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Nutritional, mineral and organic acid composition of passion fruit (*Passiflora* species)

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Abstract

This study focused on proximate composition, mineral content and organic acid properties of fruit juices from four *Passiflora* species; *Passiflora edulis* (Purple), *Passiflora edulis* (Frederick), *Passiflora maliformis*, and *Passiflora quadrangularis* and the mesocarp of *Passiflora quadrangularis.* The moisture content varied between 84.37±0.63% in *P. edulis* (Frederick) to 86.63±0.33% in mesocarp of *P. quadrangularis.* The ash content of mesocarp of *P. quadrangularis* was significantly lower (0.51±0.02%) than its juice (1.37±0.14%). Among the *Passiflora* species, *P. edulis* (Purple) and *P. edulis* (Frederick) possessed higher protein, 2.81±0.19% and 2.40±0.11%, respectively. The fiber content in *P. quadrangularis* mesocarp was significantly higher (8.49±0.40%) than other juices. *Passiflora* fruits have fat content <0.5% in edible portion. The carbohydrate content of *Passiflora* fruit juices was not significantly different with ranged 6.57±0.29% in *P. quadrangularis* to 7.44±0.69% in *P. edulis* (Frederick). Additionally, a cup of 247 mL *Passiflora* juices provided ~34% of potassium, 60-80% Magnesium, >80% phosphorus and provides an adequate level of micronutrients especially Ferum content which is 90% of daily recommended allowance of minerals. The major organic acid in *Passiflora* fruit juice was citric acid and ranged 1137.00±0.13 mg 100 g^{-1} in *P. quadrangularis* to 1487.30±0.28 mg 100 g^{-1} in *P. edulis* (Purple). Malic acid was second abundant organic acid with 156.00±0.07 mg 100 g^{-1} in *P. edulis* (Frederick) to 502.30±0.07 mg 100 g^{-1} in *P. quadrangularis*. Apart from the common species of *Passiflora edulis*, other lesser known *Passiflora* species are also gaining visibility in drinks, food and health promoter.

1. Introduction

Passiflora fruit also known as passion fruit is an exotic fruit that is popular for the startling beauty of its flower and fruity aroma. The main dispersal area extends over Central America and South America (Vanderplank, 2000; Krosnick and Freudenstein, 2005). Although 50 species bear edible fruits, only two forms of *Passiflora edulis*; i.e., *Passiflora edulis* (Purple passion fruit) and *Passiflora edulis* f. *flavicarpa* (Yellow passion fruit) are widely cultivated in commercial scale. The other species, e.g., *Passiflora quadrangularis, Passiflora incarnata, Passiflora ligularis* and *Passiflora laurifolia* are also cultivated in small scale for local consumption in certain countries.

In Peninsular Malaysia, the first record reported on the growing of *Passiflora* vines was in 1914 in small scale at Gunung Angsi, Negeri Sembilan. In the 1960s the *Passiflora* plants were grown in Ayer Hitam (Johor) and Cameron Highlands (Pahang) which were extended to be a commercial scale and the vines were successfully fruited (Chai, 1979). Thereafter, the *P. edulis* f. *flavicarpa* fruit production in these regions has been affected by a passion fruit woodiness diseases (PWD) which discouraged further expansion in commercial planting (Chai, 1979). However, in recent years this fruit is cultivated extensively due to prevalence of suitable growing conditions (Ramaiya *et al.,* 2013) and also increasing demand for passion fruits in the local markets. This provide earning opportunities for local farmers and there is an immense potentiality of boosting passion fruit industry in Malaysia (Ramaiya *et al.,* 2018). The region

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has good climate with sufficient rainfall and warm temperature with little variation in the photoperiod for growing a variety of horticultural crops very successfully.

It enters international trade mainly in the form of juice for fresh fruit (Bernacci *et al.,* 2008). The juice is much concentrated and it is highly palatable beverage when diluted and sweetened. *Passiflora* juices are also used in other products, i.e., jelly, jam, sherbets, ice creams and yogurt. *Passiflora edulis* fruits also known as "Multivitamin juice" in Germany after apple juice (Fainsod, 2001). The *Passiflora* fruit being popular and accepted worldwide due to its fresh, unique aroma and flavor which are the results of natural combinations of volatile constituents in a well-balanced system including of minerals, sugar, organic acids and phenolic compounds.

