

# **ORIGINAL RESEARCH**

**Open Access** 

# The effect of brewing time on the antioxidant properties and consumer's preference of green tea and jasmine tea

Dwi Hartanti<sup>1</sup> and Alwani Hamad<sup>2\*</sup>

<sup>1</sup> Department of Pharmaceutical Biology, Faculty of Pharmacy, Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia

<sup>2</sup> Department of Chemical Engineering, Faculty of Engineering, Universitas Muhammadiyah Purwokerto, Purwokerto, Indonesia

KEYWORDS	ABSTRACT			
Antioxidants	Isomine tea is a nonular tea type obtained from scenting tea ( <i>Camellia sinensis</i> (I))			
Brewing time	Kuntze) leaves with jasmine ( <i>Jasminum sambac</i> (L.) Aiton) flowers. This study			
Green tea	aimed to evaluate the antioxidant properties and sensory aspects of jasmine and green tea brewed at different times. The commercial jasmine and green tea were			
Jasmine tea	brewed in boiling water at a ratio of 1:100 for 0.5, 1, 2.5, 5, 10, 30, and 60 min. The			
Sensory attributes	obtained tea was evaluated for colour, pH, total flavonoid content (TFC), total phenolic content (TPC), 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity, and ferric-reducing antioxidant power (FRAP) by standard methods. Thirty-three untrained consumers evaluated the preference for tea from different brewing times. Jasmine tea exerted darker colour, lower pH, higher TFC and TPC, and higher FRAP than green tea. The values of those parameters increased with longer brewing time, with the optimum time being 30 min. However, the longer brewing generated tea liked less by consumers. The most favoured tea was jasmine green tea brewed for 5 min with aroma as the most preferred attribute. Our study suggested that brewing tea for a longer time benefited with better antioxidant properties but disadvantaged in sensory aspects.			

## Introduction

Tea (Camellia sinensis (L.) Kuntze, Theaceae) is widely consumed worldwide for its flavour, health benefits, and safety profile. Among other forms of tea, green tea is popularly associated with antioxidant properties. It does not undergo excessive withering and oxidation processes, resulting in a richer profile of antioxidants (Hu et al., 2018). Green tea and its main constituents have shown promising effects in various oxidative reaction-related health problems, i.e., breast cognition and brain function, cancer. hyperlipidemia, inflammation, photoaging, and etc. (Mancin et al., 2017; Ohishi et al., 2016; Prasanth et al., 2019; Rofida and Hartanti, 2021; Schoeneck and Iggman, 2021).

Scented tea is tea leaves mixed with other plant materials during processing to naturally absorb the plant's fragrance. Jasmine tea is prepared from tea leaves and jasmine (*Jasminum*) *sambac* (L.) Aiton, Oleaceae) flowers. Jasminescented tea is commonly prepared from various forms of tea, i.e., green tea, black tea, white tea, and oolong tea. Among those, jasmine green tea is the most popular in China (Li et al., 2018). In Indonesia, jasmine green tea is commercially available and branded as jasmine tea (*teh melati* in Indonesian). Consumers less favoured the plain and somewhat unpleasant aroma of green tea, and the scenting process with jasmine flowers greatly improved it (BPS Statistic Indonesia, 2020).

Tea brewing conditions significantly affected the obtained tea's content and bioactivity. Total phenolic content (TPC), epigallocatechin gallate content, and radical scavenging activity of fresh leaves, oolong tea, and green tea varied widely according to the brewing temperature used. In contrast, the brewing time and temperature were significantly affected the caffeine, catechin, free amino acid, and theanine contents of white tea (Kowalska et al., 2021; Zhang et al., 2017). However, such information on green tea is still limited. This study evaluated the effects of brewing time on the colour, pH, TPC, total flavonoid content (TFC), antioxidant activities, and sensory aspects of jasmine and green tea. Also, the correlation between antioxidant contents and antioxidant activities of both tea types was analyzed in this current study.

#### **Research Methods**

This study was conducted at the Laboratory of Food Bioprocess, Faculty of Engineering and Science, Universitas Muhammadiyah Purwokerto, Indonesia, on January – May 2022.

