Nutritive Values of Passion Fruit (*Passiflora* Species) Seeds and Its Role in Human Health

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Abstract: This study focused on proximate composition and mineral content of edible seeds of three *Passiflora* species; *P. edulis* (Purple), *P. quadrangularis* and *P. maliformis*. The moisture content ranged 9.18±0.34% in *P. edulis* (Purple) to 11.09±0.40% in *P. quadrangularis,* and the ash content was higher in *P. quadrangularis* (2.35±0.13%). Among the *Passiflora* seeds, *P. edulis* (Purple) possessed higher protein, 12.71±0.10% and total dietary fiber, 43.76±0.64% with 72-74% major fiber fraction of insoluble dietary fiber. The lipid content of 29.65±0.41% also was higher in *P. edulis* (Purple) indicating that the seed was rich in oil content. *Passiflora quadrangularis* possessed a higher ash content which constitutes minerals such as sodium, 5.508±5.465 mg g^{-1}; magnesium, 1.975±1.443 mg g^{-1}; calcium, 2.363±3.269 mg $g^{-1,}$ and potassium, 2.425±2.500 mg g^{-1} that plays a prominent role in human health. Based on ordination with Principal component analyses (PCA), the *Passiflora* seeds properties when compared with maize, oats, flaxseed, sesame, soybean, almond, groundnut, sunflower and pumpkin, *Passiflora* plant seeds formed an independent group correlated with variables, *i.e*., fiber, sodium, and zinc. By-products from *Passiflora* seeds can be used for pharmaceutical and nutraceutical purposes.

Keywords: By-products, Insoluble dietary fiber, Mineral content, *Passiflora* seeds, Utilization.

1. INTRODUCTION

Passiflora plant is also known as passion fruit is a high value and export orientated crop. The plants grown for their fruits and mostly for juice extract, which is often added to other fruit juices to enhance the aroma. *Passiflora* is grown extensively in warm tropical and sub-tropical regions of the world. More than 500 species have been identified and distributed throughout Central and South America. Malaysia also in the warm tropical region is suited for the cultivation of passion fruit plants. However, their cultivation is on a small scale due to the prevalence of suitable growing conditions [1]. The increasing demand for passion fruits in the local market provides income-earning opportunities for growers and local farmers.

The cultivation of *Passiflora* species has been for their edible fruits, ornamental flowers, and pharmaceutical uses. It has a soft to firm moist interior, filled with numerous seeds. It enters an international trade in the form of juice. Passion fruit plant parts are potentially valued for their uses and giving the plants value beyond that of their fruits contribution as juices and other products. The juice production industry uses approximately half of the fruit's mass and the rest (90%) are the by-products comprising rinds and seeds [2]. Studies conducted revealed seeds of *P. edulis* Sims and *P. edulis* f. *flavicarpa* are edible and rich in oil, generally disposed of after being crushed [3]. These residues imply operating costs for the industries and may become a substantial burden to the environment [4]. Various efforts have been undertaken to utilize this waste to useful products and thereby avoid waste disposal problems. Several authors have conducted researches; Malacrida and Jorge [4]; Chumjai and Tippayawong [5]; Liu *et al*. [6] and Chau and Huang [3] explored the usefulness of *Passiflora* seeds.

The seeds of the passion fruit are edible and provide a little crunch when eaten with the fruit pulp or added to salads, sauces and as a topping of ice-creams. The seeds deliver an abundance of nutritional and health benefits ranging from antioxidant protection to the maintenance of healthy cardiovascular and intestinal systems. The potential utilization of seeds as a good source of food fiber especially insoluble dietary fiber in reducing the risks of cardiovascular disease, colon cancer and obesity [3] and [7]. Chau *et al*. [8] have suggested that the passion fruit seed insoluble fibers can be an effective functional ingredient to promote intestinal function and health.

