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Antioxidant capacity and sensory evaluation of soursop leaves tea incorporated with dried fruit pulps

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Abstract

Soursop leaves tea contains antioxidant capacity; however, it is not readily acceptable due to its aroma, flavour, and taste. The present work thus assessed whether incorporating dried fruit pulps into soursop leaves tea could enhance its antioxidant capacity and sensory acceptability. The soursop leaves were processed using green tea processing method, and dried at 70°C until 5% moisture content was obtained. The soursop leaves tea was incorporated independently with dried soursop pulps, dried pineapple pulps, and dried key lime at a ratio of 2:1, and brewed at 70°C for 10 min. The dried fruit pulps were processed at 60°C until the moisture content was 9 to 18%. The physicochemical properties (pH and colour characteristics) of the brewed soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK) were analysed using pH meter and colorimeter. The results showed that SLK had the lowest lightness and pH value. The colour of the brewed samples was all in the range of yellowish green. The antioxidant capacity, total phenolic content (TPC), and total flavonoid content (TFC) analyses of the brewed samples were conducted by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method, Folin-Ciocalteu method, and aluminium chloride colorimetric method, respectively: SLP had the highest antioxidant capacity of 94.69 ± 0.50%, while SLK had the highest TPC (0.46 ± 0.01 mg GAE/mL). However, statistical data of TPC showed no significant difference between SLK and SLP. Meanwhile, SL had the highest TFC (34.85 ± 0.17 mg QE/mL). The sensory evaluation results reported that SLP had the highest acceptability of "like slightly" (6.00 ± 1.77). In conclusion, SLP had the highest antioxidant capacity, panellist acceptability, and considerably high TPC.

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Introduction

An antioxidant is a substance grouped under phenolic compounds, the secondary metabolites of plants that naturally exist in many plant-based ingredients (Shrivastava *et al*., 2019). In the human diet, consuming fruits and vegetables is a recommended way to help humans stay healthy because fruit and vegetables contain a significant amount of flavonoids and phenolics that contribute to antioxidant activity (Minatel *et al*., 2017; Ruiz Rodríguez *et al*., 2021). Antioxidants are compounds that can eliminate free radicals that comprise non-reactive and reactive species, such as reactive oxygen species (ROS) and reactive nitrogen species (RNS) (Azman *et al*., 2019; Shrivastava *et al*., 2019). Usually, free radicals can be destroyed gradually by normal metabolic processes; however, if they cannot be destroyed, they may accumulate in the human body, and lead to oxidative stress (Azman *et al*., 2019). Finally, it becomes a prelude to many diseases such as cancers, cardiovascular diseases, neurological diseases, tumours, and other non-communicable diseases (NCDs) (Alkadi, 2018).

Soursop leaf is one part of the soursop plant, and considered a by-product or waste of the plant (Orak *et al*., 2019; Santos *et al*., 2023). Soursop leaves can be processed into tea, herbal tea, or more accurately, tisanes using green or black tea processing methods (Hardoko *et al*., 2018; Nhi *et al*., 2020). Soursop leaves contain terpenoids, alkaloids, steroid compounds, flavonoids, and tannins. It has been proven that soursop leaves processed into unfermented tea (green tea) exerted antioxidants

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(Indarto *et al*., 2020), anti-uric acid (Hardoko *et al*., 2018), anti-inflammation, antidiabetic (Oliveira *et al*., 2017), anticancer, anti-cholesterol (Cornelia *et al*., 2019), and antibacterial (Grijalva-Verdugo *et al*., 2022) properties. Soursop leaves tea contains bioactive components such as antioxidants that can help scavenge free radicals, considered the starter of most diseases (Indarto *et al*., 2020; Nhi *et al*., 2020). Tannins and polyphenols in soursop leaves are related to antioxidant functions (Indarto *et al*., 2020). However, the aroma, taste, and flavour originally possessed by soursop leaves tea affect its acceptance level and marketing limitations (Hardoko *et al*., 2018).

