

ORIGINAL ARTICLE

Addition of eucalyptus oil and lemon juice to improve the physicochemical properties of Indonesian bay leaf (*Syzygium polyanthum*) herbal tea

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Abstract

Indonesian bay leaf (*Syzygium polyanthum* (Wight) Walp.) is one of the medicinal herbs that has been known for its many beneficial health effects. The main problem of bay leaf is its astringent and bitter taste. Therefore, in this research, bay leaf herbal tea was made according to the black tea processing method and added with *Eucalyptus* oil and lemon juice to improve its physicochemical and sensory properties. This research aimed to determine the optimal brewing temperature and time for bay leaf herbal tea, as well as to identify the suitable concentration of lemon juice and *Eucalyptus* oil to be added to the bay leaf herbal tea. The brewing temperatures used were 70 °C, 80 °C, and 90 °C, and the brewing times were 10, 20, and 30 minutes. Results showed that bay leaf herbal tea brewed at 90 °C for 30 minutes has the highest antioxidant activity, total phenolics, total flavonoids, and condensed tannins. Afterwards, this selected bay leaf herbal tea was added with *Eucalyptus* oil in concentrations of 0.05%, 0.10%, and 0.15%, and lemon juice with concentrations of 1%, 2%, and 3%. The addition of 0.15% *Eucalyptus* oil and 3% lemon into bay leaf herbal tea was the chosen concentration, with lower antioxidant activity, total phenolic and flavonoid contents, compared to bay leaf herbal tea without the addition of lemon juice and *Eucalyptus* oil. However, the sensory properties of bay leaf herbal tea, in terms of aroma, taste, and astringency, could be potentially increased with the addition of *Eucalyptus* oil and lemon juice.

Keywords: Antioxidant; Brewing; Phenolic; *S. polyanthum*; Tannin.

Highlights:

- The bay leaf herbal tea brewed at 90 °C for 30 minutes had the best physicochemical properties
- The addition of 0.15% *Eucalyptus* oil and 3% lemon lowers functional properties yet boosts sensory appeal of bay leaf herbal tea
- Bay leaf herbal tea had the potential to be further developed into a functional beverage



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1 Introduction

Tea is a refreshing beverage derived from the leaves of the *Camellia sinensis* (L.) Kuntze plant is widely consumed due to its health benefits. These health benefits are mainly due to the polyphenol compounds, namely catechins and theaflavins, that are present in green and black tea, respectively (Pathaw et al., 2022). Another polyphenol compound that contributes to tea's health benefit is flavonoids because of their high antioxidant activity (Li et al., 2019). Tea is also known for its anti-hypertensive, anti-inflammatory, and cardio-protective actions, as well as its effectiveness against gastric dysfunctions and osteoporosis (Samanta, 2020). Furthermore, tea is also preferred because of its refreshing sensation and excellent sensory quality to consumers (Li et al., 2019).

As the demand for a healthy lifestyle increases, the leaves of other plants can also be used to produce tea, namely herbal tea or tisane. Herbal tea is known to provide health benefits due to its high antioxidant activity. Moreover, herbal tea is also caffeine-free (Chandrasekara & Shahidi, 2018; Ravikumar, 2014). In herbal tea preparation, brewing time is important. Previous research mentioned that longer brewing time could increase the antioxidant activity of herbal tea infusions, but the optimum brewing time varies depending on the source of herbal tea (Winiarska-Mieczan & Baranowska-Wójcik, 2024). Previous research also reported that the combination of brewing time and temperature affected total phenolic content and antioxidant capacity of Roselle herbal tea (Nguyen & Chuyen, 2020) and Kenaf leaves tea (Chong & Nyam, 2022), as well as sensory properties of Linden tea (Ilyasoğlu & Zemzemoglu, 2021).

One of the plants that is traditionally consumed to cure diseases, such as diabetes mellitus, gastritis, ulcers, diarrhea, skin diseases, and infections, is Indonesian bay leaf or *daun Salam* (*Syzygium polyanthum* (Wight) Walp.). Bay leaf is widely cultivated in Indonesia and has been traditionally used as a food spice to enhance flavour (Batool et al., 2019). Bay leaves are also used by people in Riau, Sumatra, Indonesia, as one of the ingredients in soups for treating hypertension (Ismail & Ahmad, 2019). Furthermore, several studies has been done on bay leaf and one of them showed that the water extraction of bay leaf contains a high amount of flavonoids, saponin, and quinone (Batool et al., 2019). Another study by Dewijanti et al. (2020) also reported that bay leaf water extract possessed antidiabetic activity. These results showed that Indonesian bay leaf has the potential to be further developed as a functional drink. However, the drawback of bay leaf herbal tea is its astringent and bitter flavour (Yulianti et al., 2020).

