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Nutritional Composition and Sensory Evaluation of Green, Oolong and Black Teas of Sacha Inchi Leaves

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Abstract | The market for functional foods, including tea, has indeed seen growth due to increasing consumer awareness of the potential health benefits associated with these products. Tea intake is frequently hampered by its odour, colour, and taste since it is processed as a crude aqueous extract, restricting its consumption despite the fact that it provides considerable medicinal benefits due to the inclusion of important bioactive components. In this study, green tea, oolong tea, and black tea were crafted using a combination of processed Sacha Inchi *(Plukenetia volubilis* L.) leaves, the traditional tea *(Camellia sinensis)* leaves and stevia as natural sweetener and also their infusion. The black tea produced contains a high percentage of crude protein, crude fat and crude fibre which is significantly different as compared with green tea and oolong tea. The thirteen mineral elements in Sacha Inchi tea leaves powder and infusion were assessed. Potassium (K), phosphorus (P) and calcium (Ca) were found higher in both tea leaves and tea infusion, with values ranged from 5-7 mg/kg, 1-3 mg/kg, 3-6 mg/kg, and 150–203 mg/l, 22–37 mg/l,10–20 mg/l, respectively. The sensory analysis demonstrated that black tea made from Sacha Inchi leaves was the most acceptable, with a considerably higher mean overall acceptability score than oolong and green tea. Experimental analysis revealed that the Sacha Inchi tea has the potential to be a valuable source of high-value-added foods for the beverage industry.

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Introduction

Sacha Inchi (*Plukenetia volubilis* L.) is also known as sacha peanut, mountain peanut, Inca nut, or Inca peanut is an underutilised oleaginous crop native to the Amazon basin (Goyal *et al*., 2022). *Plukenetia brachybotrya, Plukenetia polyadenia, Plukenetia loretensis, and Plukenetia huayllabambana* are examples of other Plukenetia species. However, their morphological and physicochemical features are distinct from those of *P.volubilis*. Sacha Inchi is being cultivated in different regions of the world because of its high economic potential (Wang *et al*., 2018). Monoecious plants with triangle to oval-shaped leaves with a truncate to cordate base, palmate venation, and basilaminar glands separated by a tiny knob. The seeds are lenticular and measure around 1.8 cm x 0.8 cm x 1.6 cm in diameter. The testa is firm and brown with dark brown patterns (Kodahl and Sørensen, 2021).

The Rubber Industry Smallholders Development Authority (RISDA) introduced the Sacha Inchi planting in Malaysia as part of efforts to diversify agricultural activities, enhance the income of farmers, and explore alternative crops with nutritional and economic benefits (Zakaria *et al*., 2022). Sacha Inchi has indeed gained attention for its high economic value, particularly due to its nutritional content and potential applications in the food and cosmetic industries. *Plukenetia volubilis* L. (Sacha Inchi) is also known as the most promising herb plant that acts as a cholesterol level reducer and supports heart health in Peruvian traditional medicine rich in protein and vegetable oil content (Silalahi, 2022). A variety of bioactive components that are beneficial to both diet and health. The seeds can be extracted for oil, roasted for snacking, and the dried leaves can be utilized in the preparation of tea (Srichamnong *et al*., 2018). Meanwhile, in the Chinese region of Yunnan, Sacha Inchi tea has been used as an adjunctive treatment for diabetes. The effects of Sacha Inchi tea on diabetes are unclear, as are the underlying processes (Lin *et al*., 2022). Since an ingredient-based tea may act as an adjunctive treatment for diabetes, this might be done by tea from *Plukenetia volubilis* leaves. However, there was an abundance of awareness and understanding regarding Sacha Inchi leaves and tea products. Tea intake has historically been restricted by its smell, colour, and taste since it is made as a crude aqueous extract, cutting off its consumption despite great medicinal advantages due to important bioactive elements (Odoh *et al*., 2022). Tea leaf processing methods have a significant impact on the flavour, fragrance, and overall profile of the finished tea product.

Different types of tea, such as green tea, black tea, oolong tea, white tea, and others, undergo variations in these processing steps, contributing to their distinct characteristics. Moreover, the different tea processing methods result in variation of chemical components in tea beverages (Hara *et al*., 1995). Thus, the objectives of this study were to evaluate the physicochemical properties, mineral content, and consumer acceptability of green, oolong, and black teas prepared from Sacha Inchi leaves using various processing methods.