Based on previous studies, soursop leaves tea has an unacceptable taste and aroma, but is high in antioxidants (Hardoko *et al*., 2018; Indarto *et al*., 2020). Incorporating ingredients with fragrant aroma can significantly alter the unacceptable taste of soursop leaves tea (Indarto *et al*., 2020). The added ingredients, such as cinnamon, can increase the antioxidant content of the soursop leaves tea as well as alter the unacceptable taste of the tea (Indarto *et al*., 2020). Incorporating rose petals into green tea, black tea, and soursop leaves tea also shows significant increase in its antioxidant capacity (Aliakbarlu *et al*., 2018; Nhi *et al*., 2020). According to Nhi *et al*. (2020), adding herbs like stevia, liquorice, chrysanthemum, and rose to soursop leaves tea may create a synergistic impact that changes the taste, and enhances the nutritional content of the tea. A few studies reported the unacceptable taste and aroma possessed by soursop leaves tea, and the incorporation of herbs into soursop leaves tea (Aliakbarlu *et al*., 2018; Hardoko *et al*., 2018; Indarto *et al*., 2020; Nhi *et al*., 2020), but rarely studied the incorporation of fragrance or fruity aroma into soursop leaves tea. Tropical fruits, such as soursop, pineapple, and key lime, have been reported to be high in antioxidants and other bioactive compounds (Chiet *et al*., 2014; Agu and Okolie, 2017; Lubinska-Szczygieł *et al*., 2018; Orak *et al*., 2019; Altemimi *et al*., 2021; Santos *et al*., 2023). According to Vidinamo *et al*. (2022), the drying process of the fruits could increase their storage stability, extend their shelf life, and increase their antioxidant and total phenolic content due to the release of bound phenolic compounds from the plant cell wall and vacuoles during the drying process.

Therefore, the present work aimed to examine the physicochemical properties of soursop leaves tea incorporated with dried fruit pulps, and to evaluate the antioxidant capacity, total phenolic content, total flavonoid content, and acceptability of the soursop leaves tea incorporated with dried fruit pulps.

Materials and methods

Materials

Soursop (*Annona muricata* Linn.), soursop leaves, pineapple (*Ananas comosus* (L.) Merr.) cultivar Morris, and key lime (*Citrus* × *aurantifolia* Christm. Swingle) were collected from Bukit Pasir, Muar, and Tangkak, Malaysia.

Green tea process of soursop leaves

The processing of soursop leaves to obtain soursop tea followed a method adapted from green tea processing with slight modifications (Ahmed and Stepp, 2013; Aliakbarlu *et al*., 2018; Hardoko *et al*., 2018). The process began by carefully plucking fresh mature leaves, specifically those positioned third to fifth, ensuring the leaves were free from physical damage. Freshly harvested soursop leaves (moisture content of 76.46 ± 0.352%) were then thoroughly cleaned using tap water to eliminate any potential physical contaminants. The next step in the processing involved steaming the soursop leaves, using a steamer to maintain a temperature of 100°C for 8 min. After steaming, the soursop leaves were allowed to cool for 15 min. The cooled, steamed soursop leaves underwent rolling for approximately 20 min, using a mixer at level 5 (Model 5KPM50, KitchenAid, Ohio, United States). Next, the soursop leaves were dried using a food dehydrator (model 229026, HENDI, Rhenen, Netherlands) at approximately 70°C for 5 h or until the moisture content of the soursop leaves reached approximately 5%. The dried soursop leaves tea was placed in an air-tight glass jar containing silica gel to maintain the tea's moisture content.

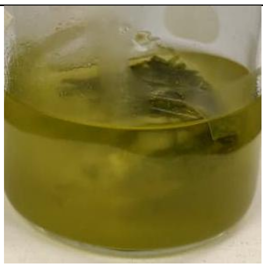
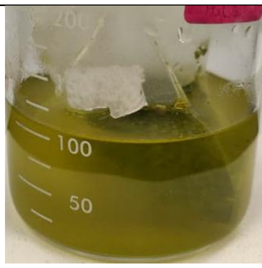
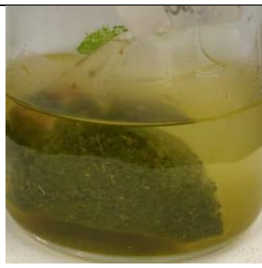
Processing of dried fruit pulps