The fermentation step during the processing of soursop leaves (Tanjung et al., 2016) and black tea (Ye et al., 2022) could reduce bitterness and astringency. Additionally, this fermentation process also produced a dark brown colour and improved the aroma of tea. Therefore, in this research, the black tea fermentation process was adopted in the preparation of bay leaf to reduce bitterness and astringency. However, Salman et al. (2022) mentioned that the higher degree of fermentation, specifically in tea, resulted in lower individual catechins and total phenolic content. To overcome this problem, other ingredients, *i.e.*, *Eucalyptus* oil and lemon juice, were added in the formulation of bay leaf herbal tea.

Eucalyptus globulus Labill. essential oil contains various phenolic compounds that contribute to antioxidant and antimicrobial properties (Park et al., 2023). The main compound in *E. globulus* essential oil is eucalyptol, which has a refreshing smell and can be used to treat respiratory diseases (Kobenan et al., 2022). Majchrzak et al. (2004) reported that the addition of ascorbic acid increased the antioxidant level of both green and black tea. Another organic acid, namely citric acid, is also reported to be able to extract more polyphenols from the tea leaf (Li et al., 2019). Lemon (*Citrus lemon* L. Osbeck) contains both citric acid and ascorbic acid, making it a source of vitamin C with strong antioxidant activity (Majchrzak et al., 2004). The addition of lemon was also expected to lighten the colour of bay leaf herbal tea, because it was reported that the colour of black tea could be lightened with acid addition (Liang & Xu, 2001).

In this research, the fresh bay leaf was initially made into dried tea leaves using the black tea processing method. Moreover, this research aimed to determine the best temperature and time of brewing of bay leaf herbal tea and to determine the chosen concentrations of lemon juice and *Eucalyptus* oil added into the bay leaf herbal tea.

2 Material and methods

The materials used in this research were Indonesian bay leaf "*Syzygium polyanthum*" bought from the shop "Bumbu Kak Ros" located at Tangerang Selatan, Indonesia, with specifications: the leaf has green colour, length and width of 7-14 cm and 2.5-5 cm, respectively, lemon "*Citrus limon* L. Osbeck" obtained from the shop "Madu Ibum" located at Tangerang City, Indonesia, with specifications: has ovoid to oblong shape with green-yellow colour, the diameter of 5-7.5 cm, length and width of 4-5 cm, and *Eucalyptus globulus* oil (CAS # 84625-31-1) bought from PT. Indesso Aroma, Bogor, Indonesia.

Chemical reagents used in this research were Folin-Ciocalteu's phenol reagent, sodium carbonate (anhydrous) for analysis EMSURE (Na₂CO₃) (CAS# 497-19-8), gallic acid (anhydrous) for synthesis (CAS# 149-91-7), aluminium chloride (anhydrous powder sublimed) for synthesis (CAS# 7446-70-0), quercetin dihydrate (CAS# 6151-25-3), methanol (CAS# 67-56-1), vanillin for synthesis (CAS# 121-33-5) (all from Merck KGaA, Darmstadt, Germany), hydrochloric acid 37% (CAS# 7647-01-0) and ethanol (CAS# 64-17-5) from PT. Smart Lab Indonesia, Tangerang, Indonesia, 1,1-diphenyl-2-picrylhydrazyl (DPPH) (CAS# 1898-66-4) from Sigma Aldrich, USA, and distilled water.

2.1 Preparation of dried bay leaf using the black tea processing method

Prior to the research stage one, bay leaves were prepared according to the preparation of black tea. The bay leaves were sorted, cleaned, and washed with distilled water and air-dried. The cleaned leaves were withered at room temperature, 24-26 °C, for 16 hours. Afterwards, the leaves were rolled for 25 minutes, followed by fermentation. Fermentation of the bay leaves was done by covering the leaves with a dry cloth for 100 minutes at room temperature with a relative humidity of 84%. The fermented leaves were oven-dried at 70 °C for 6 hours. The dried tea leaves were then analyzed (Yuniartini et al., 2015; Teshome, 2019; Hardoko et al., 2015).

2.2 Preparation of bay leaf herbal tea

In the first research stage, dried bay leaves were brewed with water at different temperatures (70 °C, 80 °C, 90 °C) and times (10, 20, 30 minutes). The amount of dried bay leaves was 4 grams in 100 ml of water (Halim & Maryani, 2022). Afterwards, the tea leaves were filtered by using a tea strainer. The herbal tea obtained was then analyzed. The optimum brewing time and temperature were then used in the second research stage.