The physical and chemical composition of *Passiflora* fruit can vary according to cultivars, environmental factors including climate and soil condition and agricultural practices (Macrae *et al.,* 2007). The quantitative information about the fruit's content are the most important factors to verify the authenticity and quality index for fruits used in food manufacturing (Chavan and Kadam, 1995; Liu *et al.,* 2006; Kelebek and Selli, 2011). Demands for *Passiflora* fruit juice are increasing not only because of the organoleptic properties but also due to its essential nutrients content. *Passiflora* fruit is a very good source of fiber, minerals especially potassium and it is low in sodium, yields zero cholesterol and possessed good amount of phenolic and ascorbic acid content (Sandi *et al.,* 2004). The organic acid composition of fruits is also of interest because of its important influence on the sensory properties of fruit juices and considered very vital for food and beverage technology for quality evaluation (Hasib *et al.,* 2002). Accurate knowledge of organic acid levels might be useful for determining the percentage juice and also for detecting misbranding or adulteration in fruit juices, since each fruit has a unique pattern of organic acids.

The physicochemical properties of *Passiflora* fruit has been investigated by researchers from various geographical locations on the most important commercial *Passiflora* fruits; *P. edulis* f. *flavicarpa* (Sandi *et al.,* 2004; Sema and Maiti, 2011; Janzantti *et al.,* 2012; Macoris *et al.,* 2012) and *P. edulis* (Frank *et al.,* 2006; Kishore *et al.,* 2011). However scientific research has not kept up with this expansion and recently greater attention is being directed to other lesser known *Passiflora* species as well. Thus, this led to the interest in researching this plant species. Therefore, the aim of this study was to determine the proximate, minerals and organic acid compositions of fruit juices come from *Passiflora* fruit species cultivated in local tropical climate. Evaluating their nutritional status can help to understand the worth of this fruit to be processed as juice and other processed products.

2. Materials and methods

2.1 Fruit harvest and storage

Five to ten kilograms (≃70-150 fruits) vine-ripened fruits (based on fruit's skin colour and firmness) of *P. edulis* (Purple), *P. edulis* (Frederick)*, P. maliformis* and about 50 kg (thirty fruits) *P. quadrangularis* were harvested randomly from twenty plants for each species at the *Passiflora* fruit farm, Universiti Putra Malaysia Bintulu Sarawak Campus, Sarawak during the fruit-bearing seasons. The fruits were brought to the laboratory and immediately inspected and cleaned with distilled water. Fruits were dissected into half and the pulps were scooped with a spoon. The pulps were mechanically separated from the seeds. The pulps were oven dried at 60ºC until constant weight was obtained and all the dried samples were homogenized to a fine powder and stored in airtight containers.

2.2 Determination of proximate composition in Passiflora fruit juices

Proximate analysis for the juice of *Passiflora* species; moisture content, ash, crude protein, crude lipid and crude fiber composition were determined using the standard methods of the Association of Official Analytical Chemists (AOAC, 2000) as described below. The moisture content of the juice sample was determined by drying the sample until constant weight was obtained based on Osborne and Voogt (1978). Ash value was determined by incinerating air-dried samples in a muffle furnace at 550ºC for 5-6 hours (method 930.05). The percentage of crude protein content was determined by multiplying the percentage of nitrogen content obtained from the samples using Kjeltec Auto Distillation 2200 Foss by a factor of 6.25 (method 955.04). The crude lipid was extracted using petroleum ether from the samples. Crude lipid was determined using 2055 Soxtec Avanti Manual System, Sweden (method 920.39). Crude fiber was estimated by acid-base digestion based on method 993.19. The seeds were also analyzed for total dietary fiber (method 985.29), insoluble fiber and soluble fiber (method 991.43) were according to an enzymatic-gravimetric procedure. Available carbohydrate was estimated by difference, by subtracting the total sum of percent crude protein, crude lipid, crude fiber, ash and moisture from 100% dry weight (DW) basis of the seeds.

2.3 Determination of mineral content in Passiflora fruit juice

The ash obtained from the determination of ash content was used to extract the minerals using the dry-ashing method as following the AOAC (2000). The mineral elements; calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), iron (Fe), zinc (Zn), copper (Cu) and manganese (Mn) concentration were determined by atomic absorbance spectrophotometer (AA800 Perkin-Elmer, Germany based on method 975.03) with each determination was performed in triplicate. Phosphorus (P) was determined by colorimetric method using UV-VIS spectrophotometer (Murphy and Ridley, 1962).