The processing of fresh fruit into dried fruit pulps commenced with the cleaning of the fresh fruit, followed by removing the fruit peel, except for the key lime. Subsequently, the fruit pulp of soursop, pineapple, and key lime were sliced into pieces measuring 1 × 1 × 0.3 cm (Kendall and Sofos, 2012). These sliced fruit pulp samples underwent a pre-treatment process by dipping in sugar syrup solution, and the syrup solution (pH 6.57 ± 0.01) was prepared by combining 500 g of sugar with 1,000 mL of water. This syrup dipping pre-treatment helps reduce oxidation, preserve the colour and vitamins, and prolong the shelf life of the fruits (Zepp *et al*., 2023). After that, the sliced fruit pulps were submerged in the prepared syrup solution for 10 min (Liu *et al*., 2022). The treated fruit pulps were removed from the syrup solution, and drained before drying (Kendall and Sofos, 2012). Then, the pre-treated fruit pulps were dried using a food dehydrator (229026, HENDI, Rhenen, Netherlands) at 60°C for 24 h until the weight of the fruit pulps reached a constant value (Gyurova and Enikova, 2014; Kumari and Bandaranayake, 2016; Liu *et al*., 2022; Zepp *et al*., 2023).

Brewing of soursop leaves tea incorporated with dried fruit pulps

Each tea sample was prepared using a 2:1 ratio of soursop leaves tea (2 g) to dried fruit pulp (1 g), enclosed in a tea bag. The final products are shown in **Error! Reference source not found.**; soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea with dried key lime (SLK). For the control sample (soursop leaves tea alone; SL), 2 g of soursop leaves tea were placed in the tea bag. Subsequently, the soursop leaves tea sample was brewed with 100 mL of water at 70°C for 10 min (Aliakbarlu *et al*., 2018; Indarto *et al*., 2020).

Table 1. Final product of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK).

SL	SLS	SLP	SLK
			
			

pH analysis

The pH of the brewed samples was measured according to Marchan *et al*. (2021) with slight modifications. The brewed soursop leaves tea incorporated with dried fruit pulps were allowed to cool down to 46 ± 1°C before analysis. The analysis was triplicated using a pH meter (Cyberscan pH 310 pH/mV/°C/°F Data Meter, Eutech Instrument, Singapore).

Colour analysis

The colour analysis of the brewed soursop leaves tea incorporated with dried fruit pulps was carried out according to Raksakantong *et al*. (2012), Hardoko *et al*. (2018), and Izli *et al*. (2018) method with slight modifications. The L* (lightness), a* (redness-greenness), and b* (yellowness-blueness) values of brewed samples were assessed using a colorimeter (MiniScan EZ 4500, HunterLab, Virginia, United States), and the instrument underwent calibration before analysis. Approximately, 20 mL of the brewed sample was placed in a Petri dish, and the analysis was carried out from three different positions.

The total colour difference, ΔE, was calculated using Eq. 1:

$$\Delta E = \sqrt{(L^*_2 - L^*_1) + (a^*_2 - a^*_1) + (b^*_2 - b^*_1)} \quad \text{(Eq. 1)}$$

where, L^*_1 = lightness of the brewed SL, L^*_2 = lightness of the brewed soursop leaves tea incorporated with dried fruit pulps, a^*_1 = redness or greenness of the brewed SL, a^*_2 = redness or greenness of the brewed soursop leaves tea incorporated with dried fruit pulps; and b^*_1 = yellowness or blueness of the brewed SL, b^*_2 = yellowness or blueness of the brewed soursop leaves tea incorporated with dried fruit pulps.

Finally, the °Hue was calculated using Eq. 2:

$$°\text{Hue} = 180 + \tan^{-1}\left(\frac{b^*}{a^*}\right)\ (a^* < 0) \qquad \text{(Eq. 2)}$$

where, a^* = redness or greenness of the brewed SL, SLS, SLP, or SLK; and b^* = yellowness or blueness of the brewed SL, SLS, SLP, or SLK. The calculated °Hue was referred to as the Hue colour scale, in which 0° or 360° represented red colour, 90° represented yellow colour, 180° represented green colour, and 270° represented blue colour.