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From the above review, the seeds could add value to the agro-industrial waste. Accessing the passion fruit seed nutritive values of various species contributes to the acquisition of knowledge to optimize the use of these raw materials for edible or industrial purposes. Some studies examined the seed properties of purple and yellow fruits, and little information exists on characteristics of other *Passiflora*. Therefore, the purpose of this study was to examine the nutritional values of the seeds of *P. edulis* (Purple), *P. quadrangularis* and *P. maliformis* which have the potential to be grown in Malaysia.

2. MATERIALS AND METHODS

2.1. Seeds Collection and Preparation

Mature fruits of *P. edulis* (Purple), *P. quadrangularis* and *P. maliformis* were harvested randomly for each species from the passion fruit farm, Universiti Putra Malaysia Bintulu Sarawak Campus (UPMKB) (N 03° 12.45' and E 113° 4.68') Bintulu, Sarawak at different harvesting period during the fruit-bearing season. The fruits were brought to the laboratory and immediately inspected and cleaned. The seeds were mechanically removed from the fruits, washed with distilled water and dried at room temperature for a week. Approximately 2 kg of seeds extracted from fruits of *Passiflora* were homogenized into a fine meal including the shell using a grinding machine and stored in an airtight container at 4^{o}C, were subsequently used for the various analyses described below.

2.2. Proximate Analysis of the Seeds

Proximate analysis of *Passiflora* species; seed moisture, ash content, crude protein, lipid, crude fiber, total dietary fiber, insoluble dietary fiber, soluble dietary fiber composition were determined using the standard methods of the Association of Official Analytical Chemists [9]. The moisture content of the seed was determined by drying until constant weight was obtained following the method of Osborne and Voogt [10]. 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 carbo-hydrate 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 [6].

2.3. Mineral Elements Analysis of the Seeds

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 [9]. Each determination was performed in triplicate. Phosphorus (P) was determined by a colorimetric method using UV-VIS spectrophotometer (UNICO, New Jersey, USA) at a wavelength of 882 nm.

2.4. Statistical Analysis

The results were statistically analyzed using SAS window programme 9.1. Mean, standard error and range for the proximate compositions and minerals content were obtained from triplicate determination. Means were compared using single-factor ANOVA, and if significant, the analysis was continued with Post- hoc Tukey's (P<0.05). The seeds properties of *Passiflora* species and other plants' seeds (*e.g.*, maize, oats, flaxseed, sesame, soybean, almond, groundnut, sunflower and pumpkin) were ordinated with principal component analysis (PCA) to obtain the relationship between variables and various seeds based on the Spearman method using XLSTAT software version 2013.5 for windows.

3. RESULTS AND DISCUSSION

3.1. Proximate Composition of *Passiflora* Seeds

Table **1** shows the proximate composition of seeds of *P. edulis* (Purple), *P. quadrangularis, P. maliformis,* and other seeds. *Passiflora* seeds contained approximately a good amount of 9-11% moisture. The seeds of *P. quadrangularis* have higher ash content, 2.35±0.13% compared to other *Passiflora* species. Samples with high ash content were suggested to speed up metabolic processes and improve growth and development. The *P. edulis* (Purple) possessed

Table 1: Proximate Composition of *Passiflora* Seeds (% dry Weight Basis of 100 g) and other Seeds