2.4 Determination of organic acid in Passiflora fruit juice

Five (5) mL of pulp was centrifuged twice at 2 500 x *g* for 5 mins and at 20 000 x *g* for another 10 mins to separate the juice from pulp. The juices were then diluted at the proportion of 1:50 with mobile phase and kept refrigerated at 4°C until analysis. Prior to injection, all juices were filtered through 0.45 µm pore size membrane filter and 10 µL were used per injection. For organic acids analysis, a UV-Vis detector monitored at 210 nm and an Aminex HPX-87H column (300 x 7.8 mm) (Bio-Rad, U.S.A) was used. The column is a cation exchange column equipped with a cation H^+. The juices were isocratically separated through the column at a flow rate of 0.8 mL min^{-1}. The temperature of the column was set at to 65°C. Mobile phase was 0.013N H_2SO_4. Organic acids in juices were identified by comparing their retention times. The standard retention times for citric, malic, lactic and acetic acids were 7.3, 8.9, 12.0 and 14.4 min, respectively.

2.5 Statistical analysis

Mean, standard deviation and range were computed for triplicate determination. The data for proximate composition, mineral content and organic acids content were statistically analysed using SAS window programme 9.1 (SAS, Buckinghamshire, UK). Means were compared using single-factor ANOVA. Post-hoc Tukey's (p<0.05) was performed if the ANOVA result was significant.

3. Results and discussion

3.1 Proximate composition of Passiflora juices

Fruits have been a part of the human diet over the years. They contain high quantity of water, carbohydrate, sugars, vitamins, minerals and organic compounds which are required by the body to function well (Onibon *et al.,* 2007; Dimari and Hati, 2010). Nutritionist has advised that intake of least five portions of fruits and vegetable a day can help people to maintain good health, protecting them from heart disease, cancer, diabetes and kidney stones (Food Commission, 2009; USDA, 2011). For the fruit of *Passiflora* species is always used for its juicy pulp, while in *P. quadrangularis*, the fruit mesocarp is also eaten, which is unique. Its texture is like a guava, fleshy and a juicy like a melon and the taste is often mild sweetness.

The proximate compositions of the *Passiflora* fruit juices are presented in Table 1. The proximate content of *Passiflora* juices was categorically represented as moisture > carbohydrate > fiber > protein > ash > fat and this trend was contradictory to the mesocarp of *P. quadrangularis* which is categorically represented as moisture > carbohydrate > fiber > fat > protein > ash. The moisture content varied between 84.37±0.63% in *P. edulis* (Frederick) to 86.63±0.33% in mesocarp of *P. quadrangularis* with the remaining elements contributing to aroma, flavor and energy. The moisture content levels of the juices were comparatively higher which indicated them as a good source of medium for the functioning of enzymes and general metabolic processes. Moisture content is also important to both the stability and quality of juices. The ash content of mesocarp of *P. quadrangularis* was significantly lower (0.51±0.02%) than its juice (1.37±0.14%) and other *Passiflora* fruit juices studied. The ash content compared favourably with some fruits such as banana and guava but higher than the oranges (0.44%), papaya (0.39%) and pineapple (0.22%). Juice samples with a high percentage of ash contents imply that the fruit contains high concentrations of various mineral contents, which are anticipated to speed up metabolic actions and improve growth and development (Martin, 1997; Bello *et al.,* 2008). Generally, the *Passiflora* fruits possessed good protein and fiber compared to the other commercial fruits; i.e., pineapple, oranges, papaya and apple possessed lower values. The protein ranged from 1.13±0.11% to 2.81±0.19% for mesocarp of *P. quadrangularis* and *P. edulis* (Purple), respectively. A similar composition was observed for *P. edulis* (Purple) reported by USDA (2011) and NZ Passion Fruit Growers (2007), 2.20% and 2.80%, respectively. However, *P. edulis* f. *flavicarpa* possessed 2-3 times lower protein, 0.67% (USDA, 2011).

Besides, the fiber content in *P. quadrangularis* mesocarp was significantly higher (8.49±0.40%) than other investigated juices which ranged 2.40±0.11% to 4.31±0.31%. Basically, the commercial fruits content lower fiber (less than ~2.50%). Adequate intake of dietary fiber can lower the risk of coronary heart disease, serum cholesterol level, constipation, hypertension,

Table 1. Proximate composition (% per 100 g DW) of *Passiflora* juices accordingly to species