Materials and Methods

Materials

The freshly harvested Sacha Inchi leaves came from the Sacha Inchi plantation in Bachok, Kelantan, Malaysia. The leaves have been selected for plucking, with focus on those that are vibrant, undamaged, and at a suitable growth stage. Hand plucking was performed to separate the leaves from the stalks. To avoid bruising or wilting, newly plucked Sacha Inchi leaves were gathered and kept in appropriate containers. The leaves were washed in clean water and then treated based on the desired outcome. Other ingredients, including dried stevia, commercial green tea, commercial oolong tea, and commercial black tea samples containing *Camellia sinensis*, were obtained from the local market.

Production of green tea, oolong tea and black tea from Sacha Inchi leaves

In this study, three varieties of tea have been developed using Sacha Inchi leaves employing varied processing method and levels of fermentation: green tea, oolong tea, and black tea. Green tea undergoes no fermentation, while oolong tea undergoes partial fermentation, and black tea undergoes full fermentation. Tea is composed of leaves from the *Camellia sinensis* plant (Awadalla *et al*., 2011). In this study, the tea composition provided for all assays was 50% commercial green, oolong, and black tea (from the *Camellia sinensis* plant), 45% Sacha Inchi tea leaves (green, oolong, and black), and 5% commercial dried stevia.

Processing of green tea from Sacha Inchi leaves

Green tea was made using the methods described by KC *et al.* (2020), with some modifications. Fresh Sacha Inchi leaves were steam-cooked at 100 °C for 14 minutes, then cooled for 15 minutes before being hand-rolled for 15 minutes. The leaves were subsequently dried in an electric oven (Luxury Electric Deck Oven, China) at 110 °C for 20 minutes.

Following this, they underwent a second rolling process for 30 minutes, completing the production of the green tea. The final weight was recorded, and the product was vacuum-sealed using the Automatic Heavy Duty Double Chambers Vacuum Packaging Machine (Jaw Feng Machinery, Taiwan). Prior to analysis, three materials were combined: 50% commercial green teas, 45% Sacha Inchi green tea leaves, and 5% commercial dried stevia.

Processing of oolong tea from Sacha Inchi leaves

The production of oolong tea from Sacha Inchi leaves was according to the method of Wong *et al.* (2022) with some modifications. The fresh Sacha Inchi leaves were subjected to indoor withering. They were placed on a plate and kept at room temperature for 2 hours. During this time, two turn-over treatments were applied, allowing the leaves to lose moisture and undergo changes in their chemical composition. The leaves were dried and fermented in a dryer (Floor Model Laboratory Dryers FDD-720, Malaysia) at 25 °C for 2 hours. Following this, they were further dried in an electric oven (Luxury Electric Deck Oven, China) at 160 °C for 20 minutes. The leaves were hand-rolled for 5 minutes, then dried in an oven at 80 °C for 20 minutes. Once fully dried, the leaves were hand-rolled again. The oolong tea produced was vacuum packaged using the Automatic Heavy Duty Double Chambers Vacuum Packaging Machine (Jaw Feng Machinery, Taiwan). Before the analysis, three materials were combined: 50% of commercial oolong tea, 45% Sacha Inchi oolong tea leaves, and 5% commercial dried stevia.

Processing of black tea from Sacha Inchi leaves

Black tea of Sacha Inchi leaves was produced according to KC *et al.* (2020) with some modifications. The fresh Sacha Inchi leaves were left to wither indoors at room temperature for two hours. Next, the leaves were hand-rolled on the table top for 25 to 35 minutes. The fermentation occurred over 14 hours in a fermentation room maintained at 25 °C. Following this, the leaves were rolled and dried in a convection oven at 200 °C for 4 minutes. The Sacha Inchi black tea that was produced was then sealed in vacuum packs using the Automatic Heavy Duty Double Chambers Vacuum Packaging Machine (Jaw Feng Machinery, Taiwan). Prior to the analysis, three materials were blended: 50% of commercial black tea, 45% Sacha Inchi black tea leaves, and 5% of the commercial dried stevia.