Antioxidant capacity by DPPH radical scavenging activity

The antioxidant capacity of brewed soursop leaves tea incorporated with dried fruit pulps was assessed using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay, following the methodology outlined by Padmini *et al*. (2015) with minor modifications. The DPPH solution of 0.1 mM was prepared by dissolving 0.0039 g of DPPH reagent in 100 mL of > 98% methanol. Then, 800 µL of brewed sample was mixed with 1,200 µL of methanol. Subsequently, 4,000 µL of the 0.1 mM DPPH solution was added to the mixture. The mixture was vortexed at 800 rpm for 10 sec using an advanced vortex mixer (F202A0176, Velp Scientifica, Usmate Velate, Italy), and incubated at ambient temperature (24 ± 1°C) in the dark for 30 min. Methanol was set as blank, and the control assay consisted of the DPPH solution without any sample. Ascorbic acid was used as the standard antioxidant. A standard curve (y = 7.1132x + 55.963; R^2 = 0.985) with known concentrations (2 - 6 ppm) was constructed using ascorbic acid. The absorbance of the samples and the standard solutions were measured at a wavelength of 517 nm using a UV-visible spectrophotometer (T80+, PG Instruments Limited, Leicestershire, United Kingdom). The ability of the samples to scavenge free radicals was determined by calculating the percentage inhibition of the DPPH radicals using Eq. 3, where abs control = absorbance of the control (absorbance of DPPH solution without any sample), and abs sample = absorbance of the sample.

$$\text{Percentage Inhibition (\%)} = \frac{\text{abs control - abs sample}}{\text{abs control}} \times 100\% \qquad \text{(Eq. 3)}$$

Total phenolic content analysis

The total phenolic content of the samples was determined by spectrophotometric procedures utilising Folin-Ciocalteu reagent according to Grijalva-Verdugo *et al*. (2022) with slight modification. The 7% (w/v) sodium carbonate solution was prepared by placing 7 g of sodium carbonate in 100 mL of deionised water. Then, 240 µL of the brewed sample was mixed with 240 µL of Folin-Ciocalteu reagent and 960 µL of distilled water. The mixture was incubated at ambient temperature in the dark for 6 min. Lastly, 2400 µL of 7% (w/v) sodium carbonate solution and 1,920 µL of distilled water were added to the mixture. The mixture was vortexed at 800 rpm for 10 sec using an advanced vortex mixer (F202A0176, Velp Scientifica, Usmate Velate, Italy), and incubated in the dark at ambient temperature for 90 min. The absorbance of the brewed samples was measured with a UV-visible spectrophotometer (T80+, PG Instruments Limited, Leicestershire, United Kingdom) at a wavelength of 750 nm. A standard curve (y = 6.7625x + 0.0153; R^2 = 0.9957) was constructed using gallic acid with known concentrations (0.200 - 0.020 mg/mL). The outcomes were reported in milligrams of gallic acid equivalents per millilitre of brewed sample (mg GAE/mL).

Total flavonoid content analysis

The total flavonoid analysis was conducted according to Grijalva-Verdugo *et al*. (2022) with slight modifications. The brewed sample, approximately 600 µL, was mixed with 180 µL of 5% (w/v) sodium nitrate ($NaNO_2$), 360 µL of 10% (w/v) aluminium chloride hexahydrate ($AlCl_3 \cdot 6H_20$), 1,200 µL of 1 M sodium hydroxide (NaOH), and 3,660 µL of distilled water. The mixture was vortexed at 1,200 rpm for 10 sec using an advanced vortex mixer (F202A0176, Velp Scientifica, Usmate Velate, Italy), and incubated at ambient temperature in the dark for 5 min. The distilled water was set as blank, and the absorbance of the brewed samples was measured at a wavelength of 510 nm using a UV-visible spectrophotometer (T80+, PG Instruments Limited, Leicestershire, United Kingdom). The standard curve (y = 0.0059x + 0.0014; R^2 = 0.9948) was constructed using quercetin with known concentrations (0.5 - 0.1 mg/mL). The results were reported as milligrams of quercetin equivalents per millilitre of brewed sample (mg QE/mL).

Sensory evaluation

The acceptability of soursop leaves tea incorporated with dried fruit pulps was assessed through sensory evaluation. The evaluation involved attributes such as colour, taste, aroma, astringency, and overall acceptability, rated on a 9-point hedonic scale (with 9 representing "like extremely"; 5 representing "neither like nor dislike"; and 1 representing "dislike extremely"). Sixty panellists participated in the sensory test (Hardoko *et al*., 2018; Indarto *et al*., 2020).

The SL, SLS, SLP, and SLK were brewed and left to cool until the temperature of the brewed samples reached 46 ± 1°C. The prepared samples were placed in transparent plastic cups, each containing 30 mL of the respective samples. The cups were coded with three random digits, and a score sheet was provided to the panellists, along with the samples, on a tray. Panellists were provided with drinking water as a palate cleanser between samples. The evaluation occurred in individual booths equipped with essential sensory evaluation facilities (Hardoko *et al*., 2018; Indarto *et al*., 2020).