Species	Moisture content*	Ash	Crude protein	Crude fiber	Crude fat	Carbohydrate	Trend analysis	References
P. edulis (Purple)	85.45 ± 0.56^{ab} (84.34-86.12)	1.18 ± 0.11^{ab} (1.02-1.29)	2.81 ± 0.19^{a} (2.59-3.00)	4.31 ± 0.31^{b} (3.92-4.93)	0.50 ± 0.14^{a} (0.48-0.53)	6.95 ± 0.73^{a} (5.54-7.97)	M > C > Fi > P > A > F	This study
P. edulis (Frederick)	84.37 ± 0.63^{b} (83.50-85.60)	1.03 ± 0.03^{b} (0.94-1.12)	2.40 ± 0.11^{ab} (2.23-2.62)	3.47 ± 0.26^{bc} (3.19-3.99)	0.51 ± 0.10^{a} (0.49-0.53)	7.44 ± 0.69^{a} (6.50-8.81)	M > C > Fi > P > A > F	This study
P. maliformis	85.44 ± 0.36^{ab} (84.87-86.10)	0.91 ± 0.01^{b} (0.84-1.03)	2.20 ± 0.14^{b} (1.93-2.34)	3.63 ± 0.18^{b} (3.27-3.83)	0.45 ± 0.02^{b} (0.42-0.47)	7.17 ± 0.64^{a} (6.22-8.39)	M > C > Fi > P > A > F	This study
P. quadrangularis	86.16 ± 0.46^{ab} (85.34-86.92)	1.37 ± 0.14^{a} (1.16-1.42)	2.35 ± 0.09^{b} (2.05-2.35)	2.40 ± 0.11^{c} (2.17-2.52)	0.35 ± 0.01^{c} (0.33-0.37)	6.57 ± 0.29^{a} (6.03-6.61)	M > C > Fi > P > A > F	This study
P. quadrangularis (mesocarp)	86.63 ± 0.33^{a} (86.00-87.12)	0.51 ± 0.02^{c} (0.47-0.54)	1.13 ± 0.11^{c} (0.93-1.31)	8.49 ± 0.40^{a} (7.29-9.27)	0.24 ± 0.01^{d} (0.23-0.25)	3.00 ± 0.19^{b} (2.65-3.31)	M > C > Fi > F > P > A	This study
P. edulis	84.70	1.00	2.80	3.30	0.50	7.39	M > C > Fi > P > A > F	NZ Passion Fruit Growers (2007)
P. edulis flavicarpa	84.21	0.70	0.67	0.20	0.18	14.25	M > C > P > A > Fi > F	USDA (2011)

Different superscript alphabets in the same column indicate differences at $p<0.05$ (ANOVA, Tukey's test). Values are given as means (%) ± standard deviation and values in parenthesis are the range. * Wet weight basis. M-moisture, C-carbohydrate, Fi-fiber, P- protein, A-ash and F-fat composition.

Table 2. Macronutrient content (mg 100 g-1 DW) of Passiflora juices accordingly to species

Species	Ca	Mg	K	Na	P	Trend	References
P. edulis (Purple)	54.91 ± 79.49^{a} (54.00-56.50)	110.00 ± 87.79^{b} (100.00-127.50)	453.33 ± 32.87^{ns} (412.50-512.50)	37.50 ± 14.43^{ab} (35.00-40.00)	115.41 ± 53.19^{b} (100.00-117.50)	K > P > Mg > Ca > Na	This study
P. edulis (Frederick)	51.75 ± 72.17^{a} (50.50-53.00)	108.00 ± 52.04^{b} (112.50-130.00)	402.50 ± 42.56^{ns} (322.50-565.00)	20.83 ± 44.09^{b} (12.50-27.50)	117.92 ± 48.05^{b} (102.50-117.50)	K > P > Mg > Ca > Na	This study
P. maliformis	54.33 ± 58.33^{a} (53.25-55.25)	170.00 ± 76.38^{a} (155.00-180.00)	362.50 ± 25.25^{ns} (330.00-397.50)	39.17 ± 50.69^{ab} (30.00-47.50)	237.50 ± 36.08^{a} (231.25-243.75)	K > P > Mg > Ca > Na	This study
P. quadrangularis	44.50 ± 90.14^{b} (43.25-46.25)	107.52 ± 28.87^{b} (102.50-112.50)	408.67 ± 44.23^{ns} (393.50-437.50)	41.67 ± 80.47^{a} (31.25-47.50)	111.67 ± 58.33^{b} (102.50-122.50)	K > P > Mg > Ca > Na	This study
P. quadrangularis (mesocarp)	53.92 ± 97.33^{a} (52.25-57.00)	75.83 ± 30.05^{c} (71.40-80.80)	283.33 ± 8.33^{ns} (262.50-295.00)	3.58 ± 7.41^{c} (2.53-5.38)	77.08 ± 29.17^{c} (72.50-82.50)	K > P > Mg > Ca > Na	This study
P. edulis (Purple)	12.00	29.00	348.00	28.00	68.00	K > P > Mg > Na > Ca	USDA (2011)
P. edulis f. *flavicarpa*	4.00	17.00	278.00	6.00	25.00	K > P > Mg > Na > Ca	USDA (2011)
P. edulis	16.00	39.00	350.00	28.00	54.00	K > P > Mg > Na > Ca	NZ Passion Fruit Growers (2007)

Different superscript alphabets in the same column indicate differences at $p<0.05$ (ANOVA, Tukey's test). Values are given as means (%) ± standard deviation and values in parenthesis are the range. * Wet weight basis. M-moisture, C-carbohydrate, Fi-fiber, P- protein, A-ash and F-fat composition.