The second research stage was done to determine the preferred concentration of lemon juice and *Eucalyptus* essential oil added based on the physicochemical properties of the bay leaf herbal tea. Preparation started by making the lemon juice by manual pressing, and then filtration was done to obtain the juice. Afterwards, different concentrations of lemon juice (1%, 2%, 3%) and *Eucalyptus* essential oil (0.05%, 0.10%, 0.15%) were added to 100 mL of the herbal tea prepared similar to the first research stage (Sipahelut et al., 2017). The obtained herbal tea was then analyzed.

2.3 Experimental design and data analysis

The experimental design used in the first research stage was a completely randomized two-factor design. The factors were brewing temperatures (70 °C, 80 °C, 90 °C) and time (10, 20, 30 minutes). Each combination was repeated three times. The data was then analyzed using Univariate analysis and Duncan Post-hoc tests with significance level of 0.05 in an SPSS program version 25.0.

The experimental design used in the second research stage was a completely randomized two-factor design. The factors were the concentrations of lemon juice (1%, 2%, 3%) and *Eucalyptus* oil (0.05%, 0.10%, 0.15%). Each combination was repeated three times. The data was then analyzed using Univariate analysis and Duncan Post-hoc tests with significance level of 0.05 in an SPSS program version 25.0.

2.4 Analyses

The analyses done for the dried bay leaves were moisture content (Nirmaan et al., 2020) and yield (Handayani et al., 2016). The brewed bay leaf herbal tea was analyzed for its colour in terms of lightness (Marete et al., 2009), pH (Lunkes & Hashizume, 2014), and antioxidant activity using the DPPH method (Anggraini et al., 2016 with modification). For the treatments that were not significantly different (based on statistical analysis) in their antioxidant activity, additional analyses were done, including total phenolic content (Javanmardi et al., 2003 with modifications), total flavonoid content (Lamien-Meda et al., 2008), and total condensed tannin content (Hardoko et al., 2015).

Bay leaf herbal tea added with lemon and *Eucalyptus* oil was also analyzed for the previously stated analyses, with the addition of sensory evaluation using a 7-point scale hedonic test (Lawless & Heymann, 2010) conducted to 30 semi-trained panellists at Universitas Pelita Harapan.

3 Results and discussion

3.1 Moisture content and yield of dried bay leaves

In this research, bay leaves processed according to the black tea preparation method had a moisture content of $3.82\% \pm 0.22$. According to Wickramasinghe et al. (2020), good quality tea leaves should contain a maximum of 7% moisture content to extend the shelf life. Therefore, the drying process of bay leaves in this research was sufficient. Meanwhile, the yield of bay leaves obtained was $33.43\% \pm 2.26$.

3.2 Effect of brewing temperature and time on the properties of bay leaf herbal tea

3.2.1 Colour (Lightness)

Colour is one of the important parameters in black tea that determines its sensory quality (Polat et al., 2025). Figure 1 shows that different brewing times and temperatures affected the colour of bay leaf herbal tea. Statistical analysis results showed that the interaction between brewing temperature and time significantly affected the lightness of the herbal tea ($p \leq 0.05$). As seen in both Figure 1 and Table 1, herbal tea brewed at a higher temperature and time showed a decreasing lightness value, in which herbal tea brewed at 90 °C for 30 minutes has the darkest colour.

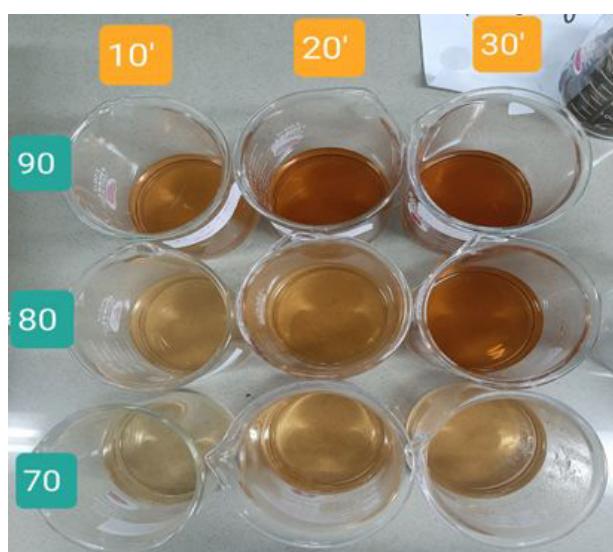


Figure 1. The bay leaf herbal tea brewed at different temperatures and times. Notes: the y-axis shows different temperatures and the x-axis shows different brewing times.

The results were similar to the research conducted by Hardoko et al. (2015), in which higher temperatures and longer time of tea brewing resulted in a darker colour of tea. It is because all forms of tannin in tea have a higher solubility in hot water, and then increases the intensity of colour in tea (Hariyadi et al., 2020; Dikatoru et al., 2024).