Statistical analysis

IBM SPSS version 26 Statistical software was used to analyse the data obtained for the physicochemical analysis (pH and colour), antioxidant analysis, total phenolic content analysis, total flavonoid content analysis, and sensory analysis. The data were statistically analysed using the One-way ANOVA, and presented in graph and table forms. The obtained results were expressed as mean ± standard deviation, with different lowercase superscripts indicating significant differences (p < 0.05) (Indarto *et al*., 2020).

Results and discussion

Physicochemical properties of brewed soursop leaves tea incorporated with dried fruit pulps

Table 2 shows the pH of the brewed soursop leaves tea incorporated with dried fruit pulps. The highest pH value, approximately 6.43 ± 0.01, was recorded in the brewed soursop leaves tea alone (SL), meanwhile the soursop leaves tea incorporated with dried key lime (SLK) had the lowest pH value of 4.44 ± 0.01. The pH of SL was approaching neutral due to brewed SL did not have additional fruit. Adding fruit may reduce the pH value of the soursop leaves tea. This result agreed with Akyuz and Yarat (2010) and Patil *et al*. (2021), in which the pH of their herbal tea was between pH 6.4 to 7.2, which is slightly alkaline.

Table 2. pH values and colour characteristics of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK).

Sample	pH	L*	a*	b*	°Hue	*ΔE*
SL	6.43 ± 0.01^{a}	50.56 ± 2.16^{a}	-0.36 ± 0.14^{a}	30.58 ± 2.94^{b}	90.68°	
SLS	4.99 ± 0.01^{c}	49.82 ± 0.30^{a}	-0.87 ± 0.12^{b}	32.25 ± 0.50^{ab}	91.55°	1.90
SLP	5.48 ± 0.01^{b}	47.02 ± 3.04^{a}	-1.76 ± 0.07^{c}	36.63 ± 0.24^{a}	92.75°	7.16
SLK	4.44 ± 0.01^{d}	31.61 ± 1.24^{b}	-1.79 ± 0.04^{c}	29.96 ± 1.52^{b}	93.43°	19.02

Means followed by different lowercase superscripts in similar column are significantly different (p < 0.05).

The brewed SLK was observed to have the lowest pH, likely due to the naturally high acidity of key lime, which had a considerably low pH value compared to the other fruits. Previous findings also reported that fruit teas had pH values between pH 2.7 to 3.6, and herbal teas had pH values between 6.4 to 7.2, based on the types of fruit and herbs added (Akyuz and Yarat, 2010; Patil *et al*., 2021). The brewed SLK's pH was relatively lower when compared to fruit teas but higher than herbal teas. This observation may be because SLK is considered a combination of fruit and herbal tea, and adding fruit may affect the pH value of the soursop leaves tea, leading to the soursop leaves tea incorporated with dried fruit pulps having less acidity than regular fruit tea. In conclusion, the pH value of the tea infusion can be affected by the ingredients added to the tea.

Table 2 shows the colour attributes of the brewed soursop leaves tea incorporated with dried fruit pulps, which were determined by the hue angle

(°hue), L* (lightness), a* (positive value indicates redness, and negative value indicates greenness), b* (positive value indicates yellowness, and negative value indicates blueness), and colour difference (ΔE). The highest and lowest lightness (L*) of brewed soursop leaves tea, approximately 50.56 and 31.61, was obtained in the SLK and SL samples, respectively. The colour of the brewed SLK sample turned darker due to non-enzymatic browning through Maillard reaction, enzymatic browning by polyphenol oxidase, and ascorbic acid oxidation during the drying process of the key lime (Hardoko *et al*., 2018). Besides, brewed SL had the highest a* value of -0.36 ± 0.14 compared to other samples. This may be due to the absence of dried fruit pulps in the brewed SL. According to Salehi *et al*. (2023), the colour of the brewed tea was affected by the natural colour in the dried fruit pulps. The brewed SLP showed the highest b* value of 36.633 due to the presence of natural yellow in the dried pineapple pulp.