Physicochemical analysis

Moisture content: An empty crucible was dried to a consistent weight in an oven at 105 °C, then cooled in a desiccator and weighted. The tea sample (2 g) was weighed in the crucible and dried at 105 °C until constant weight. The weight of the crucible containing the dried tea sample was measured after it has been cooled in a desiccator (AOAC, 2016). The moisture content was computed as follows:

$$Moisture\ content\ (\%) = \frac{Moisture\ content\ of\ the\ given\ sample\ (g)}{Weight\ of\ the\ sample\ (g)} \times \frac{100}{1}$$

Ash content: A muffle furnace was used to determine the ash content (AOAC, 2016). A heat-resistant porcelain crucible was subjected to drying in an oven at 105 °C for 10 minutes, followed by cooling in a desiccator. This porcelain crucible was then weighed. Subsequently, 2 g of the crushed tea sample was measured and reweighed in the porcelain crucible. The crucible containing the sample was then incinerated in a furnace (Furnace 62700, Barnstead-Thermolyne, USA), initially at 250 °C for 1 hour, followed by 550 °C for 7 hours. Then, the crucible was removed, desiccated, and weighed. The ash content (%) was computed as follows:

$$Ash\ content\ (\%) = \frac{Weight\ of\ the\ ash\ (g)}{Weight\ of\ crushed\ tea\ sample\ (g)} \times \frac{100}{1}$$

Crude fat: The crude fat analysis was performed using the automated Soxtherm system (Gerhardt, Germany). The extraction cup was dried in an oven at 105 °C for 6 hours, and the pre-dried cup was then weighed (W_2). Dried tea sample (3 g) of the sample (W_1) wrapped in filter paper was taken in the extraction thimble. Subsequently, 150 ml of petroleum ether was added to the extraction cup. The extraction thimble was placed into the extraction cup and after the extraction completed, petroleum ether was removed from the extraction cup and dried at 105 °C for 2 hours in an oven. The extraction cup was cooled in a desiccator and then weighed (W_3). The percentage of fat was calculated using the formula:

$$Crude\ fat\ (\%) = \frac{W_3 - W_2}{W_1} \times \frac{100}{1}$$

Where; W_1 = Weight of sample (g); W_2 = Weight of extraction cup (g); W_3 = Weight of extraction cup + fat (g).

Crude protein: Crude protein was evaluated using the Micro Kjeldahl technique (AOAC, 2016). The

Kjeldahl method was employed to calculate crude protein based on the nitrogen content in the food. This process encompassed three stages: Digestion, distillation, and titration. The tea sample (2 g) was prepared and weighed into the digestion tube, followed by the addition of 2 tablets of the catalyst Kjeltabs Cu 3.5 to the tube. Subsequently, 12 ml of concentrated sulfuric acid was introduced, and the sample was gently shaken to ensure even wetting with the acid. All samples were digested until a clear green or blue solution was obtained. During the distillation process, a conical flask was filled with 25 ml of receiver solution and positioned in the distillation unit. The designated program was activated, leading to the automatic dispensing of 70 ml of distilled water into the tube, followed by 50 ml of 32% NaOH. The receiver solution in the distillate flask turned green, signifying the presence of alkali substances. The distillate underwent titration using standardized 0.1 N hydrochloric acid until the mixture exhibited a pink or red colour. The calculation for the percentage of protein present in the sample was demonstrated as follows:

$$N\,(\%) = \frac{(S - B) \times N \times 14.007 \times 100}{Weight\ of\ sample\ (g) \times V}$$

$$Crude\ Protein\ (\%) = N\ (\%) \times F$$

Where: S = Volume of acid used for sample titration (ml); B = Volume acid used for blank titration (ml); V = Volume taken for distillation (ml); N = Normality of HCl; F = Protein factor, 6.25.