Table 3. Micronutrient content (mg 100 g^{-1} DW) of *Passiflora* juices accordingly to species

Species	Cu	Zn	Fe	Mn	Trend	References
P. edulis (Purple)	0.12 ± 0.29^{ab} (0.11-0.34)	0.30 ± 2.08^{b} (0.29-0.34)	3.13 ± 1.09^{a} (3.09-3.35)	nd	Fe > Zn > Cu > Mn	This study
P. edulis (Frederick)	0.11 ± 0.89^{ab} (0.09-0.13)	0.28 ± 1.53^{b} (0.25-0.30)	2.98 ± 0.93^{a} (2.84-3.10)	nd	Fe > Zn > Cu > Mn	This study
P. maliformis	0.11 ± 2.08^{ab} (0.10-0.17)	0.46 ± 0.88^{a} (0.45-0.48)	1.22 ± 0.33^{b} (1.15-1.25)	nd	Fe > Zn > Cu > Mn	This study
P. quadrangularis	0.16 ± 1.50^{a} (0.15-0.19)	0.42 ± 1.09^{a} (0.40-0.44)	3.37 ± 1.36^{a} (3.10-3.55)	nd	Fe > Zn > Cu > Mn	This study
P. quadrangularis (mesocarp)	0.07 ± 0.87^{b} (0.06-0.09)	0.17 ± 0.87^{c} (0.15-0.18)	1.25 ± 1.16^{b} (1.05-1.45)	nd	Fe > Zn > Cu > Mn	This study
P. edulis (Purple)	0.09	0.10	1.60	nd	Fe > Zn > Cu > Mn	USDA (2011)
P. edulis f. *flavicarpa*	0.05	0.06	0.36	nd	Fe > Zn > Cu > Mn	USDA (2011)
P. edulis	0.12	0.80	1.10	0.09	Fe > Zn > Cu > Mn	NZ Passion Fruit Growers (2007)

Different superscript alphabets in the same column indicate differences at $p<0.05$ (ANOVA, Tukey's test). Values are given as means (mg) ± standard deviation and values in parenthesis are the range. nd-not detected, na-not available.

diabetes, colon and breast cancer (Chau and Huang, 2004). Most fruits have fat content <0.5% in edible portion. This is in line with fat content observed in *Passiflora* fruit juices with ranged 0.24±0.01% to 0.51±0.10%. The amount of fats will make certain vitamins available for use in the body and makeup part of all body cells and help to maintain body temperature. The carbohydrate content of *Passiflora* fruit juices was not significantly different with ranged 6.57±0.29% in *P. quadrangularis* to 7.44±0.69% in *P. edulis* (Frederick). The mesocarp of *P. quadrangularis* possessed significantly two times lower carbohydrate content 3.00±0.19% compared to its juice (6.57±0.29%). The carbohydrate values obtained were within the range of previously reported content in *P. edulis* was 7.39%. *Passiflora* fruit juices with low carbohydrate might be ideal for diabetic and hypertensive patients requiring low sugar diets.

3.2 Mineral content of Passiflora juices

Minerals are of prime importance in determining the fruit nutritional value. The ash content of the *Passiflora* fruit juices was relatively high (0.51-1.37%) as compared to other commercial fruits; e.g., oranges, banana and papaya which further confirm its high mineral content. This is agreeable with a previous study of Rao (1996), where a high amount of ash content in plants is an indication that the plant provides considerable amount of minerals that essential for the body. The macronutrient and micronutrient content of *Passiflora* juice are presented in Table 2 and Table 3, respectively. The *Passiflora* fruit juices were found to contain appreciable quantity of K, Ca, Mg, Na, P and Fe. The trend of macronutrients content in all the *Passiflora* fruit juices studied was categorical as, i.e., K > P > Mg > Ca > Na. The trend of macronutrient content can be varied even in similar species, e.g., *P. edulis* reported by possessed lower Ca content than Na. This may be attributed to environmental conditions which have effects on the plant nutrition attributes (Martin, 1997; Babasaheb, 2000; Wardlaw, 2003).