#### Materials

Jasmine and green tea samples were purchased from a local supermarket in Purwokerto, Central Java, Indonesia. Jasmine tea comprises 20% jasmine flower and 80% green tea, while green tea is the dried unfermented tea leaves. Both tea types were from the same brand produced by a tea processing plant in Tegal, Central Java. Ethanol, Folin-Ciocalteu reagent, Gallic acid, Quercetin, Trolox, AlCl<sub>3</sub>, CH<sub>3</sub>COONa, DPPH (2,2-diphenyl-1-picrylhydrazyl), FeCl<sub>3</sub>, HCl, TPTZ (2,4,6-Tris(2pyridyl)-s-triazine), and NaOH, all were bought from Sigma-Aldrich (USA), were also used in this study.

## Preparation of tea samples

One tea bag (2 g) of each tea type was brewed in 200 mL of freshly boiled water. The teas were allowed to stand for 0.5, 1, 2.5, 5, 10, 30, and 60 minutes before the bag was removed. The brewed teas were allowed to reach room temperature and were freshly analyzed.

## Determination of pH

The pH of the teas was measured by a pH meter (Ohaus, USA).

## **Determination of TPC**

TPC of the teas was analyzed according to the standard method in the Indonesian Herbal Pharmacopeia (IHP) with a slight modification (Indonesian MoH, 2017). A reaction mixture of 1000  $\mu$ L of tea sample or Gallic acid solution and 5000  $\mu$ L of 7.5% Folin-Ciocalteu reagent was stood for 8 min. The mixture was added with 4000  $\mu$ L of 1% NaOH and was stood for 60 minutes. The absorbance of the mixture was read at a UV-Vis Spectrophotometer (Shimadzu, Japan) at 730 nm.

The standard curve was prepared from Gallic acid at 0-100  $\mu$ g/ml, and the TPC was presented as mg Gallic acid equivalent (GAE)/g dry weight (DW) tea.

# **Determination of TFC**

The TFC of the teas was analyzed according to the standard method in the Indonesian Herbal Pharmacopeia (IHP) with a slight modification (Indonesian MoH, 2017). A reaction mixture of 500  $\mu$ L of tea sample or Quercetin solution and ethanol (1500  $\mu$ L), 10% AlCl<sub>3</sub> (100  $\mu$ L), 1M CH<sub>3</sub>COONa (100  $\mu$ L), and water (2800  $\mu$ L). After 30 minutes, the absorbance was read at 370 nm. The standard curve was prepared from Quercetin at 0-250  $\mu$ g/ml, and the TFC was presented as mg Quercetin equivalent (QE)/g DW tea.

#### Determination of DPPH scavenging activity

DPPH scavenging activity of the teas was determined according to the standard method with a slight modification (Thaipong et al., 2006). A reaction mixture of 500  $\mu$ L of tea sample or Trolox solution and 5000  $\mu$ L of 25  $\mu$ g/ml DPPH was allowed to stand in the dark for 30 minutes. The absorbance of the mixture was read at 517 nm. The standard curve was prepared from Trolox at 0-400  $\mu$ M, and the DPPH scavenging activity was presented as  $\mu$ M Trolox equivalent (TE)/g DW tea.

## Determination of FRAP

FRAP of the teas was determined according to the standard method with a slight modification (Thaipong et al., 2006). Briefly, the freshly mixed 10 parts of 300 mM CH<sub>3</sub>COONa buffer, a part of 10 mM TPTZ in HCl, and a part of 20 mM FeCl<sub>3</sub> at the final pH of 3,6 were used as the FRAP reagent. A reaction mixture of 210  $\mu$ L of tea sample or Trolox solution and 3990  $\mu$ L of FRAP reagent stood for 30 minutes. The absorbance of the mixture was read at 594 nm. The standard curve was prepared from Trolox at 0-225  $\mu$ M, and the FRAP was presented as  $\mu$ M TE/g DW tea.

## Sensorial analysis

Based on the result of the antioxidant evaluations, both jasmine and green tea brewed for 5, 10, and 30 minutes were subjected to sensory analysis. Tea samples were prepared the same way as those used for the chemical evaluations and antioxidant assays. Thirty-three untrained participants (9 men and 24 women, 19–58 years) who signed informed consent evaluated their preference for tea samples prepared as in the antioxidant properties evaluation. In the monadic presentation, tea was blind-coded with 4-digit random numbers, and was served to participants. Participants were asked to evaluate aroma, colour, taste, aftertaste, and overall liking. A 4-point hedonic scale, in which one was for extremely disliking and four was for being extremely like, was used to measure those attributes. The questionnaire also contained openended questions about the most liked tea sample and its reason.