Crude fibre: The fibre content was determined based on AOAC (2016) technique by Fibertherm system, Germany. The fibre bag was weighed (W_1) and added with the tea sample approximately 1 g (W_2). Following the completion of the analysis, the fiber bag was positioned in the crucible and subjected to drying for 4 hours at 105 °C (W_3). Subsequently, the crucible with the dry fiber bag was placed in the furnace at 550 °C for 4 hours. Afterward, the crucible containing ash was taken out, allowed to cool in the desiccator, and weighed once it reached room temperature (W_4). The measurements included the weight of the blank (W_5), the weight of the empty crucible (W_6), and the weight of the crucible with the ash of the empty fiber bag (W_7).

$$W_5\ (Blank\ value) = W_7 - W_6$$

$$Crude\ fibre\ (\%) = \frac{[(W_3 - W_1) - (W_4 - W_5)]}{W_2} \times 100$$

Total carbohydrate

Available carbohydrate and the total carbohydrates content of the Sacha Inchi leaves ware estimated by difference:

$$Total\ carbohydrate\ (\%) = 100\% - (moisture + ash + crude\ protein + crude\ fat)$$

$$Available\ carbohydrate\ (\%) = Total\ carbohydrate - (fiber)$$

Colour profile measurement

Colour parameters (L*, a*, b*) of the samples were assessed according to the method of Ramly *et al.* (2021), using colorimeter Minolta Chroma Metre CR-400 (Konica Minolta, Japan). Prior to testing the samples, the device was calibrated using a white background calibration plate. The tea infusion samples were placed in petri dishes on a white backdrop. Then, L*, a*, and b* values were measured based on the CIELAB colour system which explains that the colour of infusion tea becomes lighter upon the increasing value of colour lightness. L* is the brightness from black (0) to white (100), a* is the colorimeter value for green (-) to red (+), and b* is the colorimeter value for blue (-) to yellow (+) were recorded.

pH value

pH of Sacha Inchi leaves tea was measured, corrected, and stabilized in 1 minute at 25 °C. The pH value was obtained after immersing the electrodes of a pH meter (Mettler Toledo, Germany) in the sample solution. Prior to analysis, the pH meter underwent calibration using buffer solutions with pH values of 4.0, 7.0, and 10.0 (Ahmat-Azemi *et al.*, 2021).

Energy content

The samples energy content was computed in kilojoules per hundred grams (Idris *et al.*, 2019) by summing the values for carbohydrate, crude fat, and crude protein, which were 16.736 KJ, 37.656 KJ, and 16.736 KJ, respectively, as indicated below:

$$Energy\ value\ KJ/100g = [Crude\ protein\ (\%) \times 16.736] + [Crude\ fat\ (\%) \times 37.656] + [Carbohydrate\ (\%) \times 16.736]$$

Mineral analysis

The analysis of minerals in Sacha Inchi leaves and tea infusions provides valuable information about the nutritional content and potential health benefits associated with these substances. The analytical technique to determine the mineral was done by using a Varian Vista MPX Charge Coupled Device (CCD) Simultaneous Inductively Coupled Plasma Optical

Emission Spectrophotometer (ICP-OES) and ICP-OES Analyzers with Qtegra software, ICAP 7600 DUO (Thermo Fisher Scientific, United Kingdom).

Mineral analysis of dry tea

Before analysis, all tea samples were ground to an approximate consistency. Each of Sacha Inchi tea leaves sample (0.5 g) was added into 9 ml of 65% HNO_3. The mixture was then digested in a microwave digestion system. The digested tea leaves were diluted by marking up the solution up to 25 ml with ultra-pure water. The same digestion protocol was applied on a blank sample. Subsequently, 10 ml of the sample was transferred into a test tube for mineral analysis using ICP-OES (Thermo Scientific iCAP 7000 Series, UK). The obtained results from the instrument were expressed in mg/kg. For the (ICP-OES) determination of the mineral content, an aliquot of the digest was employed.

Mineral analysis of infusion liquid

The tea infusions were prepared by mixing 200 ml of boiling deionized water with 2 g of dried tea. The sample was swirled with a glass rod for 30 seconds to ensure proper wetting. The resultant infusion was covered and steeped for approximately 6 minutes. The steeped infusion was immediately decanted through a fine stainless-steel filter and allowed to cool to avoid contact with the tea leaves. After cooling the infusion, it was filtered and emptied into a test tube for mineral analysis using ICP-OES (Thermo Scientific iCAP 7000 Series, UK).