The hue angle (°Hue) represented the colour of the brewed soursop leaves tea incorporated with dried fruit pulps. The hue angle of the brewed SL, SLS, SLP, and SLK were recorded in the range of 90.68°, 91.55°, 92.75°, and 93.43°, respectively. According to Dini *et al*. (2019), the hue angle between 90° to 120° was considered greenish yellow. Theppakorn (2015) study also stated that green tea should have an infusion of green to yellowish green due to the absence of theaflavin and thearubigin, and the presence of chlorophyllide in the tea. Theppakorn (2015) reported that the hue angle of green tea with a value of 90° was noted as green, and over 90° was recorded as greenish yellow. The colour difference (ΔE) of the brewed SLK was observed to have the highest colour difference, which was 19.02. Based on Hardoko *et al*. (2018) and Salehi *et al*. (2023) observations, the colour of the brewed samples may be affected by the pigments that come from the fruits added. The drying process that caused the Maillard reactions, non-enzymatic, and enzymatic browning turned the colour of the key lime darker, leading to a significant colour difference when compared with other samples.

Antioxidant capacity, total phenolic content, and total flavonoid content of brewed soursop leaves tea incorporated with dried fruit pulps

The DPPH scavenging ability of the brewed tea increased due to the presence of dried fruit pulps. Based on Figure 1, among all samples, SLP demonstrated the highest scavenging activity, 94.69 ± 0.50%, suggesting that SLP had the highest antioxidant capacity. The brewed SL sample recorded the lowest DPPH scavenging activity, approximately 93.00 ± 0.62%, which indicated that the antioxidant capacity of the brewed soursop leaves tea was low in the absence of dried fruit pulps. According to Pękal *et al*. (2011), adding blue fruit, forest fruit, and tropical fruit enhanced the antioxidant capacity of black tea. Aliakbarlu *et al*. (2018) also reported that the scavenging activity of tea incorporated with rose petals increased significantly from 29.35 to 51.2% compared to the control sample. Based on the report by Indarto *et al*. (2020), the addition of cinnamon boosted the antioxidant capacity of soursop leaves tea, with the scavenging activity increasing from 10.05 to 29.19%. Therefore, it could be concluded that adding dried fruit pulps high in antioxidants could enhance the antioxidant capacity of soursop leaves tea.

Based on Figure 2, incorporating dried fruit pulps could increase the total phenolic contents (TPC) of the soursop leaves tea. The incorporation of dried key lime and pineapple significantly increased the TPC of brewed soursop leaves tea to 0.46 ± 0.01 mg GAE/mL. However, statistical analysis showed there was no significant difference ($p > 0.05$) in the TPC between SLK and SLP (0.45 ± 0.01 mg GAE/mL). Pękal *et al*. (2011) reported that incorporating tropical fruit into black tea could improve the TPC of the black tea from 8.48 to 8.51 mg GAE/L, and this corroborated the results observed in the present work. The sample with the lowest TPC was brewed SL (0.29 ± 0.00 mg GAE/mL). The values of TPC obtained for brewed SL were similar to Grijalva-Verdugo *et al*. (2022) study; 0.205 to 0.207 mg GAE/mL, depending on the harvesting regions. Nevertheless, it is essential to note that the variations of the TPC might be caused by the timing of harvest, the maturity of the leaves, the environmental conditions in which the plants grow, the amount of sun exposure, the kind of soil present (pH), and the specific production location (Anwar *et al*., 2017; Grijalva-Verdugo *et al*., 2022).

Figure 3 shows the samples' total flavonoid contents (TFC). The brewed SL recorded the highest TFC of 34.85 ± 0.17 mg QE/mL; meanwhile, the lowest TFC of 25.53 ± 0.68 mg QE/mL was obtained

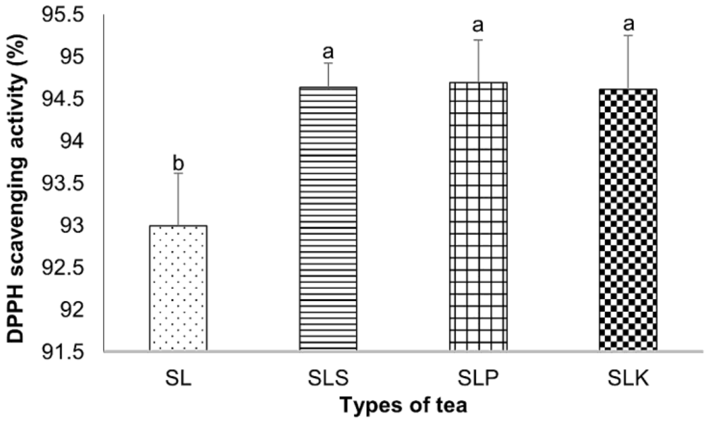


Figure 1. Antioxidant capacity of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK).