#### Data analysis

The data in triplicate were reported as the mean value  $\pm$  standard deviation (SD). The effects of tea type and brewing time on TPC, TFC, DPPH radical scavenging activity, FRAP, and each attribute of sensory aspects of teas were analyzed by two-way ANOVA. The mean separation of those parameters between the group was evaluated by one-way ANOVA and the post-hoc Duncan's test. The correlation between TPC and TFC with the antioxidant activities of each tea sample was analyzed by the Pearson correlation test. All statistical analysis was performed in the IBM SPSS Statistics ver 13.0 (IBM, USA) at p  $\leq$  0.05.

#### **Results and Discussion**

Jasmine tea visually showed a darker colour than the green one. The colour of green tea was pale yellow to pale brown. On the other hand, the colour of jasmine tea was yellow and gradually turned to dark brown with the increasing brewing time (Figure 1). The greenish-yellow to pale yellowish shade of green tea was attributable to the flavonol and flavone pigments (Sakamoto, 1971). Those compounds were soluble in hot water, and the amount extracted increased with prolonged brewing time. Adding jasmine flowers to tea leaves during processing likely contributed to the development of the reddish-brown colour. Like other flowers, jasmine contains betalain, carotenoid, chlorophyll, and flavonoid pigments (Narbona et al., 2021). Carotenoids consisted of orange carotene and yellow xanthophyll subgroups and were likely responsible for a darker colour observed in jasmine tea (Fu et al., 2022).

Both types of tea (p = 0.000) and brewing time (p = 0.000) affected the pH of the tea. Green tea exerted a higher pH than jasmine tea. The longer brewing time resulted in tea with a lower pH. The highest and lowest pH of both teas were observed at 0.5 and 60 min of brewing, with the values of  $5.27\pm0.04$  and  $5.23\pm0.01$  for jasmine tea and 5.88±0.13 and 5.30±0.06 for green tea (Figure 2). The organic acids, mainly citric, malic, and oxalic, contributed to tea's low pH. The longer brewing time extracted more organic acids and eventually lowered the pH of the tea samples. The teas' pH varied according to the tea type, temperature, and brewing time (Panpan et al., 2013). Our result suggested that the jasmine flower addition significantly lowered the pH of tea. Unfortunately, the data on the acidity or the organic acid content of the jasmine flower was unavailable.

The flavonoids extracted from the tea were affected by tea type (p = 0.000) and brewing time (p = 0.000). Jasmine tea contained a significantly higher flavonoid content than the green one. The low level of flavonoid content was extracted from jasmine tea in 0.5 min brewing ( $6.68\pm0.24$  mg QE/g DW), which was increased with the brewing time and reached a maximum after 30 min ( $34.94\pm0.47$  mg QE/g DW). A similar pattern was observed in green tea, with TFC at min 0.5 and 30 min was  $3.98\pm0.18$  and  $26.30\pm1.27$  mg QE/g DW, respectively. Interestingly, the TFC of both teas decreased after 60 min brewing (Figure 3).



**Figure 1**. Jasmine (upper panel) and green tea (lower panel) were obtained from different brewing times, i.e., 0.5 min (A), 1 min (B), 2.5 min (C), 5 min (D), 10 min (E), 30 min (F), and 60 min (G)



Figure 2. The pH profile of jasmine and green tea was obtained from different brewing times. The different alphabet on each bar represented the statistically different value, tested at a p-value of <0.05



**Figure 3.** The profile of the TFC of jasmine and green tea is brewed at different times. The different alphabet on each bar represented the statistically different value, tested at a p-value of <0.05