3.2.2 pH

The acidity of the herbal tea was analyzed, as it also contributes to the acceptance of consumers. Statistical analysis results showed that the interaction between the brewing temperature and time significantly affected the pH of the bay leaf herbal tea ($p \leq 0.05$). Moreover, both brewing temperature and time significantly affect the pH of the herbal tea ($p \leq 0.05$). These results can be seen in Table 1.

In general, longer brewing time decreases the pH of bay leaf herbal tea. This result is supported by research from Maharani et al. (2020), stating that increasing brewing time in cascara husk tea caused the decrease of pH from 4.62 (5 minutes brewing time) to 4.55 (15 minutes brewing time). This is due to more phenolic acids and other acidic compounds that are extracted as brewing time is increased. Moreover, related to brewing temperature, it was also an interesting finding that herbal tea brewed at 80 °C had significantly higher pH compared to 70 °C and 90 °C, except for the tea brewed for 30 minutes.

3.2.3 Antioxidant activity

Based on statistical analysis, an interaction between brewing temperature and time significantly affected the antioxidant activity of the bay leaf herbal tea ($p \leq 0.05$). As seen in Table 1, herbal tea brewed at 90 °C for 30 minutes had the highest antioxidant activity; however, it was not significantly different from the tea brewed at 80 °C for 30 minutes and 90 °C for 20 minutes ($p > 0.05$).

The results also showed that antioxidant activity was proportional to the increase in temperature and time of brewing. These results were in accordance with research conducted by Dewata et al. (2017). However, Halim & Maryani (2022) reported that the antioxidant capacity of bay leaf tea decreased when a higher temperature was applied in brewing, meanwhile, longer brewing time enhanced the antioxidant capacity. The longer brewing time of bay leaf herbal tea promoted the release of phenolic compounds, flavonoids, and tannins into the tea. The increase in antioxidant activity might be because of the high temperature and longer time used to brew the herbal tea which can destroy the cell wall and enable more phenolic compounds to be diffused out. These phenolic compounds in bay leaf, such as flavonoids, 2,3-dihydro-3,5-dihydroxy-6-methyl-4H-pyran-4-one, pyrogallol (1,2,3-benzenetriol), α -tocopherol, and β -tocopherol, contribute to the antioxidant activity (Rahim et al., 2018; Harismah & Chusniatun, 2016).

Table 1. Physicochemical characteristics of bay leaf herbal tea with different brewing temperatures and times.

Brewing temperature (°C)	Brewing time (min)	Colour (lightness, L*)	pH	Antioxidant activity (IC ₅₀ , ppm)
70	10	(54.72 ± 0.88) ^{ab}	(5.23 ± 0.04) ^b	(37657.47 ± 440.45) ^a
	20	(54.19 ± 1.47) ^{bc}	(5.11 ± 0.02) ^d	(28932.12 ± 3152.62) ^b
	30	(53.17 ± 0.38) ^d	(5.05 ± 0.02) ^e	(11711.64 ± 680.60) ^c
80	10	(55.18 ± 0.46) ^a	(5.33 ± 0.02) ^a	(25937.31 ± 2472.38) ^d
	20	(55.19 ± 0.63) ^a	(5.15 ± 0.04) ^c	(15751.93 ± 1054.58) ^e
	30	(54.92 ± 0.72) ^{ab}	(5.05 ± 0.06) ^e	(9600.23 ± 545.73) ^g
90	10	(53.41 ± 1.67) ^{cd}	(5.20 ± 0.05) ^b	(13535.61 ± 1014.10) ^f
	20	(51.67 ± 0.71) ^e	(5.03 ± 0.02) ^e	(10204.80 ± 264.58) ^g
	30	(47.50 ± 0.38) ^f	(4.96 ± 0.02) ^f	(8984.75 ± 269.57) ^g

Notes: different letter notations on the same column indicate a significant difference ($p \leq 0.05$).

Based on the previous analyses depicted in Table 1, there were three treatments that resulted in similar antioxidant activity, *i.e.*, the bay leaf herbal tea brewed at 80 °C for 30 minutes, 90 °C for 20 minutes, and 90 °C for 30 minutes. Therefore, to choose the selected treatment for the second research stage, several additional analyses were done, including total phenolic content, total flavonoid content, and total condensed tannin.

3.2.4 Total phenolic content, total flavonoid content, and total condensed tannin

Table 1 shows the results of total phenolic content, total flavonoid content, and total condensed tannin analyses. Based on statistical analysis results, the treatment that resulted in the highest value in all parameters was the herbal tea brewed at 90 °C for 30 minutes.