Sensory evaluation

The sensory analysis of the tea samples was conducted following Haw *et al.* (2020) with some modifications. The evaluation was performed at 27 ± 2 °C using a 7-point hedonic scale. Two grams each of green tea, oolong tea, and black tea were measured, placed in separate tea bags, and steeped in 200 ml of hot water for 3 minutes. After the infusion was complete, the tea bags were removed, and the tea samples were allowed to cool to room temperature. Then, 10 ml portions of green tea, oolong tea, and black tea were served to each respondent in suitable cups. The sensory properties evaluated included colour, aroma, taste, aftertaste, and overall acceptability. Scores ranged from 1, indicating dislike extremely, to 7, indicating like extremely. The data were calculated by the average scores of all tested attributes. The respondents were 70 untrained personals with the age range from 18–30 years old. This study has been assigned with a study protocol Code UniSZA/UHREC/2023/516. Eligible subjects that fulfilled the inclusion criteria, were selected to participate in this sensory evaluation including those with no allergies to food or medicine.

Statistical analysis

The tea samples were replicated three times, and the results are presented as the mean ± standard deviations (SD). For data analysis, SPSS 20.0 was used. One-way ANOVA and Duncan's multiple range test were used to compare sample groups with a p-value of <0.05 (Wuttisin *et al.*, 2021).

Results and Discussion

Physicochemical properties

Table 1 shows the proximate composition and energy content of Sacha Inchi leaves green tea, oolong tea, and black tea. The moisture content of tea is a crucial indicator of its quality. All the prepared tea leaves contained 6.19-8.23% of moisture content (Table 1), which is less than 14% moisture, thus indicating good storage stability (Noor Aziah and Komathi, 2009). The moisture content of green tea was significantly higher compared to oolong and black tea. This might due to the exclusion of the fermentation process of the green tea compared to oolong and black tea since during this process much of the polyphenols that retain moisture in oolong and black tea are destroyed which resulted to low moisture content (Adnan *et al.*, 2013). A study done by Ifemeje *et al.* (2020) noted that the moisture levels in *Camellia sinensis* tea exceeded the suggested threshold of 6.5%, which could potentially impact the samples' shelf life negatively. However, the moisture content of Sacha Inchi black tea was 6.19% which was lower than 6.5% and it is likely to have a longer shelf life as it would have been processed under conditions that minimize the potential for contamination or degradation.

The content of ash of Sacha Inchi tea was highest in oolong tea but not significantly different compared to black tea. To maintain tea product quality during storage, the recommended ash content should not exceed 5.54% (Ifemeje *et al.*, 2020). The value of ash content is high, most likely owing to high mineral content in tea, and the greater ash content in tea may be related to decreased moisture content (Adnan *et al.*, 2013). The protein and fat content of Sacha Inchi black tea analyzed was higher than oolong and green tea. The protein and fat content in black tea can differ significantly from other types of tea, and this discrepancy is often attributed to the fermentation or oxidation process employed during black tea manufacturing. Black tea undergoes a more extensive oxidation process than green or oolong tea, resulting in significant changes to its chemical composition. This process can be beneficial for extracting these components, as oxidation is controlled by leaf enzymes during tea processing (Cui *et al*., 2017).

Table 1: *Proximate composition and energy content (n=3) of green, oolong and black tea from Sacha Inchi leaves.*

Composition (%)	Sacha Inchi tea		
	Green tea	**Oolong tea**	**Black tea**
Moisture	8.23 ± 0.1[a]	6.92 ± 0.17[b]	6.19 ± 0.09[b]
Ash	6.92 ± 0.13[b]	7.42 ± 0.06[a]	7.38 ± 0.15[a]
Crude protein	18.86 ± 0.10[b]	20.05 ± 0.89[b]	22.97 ± 0.63[a]
Crude fat	3.20 ± 0.40[b]	3.30 ± 0.60[b]	5.18 ± 0.34[a]
Crude fiber	14.30 ± 0.25[c]	15.51 ± 0.49[b]	17.69 ± 0.15[a]
Carbohydrate	48.51 ± 0.65[a]	46.79 ± 0.35[b]	40.26 ± 0.17[c]
Total carbohydrate	62.80 ± 0.45[a]	62.66 ± 0.31[a]	58.28 ± 0.86[b]
Energy (KJ /100g)	1247.63±6.55[a]	1243.07±7.98[a]	1258.92±11.38[a]

All data are presented by means ± standard deviation. Mean and standard deviation followed by the different letter in the same row are significantly different at $p < 0.05$.