Seeds	*P. edulis* (Purple)^{P}	*P. quadrangularis*^{P}	*P. maliformis*^{P}	*P. edulis*^{1}	*P. edulis*^{2}	Maize	Oats	Flax	Sesame	Soybean	Almond	Groundnut	Sun flower	Pumpkin
Moisture content	9.18±0.34^{b} (8.77-9.87)	11.09±0.40^{a} (10.54-11.87)	9.42±0.44^{b} (8.56-9.95)	10.80	6.60	9.84	9.13	4.23	5.18	4.70	9.30	7.48	6.74	5.00
Ash content	1.35±0.01^{b} (1.34-1.37)	2.35±0.13^{a} (2.09-2.49)	1.60±0.04^{b} (1.53-1.68)	1.46	1.34	0.70	1.81	3.48	4.13	4.60	4.80	1.48	3.88	5.50
Crude protein	12.71±0.10^{a} (12.58-12.91)	11.41±0.06^{b} (11.30-11.47)	10.44±0.32^{c} (9.89-10.98)	10.80	8.25	12.58	13.92	21.27	18.30	36.00	32.60	24.70	18.23	27.48
Crude lipid	29.65±0.41^{a} (28.70-30.05)	25.81±0.44^{b} (25.15-26.61)	24.34±0.46^{b} (23.72-25.28)	23.40	24.5	5.30	8.50	38.53	44.53	19.80	13.30	46.10	36.14	38.00
Crude fiber	26.98±0.48^{a} (26.23-27.87)	23.10±0.56^{b} (22.06-23.96)	22.01±0.46^{b} (21.14-22.72)	17.48	32.40	1.04	9.10	8.12	3.67	7.30	0.40	2.83	11.35	1.00
Total DF	43.76±0.64^{a} (42.63-44.85)	34.68±0.63^{b} (33.56-35.76)	32.78±0.42^{b} (32.07-33.53)	na	64.80	na	na	na	na	na	na	na	na	na
Soluble DF	12.31±0.08^{a} (12.21-12.47)	8.75±0.04^{b} (8.70-8.84)	8.27±0.09^{c} (8.12-8.44)	na	64.01	na	na	na	na	na	na	na	na	na
Insoluble DF	31.45±0.66^{a} (30.36-32.65)	25.93±0.67^{b} (24.72-27.06)	24.50±0.33^{b} (23.96-25.09)	na	0.73	na	na	na	na	na	na	na	na	na
AC	20.51±0.75^{c} (19.30-21.88)	28.33±0.94^{b} (26.07-30.80)	34.91±0.83^{a} (33.24-35.74)	36.06	33.51	70.62	66.64	24.37	24.19	27.40	49.90	17.41	23.66	28.03

Different superscript letters within the same row indicate significant differences (Tukey's test, $P<0.05$) among the means of each variable of the *Passiflora* species. *Value expressed in % of wet weight. DF- dietary fiber, AC- available carbohydrate, na- not available. *P. edulis* (Purple)^{p}, *P. quadrangularis*^{p}, *P. maliformis*^{p} seeds– values of the present study, *P. edulis*^{1}- *P. edulis* 'Tainung No. 1' [6], *P. edulis*^{2} [3], maize [13], oats [14], flaxseed [34], sesame seed [35], soybean [20], almond [21], groundnut [36], sunflower seed [19] and pumpkin seed [24].

significantly lower ash content with 1.35±0.01%, and the value was within the range obtained in *P. edulis* 'Tainung No. 1' and *P. edulis* f. *flavicarpa*; 1.46±0.38% [6] and 1.27±0.02% [4], respectively.

Based on ordination with PCA and illustrated in biplots (Figure **1**), the nutritive values of *Passiflora* seeds were comparable with various seeds such as maize, oats, flaxseed, sesame, soybean, almond, groundnut, sunflower, and pumpkin. Each type of seed exhibits specific nutritional compounds and with different compositions and properties. The PCA indicates that the first two PCs for the seeds accounted for 81.94% of the total variance. All the variables examined were well segregated on the PC1 and PC2 sites (Figure **1a**). Four main groups were obtained for *Passiflora* species seeds and other plant seeds based on their content similarities. From the biplot generated (Figure **1b**), the examined *Passiflora* seeds; *P. edulis* (Purple), *P. quadrangularis* and *P. maliformis* formed an independent group (Group 1) together with *P. edulis*^{1} 'Tainung No. 1' [6] and *P. edulis*^{2} [3]. This group possessed the highest fiber content compared with other seeds. The *Passiflora* seeds showed a high percentage of crude fiber (22.01±0.46-26.98±0.48%).

