

## Functional and sensory properties of Indonesian bay leaf (*Syzygium polyanthum*) herbal tea

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### Abstract

Indonesian bay leaf (*Syzygium polyanthum*) has been reported to contain antioxidants and antidiabetic agents that can bring many health benefits. To increase its consumption, it can be processed into herbal tea with a simple processing method. The objective of this research was to determine the effect of drying temperature, brewing temperature, and brewing time on functional properties and sensory acceptance of Indonesian bay leaf herbal tea. Indonesian bay leaf was dried at three different temperatures (40, 50 and 60°C) for 24 hrs to increase its shelf life. A drying temperature of 40°C was selected for its highest antioxidant properties among the dried Indonesian bay leaf. Indonesian bay leaf herbal tea was prepared with different brewing temperatures (80, 90 and 100°C) and brewing times (10, 20 and 30 mins). Results showed that lower brewing temperature (80°C) and longer brewing time (30 mins) could increase its functional properties, with the highest antioxidant activity (IC<sub>50</sub>) of 984.07±28.92 ppm. Indonesian bay leaf herbal tea brewed for 30 mins showed the highest  $\alpha$ -glucosidase inhibition activity of 4704.79±26.31 ppm, about 85 times weaker compared to acarbose. However, brewing time and temperature did not affect the sensory acceptance of bay leaf herbal tea with an overall hedonic score ranging from 4-5 (slightly like).

## 1. Introduction

Indonesian bay leaf (*Syzygium polyanthum*), also known as “*daun salam*”, is a popular flavouring herb in Indonesia. Different from the true bay leaf or laurel leaf (*Laurus nobilis*) that is included *Lauraceae*, Indonesian bay leaf is included in the family of *Myrtaceae*. The taste of bay leaf is slightly sour or astringent with a weak aroma (Ravindran, 2017). In Indonesia, bay leaf is used as herb incorporated in dishes or as a traditional medicine to cure diarrhoea and stomachache (Jediut *et al.*, 2018). It can also be used to cure gout, stroke, ulcer, gastritis, skin diseases, and stomach inflammation (Harismah dan Chusniatun, 2016; Jediut *et al.*, 2018; Ismail and Ahmad, 2017).

Previous research has reported that Indonesian bay leaf (*S. polyanthum*) contains several bioactive compounds. Hidayati *et al.* (2017) reported that methanol extract of the bay leaf could be a great potential source of antioxidants due to high phenolic and flavonoid content. Another study from Widyawati *et al.* (2015) and Kusuma *et al.* (2011) also shows that qualitative analysis of bay leaf extract indicated the

presence of tannins, glycosides, flavonoids, alkaloids, steroids, triterpenoid, and saponins. Moreover, bay leaf extract can effectively decrease blood glucose with the extent of the hypoglycemic effect is in linear proportion to the dosage, with the most significant dosage of 50 mg/kg (Wahyuni and Wita, 2017). This result is supported by another study that shows that bay leaf extract exerts an antihyperglycemic effect by inhibiting glucose absorption from the intestine and increasing glucose uptake by muscle in Streptozotocin-induced diabetic rats (Widyawati *et al.*, 2015). However, the utilization of Indonesian bay leaf is still limited in its fresh form (Perdana *et al.*, 2016; Dewijanti *et al.*, 2018), as food flavouring or traditional medicine (Harismah dan Chusniatun, 2016; Abdulrahman *et al.*, 2018). One of the simplest methods to increase bay leaf consumption is by making it into herbal tea.

Herbal tea is made from a variety of plants and leaves other than usual tea plants (*Camellia sinensis*). It can be brewed from the leaves, flowers, seeds, fruits, stems, and roots of a plant. Herbal tea has been widely used for disease prevention. They are designed for having specific therapeutic or medical benefits (Zhao *et*

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*al.*, 2013; Ravikumar, 2014). In this research, Indonesian bay leaf was brewed into herbal tea as a more convenient alternative to bay leaf extract because the extraction process is replaced by steeping the tea leaf with hot water. Furthermore, previous treatment, i.e., drying processing of tea leaf enhances the flavour of tea and makes them shelf-stable. This research aimed to determine the effect of drying temperature on antioxidant activity, total phenolic, total flavonoid, and total condensed tannin of the bay leaf and to determine the effect of brewing time and temperature on functional and sensory properties of the Indonesian bay leaf herbal tea.