There are three subclasses of flavonoids in tea, i.e., catechins, oligomeric flavonoids, and flavonols. The presence of catechins is dominant in green tea, while oligomeric flavonoids are vastly found in black tea (Dwyer and Peterson, 2013). Catechins and flavonols are soluble in hot water, but the solubility is decreased with the decreasing temperature (Cuevas-Valenzuela et al., 2014). After 30 minutes of brewing, the water temperature dropped, and the flavonoid extraction rate slowed down while the already extracted flavonoids became insoluble. Hence, the TFC of teas in 60 minutes of extraction was lower than those brewed for 30 minutes. The TFC of green tea is mainly affected by the drying method and the maturity of the leaves used. The TFC of green tea collected in Lahijan City (Iran) ranged from 14.3-38.18 mg QE/g DW, according to the different drying methods used (Roshanak et al., 2016). Similarly, Azores (Portugal)-originated green teas prepared from other parts of tea leaves and twigs exerted TFC of 23.84-72.02 Rutin equivalent (RE)/ g DW (Paiva et al., 2020). Our data suggested that the jasmine flower significantly contributed to the TFC of jasmine tea. Jasmine flowers contain flavonoids, among other phytochemicals (Kunhachan et al., 2012). The methanol extract of jasmine flower from Foshan (China) had a TFC of 4.70 mg RE/g DW, while that of Kuliyapitiya (Sri Lanka) was 6.6 mg RE/g DW (Chen et al., 2018; Janarny et al., 2021).

Jasmine and green tea exerted an equal content of phenolic compounds (p = 0.792), while brewing time affected their TPC (p = 0.000). The TPC of both teas showed a similar pattern to that of TFC. Brewing for 30 min likely generated tea with the optimum TPC, i.e.,  $84.05\pm7.93$  and  $88.66\pm4.81$  mg GAE/g DW for both jasmine and green tea, respectively (Figure 4).



**Figure 4.** The profile of TPC of jasmine and green tea was obtained from different brewing times. The different alphabet on each bar represented the statistically different value, tested at a p-value of <0.05

The phenolic compounds in green tea were flavanols, flavonols, and phenolic acids (Lorenzo and Munekata, 2016). The solubility of phenolic acids in water is better than those of catechins and flavonols, which are soluble in water at room temperature (Cuevas-Valenzuela et al., 2014; Furia et al., 2021). However, the phenolic acid content in tea is much lower than in catechins, so the TPC of tea brewed for 30 and 60 minutes was statistically equal (Lorenzo and Munekata, 2016). As in TFC, the TPC of green tea vary according to numerous factors. Chinese green tea of various origins showed a TPC of 148.16-252.65 mg GAE/g DW, while those extracted in different parameters were 152-243 mg GAE/g DW (Luo et al., 2020; Zhao et al., 2019). Also, Japanese matcha green tea showed a TPC of 1345.41±238.69 - 1577.01±43.22, depending on the extraction temperature used (Jakubczyk et al., 2020). On the other hand, the TPC of jasmine green tea was affected by the ratio of tea-to-water used, with values ranging from 1061.0±127 3021.6±52.2 mg GAE/1 (Koutelidakis et al., 2016). The TPC of jasmine flowers is also widely varied. For example, the flowers collected from Changhua County (Taiwan) showed a TPC of 20.65±0.82 - 182.36±9.23 mg GAE/g DW according to the solvents and extraction methods utilized (Wu et al., 2021). Also, one obtained from China showed a TPC of 9.37±0.38 mg GAE/g DW (Chen et al., 2018). However, the jasmine flower likely did not contribute to the TPC of the jasmine tea in this study. Further studies are needed to understand this phenomenon.

As in the TPC determination, the type of tea did not affect the DPPH scavenging activity (p = 0.088), while the brewing time defined the movement (p = 0.000). Brewing for 30 minutes

exerted tea with the best radical scavenging activity. DPPH scavenging activity of both teas gradually increased with the brewing time and remained static toward the end of extraction time. The highest scavenging potential was shown by both jasmine ( $4246.32\pm394.27$  mM TE/g DW) and green tea ( $5061.91\pm59.80$  mM TE/g DW) extracted for 30 min (Figure 5).