The crude fiber is essential in maintaining internal distention for a normal peristaltic movement of the intestinal tract. Since seeds of *Passiflora* are high with fiber, it can be a source of food fiber and supplement to scarce cereal grains as sources of energy in feed formulation [11]. The fiber content was relatively higher than grain from legumes, *e.g.*, chickpea-17.2% and cowpea-14.8% [12], maize -1.04% [13] and oats - 9.10% [14], all serve as a source of dietary fiber. Diets low in crude fiber is undesirable as it could cause constipation associated with diseases of colon like piles. Also, we tested the dietary fiber for *Passiflora* seeds, and it showed the seeds are rich in dietary fibers. The crude fiber is only one-seventh to one-half of total dietary fiber. Seeds of *P. edulis* (Purple) possessed higher dietary fiber of 43.26±0.64% in their compositions, providing an alternative source of food fiber. *Passiflora* seeds are rich in insoluble dietary fiber. In the total dietary fiber content of *P. edulis* (Purple); insoluble dietary fiber 31.45% (72% of dietary fiber) was significant fiber fraction in total dietary fiber. The consumption of insoluble fibers is considered for healthy gut because they transport toxins out of the body and helps prevent constipation and hemorrhoids [15]. Chau *et al*. [8] suggested by adding *Passiflora*

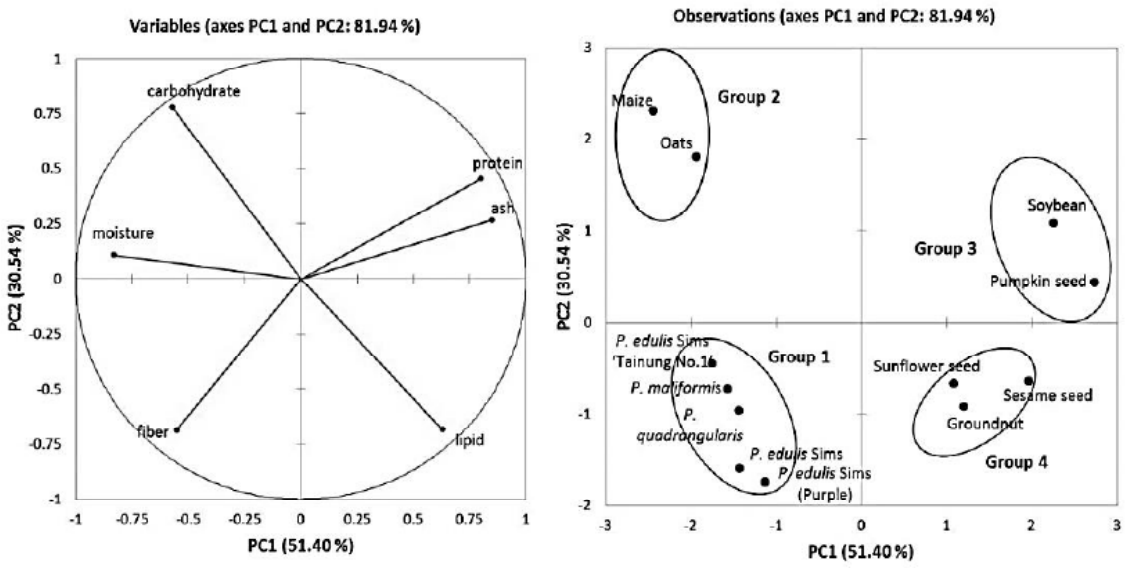

Figure 1: (**a**) Plot of proximate compositions of *Passiflora* seeds and other edible seeds. The percentage in parenthesis represents the variation of each component. (**b**) Positions of PC score of 14 seeds analyzed according to PC1 and PC2.

seeds' insoluble fiber to a fiber-free diet could enhance the intestinal amylase activity, reduce the bacterial enzyme activities in faeces, lowering the exposure of intestinal mucosa to the toxic ammonia and other compounds along the intestinal tract, thus potentially reduce the risk of tumors in the colon. Besides, *Passiflora* seeds' soluble fiber ranged 8.27±0.09-12.31±0.08% and had many benefits, including moderating blood glucose levels and lowering cholesterol.