## 2. Materials and methods

### 2.1 Materials and equipment

The materials used in this research were Indonesian bay leaf *Syzygium polyanthum* bought from the local market in Tangerang, Indonesia, ethanol 96%, 1,1-diphenyl-2-picrylhydrazyl (DPPH) solution, AlCl<sub>3</sub> 2%, Folin-Ciocalteu reagent, Na<sub>2</sub>CO<sub>3</sub>, quercetin, gallic acid, vanillin, phosphate buffer (pH 7) containing 200 mg of Bovine serum albumin, dimethyl sulfoxide (DMSO), methanol purchased from Merck, Jakarta, Indonesia, hydrochloric acid 37% purchased from SMART-LAB, Tangerang, Indonesia,  $\alpha$ -glucosidase and 20 mM *p*-nitrophenyl  $\alpha$ -D-glucopyranoside purchased from Megazyme, Wicklow, Ireland, and distilled water. The equipment used were analytical balance (Ohaus, Germany), chromameter (Konica Minolta, Japan), cuvette, UV-Vis spectrophotometer (DLAB, USA), oven (Mettler UNE800, Germany), pH meter (Ohaus, Germany), water bath (Mettler, Germany), and glassware.

### 2.2 Preparation of dried Indonesian bay leaf

Indonesian bay leaves were sorted and foreign materials were removed. Sorted leaves were then gently rinsed in tap water for cleaning. Cleaned leaves were blanched in hot water at 85°C for 2 mins. Cleaned Indonesian bay leaves were spread thinly on aluminium trays and dried in an oven set at the temperature of 40, 50, and 60°C for about 24 hrs until a moisture content of 5% (Akila *et al.*, 2018 with modification). Dried Indonesian bay leaves were size reduced for further analysis on moisture content (AOAC, 2005), antioxidant activity using the DPPH method (Elmastaş *et al.*, 2006), total flavonoid (Oktavia, 2011), total condensed tannin (Herald *et al.*, 2014), and total phenolic content (Hartanti *et al.*, 2019). For analysis, 2.5 g of dried Indonesian bay leaves were submerged in 125 mL ethanol for 24 hrs for the analysis of antioxidant activity, total flavonoid content, and total condensed tannin. Indonesian bay leaves were steeped in hot demineralized water (100°C)

for 5 mins prior to total phenolic content analysis. The supernatant used in the analysis was obtained by passing the sample solution through Whatman no. 1 filter paper.

### 2.3 Determination of the effect of brewing time and temperature on sensory and functional properties of bay leaf herbal tea

Herbal tea was prepared by brewing dried bay leaves at different times and temperatures. The proportion of tea and water was derived from Franks *et al.* (2019) with modification. Dried Indonesian bay leaf was weighed about 2.5 g and added with 125 mL of hot demineralized water under different temperatures of 80, 90, and 100°C for different brewing times (10, 20, and 30 mins). The tea was cooled under room temperature for approximately 15 – 17 mins prior to analysis. Herbal tea from each treatment was analyzed for its antioxidant activity using the DPPH method (Elmastaş *et al.*, 2006), total flavonoid (Oktavia, 2011), total condensed tannin (Herald *et al.*, 2014), total phenolic content (Hartanti *et al.*, 2019), and  $\alpha$ -glucosidase inhibition activity.

### 2.4 $\alpha$ -glucosidase Inhibition analysis

$\alpha$ -glucosidase inhibition was measured according to the method from Saraswaty (2012) and Wang *et al.* (2018). The inhibitory activity towards  $\alpha$ -glucosidase was performed by some preliminary steps: 1 mg of  $\alpha$ -glucosidase enzyme was firstly diluted in 100 mL phosphate buffer (pH 7) containing 200 mg of bovine serum albumin. While reagent mixtures were prepared as follows: 250  $\mu$ L of 5 mM *p*-nitrophenyl  $\alpha$ -D-glucopyranoside and 500  $\mu$ L of phosphate buffer mixed with 10  $\mu$ L of sample in DMSO. The reagent mixtures were pre-incubated in a water bath at 37°C for 5 mins. The reaction began after the addition of 250  $\mu$ L of enzyme solution prepared in the preliminary steps and continued with incubation for 15 mins. The reaction was terminated by the addition of 1000  $\mu$ L 200 mM Na<sub>2</sub>CO<sub>3</sub> and the amount of *p*-nitrophenol resulting was measured using a spectrophotometer at 410 nm. There were two controls: negative control was the mixture of reagent without the addition of enzyme solution and acarbose was used as a positive control of  $\alpha$ -glucosidase inhibitor. Inhibition activity was calculated using the following formula:

$$\alpha - \text{glucosidase inhibition activity (\%)} = \frac{C - S}{C} \times 100\%$$

