86.55±0.46% and 85.77±0.33%, respectively. The moisture content in the pulp of *P. quadrangularis* was slightly higher compared to the reported values for *P. edulis* Sims (72.93%, [6]) and *P. edulis* f. *flavicarpa* (84.21% [34]). Furthermore, the energy value for fruits was inversely proportional to the available moisture content [35]. The ash content differed significantly ($p<0.05$) among pulp, mesocarp, and seeds. The higher ash content of 5.45±0.10% was recorded in the seeds, followed by the pulp (1.63±0.15%) and mesocarp (1.08±0.04%). Based on the comparison between the ash content of purple passion fruit (0.80%), oranges (0.23%), and pineapple (0.22%) [36], it possessed lower ash content compared to *P. quadrangularis*.

The protein content of pulp (2.55±0.14%) was significantly higher compared to the mesocarp (0.93±0.05%) (Table 3). The same content was found for *P. edulis* (Purple), as recorded by USDA [36] and Ramaiya *et al.* [6] at 2.20% and 2.81%, respectively, while *P. edulis* f. *flavicarpa* had two or three times less protein at 0.67% [36]. Similarly, the seeds possess higher protein content (12.17±0.21%). Moreover, lipids or fats are necessary as they provide carotenoids and energy and assist in absorbing and transporting fat-soluble vitamins through the intestine [37]. The seeds of *P. quadrangularis* contained higher crude fat (16.62±1.96%) compared to the pulp (0.33±0.01%) and mesocarp (0.22±0.02%), which is slightly lower than the seeds of *P. edulis*. These seeds have exhibited an oil content ranging from 18.5% to 29.4% [38,39,40].

The fibre content of *P. quadrangularis* seeds (22.39±0.30%) was substantially higher than that of the mesocarp and pulp at 7.63±0.20% and 2.36±0.07%, respectively. This is comparable with pineapple, which was two times lower (1.40%) compared to the pulp of *P. quadrangularis*. While the mesocarp of *Cucumis melo* (0.14%) [36] has a lower fibre content than the mesocarp of *P. quadrangularis*. The seed and pulp of passion fruit can be consumed to relieve constipation [41]. Sufficient consumption of dietary fibre could reduce the possibility for coronary heart disease, constipation, serum cholesterol levels, and hypertension [42]. Notably, higher carbohydrate content was found in seeds (32.17±1.89%), while the pulp content was at 7.36±0.21% and a minimum of 3.59±0.57% for the mesocarp. The carbohydrate content in the mesocarp of *P. quadrangularis* is suitable to be consumed by people with diabetes and hypertension, where low-sugar diets are required. According to Vicente *et al.* [43], carbohydrates from the fruit could act as a supplement of scarce cereals.

4. Conclusion

It was found that the optimum harvesting period of *P. quadrangularis* was 55-60 days after anthesis to be consumed as a fresh, both mesocarp and pulp. Meanwhile, fruits harvested at day 50 after anthesis are relatively hard, and the pulp was sour with low juice production and much more suitable for cooking vegetables. Notably, the findings could be useful for suggesting the correct harvesting time of *P. quadrangularis* fruit to deliver quality fruit for fresh consumption, which also benefits the intake of health-promoting compounds and processed product developments. The trained sensory panelists preferred fruit harvested at day 60 after anthesis, as evidenced by high scores on the unstructured scale line. Similarly, the consumers who preferred fully ripened fruits for direct consumption evidently showed a high acceptance score by the hedonic scale, while dishes suggested being prepared from unripe fruits. Results affirm the importance of harvest maturity on *P. quadrangularis* fruit quality attributes and overall consumer acceptance.

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