Table 2. Total phenolic content, total flavonoid content, and total condensed tannin of selected treatments.

Treatment (brewing temperature, time)	Total phenolic content (mg GAE/L)	Total flavonoid content (mg QE/mL)	Total condensed tannin (mg CE/mL)
80 °C, 30 min	(294.63 ± 19.85) ^a	(50.87 ± 3.81) ^a	(956.00 ± 94.64) ^a
90 °C, 20 min	(493.08 ± 29.96) ^b	(67.64 ± 2.47) ^b	(1299.33 ± 127.47) ^b
90 °C, 30 min	(564.06 ± 11.33) ^c	(140.11 ± 14.10) ^c	(1328.40 ± 66.32) ^b

Notes: different letter notations **on the same column** indicate a significant difference ($p \leq 0.05$).

Table 2 also shows that total phenolic content is proportional to antioxidant activity, meanwhile, the total flavonoid content and total condensed tannin are directly proportional to the total phenolic content and the antioxidant activity of the bay leaf herbal tea. Therefore, it could be indicated that the main contributor to antioxidant activity in bay leaf herbal tea is phenolic compounds. Moreover, the total phenolic content of bay leaf herbal tea prepared using the black tea method can be considered as high compared to the “black tea” soursop leaves studied by Hardoko et al. (2015), which had a total phenolic content of 372.19 ± 14.97 mg GAE/L and it was brewed at a higher temperature, *i.e.*, 100 °C for 30 minutes. Dewijanti et al. (2019), Awwalia et al. (2024), and Harismah & Chusniatun (2016) also reported that various flavonoid compounds are present in the bay leaf, namely quercetin, quercitrin, myricetin, myricitrin, fluoretin, catechin, rutin, apigenin, kaempferol, and luteolin.

Tannins are compounds that contribute to astringency and bitterness in food products (Soares et al., 2020). In nature, condensed tannins are present more abundantly compared to hydrolyzable tannins (Das et al., 2020). However, many health benefits, such as antioxidant activity, anticancer, antiulcer, and cardioprotective activity, are mostly derived from condensed tannins (Bule et al., 2020). Tannins are the main polyphenolic secondary metabolites of plants (Das et al., 2020). Therefore, higher phenolic content is supported by higher total condensed tannin content.

Regarding brewing time and temperature, these results showed that higher temperatures and longer brewing times would extract more phenolic compounds in bay leaf herbal tea. These results are slightly different from previous research by Halim & Maryani (2022), which stated that longer brewing time resulted in higher phenolic, flavonoid, and condensed tannin content, whereas higher brewing temperature resulted in lower values in all those parameters.

In conclusion, Table 2 shows that bay leaf herbal tea brewed at 90 °C for 30 minutes resulted in the highest antioxidant activity, total phenolic content, total flavonoid content, and total condensed tannin. Therefore, this brewing time and temperature combination was selected to be further analyzed in the second research stage.

3.3 Effect of *Eucalyptus* oil and lemon concentration on the physicochemical properties of bay leaf herbal tea

3.3.1 Colour (Lightness)

Statistical analysis results showed that the interaction between *Eucalyptus* oil and lemon concentration did not significantly affect the colour (lightness) of the bay leaf herbal tea ($p > 0.05$). The lightness of the bay leaf herbal

tea, added with different concentrations of *Eucalyptus* and lemon, was in the range of 52.35 ± 0.57 to 52.98 ± 1.82 . *Eucalyptus* essential oil has a clear colour, therefore, it did not contribute to the colour of the bay leaf herbal tea. Theaflavins, compounds that contribute to tea colour (Jin et al., 2024), are better extracted at lower pH conditions (Kong et al., 2023). However, results in this research suggested that concentrations of lemon used (1% to 3%) were not sufficient to significantly provide the acidic condition to extract more theaflavins.

3.3.2 pH

Statistical analysis results showed that there was a significant effect of lemon concentration on the pH of the bay leaf herbal tea ($p \leq 0.05$). Meanwhile, there was no significant effect of *Eucalyptus* oil concentration on the pH of the herbal tea ($p > 0.05$), and the interaction between *Eucalyptus* oil and lemon concentration also did not significantly affect the pH of the bay leaf herbal tea ($p > 0.05$). As seen in Figure 2, the pH of bay leaf herbal tea significantly decreases with the increase in lemon concentration. The decrease in pH was caused by the increase of citric acid, a main acid present in lemon.