Where C = the absorbance of positive control and S = the absorbance of the sample after reduced by negative control of the sample.

### 2.5 Sensory evaluation of Indonesian bay leaf herbal tea

Sensory evaluation of bay leaf herbal tea was conducted to determine its acceptance by panellists. The

sensory evaluation was carried out using a 7-scale hedonic test (1 = dislike extremely - 7 = like extremely). The parameters observed by 70 semi-trained panellists were color, aroma, astringency, taste, aftertaste, and overall acceptance (Stone *et al.*, 2012).

## 2.6 Data analysis

All data obtained in this research were analyzed statistically using Univariate Analysis and Post Hoc Test using Duncan. The software used was SPSS version 22.

## 3. Results and discussion

### 3.1 Effect of drying temperature on Indonesian bay leaf functional properties

Drying was performed in this research since in tea manufacturing, one of the important stages is drying to remove moisture and increase the shelf life (Chong and Lim, 2012). The moisture content of 10% to 11% may lead to spoilage (Lund *et al.*, 2000). Results showed that drying at 40, 50, and 60°C for 24 hrs could reduce Indonesian bay leaf moisture content (%wb) to less than 5%, i.e., 4.46±0.05%, 4.40±0.13%, and 4.37±0.08%, respectively, making it more shelf-stable during storage.

To determine the effect of drying temperature on functional properties of Indonesian bay leaf, several analyses were done, and the result can be observed in Table 1. Antioxidant activity of Indonesian bay leaf was expressed as IC<sub>50</sub> value on a dry basis. The statistical analysis of the antioxidant activity showed that there was a significant effect ( $p \leq 0.05$ ) of the drying temperature on the antioxidant activity. Indonesian bay leaf dried under 40°C (IC<sub>50</sub> = 477.87±5.97 ppm) displayed the highest antioxidant activity and significantly different than Indonesian bay leaf dried under 50°C and 60°C. This suggests that temperature affects the antioxidant activity through the initiation of some chemical reactions that might cause oxidative damages (Thamer *et al.*, 2018).

The fresh Indonesian bay leaf (IC<sub>50</sub> = 130.50±1.32 ppm) exerts a higher antioxidant activity compared to those dried Indonesian bay leaf as Indonesian bay leaf dried under 40, 50 and 60°C that IC<sub>50</sub> values of more than 500 ppm which was considered low. This result showed that the drying process on Indonesian bay leaf

displayed a relatively weak antioxidant activity due to the reduction of antioxidants. According to Ahmad *et al.* (2015), antioxidant capacity with an IC<sub>50</sub> value above 150 ppm is considered weak. A previous study on the antioxidant activity of the dried Indonesian bay leaf methanolic extract showed an antioxidant activity with the IC<sub>50</sub> of 90.85 µg/mL (Har and Intan, 2012). However, IC<sub>50</sub> of Indonesian bay leaf dried at 40°C is also comparable to IC<sub>50</sub> of fenugreek methanolic extract (444.1±5.5 ppm), lower than cardamom methanolic extract (681.5±8.4 ppm) (Khalaf *et al.*, 2008), and lower than Roselle leaves that were oven-dried at 60°C (2.2 mg/mL or 2200 ppm). This means that the antioxidant activity of bay leaf is higher compared to cardamom or fenugreek extract and dried Roselle leaves. However, green tea leaves that were oven-dried at 60°C has lower IC<sub>50</sub>, i.e., 167.166 ppm (Roshanak *et al.*, 2016) compared to dried Indonesian bay leaf.