Group 2 composed of maize and oats which had the highest carbohydrate; 70.62% [13] and 66.64% [14], respectively. Seeds of these two plants possessed twice higher carbohydrate content than *Passiflora* seeds. The carbohydrate content in *Passiflora* seeds ranged 20.51±0.75-34.91±0.83% indicating that the seed also could serve as a source of energy and roughage in animal feeds [6]. Almond, soybean and pumpkin seeds were the members in Group 3 with the higher protein and ash content. All these seeds serve as protein source especially soybean with 36%. Protein is essential components of diet needed for the survival of animals and humans, their basic function in nutrition is to supply an adequate amount of amino acids [16]. The *Passiflora* seeds examined also contains ample amount of protein like other cereal plants. The protein content of the *Passiflora* seeds ranged 10.44±0.32% in *P. maliformis* to 12.71±0.10% in *P. edulis* (Purple). The present protein content of the *P. edulis* (Purple) seed was slightly higher than those reported by Liu *et al*. [6] which was 10.8%. The value was comparable to oats-10.8%, barley-11.1% [17]; some selected cultivars of olive >2.0% [18] and sunflower seed-18.23% [19]. Although, the protein value of *Passiflora* seeds were lower than soybean, yet, the values were within the range of recommended level in food and the values obtained was an indication that the seeds might be useful in the formulation of animal feeds.

Flaxseed, sesame, groundnut, and sunflower seeds in Group 4 having higher lipid content, 38.53%, 44.53%, 46.10%, and 36.14%, respectively. The lipid content is essential in diets as it promotes fat-soluble vitamin absorption. The oil content of these seeds was slightly higher than the *Passiflora* seeds. The lipid content ranged from 24.34% in *P. maliformis* to 29.65% in *P. edulis* (Purple) indicating that seeds were also a good oil source, especially when compared to maize 5.30% oil [13], soybean 19.80% [20] and almond 13.30% [21]. The high percentage of oil makes *Passiflora* seeds a clear potential for the oil industry. Studies conducted in other countries have shown that the seeds of *Passiflora* species yielded 21-30% oil [22], [6] and [4] using petroleum ether extraction. According to Egbekun and Ehieze [23], differences in nutritive values may be attributed to differences in plant variety, climatic and geographical differences, ripening stage and the extraction method.

3.2. MINERAL CONTENT OF *PASSIFLORA* SEEDS

Table **2**. shows the mineral element contents of seeds of *P. edulis* (Purple), *P. quadrangularis*, *P. maliformis*, and other plant seeds. The human body requires some essential minerals in order to maintain

Table 2: Mineral Elements Content of *Passiflora* Seeds (mg g^{-1} Dry Weight) and other Seeds