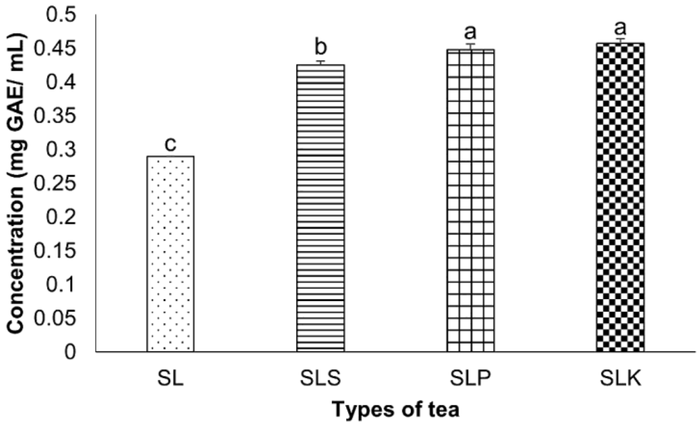


Figure 2. Total phenolic content of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK).

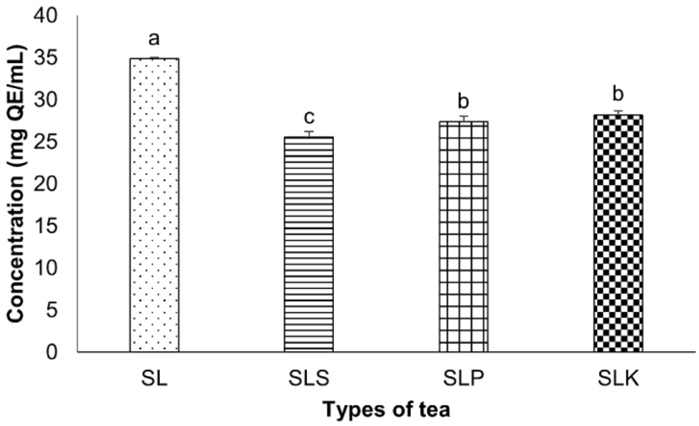


Figure 3. Total flavonoid content of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK).

in the SLS sample. The results showed that incorporating dried fruit pulps into the tea soursop leaves significantly lowered the TFC values. According to Pękal *et al*. (2011), incorporating blue fruit, forest fruit, and citrus fruit into black tea decreased the TFC values of the black tea, which was similar to the present work. Kumari and Kumar (2022) also reported that the inclusion of herbals such as Timur, mint, Kachnar, and lemongrass in green or black tea resulted in a reduction of the tea's TFC, which corroborated the findings of the present work. Based on previous studies, dried fruit tea with high TPC usually would also have high antioxidant capacity, however, the dried fruit tea with high TFC did not have high TPC and antioxidant capacity. This may be due to flavonoids being considered as subclass within the broader category of phenolic compounds which cause their contribution to the TPC to be lower compared to other dominant phenolic constituents such as hydroxycinnamic acids and hydroxybenzoic acids, which indicated that TFC had less effect to the TPC and antioxidant capacity. There has also been reported that no correlation was seen between total flavonoid content and antioxidant capacity in fruit tea infusions (Şahin, 2013; Sivakumaran *et al*., 2017).

Overall, the result from the present work demonstrated that the brewed SLP and SLK had high TPC. According to Pękal *et al*. (2011), adding fruit pulps to black tea could affect the TFC content of the brewed tea. Additionally, as reported by Grijalva-Verdugo *et al*. (2022), the size of the leaves, the maturity of the leaves, infusion time, harvesting time, and plantation area could affect the relationship between antioxidants, TPC, and TFC. Kumari and Kumar (2022) findings also showed that the inclusion of herbals into tea (green and black tea) could cause a reduction in TFC, but the reduction in TFC did not contribute to the negative effect on the antioxidant capacity of the tea. Therefore, from the results, it could be concluded that the amount of TPC was related to the capacity of antioxidants; however, TFC had less impact on the antioxidant capacity. Nevertheless, although the incorporation of dried fruit pulps into soursop leaves tea decreased the TFC of the tea, it did not compromise its antioxidant capacity.