The increase of drying temperature could also cause the reduction of antioxidant capacity as high drying temperature may lead to the depletion of phenolics, flavonoids and tannins (Thamer *et al.*, 2018). It is also expressed in the results shown in Table 1, that higher drying temperature significantly decreases the total phenolics, flavonoid, and condensed tannin of Indonesian bay leaf. Dried Indonesian bay leaf under 40°C (7.33±0.54 mg GAE/g sample) had the highest phenolic content compared Indonesian bay leaf dried at 50°C and 60°C. Furthermore, Indonesian bay leaf dried under different temperatures (40, 50, and 60°C) displayed total phenolic content that was slightly lower than fresh Indonesian bay leaf (10.76±1.50 mg GAE/g sample). This can happen because phenolic compounds are also very sensitive to high temperatures or the presence of oxygen (Nguyen and Chuyen, 2020).

Furthermore, dried Indonesian bay leaf with 40°C drying temperature (18.94±2.49 mg QE/g sample) had the highest flavonoid content compared to the other dried Indonesian bay leaf, although it was not significantly different from Indonesian bay leaf dried at 50°C (16.60±2.20 mg QE/g sample) and Indonesian bay leaf dried at 60°C (15.09±2.35 mg QE/g sample), regardless the high flavonoid content of fresh bay leaf (67.97±6.32 mg QE/g sample). According to Sukmasari *et al.* (2018),

Table 1. Functional properties of Indonesian bay leaf at different drying temperatures

Treatment	Antioxidant activity (ppm)	Total phenolic content (mg GAE/g leaf db)	Total condensed tannin (mg CE/g leaf db)	Total flavonoid content (mg QE/g leaf db)
Fresh Indonesian Bay leaf	130.50±1.32 <sup>a</sup>	10.76±1.50 <sup>c</sup>	110.80±1.88 <sup>a</sup>	67.97±6.32 <sup>b</sup>
Dried Indonesian Bay leaf (40°C)	477.87±5.97 <sup>b</sup>	7.33±0.54 <sup>b</sup>	29.85±0.74 <sup>b</sup>	18.94±2.49 <sup>a</sup>
Dried Indonesian Bay leaf (50°C)	576.53±8.69 <sup>c</sup>	6.41±0.82 <sup>ab</sup>	26.48±0.77 <sup>c</sup>	16.60±2.20 <sup>a</sup>
Dried Indonesian Bay leaf (60°C)	624.22±5.19 <sup>d</sup>	5.35±0.76 <sup>a</sup>	20.37±0.34 <sup>d</sup>	15.09±2.35 <sup>a</sup>

Values are presented as mean±SD. Values with different superscript within the same column are significantly different ( $p \leq 0.05$ ). db, dry basis.

flavonoid content was not necessarily linked to total phenolic content depending on the types of solvents used for making extracts. The extract of *Syzygium cumini* using ethyl acetate and acetone showed a high total flavonoid and low total phenolic content. Therefore, a sample with low phenolic content might have high flavonoid content depending on the solubility of the compounds in the solvents. In this research, dried leaves were submerged in hot water for phenolic analysis, whereas for other analyses, the leaves were submerged in ethanol.

Total condensed tannin plays a determinant role in the quality of plants as it was much more resistant to microbial degradation than hydrolysable tannin and it exhibited a stronger antioxidant activity and  $\alpha$ -glucosidase inhibition activity than hydrolysable tannin (Ashok and Upadhyaya, 2012). Based on the statistical analysis, there was a significant effect ( $p \leq 0.05$ ) of drying temperature on total condensed tannin. The condensed tannin of Indonesian bay leaf dried at 40°C, 50°C, and 60°C was significantly lower than fresh Indonesian bay leaf. A reduction in condensed tannins along with the increase of temperature was coherent with the results from a study conducted by Palmer *et al.* (2000) who found higher amounts of condensed tannins in freeze-dried samples than oven-dried samples. Tannins are compounds naturally present in plant tissue that have been known to give many beneficial health effects, such as antiviral and antimicrobial. However, tannins also cause astringent and unpleasant taste, such as the dry and puckery feeling in the mouth (Ashok and Upadhyaya, 2012). Moreover, a lower amount of condensed tannin in dried Indonesian bay leaf compared to dried soursop leaves brew (181.32±31.62 ppm) (Hardoko *et al.*, 2018) indicates that Indonesian bay leaf herbal tea could offer better sensory acceptability compared to soursop leaves brew. Even though dried Indonesian bay leaf had lower antioxidant activity compared to its fresh form, it offers longer shelf life as the moisture content is reduced significantly. Based on this consideration, a further experiment was done using Indonesian bay leaf dried at 40°C.