Seeds	*P. edulis* (Purple)^{P}	*P. quadrangularis*^{P}	*P. maliformis*^{P}	*P. edulis*^{1}	Maize	Oats	Flax	Sesame	Soybean	Almond	Groundnut	Sunflower	Pumpkin
Na	2.417±0.833^{b} (2.400-2.425)	5.508±5.465^{a} (5.400-5.575)	2.104±1.443^{c} (2.075-2.125)	2.980	0.550	0.050	0.324	0.090	0.020	0.277	0.072	0.036	1.704
K	3.525±1.443^{a} (3.500-3.550)	2.425±2.500^{c} (2.403-2.475)	3.058±3.633^{b} (3.013-3.125)	0.850	3.210	3.360	8.263	6.450	17.970	0.422	6.677	8.606	2.372
Mg	1.383±2.205^{b} (1.350-1.425)	1.975±1.443^{a} (1.950-2.010)	1.258±3.632^{b} (1.200-1.325)	1.540	0.985	1.190	4.305	3.250	2.800	0.359	1.786	1.321	0.674
Ca	1.731±2.948^{b} (1.675-1.775)	2.363±3.269^{a} (2.314-2.425)	1.742±2.958^{b} (1.702-1.800)	0.540	0.430	0.480	2.408	0.780	2.770	0.272	0.536	0.714	0.098
P	1.153±1.788^{c} (1.117-1.175)	2.243±1.009^{a} (2.225-2.226)	1.548±2.351^{b} (1.520-1.595)	1.250	2.996	1.530	6.420	6.600	7.040	0.243	3.607	6.600	0.477
Fe	0.062±0.117^{a} (0.059-0.064)	0.047±0.377^{b} (0.042-0.055)	0.039±0.132^{b} (0.037-0.041)	0.200	0.042	0.045	0.061	0.052	0.157	0.064	0.029	0.039	0.038
Zn	0.056±0.247^{ns} (0.052-0.060)	0.064±0.252^{ns} (0.061-0.070)	0.057±0.07^{ns} (0.056-0.058)	0.055	0.039	0.026	0.045	0.050	0.049	0.018	0.034	0.054	0.141
Cu	0.014±0.100^{b} (0.012-0.015)	0.022±0.100^{a} (0.021-0.024)	0.024±0.104^{a} (0.022-0.025)	0.013	0.014	0.004	0.020	0.018	0.017	0.010	0.007	0.019	0.022
Mn	nd	nd	nd	0.014	0.010	0.049	0.028	0.019	0.025	0.023	0.021	0.021	0.001
Na/K ratio	0.685	2.271	0.688	3.506	0.171	0.015	0.039	0.014	0.001	0.656	0.011	0.004	0.718
Ca/P ratio	1.501	1.053	1.125	0.432	0.144	0.314	0.375	0.118	0.393	1.119	0.198	0.108	0.205

Different superscript letters within the same row indicate significant differences (Tukey's test, $P<0.05$) among the means of each variable of the *Passiflora* species. nd- not detected, ns-not significant. *P. edulis* (Purple)^{p}, *P. quadrangularis*^{p}, *P. maliformis*^{p} seeds– values of present study, *P. edulis*^{1}- *P. edulis* 'Tainung No. 1'[6], maize [13], oats [14], flaxseed [34], sesame seed [37], soybean [37], almond [21], groundnut [37], sunflower seed [37] and pumpkin seed [24].

good health. Seeds of *Passiflora* species exhibited to be a good source of important minerals. The trend of mineral content in the *Passiflora* seed studied was not consistent with species, *e.g*., *P. edulis* (Purple) the trend was K > Na > Ca > Mg > P > Fe > Zn > Cu while in *P. quadrangularis* was Na > K > Ca > P > Mg > Zn > Fe > Cu. Concurrent with the higher ash amount, *P. quadrangularis* possessed abundant of mineral contents as well. The mineral contents of *Passiflora* seeds and other plant seeds were ordinated with PCA and illustrated as biplots in Figure **2**. For the mineral concentration, the first two principal components explained 70.89% of the total variance, with PC1 and PC2 representing 39.22% and 31.66% of the total variance, respectively (Figure **2a**).

The biplot generated four main groups (Figure **2b**) based on their mineral amount. Group 1 consisted of present studied *Passiflora* seeds; *P. edulis* (Purple), *P. quadrangularis* and *P. maliformis*, together with *P. edulis* 'Tainung No. 1' and pumpkin seeds [24]. They have similar in sodium, zinc, and copper content. All the *Passiflora* seeds contain higher sodium amount compared to other seeds such as soybean, sesame, sunflower, and groundnut possessed less than 0.100 mg g^{-1}. Comparatively, the sodium content in *P. quadrangularis* (5.508±5.456 mg g^{-1}) was two times higher than present values detected in *P. edulis* (Purple) (2.417±0.833 mg g^{-1}) and *P. maliformis* (2.104±1.443) and also previously reported in *P. edulis* 'Tainung No. 1' (2.980±0.002 mg g^{-1}) [6]. This element is required by the body to regulate blood pressure, and it helps regulate the fluid balance in the body [25]. Besides, *Passiflora* seeds also provide an adequate level of micronutrients; zinc and copper. The zinc content was not significant among the *Passiflora* seeds which ranged 0.056±0.247-0.064±0.252 mg g^{-1}. Zinc is an essential trace element for protein and nucleic acid synthesis and normal body development [25] and [26]. It is a component of many enzymes such as carbonic anhydrase, essential for normal body function and the 20 g of seeds could supply the 11 mg day^{-1} which are the required by dietary reference intake (DRI) (Table **2**). The concentrations of copper in *Passiflora* seeds was found to be slightly higher than the permissible limit set by FAO/WHO [27] which is 0.01 mg g^{-1}.