DPPH represents free radicals in the body that, upon release, can disrupt the cell membrane and cause damage to the organelles and the whole cells. The antioxidants can prevent the harmful effects of free radicals. An antioxidant compound donates an electron to the radical and stops the damaging reaction. DPPH assay also evaluates an antioxidant compound's ability to contribute Hydrogen atoms (Craft et al., 2012; Pisoschi et al., 2016; Santos-Sánchez et al., 2019). Green tea typically showed high DPPH scavenging activity. For example, according to the subjected extraction temperature, Japanese matcha green tea showed DPPH inhibition of 12.08±0.58 - $23.48 \pm 5.54\%$ (Jakubczyk et al., 2020). Also, the IC<sub>50</sub> value of a commercial United Kingdom green tea was 315.41±24.18 µg/ml (Sirichaiwetchakoon et al., 2020). Individually, green tea leaves exerted a much higher DPPH scavenging activity than jasmine flowers, with quenching values of 94.5±0.15 and 13.0±1.07%, respectively (Tsai et al., 2008). The relatively low DPPH scavenging activity of jasmine flowers did not likely contribute to the activity of jasmine tea. Hence, both tea types showed a similar DPPH scavenging activity in this study.

The type (p = 0.000) and brewing time (p = 0.000) affected the FRAP of the teas. Jasmine tea exerted a significantly higher reduction capacity than its green counterpart. The activity of both teas

increased with the brewing time. The most suitable brewing time for jasmine tea was 10 min, with a FRAP value of  $11470.24\pm447.17$  mM TE/g DW, with the prolonged brewing time did not affect the FRAP. On the other hand, the optimum brewing time for green tea with the highest FRAP was 30 min, with a value of  $9178.57\pm789.11$  mM TE/g DW. As in the jasmine tea, a prolonged brewing time of 60 minutes did not favourable affect on green tea's FRAP (Figure 6).

As in the DPPH scavenging assay, the FRAP of green tea varied according to numerous factors. The different brewing temperatures of Japanese matcha green tea exerted FRAP of 5863.03±156.51

- 6129.53±68.40 µM Fe(II)/l (Jakubczyk et al., 2020). Similarly, teas of different origins in China showed a varied FRAP, with the values ranged  $2824.80\pm107.63 - 4099.47\pm105.10 \,\mu\text{M Fe}^{2+}/\text{g DW},$ while those from Korea were 1555.06±20.57 -1697.81±6.37 mM TE/g DW (Lee et al., 2014; Zhao et al., 2019). On the other hand, the profile of FRAP of jasmine flowers is still limited. The only report available mentioned that it was pretty low considered insignificant and compared hesperidin (Widowati et al., 2018). Hence, further studies are needed to understand the contribution of jasmine flowers' addition to green tea toward jasmine green tea's FRAP.



**Figure 5.** The profile of the DPPH scavenging activity of jasmine and green tea was obtained from different brewing times. The different alphabet on each bar represented the statistically different value, tested at a p-value of <0.05



**Figure 6.** The profile of FRAP of jasmine and green tea was obtained from different brewing times. The different alphabet on each bar represented the statistically different value, tested at a p-value of <0.05

		<b>K-value</b>				
Antioxidant content	Jasr	nine tea	Green tea			
	DPPH SA	FRAP	DPPH SA	FRAP		
TFC	0.964	0.871	0.955	0.899		
TPC	0.908	0.939	1.000	0.988		
Note: $R = Pearson's$ correlation co	efficient, DPPH SA = D	PPH scavenging a	ctivity			

# Table 1. Correlation between bioactive content and the antioxidant activity in tea brewed for 39 min

<b>Table 2.</b> The preference scores of jasmine and green tea samples $(N = 33)$										
Tea type	Brewing	Flavour	Colour	Aroma liking	Aftertaste liking	<b>Overall liking</b>				
	time (min)	liking	liking							
Jasmine tea	5	1.88±1.29 <sup>b</sup>	2.82±1.04°	2.67±0.99 <sup>b</sup>	1.97±1.15°	2.30±1.13°				
	10	$1.64 \pm 1.27^{ab}$	$2.64 \pm 1.08^{bc}$	$2.70 \pm 1.07^{b}$	1.81±1.22°	1.88±0.99 <sup>bc</sup>				
	30	$1.88 \pm 1.24^{b}$	$2.52 \pm 1.18^{bc}$	2.73±1.23 <sup>b</sup>	$1.72 \pm 1.20^{bc}$	1.94±1.25 <sup>bc</sup>				
Green tea	5	$1.21{\pm}1.29^{ab}$	1.91±1.00 <sup>a</sup>	1.76±1.28ª	1.13±1.04 <sup>ab</sup>	$1.55{\pm}1.03^{ab}$				
	10	0.94±1.11ª	$2.09 \pm 1.00^{ab}$	1.76±1.20 <sup>a</sup>	1.50±1.22 <sup>abc</sup>	$1.39 \pm 1.14^{ab}$				
	30	1.00±1.35 <sup>a</sup>	2.06±1.29 <sup>ab</sup>	1.76±1.32 <sup>a</sup>	$1.03 \pm 1.06^{a}$	$1.76 \pm 3.78^{a}$				
	30	1.00±1.35ª	$2.06 \pm 1.29^{ab}$	$1./6\pm1.32^{a}$	1.03±1.06ª	$1./6\pm 3./8^{a}$				