### 3.2 Effect of brewing time and temperature on antioxidant activity of bay leaf herbal tea

The statistical analysis on antioxidant activity showed that brewing time and brewing temperature significantly affect ( $p \leq 0.05$ ) the antioxidant capacity of Indonesian bay leaf herbal tea. There was also a significant interaction between the brewing temperature and brewing time of Indonesian bay leaf herbal tea. Results of statistical analysis can be observed in Figure 1. Figure 1 shows that Indonesian bay leaf brewed at 80°C for 30 mins displayed the highest antioxidant

activity ( $IC_{50}$  of 954.15±10.01 ppm), whereas the highest brewing temperature (100°C) for shortest time (10 mins) displayed the lowest antioxidant activity ( $IC_{50}$  of 1759.91±50.11 ppm).

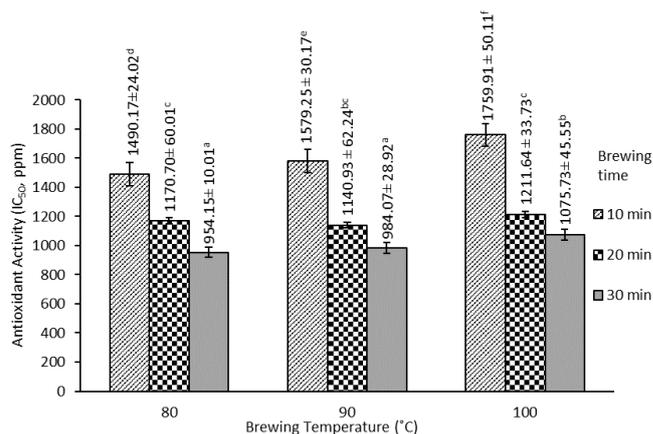


Figure 1. Effect of brewing temperature and time on antioxidant activity ( $IC_{50}$ ) of Indonesian bay leaf herbal tea. Values above bars are presented as mean±SD. Values with different superscripts are significantly different ( $p \leq 0.05$ ).

Higher temperature reduced the antioxidant capacity, however, longer brewing time enhanced the antioxidant capacity of the bay leaf herbal tea. The longer brewing time of bay leaf herbal tea promoted the release of phenolic compounds, flavonoids, and tannins into the tea. The antioxidant capacity was reduced with the increase of brewing temperature. This might be due to the degradation of phenolic and flavonoids content in higher temperatures (Hajiaghaalipour *et al.*, 2016). Antioxidant activity of Indonesian bay leaf herbal tea brewed at 80°C for 30 mins is higher compared to Cheeseweed (*Malva parviflora* L.) leaves and stems infused in water at 60°C for 24 hrs, with  $IC_{50}$  value of 1.5 mg/mL (or 1500 ppm) and 1.8 mg/mL (or 1800 ppm), respectively (Farhan *et al.*, 2012) and some plant aqueous extract (30 g powder in 150 mL water) prepared at 100°C for 10 min, i.e. Indian bay leaf (*Cinnamomum tamala*) with  $IC_{50}$  of 6.9±0.05 mg/g (or about 6900 ppm), coriander seeds (*Coriandrum sativum*) with  $IC_{50}$  of 2.86±0.07 mg/g (or about 2860 ppm), and cardamom seeds (*Ellettaria cardamomum*) aqueous extract with  $IC_{50}$  of 61.75±3.03 mg/g (or about 61750 ppm) (Deepa *et al.*, 2013). However, the antioxidant activity of Indonesian bay leaf herbal tea in this research is also lower compared to other herbal infusions from *Lamiaceae* family, such as infusion of peppermint ( $IC_{50}$  = 35.75 ppm), basil ( $IC_{50}$  = 26.37 ppm), and thyme ( $IC_{50}$  = 39.20 ppm) (Albayrak *et al.*, 2013).