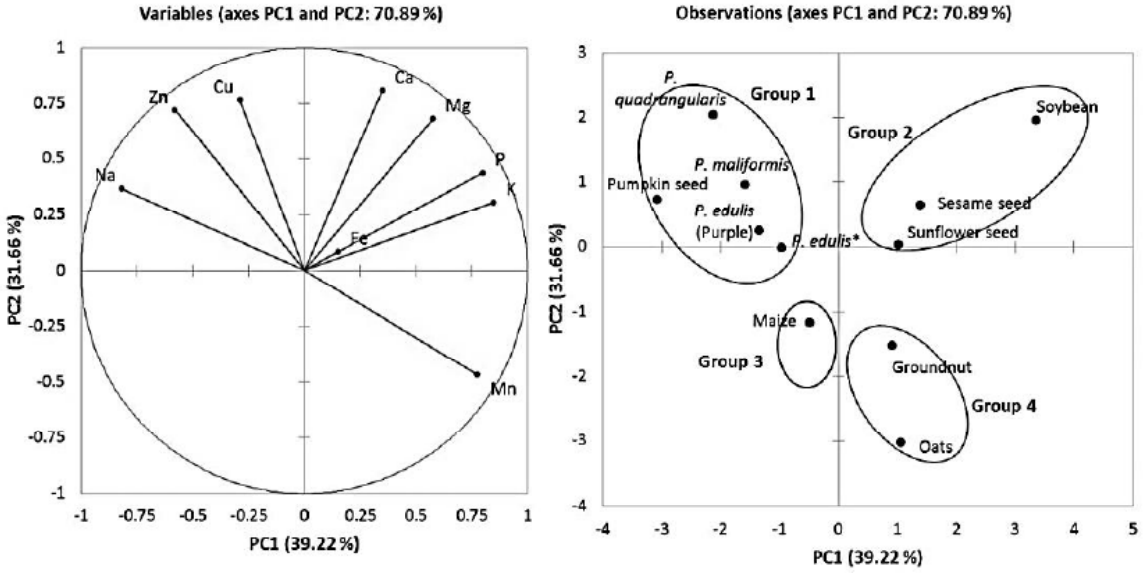

Figure 2: (**a**) Plot of the mineral content of *Passiflora* seeds and other edible seeds. The percentage in parenthesis represents the variation of each component. (**b**) Positions of PC score of 13 seeds analyzed according to PC1 and PC2.

However, the amount was found to be within the limits of Malaysian Food Regulations [28], which is 0.03 mg g^{-1} food. Copper content in *Passiflora* seeds (0.014±0.100-0.024±0.104 mg g^{-1}) is comparable with pumpkin seed, 0.022 mg g^{-1} [24].