The nutrients were found to be available in good quality and quantity and they were found to meet the daily requirement in children, adult, pregnant and lactating mothers. As in many other fruits, K is the most abundant mineral in the *Passiflora* fruit. The levels of K range from 283.33±8.33 mg 100 g^{-1} for *P. quadrangularis* mesocarp to 453.33±32.87 mg 100 g^{-1} in *P. edulis* (Purple). Potassium concentration in *P. edulis* (Purple) was slightly higher than the reported value (348 mg 100 g^{-1}) by USDA (2011). The K content of *Passiflora* fruit juices was similar to guava (417 mg 100 g^{-1}) and significantly higher than other fruits that possessed the least K content; orange (181 mg 100 g^{-1}) and pineapple (109 mg 100 g^{-1}) as reported by USDA (2011). *Passiflora* fruit provides a significant source of the K, an important in blood pressure control and acid-base balance (Martin, 1997; Wardlaw, 2003).

Passiflora fruit excels as an alternative to other fruits such as oranges and banana. The recommended dietary allowance (RDA) for men and women (19-30 years old) are presented in Table 4 and Table 5. A cup or an equivalent of 247 g of *Passiflora* fruit juice provides 1119.73 mg of potassium or about 23% out of the daily estimated recommendation of 4700 mg. The least P level was recorded in mesocarp of *P. quadrangularis*, 77.08±29.17 mg 100 g^{-1} and highest in *P. maliformis* (237.50±36.08 mg 100 g^{-1}). The obtained value for *P. edulis* (Purple) was approximately two times higher (115.41±53.19 mg 100 g^{-1}) than the reported values, 68 mg 100 g^{-1} (USDA, 2011) and 54 mg 100 g^{-1} (NZ, 2007). Phosphorus is important to the fundamental process of metabolism in the body and gives strength and rigidity to bones and teeth (Martin, 1997; Babasaheb, 2000; Wardlaw, 2003).

Table 4. Macronutrients of Passiflora fruit juices (1 cup=247 g=8.7 oz) and percentage (%) of DRI for *♂-men, ♀- women

Species	Calcium			Magnesium			Potassium			Sodium			Phosphorus		
	mg in 1 cup/ 247 g	% adult 19-30 y/o		mg in 1 cup/ 247 g	% adult 19-30 y/o		mg in 1 cup/ 247 g	% adult 19-30 y/o		mg in 1 cup/ 247 g	% adult 19-30 y/o		mg in 1 cup/ 247 g	% adult 19-30 y/o	
		♂	♀		♂	♀		♂	♀		♂	♀		♂	♀
P. edulis (Purple)	135.63	13.5	13.5	271.70	67.9	87.6	1119.73	23.8	23.8	92.63	6.1	6.1	285.06	40.7	40.7
P. edulis (Frederick)	127.82	12.7	12.7	266.76	66.6	86.0	994.18	21.1	21.1	51.45	3.4	3.4	291.26	41.6	41.6
P. maliformis	134.20	13.4	13.4	419.90	104.9	135.4	895.38	19.0	19.0	96.75	6.4	6.4	586.63	83.8	83.8
P. quadrangularis	109.92	10.9	10.9	265.57	66.3	85.6	1009.41	21.4	21.4	102.92	6.8	6.8	275.82	39.4	39.4
P. quadrangularis (mesocarp)	133.18	13.3	13.3	187.30	46.8	60.4	699.83	14.8	14.8	8.84	0.5	0.5	190.39	27.2	27.2

Table 5. Micronutrients of Passiflora fruit juices (1 cup=247 g=8.7 oz) and percentage (%) of DRI for *♂-men, ♀- women

Species	Copper			Zinc			Iron		
	mg in 1 cup/ 247 g	% adult 19-30 y/o	% adult 19-30 y/o	mg in 1 cup/ 247 g	% adult 19-30 y/o	% adult 19-30 y/o	mg in 1 cup/ 247 g	% adult 19-30 y/o	% adult 19-30 y/o
		♂	♀		♂	♀		♂	♀
P. edulis (Purple)	0.30	32.93	32.93	0.74	6.74	9.26	7.73	96.64	42.95
P. edulis (Frederick)	0.27	30.19	30.19	0.69	6.29	8.65	7.36	92.01	40.89
P. maliformis	0.27	30.19	30.19	1.14	10.33	14.20	3.01	37.67	16.74
P. quadrangularis	0.40	43.91	43.91	1.04	9.43	12.97	8.32	104.05	46.24
P. quadrangularis (mesocarp)	0.17	19.21	19.21	0.42	3.82	5.25	3.09	38.59	17.15