In terms of total phenolic, total flavonoid, and total condensed tannin, statistical results using Univariate showed that interaction between the brewing temperature and the brewing time of the bay leaf herbal tea did not significantly affect ( $p > 0.05$ ) those parameters. However,

Table 2. Effect of brewing temperature on total phenolic, total flavonoid, and total condensed tannin content

Brewing temperature (°C)	Total phenolic content (mg GAE/g leaf db)	Total flavonoid content (mg QE/g leaf db)	Total condensed tannin (mg CE/g leaf db)
80	0.95±0.37 <sup>a</sup>	0.22±0.05 <sup>a</sup>	8.69±1.79 <sup>a</sup>
90	0.80±0.39 <sup>ab</sup>	0.19±0.03 <sup>b</sup>	8.45±1.61 <sup>b</sup>
100	0.56±0.29 <sup>b</sup>	0.16±0.04 <sup>c</sup>	8.03±1.58 <sup>c</sup>

Values are presented as mean±SD. Values with different superscript within the same column are significantly different ( $p \leq 0.05$ ). db, dry basis.

Table 3. Effect of brewing time on total phenolic, total flavonoid, and total condensed tannin content

Brewing temperature (°C)	Total phenolic content (mg GAE/g leaf db)	Total flavonoid content (mg QE/g leaf db)	Total condensed tannin (mg CE/g leaf db)
10	0.48±0.17 <sup>a</sup>	0.15±0.03 <sup>a</sup>	6.49±0.28 <sup>a</sup>
20	0.75±0.30 <sup>b</sup>	0.19±0.05 <sup>b</sup>	8.36±0.32 <sup>b</sup>
30	1.08±0.35 <sup>c</sup>	0.23±0.03 <sup>c</sup>	10.31±0.43 <sup>c</sup>

Values are presented as mean±SD. Values with different superscript within the same column are significantly different ( $p \leq 0.05$ ). db, dry basis.

both brewing temperature and brewing time significantly affect ( $p \leq 0.05$ ) the total phenolic content, total flavonoid, and total condensed tannin of Indonesian bay leaf herbal tea. These results can be further observed in Table 2 and Table 3.

Results showed the similar pattern to antioxidant activity results, in which Indonesia bay leaf herbal tea brewed at 80°C had the highest phenolic content, flavonoid content, and total condensed tannin, i.e., 0.95±0.37 mg GAE/g sample, 0.22±0.05 mg QE/g sample, and 8.69±1.79 mg CE/g sample, respectively. This can be explained as phenolic compounds mainly contribute to antioxidant activity (Wojdyło *et al.*, 2007). This result is contrary to previous research, which stated that green tea, corn silk, senna, and rosemary brewed at 100°C had a higher amount of phenolic, flavonoid, and condensed tannin compared to those brewed at 60°C and 80°C (Kiliç *et al.*, 2017). Moreover, tea brewed for a long time had a greater quantity of phenolic compounds, flavonoid compounds, and condensed tannin. The brewing time and temperature had been reported to be the most critical factors that affect total phenolic content and antioxidant activity. Increasing water temperature for brewing increases total phenolic content to a certain level and then decreased afterwards, while the solubility of phenolic compounds increased with an increase in time until it reaches the maximum level (İlyasoğlu and Arpa, 2017). Longer brewing time has also been reported to increase the total phenolic content of Roselle herbal tea (Nguyen and Chuyen, 2020).

In terms of total phenolic content, Indonesian bay leaf herbal tea contains a much lower amount of phenolic compounds compared to green tea, black tea, and chamomile infusions, i.e. 150±27.7 mg GAE/g, 130±18.2 mg GAE/g, and 44±7.9 mg GAE/g, respectively (Rusaczonok *et al.*, 2010). It is also lower

compared to coriander seeds aqueous extract, i.e., 3.14±0.12 mg GAE/g, but higher compared to cardamom and Indian bay leaf aqueous extract, i.e., 0.55±0.08 mg GAE/g and 0.16±0.05 mg GAE/g, respectively (Deepa *et al.*, 2013). These results show that phenolic compounds extracted from brewing could be various depending on the type and part of a plant used.