Sensory evaluation of soursop leaves tea incorporated with dried fruit pulps

The sensory evaluation was carried out using the affective test method using a 9-point hedonic scale. Based on the results shown in Table 3, the colour aspect of the brewed soursop leaves tea incorporated with dried fruit pulps, the panellists preferred the brewed SL followed by brewed SLP and SLS. The brewed SLK had the lowest acceptability due to the darker colour of the brewed sample. It was due to non-enzymatic browning through the Maillard reaction, enzymatic browning by polyphenol oxidase, and ascorbic acid oxidation of the key lime that happened during the drying (Hardoko *et al*., 2018). For the aroma aspect, there were no significant differences between the samples. All samples were in the range of "neither like nor dislike". For the taste of brewed samples, the brewed SLP had the highest panellists' acceptability with a mean of 5.80 ± 2.02, which was "neither like nor dislike", followed by brewed SLS and brewed SL with a score of "dislike slightly", and the lowest acceptability was observed in brewed SLK due to the panellists could not accept the astringency taste of the tea.

The panellists could tolerate the astringency taste of the brewed SL despite recording the highest TFC. According to Pękal *et al*. (2011), this may be due to the tasteless flavonoid contained in the brewed SL which did not affect the taste of the tea. The TFC of the brewed SLK was the second highest compared to the others, and based on the sensory result in Table , the panellists could not accept the astringencies of the brewed SLK (3.68 ± 2.44). According to

Table 3. Sensory evaluation scores of soursop leaves tea (SL), soursop leaves tea incorporated with dried soursop pulps (SLS), soursop leaves tea incorporated with dried pineapple pulps (SLP), and soursop leaves tea incorporated with dried key lime (SLK) based on 9-point hedonic scale.

Sample	Colour	Aroma	Taste	Astringency	Overall Acceptability
SL	6.27 ± 1.78^{a}	5.67 ± 1.83^{a}	4.62 ± 2.00^{b}	5.03 ± 2.04^{a}	5.02 ± 2.05^{b}
SLS	5.92 ± 1.25^{ab}	5.27 ± 1.61^{a}	4.68 ± 2.05^{b}	5.22 ± 2.14^{a}	5.00 ± 1.96^{b}
SLP	6.10 ± 1.45^{ab}	5.68 ± 1.60^{a}	5.80 ± 2.02^{a}	5.48 ± 2.06^{a}	6.00 ± 1.77^{a}
SLK	5.50 ± 1.61^{c}	5.67 ± 1.94^{a}	3.37 ± 2.19^{c}	3.68 ± 2.44^{b}	3.63 ± 2.05^{c}

Means followed by different lowercase superscripts in similar column are significantly different ($p < 0.05$).

Drewnowski and Gomez-Carneros (2000) and Herawati *et al*. (2020), this may be due to the flavonoids contained in brewed SLK being bitter (naringin), which contributed to the astringencies of the tea.

The overall acceptability of brewed SLP (6.00 ± 1.77) was higher than other samples. According to Lasekan and Hussein, (2018), most of the pineapple fruit were sweet, with some sweet and sour varieties. Therefore, the addition of pineapple fruit pulps which are sweet and sour taste in nature could aid in masking the astringency taste of the tea, thus improving its taste. The acceptability of the brewed soursop leave tea decreased to "dislike moderately" (3.63 ± 2.05) when the tea was incorporated with key lime. This was due to the bitter taste of the key lime that contributes to the astringency taste of the tea. The brewed SL and SLS had the same overall acceptability, which was "neither like nor dislike". Therefore, adding dried fruit pulps could slightly enhance the panellist's acceptability. However, dried fruit pulps with a bitter taste should be avoided due to the fact that it may significantly reduce the acceptability of soursop leaves tea by the panellists.

Conclusion

The incorporation of dried fruit pulps into soursop leaves tea significantly increased the antioxidant capacity and total phenolic content of the soursop leaves tea. Although the incorporation of dried fruit pulps decreased the total flavonoid content, this did not negatively affect the antioxidant capacity of the tea. Additionally, incorporating dried fruit pulps with a sweet taste enhanced the panellist's acceptability, but dried fruit pulps with a bitter taste should be avoided due to its astringency taste that may significantly decrease the acceptability of soursop leaves tea by panellists. Overall, the brewed SLP had the highest antioxidant capacity and panellist acceptability. The results of total phenolic content showed that the brewed SLK and SLP were not statistically different, with the brewed SLP having high total phenolic content.

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