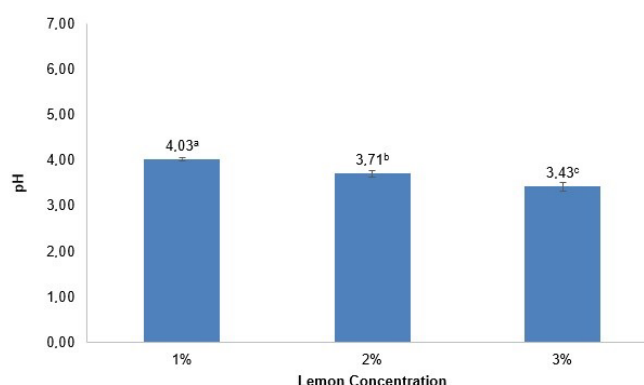


Figure 2. Effect of lemon concentration on the pH of bay leaf herbal tea. Note: The different letter notations indicate a significant difference ($p \leq 0.05$).

3.3.3 Antioxidant activity

Based on the statistical analysis, the interaction between *Eucalyptus* oil and lemon concentration did not significantly affect the antioxidant activity of bay leaf herbal tea ($p > 0.05$). However, there was a significant effect of *Eucalyptus* oil and lemon concentration individually on the antioxidant activity of bay leaf herbal tea ($p \leq 0.05$). These results can be observed in Figures 3 and 4.

As seen in Figure 3, the highest antioxidant activity occurred in herbal tea added with 0.15% of *Eucalyptus* oil. It is because *Eucalyptus* oil possesses some phenolic compounds, flavonoids, and some bioactive compounds, namely globulisin A and eucaglobulin, that can scavenge the free radical of DPPH (Belkhodja et al., 2021).

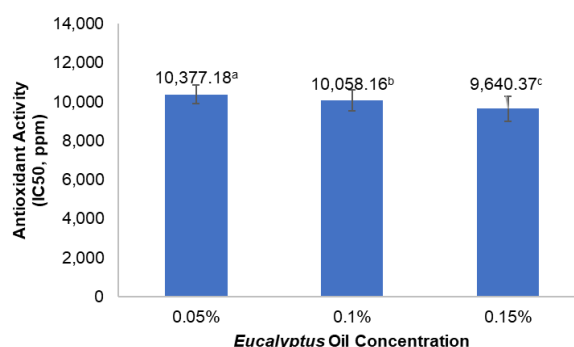


Figure 3. Effect of *Eucalyptus* oil concentration on the antioxidant activity of the bay leaf herbal tea. Note: The different letter notations indicate a significant difference ($p \leq 0.05$).

Based on Figure 4, the highest antioxidant activity was found in herbal tea added with 3% lemon ($p \leq 0.05$). Ravindran (2017) and Krisnawan et al. (2017) stated that lemon provides antioxidant activity due to the presence of vitamin C, citric acid, essential oil, polyphenol, coumarin, flavonoid, and bioflavonoid.

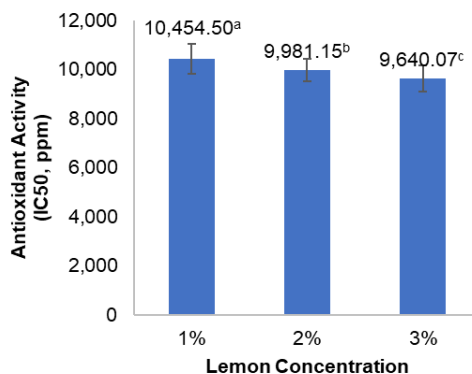


Figure 4. Effect of lemon concentration on the antioxidant activity of the bay leaf herbal tea. Note: The different letter notations indicate a significant difference ($p \leq 0.05$).

3.3.4 Total phenolic content

Based on the statistical analysis, the interaction between the *Eucalyptus* oil and lemon concentration significantly affected the total phenolic content of bay leaf herbal tea ($p \leq 0.05$). Moreover, *Eucalyptus* oil and lemon concentration individually also significantly affected the total phenolic content of herbal tea ($p \leq 0.05$). The results also showed an increase in the total phenolic content of bay leaf herbal tea as *Eucalyptus* oil and lemon concentrations increased. These results can be observed in Table 3.

Table 3 shows that the highest phenolic content was found in herbal tea added with 0.15% *Eucalyptus* oil and 3% lemon (557.84 ± 27.91 mg GAE/L), and it was significantly different from the other treatments ($p \leq 0.05$). The results of the experiment were in accordance with research conducted by Al-Ghafari et al. (2016), which reported that the addition of lemon can increase the total phenolic content of the tea, as lemon contains phenolic compounds that contribute to antioxidant activity. Li et al. (2019) also suggested that citric acid can enhance the release of phenolic compounds in tea due to the decrease in tea pH. In addition, Sharma et al. (2021) reported that the *Eucalyptus globulus* essential oil contains phenolic and flavonoid compounds.