Similar to total phenolic content and total flavonoid content, higher brewing temperature decreased the quantity of condensed tannin regardless of the effect of brewing time. The reduction of total condensed tannins was reduced due to the increased brewing temperature that caused the destruction of condensed tannin, while longer brewing time allowed the leaching of condensed tannins (Krzyzowska *et al.*, 2017). The tannin content of bay leaf herbal tea is considered to be low in comparison to black tea brewed at 90°C for 3 mins (76.8 mg/g) (Negukhula, 2010), but higher compared to coriander seeds, cardamom, and Indian bay leaf aqueous extract, which have total tannin content of 1.4±0.03 mg CE/g, 0.22±0.07 mg CE/g, and 1.4±0.07 mg CE/g, respectively (Deepa *et al.*, 2013).

### 3.3 Effect of brewing time and temperature on $\alpha$ -glucosidase inhibition activity of bay leaf herbal tea

The effectiveness of bay leaf decoction (*S. polyanthum*) or extract (*Laura nobilis*) as an antidiabetic agent in reducing blood glucose had been reported from previous research (Dewijanti *et al.*, 2018; Al Chalabi *et al.*, 2020). However, the experiment on its  $\alpha$ -glucosidase inhibition activity of bay leaf herbal tea under different brewing time and temperature have not been studied.  $\alpha$ -glucosidase inhibitors are important to regulate postprandial hyperglycemia (PPHG) in diabetic patients. Moreover, inhibition of this enzyme could reduce starch digestion and slow down the increase of blood glucose content (Ahamad *et al.*, 2011; Xu *et al.*, 2019).

Statistical analysis of the  $\alpha$ -glucosidase inhibition activity showed that there was no significant interaction ( $p>0.05$ ) between the brewing temperature and brewing time of Indonesian bay leaf herbal tea. The brewing temperature did not give a significant effect ( $p>0.05$ ) on the inhibition activity towards  $\alpha$ -glucosidase, while brewing time significantly affect ( $p\leq 0.05$ )  $\alpha$ -glucosidase inhibition activity of Indonesian bay leaf herbal tea. These results can be seen in Table 4. This means that regardless of the temperature used for brewing, longer brewing time yielded greater antidiabetic properties. Herbal tea brewed for 30 mins had the highest  $\alpha$ -glucosidase inhibition activity ( $IC_{50}$ ), i.e.,  $4704.79\pm 26.31$  ppm. Meanwhile,  $IC_{50}$  of acarbose as a positive control was  $56.60\pm 0.46$  ppm. This result shows that Indonesian bay leaf herbal tea was about 85 times weaker inhibition activity towards  $\alpha$ -glucosidase compared to acarbose. It is also lower compared to crude water extract of Qingzhuan dark tea ( $IC_{50} = 2.47\pm 0.30$  mg/mL or about 2470 ppm) (Liu *et al.*, 2016), slightly lower than green tea infusion ( $IC_{50} = 3.91$  mg/mL or about 3910 ppm) (Rodrigues *et al.*, 2019) but higher when compared to another beverage, such as sappanwood (*Caesalpinia sappan* L.) and lemongrass extract (*Cymbopogon citratus*) beverage ( $IC_{50} = 10932.50\pm 273.25$  ppm) (Siregar and Verena, 2019).

Table 4. Effect of brewing time on  $\alpha$ -glucosidase inhibition activity

Brewing time (min)	$\alpha$ -glucosidase inhibition activity (ppm)
10	$4977.99\pm 45.87^a$
20	$4832.81\pm 43.49^b$
30	$4704.79\pm 26.31^c$

Values with different superscripts are significantly different ( $p\leq 0.05$ ). Data was obtained from average of  $\alpha$ -glucosidase inhibition activity at different brewing temperature.

$\alpha$ -glucosidase inhibition activity of the plant is related to its antioxidant activity and phytochemical compounds. Phytochemical compounds in a plant show a positive correlation with antioxidant and  $\alpha$ -glucosidase inhibitory activity (Chen *et al.*, 2019). Furthermore, tannin content and flavonoid content in tea leaf were the

main potential indicators of medical usage. The presence of both condensed tannin and flavonoid contributed to a reduction of blood glucose levels due to its antioxidant constituent (Kunyanga *et al.*, 2011 and Castiglioni *et al.*, 2015).  $\alpha$ -glucosidase inhibition activity of White tea was also found to be strongly correlated with its phenolic content (Xu *et al.*, 2019). Therefore, relatively low total condensed tannin content and total flavonoid content observed in Indonesian bay leaf herbal tea might contribute to a relatively weak  $\alpha$ -glucosidase inhibition.