The Mg content in *Passiflora* fruit juices ranged 75.83±30.05 to 170.00±76.38 mg 100 g^{-1}. Magnesium is an essential component of a healthy human diet. It is a co-factor in a number of enzyme systems and along with Ca it is involved in neuro-chemical transmission and muscular excitability (Martin, 1997; Wardlaw, 2003). The daily value for Mg is 400 mg for male and 310 mg for female at age of 19-30 years old. Calcium is essential in bone formation and strength. The Ca content in *Passiflora* fruit juices ranged 14.50±90.14 mg 100 g^{-1} in *P. quadrangularis* to 24.91±79.49 mg 100 g^{-1} in *P. edulis* (Purple). Intake of the *Passiflora* fruits would be helpful for the normal functioning of the blood coagulation. The Na content in *Passiflora* fruits juices was ranged 20.83±44.09 to 41.67±80.47 mg 100 g^{-1} and the least content was observed in *P. quadrangularis* mesocarp (3.58±7.41 mg 100 g^{-1}). The Na content in *Passiflora* fruits was higher than other fruits; i.e., papaya (8.00 mg 100 g^{-1}) and guava (2.00 mg 100 g^{-1} some fruits like oranges and apple does not contain Na. The present Na content was slight higher than previously reported works for *P. edulis* (Purple) and *P. quadrangularis*; 28.00 mg 100 g^{-1} (USDA, 2011). A cup of *Passiflora* fruit juice supplies 3-6% of the daily requirement for Na (Table 4).

Nutritionally, one serving of 274 g of *Passiflora* fruit juice provides an adequate level of micronutrients especially Fe content. The trend for micronutrient in *Passiflora* fruit juices was Fe > Zn > Cu. Manganese (Mn) was not detectable in investigated *Passiflora* fruit juices. However, a trace amount of this element was detected in *P. edulis* (Purple) with 0.09 mg 100 g^{-1} (USDA, 2011) and other commercial fruits; i.e., oranges (0.03 mg 100 g^{-1}), banana (0.27 mg 100 g^{-1}) and pineapple (0.93 mg 100 g^{-1}). The micronutrient trend in *Passiflora* fruit juices was similar to reported *Passiflora* fruits (USDA, 2011) and commercial fruits i.e., oranges and papaya (USDA, 2011). Among the studied species, *P. edulis* (Purple), *P. edulis* (Frederick) and *P. quadrangularis* significantly high in Fe content; 3.13±1.09 mg 100 g^{-1}, 2.98±0.93 mg 100 g^{-1} and 3.37±1.36 mg 100 g^{-1}, respectively and the least content were recorded in *P. maliformis* and mesocarp of *P. quadrangularis*; 1.22±0.33 mg 100 g^{-1} and 1.25±1.16 mg 100 g^{-1}, accordingly. *Passiflora* fruit is a rich source of non-heme or plant-based, iron. Iron is very important in the formation of red blood cells. It is a vital element in the diet of pregnant women and infants (Martin, 1997; Babasaheb, 2000; Oluyemi *et al.,* 2006). The recommended dietary allowance of iron for men (19-30 years old) is 8 mg, 18 mg for women and during pregnancy is 27 mg (Bello *et al.,* 2008; Dimari and Hati, 2010).

A cup of *P. edulis* and *P. quadrangularis* juices can provide >90% for men and >40% for women of the recommended allowance for Fe (Table 5). The concentrations of Zn and Cu in *Passiflora* juices was found to be within the limits of recommended maximum level allowed in food based on Malaysian Food Regulations (1985) limit with (3.00 and 4.00 mg 100 g^{-1}, respectively). Similar with other fruits Cu content in *Passiflora* juices ranged 0.07±0.87 mg 100 g^{-1} to 0.16±1.50 mg 100 g^{-1}. The mesocarp of *P. quadrangularis* possessed the lowest concentration of Zn (0.17±0.87 mg 100 g^{-1}) while *P. maliformis* (0.46±0.88 mg 100 g^{-1}) had the highest. *Passiflora* fruit juices also contain approximately 10% of the daily requirements for Zn and 30% of Cu. Based on the results above, the *Passiflora* species growing in UPMKB, although grown under the same soil and environment conditions, yet possessed different nutrient content and this may be attributed to cultivars or species itself. The nutrient content varied even among similar species which grown under different geographical location and it could be due to the effects of different environment (Wardlaw, 2003).

3.3 Organic acids content of Passiflora juices

Organic acids play important roles in *Passiflora* fruit juices because of their influence on the organoleptic properties (flavor, color and aroma) as well as the stability and microbiological control of the products (Hasib *et al.,* 2002). Three organic acids were identified and quantified in *Passiflora* fruit juice was citric, malic and acetic acids (Table 6). There was significant difference between organic acids level and *Passiflora* fruit species. The major organic acid in *Passiflora* fruit juice was citric acid and ranged 1137.00±0.13 mg 100 g^{-1} in *P. quadrangularis* to 1487.30±0.28 mg 100 g^{-1} in *P. edulis* (Purple). One distinctive quality of the *Passiflora* species is the high citric acid content (Fainsod, 2001). Like lemon and lime juice, *Passiflora* fruit juice is quite acidic.