Furthermore, bay leaf herbal tea obtained in this research had higher total phenolic content compared to the black tea added with 2% and 4% of *Averrhoa bilimbi* L., which had total phenolic content of 512.56 ± 0.22 mg GAE/L and 524.72 ± 0.15 mg GAE/L, respectively (Anggraini et al., 2016).

3.3.5 Total flavonoid content

Based on the statistical analysis, the interaction between *Eucalyptus* oil and lemon concentration significantly affected the total flavonoid content of bay leaf herbal tea ($p \leq 0.05$). Moreover, both *Eucalyptus* oil and lemon concentrations significantly affected the total flavonoid content of bay leaf herbal tea ($p \leq 0.05$). These results can be seen in Table 3.

Table 3 shows that the highest total flavonoid content was found in bay leaf herbal tea added with 0.15% *Eucalyptus* oil and 3% lemon, and it was significantly different from the other treatments ($p \leq 0.05$). An increasing total flavonoid content was observed with the increase of *Eucalyptus* oil and lemon concentration. Xi et al. (2017) reported that there were 0.26 to 0.44 mg/g of total flavonoid content present in lemon. The results of the total flavonoid content in this research showed a direct relationship with the total phenolic content obtained, as a flavonoid is a part of phenolic compounds (Vuolo et al., 2019).

Table 3. Total phenolic content and total flavonoid content of bay leaf herbal tea added with different concentrations of lemon and *Eucalyptus* oil.

Concentration of lemon (%)	Concentration of <i>Eucalyptus</i> oil (%)	Total phenolic content (mg GAE/L)	Total flavonoid content (mg QE/L)
1	0.05	(388.86 ± 5.53) ^a	(47.99 ± 0.86) ^a
	0.1	(402.91 ± 42.1) ^{ab}	(49.56 ± 0.46) ^b
	0.15	(526.10 ± 4.62) ^f	(52.37 ± 0.63) ^d
2	0.05	(430.59 ± 11.33) ^{cd}	(51.50 ± 0.74) ^c
	0.1	(412.77 ± 10.29) ^{bc}	(51.89 ± 0.52) ^{cd}
	0.15	(535.38 ± 21.91) ^f	(54.49 ± 0.52) ^e
3	0.05	(437.55 ± 7.41) ^d	(59.39 ± 0.58) ^f
	0.1	(486.54 ± 5.50) ^e	(60.88 ± 0.91) ^g
	0.15	(557.84 ± 27.91) ^g	(68.75 ± 0.38) ^h

Notes: different letter notations on the same column indicate a significant difference ($p \leq 0.05$).

3.3.6 Total condensed tannin

The statistical analysis results showed that the interaction between *Eucalyptus* oil and lemon concentration did not significantly affect the condensed tannin content of bay leaf herbal tea ($p > 0.05$). However, both *Eucalyptus* oil and lemon concentration significantly affected the condensed tannin content of the bay leaf herbal tea ($p \leq 0.05$). These results can be seen in Figure 5 and Figure 6.

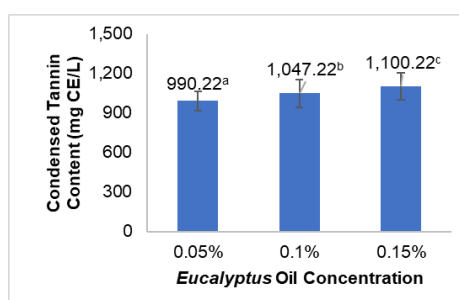


Figure 5. Effect of *Eucalyptus* oil on the total condensed tannin of the bay leaf herbal tea. Note: The different letter notations indicate a significant difference ($p \leq 0.05$).

As seen in Figure 5, the higher *Eucalyptus* oil concentration increased the condensed tannin content. However, there has been no report that stated *Eucalyptus* oil contains tannin. The results in Figure 6 showed that the addition of lemon significantly reduced the condensed tannin present in herbal tea, which may lead to the reduction of astringency. Comparable results were reported by Chakrabarti et al. (2017), that the addition of lemon juice reduces the tannin content in the black tea, as the polyphenols present in the lime juice can neutralize tannin. Thus, reducing the astringency of tea.

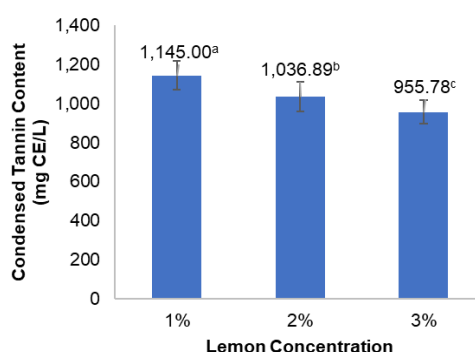


Figure 6. Effect of lemon concentration on the total condensed tannin of the bay leaf herbal tea. Note: The different letter notations indicate a significant difference ($p \leq 0.05$).