The crude fibre content was significantly different between all samples. The low fibre content in tea samples may be attributed by the processing of the tea leaves. In addition to this, crushing, tearing in the rolling process also destroys the leaf structure that might affect fibre content (Adnan *et al*., 2013). Plants produce crude fibre from structural components such as cellular walls, sclerenchyma, collenchyma, and transportation tissues. Young cells have thin cellular walls that harden as the plant matures, protecting the plants from excessive transpiration and the effect of other unfavourable elements. In this study, the content of crude fibre was highest in the Sacha Inchi black tea. The predominant component of black tea's insoluble materials is crude fibre. The fibre content of tea products varies and ranges between 7 and 20%.

The results showed that Sacha Inchi green tea had the highest level of total carbohydrates compared to oolong tea and black tea. During the black tea production process, the content of sucrose and glucose in freshly harvested tea leaves reduced dramatically. This might be connected to the formation of browning compounds/Maillard reaction products such acrylamide at temperatures exceeding 120 °C during the roasted green tea processing process. The Maillard reaction represents a chemical process in which reducing sugars (such as glucose and fructose) interact with amino acids, resulting in the formation of brown pigments and imparting a caramel flavor (Nelum *et al*., 2022). Green tea has a variety of chemical components that contribute to its flavour; the sweetness of sugars found in green tea may be essential for the tea to taste pleasant (Liu *et al*., 2018). Based on the result in Table 1, Sacha Inchi black tea yields the highest energy content compared to green and oolong tea and this might due to the leaves were more oxidized and steeped for a longer period of time.

pH and colour

Table 2 displays the pH values for Sacha Inchi leaves' green, oolong, and black tea, falling within the range of 5.11 and 5.34. The results indicated that Sacha Inchi oolong tea has the lowest pH value, followed by black tea and green tea. Sacha Inchi oolong tea also exhibits the highest total acidity. These variations in pH and total acidity are associated with the different types of tea, impacting the extent of organic acid production. The pH value of oolong tea and black tea Sacha Inchi tea was lower compared to green tea due to the inclusion of the fermentation process during processing. Green tea is non-fermented, while black and oolong tea are fully fermented and semi-fermented. This conclusion agreed with Kaewkod's (2019) observation that the pH value declined during the fermentation process owing to the generation of organic acids.

Table 2: *pH value and colour profile (n=3) of green, oolong and black tea from Sacha Inchi leaves (infusion).*

Analysis	Sacha Inchi tea		
	Green tea	**Oolong tea**	**Black tea**
pH	5.34 ± 0.15[a]	5.11 ± 0.02[b]	5.12 ± 0.02[b]
Lightness (L*)	60.56 ± 2.07[a]	53.39±1.48[b]	51.11±2.39[b]
Redness (a*)	-2.11 ± 0.09[b]	0.66 ± 0.38[a]	0.83 ± 0.52[a]
Yellowness (b*)	19.01 ± 1.27[b]	29.07±0.49[a]	28.82±0.53[a]

All data are presented by means ± standard deviation. Mean and standard deviation followed by the different letter in the same row are significantly different at $p < 0.05$.

One essential way to determine the type of tea is to look at its colour during infusion. In this study, lightness (L*), redness (a*) and yellowness (b*) measurement were obtained for green tea, oolong tea and black tea from Sacha Inchi leaves. The L* value of green tea was significantly different compared to oolong tea and black tea. The lightness of green tea, oolong tea and black tea decrease due to the processing and level of fermentation. This was in agreement with the findings of Ifemeje *et al.* (2020), which stated that various tea leaves processing methods with different levels of fermentation can directly affect the colour of tea. The green tea consists of green colour which proven by the data that obtained which the a* value is -2.11. This negative a* value indicates the presence of greenness in the colour. The redness of black tea is highest which makes the colour of yellowness of black tea lower compared to oolong tea. The longer withering in the tea process affects the result of colour which makes the tea become darker (Hossain *et al.*, 2022).