Note: Different alphabets in each column represented a statistically different value of each sensorial attribute at p<0.050

The correlation evaluation between antioxidant content and the antioxidant activity was subjected to tea extracted for 30 minutes as they showed optimum value for most parameters. TFC was strongly correlated to both DPPH scavenging activity and FRAP. TPC showed the same trend in both antioxidant mechanisms (Table 1). Hence, flavonoids and phenolic compounds were likely responsible for DPPH scavenging activity and FRAP of both jasmine and green tea. Thus, the phenolic compounds were likely the main contributor to the green and jasmine tea's free radical scavenging and ferric-reducing capacities. The antioxidant action of phenolic compounds and flavonoids is mediated by the transfer of hydrogen atoms from the hydroxyl group, which has been well understood as one of the antioxidant mechanisms performed in the DPPH assay. In addition, the double bonds of phenolic compounds might supply a single electron for transferring during the redox reaction, which was the mechanism of antioxidant tested in the FRAP assay (Craft et al., 2012; Pisoschi et al., 2016; Santos-Sánchez et al., 2019). A strong correlation between TPC and FRAP was reported in Sri Lankan commercial green tea products, while that of TPC and DPPH scavenging capacity was said in Romanian commercial ones (Dobrinas et al., 2021; Molan et al., 2009). On the other hand, a strong positive correlation between TFC and DPPH scavenging activity and TFC and FRAP was

reported in Lahijan (Iran)-originated green tea and in Malaysian commercial green tea (Abdullah and Mazlan, 2020; Samadi and Fard, 2020).

A consumer preference test was performed to understand how the different types of tea and brewing time tea affected the consumers liking the tea samples. The type of tea significantly affected the panelists' liking toward flavor (p = 0.000), color (p = 0.000), aroma (p = 0.000), aftertaste (p =(0.000), and overall (p = (0.000)) of the tea. However, the brewing time did not define those attributes, with a p-value of 0.501, 0.905, 0.989, 0.390, and 0.124, respectively. Overall, the panelists' liked the jasmine tea better than the green one. Tea with the highest preference score for flavour, colour, aroma, aftertaste, and overall liking was jasmine tea brewed for 5 min (Table 2). Similarly, the answers to open-ended questions showed that jasmine tea brewed for 5 min was the favourite tea sample of 45.45% of panelists. A total of 46.67% of those who liked jasmine tea brewed for 5 min cited that the attribute they liked most was the refreshing aroma, while 40.00% wanted it for its lovely colour and subtle flavour.

Our result suggested that scenting jasmine flowers to green tea contributed strongly to consumer liking toward aroma. It might be attributable to the pleasant fragrance of jasmine flowers, mainly linalool and benzyl acetate (Chen et al., 2021). Correlating this preference evaluation to our TPC and TFC results, the panelists likely

liked teas with lower flavonoids and phenolic compounds over those with higher contents. Catechins, tea's main flavonoids, and phenolic compounds were previously associated with negative consumer preference due to their bitterness and astringency (Kim et al., 2016).

#### Conclusion

The influence of the brewing time of jasmine and green tea on their TFC, TPC, antioxidant activity, and consumer preference were investigated in this study. Overall, jasmine tea brewed for 30 minutes generated the highest TFC and TPC as well as the best DPPH scavenging activity and FRAP. However, the consumers like jasmine tea brewed for 5 min most for its refreshing aroma, nice colour, and subtle flavour.