3.4 Comparison between the chosen concentration and the control

The control in the second research stage was bay leaf herbal tea brewed at 90 °C for 30 minutes without the addition of *Eucalyptus* oil and lemon. Meanwhile, the chosen treatment in the second research stage was determined by the antioxidant activity, supported by the total phenolic, total flavonoid, and condensed tannin content. Therefore, the chosen treatment was bay leaf herbal tea added with 0.15% *Eucalyptus* oil and 3% lemon. The comparison of both treatments can be seen in Table 4.

Based on the tea colour, the chosen treatment had a higher lightness value. This was caused by the addition of lemon as a source of acid, which enhances the release of theaflavins, which provide a yellow colour to the tea and reduce the tannin content. Thus, resulting in a brighter colour of tea (Chakrabarti et al., 2017; Hardoko et al., 2015).

Table 4. Comparison of the physicochemical characteristics of the control and chosen treatment.

Parameters	Control	Chosen Treatment
L*	47.50 ± 0.38	52.98 ± 1.82
pH	4.96 ± 0.02	3.43 ± 0.02
Total phenolic content (mg GAE/L)	564.06 ± 11.33	557.84 ± 27.91
Total flavonoid content (mg QE/L)	140.11 ± 14.10	68.75 ± 0.39
Condensed tannin content (mg CE/L)	1328.40 ± 66.32	1014.67 ± 59.58
Antioxidant activity (IC ₅₀ , ppm)	8984.75 ± 269.58	9178.11 ± 369.98

Moreover, the total phenolics, total flavonoids, condensed tannin content, and antioxidant activity of the bay leaf herbal tea have decreased with the addition of *Eucalyptus* oil and lemon, as seen in Table 4. The decrease in antioxidant activity may be caused by bay leaf herbal tea as a better oxidant compared to lemon and *Eucalyptus* oil (Bartoszek et al., 2018), as those ingredients were added in a small concentration. The decrease of the condensed tannin content can be explained by the ability of the phenolic compounds present in the lemon that neutralize the tannin (Chakrabarti et al., 2017) and contribute to the increasing of sensory acceptance in terms of the astringency of bay leaf herbal tea. The complete results of sensory acceptance comparison between the control and the chosen treatment can be seen in Table 5.

Table 5 shows that the addition of *Eucalyptus* oil and lemon resulted in herbal tea with better acceptance in terms of aroma, astringency, acid taste, and overall acceptance. The overall acceptance of the chosen treatment was slightly liked, while the control was neither liked nor disliked by the panellists. Therefore, the chosen treatment was preferred by the panellists.

Table 5. Comparison of the sensory acceptance between the control and the chosen treatment.

Parameters	Control	Chosen Treatment
Colour	5.90 ± 0.55	5.00 ± 1.05
Aroma	4.07 ± 1.08	5.00 ± 1.11
Astringency	3.37 ± 1.28	5.03 ± 1.03
Acid Taste	4.23 ± 0.73	4.50 ± 1.11
Overall Acceptance	4.30 ± 0.75	4.73 ± 1.17

Notes: 1= dislike extremely; 7= like extremely.

4 Conclusions

The best properties of bay leaf herbal tea were obtained from brewing temperature and time of 90 °C for 30 minutes. This resulted in the highest antioxidant activity (IC₅₀ = 8984.75 ± 269.57 ppm), total phenolic content (564.06 ± 11.33 mg GAE/L), total flavonoid content (140.11 ± 14.10 mg QE/L), and condensed

tannin content (1328.40 ± 66.32 mg CE/L). It had an overall acceptability value of 4.30 ± 0.75 , which indicated that the panellists neither liked nor disliked.

The selected concentration of the *Eucalyptus* oil and lemon juice was 0.15% and 3%, respectively, because it had the best properties, in terms of high antioxidant activity, total phenolic, and total phenolic content with decreased condensed tannin content. However, when compared to herbal tea without the addition of *Eucalyptus* oil and lemon, it had lower antioxidant activity ($IC_{50} = 9178.11 \pm 369.98$ ppm), total phenolic content (557.84 ± 27.91 mg GAE/L), total flavonoids (68.75 ± 0.39 mg QE/L) and condensed tannin (1014.67 ± 59.58 mg CE/L). Furthermore, this herbal tea has improved sensory properties in terms of astringency, aroma, and taste. It also had a better overall acceptance value of 4.73 ± 1.17 , which indicated that the panellists slightly liked the herbal tea.

Supplementary Data Availability Statement

All data analyzed in this study are included in this published article

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