Flaxseed, soybean, sesame and sunflower seeds are in Group 2. This group includes those with higher primary macronutrients; potassium, magnesium, calcium, phosphorus, and micronutrient of zinc. The potassium content of those plants seeds is 2-5 times higher than those obtained from *Passiflora* seeds. The *Passiflora* seeds constitute the excellent amount of potassium concentration in all three species (2.425±2.500-3.525±1.443 mg g^{-1}) as it is an essential nutrient to regulate blood pressure and has an essential role in protein and amino acid synthesis [29] and [30]. Calcium is a major requirement in bone formation and strength [31]. Calcium constitutes a large proportion of the bone and is essential in human blood and other extracellular fluid. The calcium content is higher in flaxseed (2.408 mg g^{-1}) and followed by *Passiflora* seeds ranged 1.258±3.632 mg g^{-1} in *P. maliformis* to 1.975±1.443 in *P. quadrangularis* (Table **2**). Higher magnesium content was detected in sesame, soybean, and flaxseed while sunflower possessed similar concentration as *Passiflora* seeds which ranged 1.258±3.632-1.975±3.632 mg g^{-1}. *Passiflora* seeds provide magnesium in a reasonable amount, which is an essential mineral that plays a prominent role in human health particularly in carbohydrate metabolism. It is also essential for a proper heartbeat and nerve transmission [25]. Phosphorus is essential to the fundamental process of metabolism in the body. It combines with calcium to form a relatively insoluble compounds-calcium phosphate, which gives strength and rigidity to bones and teeth. The phosphorus content of members of this group is two times higher than *Passiflora* seeds. There was a variation in phosphorus content where the least amount in seeds of *P. edulis* (Purple), 1.153±1.788 mg g^{-1} and highest in *P. quadrangularis* (1.548±2.351 mg g^{-1}). The obtained values were similar to the reported values, 1.250 mg g^{-1} for *P. edulis* 'Tainung No. 1' [6].

Furthermore, among the seeds, the higher iron content was recorded in *P. edulis* (Purple) 0.062±0.117 mg g^{-1} and lower amount from *P. maliformis* (0.039±0.132 mg g^{-1}). Passion fruit is a rich source of nonheme or plant-based, iron. Iron is very important in formation of red blood cells. It is a vital element in the diet of pregnant women, and infants [32]. Iron is required for energy and endurance because it delivers oxygen throughout the body. However, it is necessary only in small amounts for optimal health.

Maize and almond were in Group 3, not distinctly correlated to any of the mineral elements possessed the least amount of macronutrients. The last group groundnut and oats clustered together as they had higher manganese content compared to the others. Manganese was not detectable in the examined *Passiflora* seeds. However, a trace amount of this element was detected in *P. edulis* 'Tainung No. 1' with 0.0014±0.001 mg g^{-1} [6]. Additionally, the ratio of Ca/P and Na/K are an important indicator of edible food.

Higher Ca/P ratio helps to increase absorption of calcium in the small intestine. The obtained results of the Ca/P ratio of *Passiflora* seeds were good with ratio falls between 1.05-1.50 [33]. The Na/K ratio is required in order to maintain the osmotic balance of the body fluids to control glucose absorption and the prevention of high blood pressure [33]. The Na/K ratio for the *P. edulis* (Purple) and *P. maliformis* seeds were ~0.68 which falls within the recommended range less than 1.0 [33]. Consumption of seeds of *P. edulis* (Purple) *and P. maliformis* would probably reduce high blood pressure related ailments. The above comparison revealed that *Passiflora* seeds possessed the favorable amount of nutrient and the intake of the *Passiflora* seeds would be helpful for the normal functioning of the cardiac muscles, blood coagulation, milk clotting and the regulation of cell permeability. The present result indicated that *Passiflora* seeds, considered as wastes or by-products could be extracted for oil, and potentially incorporated and formulated in the human diet, commercial products, and animal feed.

CONCLUSION

The present study has shown, *Passiflora* seeds possessed high nutritive values including dietary fiber, protein, carbohydrate, and essential minerals; sodium, potassium, calcium, magnesium, zinc, and iron which could add value to the human diet, nutritional supplement and also the animal feeds formulation. Besides, it will encourage cultivation of the highly valuable *Passiflora*, for processing them as juice and other processed products. *Passiflora* seeds are rich in oil content. Thus the seeds could be utilized as raw material in industrial applications and producing edible oil. Although the materials employed in this study are considered as agro wastes, the results of the present study indicated that we could maximize the utility of *Passiflora* seeds.

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