### 3.4 Effect of brewing time and temperature on sensory properties of bay leaf herbal tea

Sensory evaluation was done to determine the acceptance of Indonesian bay leaf herbal tea prepared with different brewing temperatures and times. It is because bay leaf contains tannins, which contributes to astringency and puckering sensation in the mouth when consumed (Ashok and Upadhyaya, 2012). Based on the statistical analysis, there was no significant effect ( $p>0.05$ ) of brewing temperature and brewing time on the preference of panellists to the samples. Table 5 shows the results of a hedonic test on the color, aroma, astringency, taste, aftertaste, and overall acceptance of Indonesian bay leaf herbal tea. The hedonic score for all parameters observed on Indonesian bay leaf herbal tea brewed at different temperatures and times were in the range of 4.5 to 5, which means that Indonesian bay leaf herbal tea was acceptable and slightly liked by the panellists. It also means that relatively low tannin, flavonoid, and phenolic content contributes to a more acceptable astringency and bitter aftertaste in Indonesian bay leaf herbal tea.

## 4. Conclusion

Indonesian bay leaf herbal tea could be beneficial for health as it contains antioxidants and antidiabetic properties. However, the drying and brewing process at higher temperatures affect the antioxidant capacity, total phenolic content, total flavonoid content, total condensed tannin content, and  $\alpha$ -glucosidase inhibition activity. The best drying temperature in the making of dried

Table 5. Sensory (hedonic) results of Indonesian bay leaf herbal tea

Brewing temperature (°C)	Brewing time (min)	Color	Aroma	Astringency	Taste	Aftertaste	Overall
80	10	$4.5\pm 1.1$	$4.6\pm 1.2$	$4.52\pm 1.32$	$4.54\pm 1.22$	$4.66\pm 1.15$	$4.67\pm 1.25$
80	20	$4.7\pm 1.1$	$4.5\pm 1.1$	$4.57\pm 1.11$	$4.53\pm 1.35$	$4.56\pm 1.22$	$4.74\pm 1.09$
80	30	$4.7\pm 1.1$	$4.6\pm 1.2$	$4.47\pm 1.33$	$4.51\pm 1.39$	$4.60\pm 1.27$	$4.77\pm 1.21$
90	10	$4.5\pm 1.0$	$4.6\pm 1.1$	$4.61\pm 1.20$	$4.56\pm 1.42$	$4.66\pm 1.20$	$4.67\pm 1.39$
90	20	$4.8\pm 1.0$	$4.7\pm 1.2$	$4.27\pm 1.24$	$4.47\pm 1.28$	$4.56\pm 1.19$	$4.67\pm 1.16$
90	30	$4.6\pm 1.0$	$4.5\pm 1.3$	$4.37\pm 1.26$	$4.29\pm 1.31$	$4.30\pm 1.31$	$4.59\pm 1.19$
100	10	$4.6\pm 1.1$	$4.6\pm 1.3$	$4.37\pm 1.24$	$4.57\pm 1.33$	$4.44\pm 1.22$	$4.76\pm 1.13$
100	20	$4.8\pm 1.1$	$4.6\pm 1.2$	$4.37\pm 1.22$	$4.41\pm 1.28$	$4.27\pm 1.32$	$4.59\pm 1.19$
100	30	$4.9\pm 1.0$	$4.6\pm 1.2$	$3.46\pm 1.13$	$4.41\pm 1.34$	$4.51\pm 1.20$	$4.64\pm 1.23$

Indonesian bay leaf was 40°C, which produced the highest antioxidant activity, total phenolic content, total flavonoid content, and total condensed tannin. Lower brewing temperature and longer brewing time affected increased the functional properties of Indonesian bay leaf herbal tea. Brewing at 80°C for 30 mins resulted in the highest antioxidant activity.  $\alpha$ -glucosidase inhibition activity of herbal tea was 85 times weaker compared to acarbose with the best IC<sub>50</sub> value was found at 30 mins brewing time. The hedonic sensory test showed that most panellists slightly liked the brewed bay leaf herbal tea despite the different brewing times and temperatures. This indicates a possibility for the commercialization of Indonesian bay leaf as functional herbal tea.

### Conflict of Interest

The authors declare no conflict of interest.

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