Table 3: *Mineral composition (n=3) of green tea, oolong tea and black tea from Sacha Inchi tea leaves.*

Mineral (mg/kg)	Sacha Inchi tea powder		
	Green tea	Oolong tea	Black tea
Magnesium (Mg)	0.87±0.11[a]	0.99 ± 0.14[a]	1.13 ± 0.19[a]
Manganese (Mn)	0.13±0.02[a]	0.15 ± 0.09[a]	0.08 ± 0.09[a]
Iron (Fe)	0.06±0.00[a]	0.08 ± 0.03[a]	0.11 ± 0.07[a]
Calcium (Ca)	3.59 ± 1.18[a]	4.40 ± 2.08[a]	6.01 ± 1.94[a]
Copper (Cu)	0.01 ± 0.00[a]	0.01 ± 0.00[a]	0.01 ± 0.00[a]
Sulphur (S)	1.26 ± 0.14[b]	1.31 ± 0.12[ab]	1.52 ± 0.11[a]
Zink (Zn)	0.01 ± 0.00[b]	0.03 ± 0.01[ab]	0.04 ± 0.01[a]
Aluminium (Al)	0.19± 0.03[a]	0.23 ± 0.07[a]	0.14 ± 0.09[a]
Phosphorus (P)	1.89 ± 0.15[a]	1.98 ± 0.34[a]	2.20 ± 0.16[a]
Potassium (K)	5.02 ± 1.94[a]	5.62 ± 1.92[a]	7.09 ± 0.68[a]
Arsenic (As)	N/A	N/A	N/A
Cadmium (Cd)	N/A	N/A	N/A
Lead (Pb)	N/A	N/A	N/A

N/A = Not Available; All data are presented by means ± standard deviation. Mean and standard deviation followed by the different letter in the same row are significantly different at $p < 0.05$.

Mineral content

The mineral composition of Sacha Inchi tea leaves powder and infusion were shown in Tables 3 and 4, respectively. Preparation method has a great influence to maintain the mineral content in tea leaves and their infusion (Moses *et al.*, 2015). Thirteen (13) mineral elements (Mg, Mn, Fe, Ca, Cu, S, Zn, Al, P, K, As, Cd and Pb) were determined in the Sacha Inchi tea leaves powder and their infusion. Based on Tables 3 and 4, potassium (K), phosphorus (P) and calcium (Ca) composition were higher compared to another element of mineral in Sacha Inchi tea leaves powder and infusion. Calcium is one of the mineral components required for plant development. Sacha Inchi tea's high calcium content makes it an excellent nutrient source for older adults who are at risk for osteoporosis. It also plays a positive role in a number of essential bodily processes, including blood coagulation, blood pressure regulation, the growth and maintenance of bones and teeth, and cofactors in enzyme processes (Christine *et al.*, 2017). Potassium has the highest value compared to another element (Table 4). Black tea contains the highest level of potassium (K) (202.52 mg/l) and has a potential to prevent high blood pressure (Christine *et al.*, 2017). Meanwhile, in the tea infusion of Sacha Inchi tea leaves, the amount of phosphorus (P) is higher compared to Sacha Inchi leaves powder. In tea infusion, phosphorus (P) of black tea and oolong tea were higher compared to green tea which was 22.92 mg/l .

Table 4: *Mineral composition (n=3) of green tea, oolong tea and black tea from Sacha Inchi tea infusion.*

Mineral (mg/l)	Sacha Inchi tea infusion		
	Green tea	Oolong tea	Black tea
Magnesium (Mg)	12.08 ± 0.36[b]	14.36 ± 2.19[b]	19.70 ± 0.66[a]
Manganese (Mn)	1.21 ± 0.06[b]	0.50 ± 0.09[c]	2.56 ± 0.23[a]
Iron (Fe)	0.03 ± 0.01[b]	0.02 ± 0.01[b]	0.05 ± 0.01[a]
Calcium (Ca)	10.79 ± 0.60[b]	11.37 ± 2.91[b]	19.17 ± 1.79[a]
Copper (Cu)	0.13 ± 0.10[a]	0.14 ± 0.10[a]	0.18 ± 0.01[a]
Sulphur (S)	11.91 ± 0.27[b]	13.56 ± 1.46[b]	17.43 ± 0.51[a]
Zink (Zn)	0.12 ± 0.06[a]	0.26 ± 0.22[a]	0.51 ± 0.35[a]
Aluminium (Al)	1.48 ± 0.08[b]	1.22 ± 0.27[b]	2.89 ± 0.28[a]
Phosphorus (P)	22.92 ± 0.42[b]	36.50 ± 1.72[a]	36.48 ± 0.61[a]
Potassium (K)	150.26±3.34[b]	181.40±28.29[ab]	202.51±5.09[a]
Arsenic (As)	0.01 ± 0.01[a]	0.01 ± 0.01[a]	0.02 ± 0.01[a]
Cadmium (Cd)	N/A	N/A	N/A
Lead (Pb)	N/A	N/A	N/A