Malic acid was second abundant organic acid in the *Passiflora* fruit juices with 156.00±0.07 mg 100 g^{-1} in *P. edulis* (Frederick) to 502.30±0.07 mg 100 g^{-1} in *P. quadrangularis*. In *P. edulis* f. *flavicarpa*, citric acid constitute about 83.00% of the acids, followed by malic, which constituted about 15.90% of the acid content (Joy, 2010). Although Purple *Passiflora* fruit (*P. edulis*) was found to contain the same acids as Yellow *Passiflora* fruit (*P. edulis* f. *flavicarpa),* the relative abundance of each of the acids differed markedly as shown in the present study compared to previous works. Mesocarp of *P. quadrangularis* possessed the least organic acids compared to its juices. The content of citric acid in mesocarp is 15 times lower (72.00±0.03 mg 100 g^{-1}) than its juice.

Table 6. Organic acids content (mg 100 g^{-1} FW) of *Passiflora* juices accordingly to species

Species	Citric acid	Acetic acid	Malic acid	Lactic acid	References
P. edulis (Purple)	1487.30±0.28^{a} (1440.00-1538.00)	11.00±0.01^{a} (10.00-12.00)	257.70±0.14^{bc} (234.00-283.00)	nd	This study
P. edulis (Frederick)	1290.30±0.15^{b} (1263.00-1314.00)	9.00±0.01^{a} (8.00-10.00)	156.00±0.07^{c} (146.00-169.00)	nd	This study
P. maliformis	1554.00±0.36^{a} (1483.00-1597.00)	11.70±0.01^{a} (10.00-14.00)	174.70±0.04^{c} (169.00-183.00)	nd	This study
P. quadrangularis	11370.00±0.13^{c} (1108.00-1154.00)	12.30±0.01^{a} (10.00-14.00)	502.30±0.07^{a} (489.00-510.00)	nd	This study
P. quadrangularis (mesocarp)	72.00±0.03^{d} (68.00-78.00)	2.30±0.001^{b} (1.00-3.00)	22.30±0.02^{d} (18.00-26.00)	nd	This study
P. edulis	34.00	na	9.95	18.78	Joy (2010)
P. edulis	340	na	130	na	USDA (2011)
P. edulis f. *flavicarpa*	142.79	na	272.20	1.45	Joy (2010)

Different superscript alphabets in the same column indicate differences at $p<0.05$ (ANOVA, Tukey's test). Values are given as means (mg) ± standard deviation and values in parenthesis are the range. nd-not detected, na-not available.

A lower concentration of acetic acid (9.00±0.01-12.30±0.01 mg 100 g^{-1}) was also detected in *Passiflora* fruit juices. Lactic acid was not detected in examined samples. However, Joy (2010), reported the presence of lactic acid in *P. edulis* (Purple) and *P. edulis* f. *flavicarpa* which were 18.78 and 1.45 mg 100 g^{-1}. Citric acid is a naturally occurring weak organic acid and very soluble and used as an additive to many drinks to enhance flavor and increase stability in soft drinks and syrups. It is also used to prevent color change by oxidation (Fainsod, 2001).

Citric and malic acid content in the *Passiflora* fruit could be responsible for the usual sourness of the fruits. It is an important component of cell metabolism in fruits and is the primary acid found in some fruits which plays a major role in metabolism in the human body. Citric and malic acid is also an indicator of the freshness of fruits and is used as a common parameter to evaluate the quality of agricultural products and food control points in the food process (Hasib *et al.,* 2002).

4. Conclusion

The present findings showed the *Passiflora* fruit juices are a natural nutritious drink with contain all the necessary essential nutrients required by the body in the right proportion that meets the daily body requirements. The juices extracted from pulps of *P. edulis, P. maliformis* and *P. quadrangularis* possessed a rich source of fiber, protein and carbohydrate content. A cup of 247 mL *Passiflora* fruit juices provided ~24% of K, 60-80% Mg, >80% P and 90% Fe of recommended dietary allowance of minerals. Besides the juice, edible mesocarp of *P. quadrangularis* also contained ample of nutrient and favorable for human consumption. In addition, citric acid was the most dominant organic acid in *Passiflora* fruit juices followed by malic acid. A similar trend was recorded for mesocarp of *P. quadrangularis* with lower concentration compared to its juice. The quantitative information that gathered in this study, help to understand the worth of these fruits to be processed as juice and other processed products.

Conflict of Interest

The authors declare that they have no conflict of interest.

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