N/A = Not Available; All data are presented by means ± standard deviation. Mean and standard deviation followed by the different letter in the same row are significantly different at $p < 0.05$.

Sensory evaluation

The sensory mean ratings for the leaves of Sacha Inchi infusion tea are displayed in Table 5. The result showed that the of colour, aroma, taste, aftertaste, and overall acceptability attributes were most favorable for black tea derived from Sacha Inchi leaves compared to oolong and green tea. The colour of black tea showed the highest score, probably due to their personal experience that they might be attracted to the colour which was darker compared to other samples. The colour of tea product is related to the level of fermentation (Ifemeje *et al*., 2020). Aroma and taste are intimately connected. The aroma of black tea was significantly different compared to the oolong and green tea. This might be due to its production process which involves the process of withering and fully fermentation which contributed to the better aroma quality. During the fermentation phase, the enzymatic processes in tea leaves intensified, resulting in a decrease in the concentration of astringent and bitter chemicals in tea leaves, and the accumulation of particular volatile molecules, which eventually formed the distinctive scent of tea (Ye *et al*., 2023). Thus, the aroma became stronger and more which proven by sensory evaluation analysis in Table 5 which showed that the score for the aroma attributes was highest in Sacha Inchi black tea.

Table 5: *Sensory mean score (n=70) of green tea, oolong tea, and black tea from Sacha Inchi leaves.*

Sensory attributes	Sacha Inchi tea infusion		
	Green tea	Oolong tea	Black tea
Colour	4.56 ± 1.22[c]	5.44 ± 1.00[b]	5.90 ± 0.89[a]
Aroma	4.71 ± 1.19[b]	4.86 ± 1.03[b]	5.41 ± 1.19[a]
Taste	4.27 ± 1.32[b]	4.43 ± 1.22[b]	5.10 ± 1.19[a]
After taste	4.09 ± 1.45[a]	4.13 ± 1.18[a]	4.49 ± 1.22[a]
Overall acceptability	4.49 ± 1.26[b]	4.63 ± 1.02[b]	5.16 ± 1.14[a]

Score 1-dislike extremely, score 7-like extremely; all data are presented by means ± standard deviation. Mean and standard deviation followed by the different letter in the same row are significantly different at $p < 0.05$.

Conclusions and Recommendations

Black tea made from Sacha Inchi leaves exhibits the highest levels of crude protein, crude fat, crude fiber, and energy content in comparison to green and oolong tea. Green tea from Sacha Inchi leaves contain highest pH value and colour lightness (L*). The Sacha Inchi tea infusion showed the higher mineral content detected compared to Sacha Inchi tea leaves powder. Potassium, phosphorus and calcium were high in both tea leaves and tea infusion especially in black tea. Black tea obtained the highest mean score for all sensory attributes. All three forms of tea brewed from Sacha Inchi have the potential to be commercialised owing to their nutritional content. The consumption of these Sacha Inchi teas as a dietary supplement might help to compensate for mineral deficiencies.

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Novelty Statement

Various Sacha Inchi teas may contain beneficial elements in terms of physicochemical properties, mineral content, and consumer acceptability. The demand and market of tea product as functional food increase due to healthy lifestyle and it is important to explore the potential of Sacha Inchi tea.

Author's Contribution

Nur Nabilah Norsham: Carried out the experiments and also prepared the manuscript.
Zarinah Zakaria: Supervised the experiments, provided direction during data processing, wrote and evaluated the manuscript.
Nur Hasyimah Mat Shah, Nurul Zaizuliana Rois Anwar, Napisah Hussin, Fauziah Tufail Ahmad, Faridah Yahya and Norshazila Shahidan: Supervised the experiments and reviewed the manuscript.

Conflict of interest
The authors have declared no conflict of interest

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