#### Declarations

**Conflict of interests** The authors declare no competing interests.

**Open Access** This Article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License that allows others to use, share, adapt, distribute and reproduce the work in any medium or format with an acknowledgment to the original author(s) and the source. Publication and distribution of the work in the institutional repository or in a book are permessible as long as the author give an acknowledgment of its initial publication in this journal. To view a copy of this licence, visit https://creativecommons.org/licenses/bysa/4.0/

#### References

- Abdullah, S. S. S., and Mazlan, A. N. (2020) 'Quantification of polyphenols and antioxidant activity in several herbal and green tea products in Malaysia', *Materials Today: Proceedings*, 31 (1), pp. 106 – 113
- BPS Statistic Indonesia. (2020) Indonesian Tea Statistics 2020, BPS – Statistics Indonesia, Jakarta.
- Chen, G. L., Chen, S. G., Xiao, Y., and Fu, N. L. (2018) 'Antioxidant capacities and total phenolic contents of 30 flowers', *Industrial Crops and Products*, 111, pp. 430–445
- Chen, K., Zhang, M., Bhandari, B., and Mujumdar, A. S. (2021) 'Edible flower essential oils: A review of chemical compositions, bioactivities, safety and applications in food preservation', *Food Research International*, 139, pp. 1-13
- Craft, B. D., Kerrihard, A. L., Amarowicz, R., and Pegg, R. B. (2012) 'Phenol-based antioxidants and the in vitro methods used for their assessment', *Comprehensive Reviews in Food Science and Food Safety*, 11 (2), pp. 148–173

- Cuevas-Valenzuela, J., González-Rojas, Á., Wisniak, J., Apelblat, A., and Pérez-Correa, J. R. (2014)
  'Solubility of (+)-catechin in water and waterethanol mixtures within the temperature range 277.6–331.2 K: Fundamental data to design polyphenol extraction processes', *Fluid Phase Equilibria*, 382, pp. 279–285
- Dobrinas, S., Soceanu, A., Popescu, V., Popovici, I. C., and Jitariu, D. (2021) 'Relationship between total phenolic content, antioxidant capacity, Fe and Cu content from tea plant samples at different brewing times', *Processes*, 9, pp. 1-11
- Dwyer, J. T., and Peterson, J. (2013) 'Tea and flavonoids: Where we are, where to go next', *The American Journal of Clinical Nutrition*, 98 (6,) pp. 1611–1618
- Fu, X., Chen, J., Li, J., Dai, G., Tang, J., and Yang, Z. (2022) 'Mechanism underlying the carotenoid accumulation in shaded tea leaves', *Food Chemistry: X*, 14, pp. 1-10
- Furia, E., Beneduci, A., Malacaria, L., Fazio, A., Torre, C. La and Plastina, P. (2021), 'Modeling the solubility of phenolic acids in aqueous media at 37 °C', *Molecules*, 26, pp. 1-14
- Hu, J., Webster, D., Cao, J., and Shao, A. (2018) 'The safety of green tea and green tea extract consumption in adults - Results of a systematic review', *Regulatory Toxicology and Pharmacology*, 95, pp. 412–433
- Indonesian MoH. (2017) *Indonesian Herbal Pharmacopeia 2017*, 2nd ed., Ministry of Health Republic of Indonesia, Jakarta.
- Jakubczyk, K., Kochman, J., Kwiatkowska, A., Kałduńska, J., Dec, K., Kawczuga, D., and Janda, K. (2020) 'Antioxidant properties and nutritional composition of matcha green tea', *Foods*, 9 (4), pp. 1-10
- Janarny, G., Ranaweera, K. K. D. S., and Gunathilake, K. D. P. P. (2021) 'Antioxidant activities of hydromethanolic extracts of Sri Lankan edible flowers', *Biocatalysis and Agricultural Biotechnology*, 35, pp. 1-8
- Kim, Y., Lee, K. G., and Kim, M. K. (2016) 'Volatile and non-volatile compounds in green tea affected in harvesting time and their correlation to consumer preference', *Journal of Food Science* and Technology, 53 (10), pp. 3735–3743
- Koutelidakis, A. E., Andritsos, N. D., Kabolis, D., Kapsokefalou, M., Drosinos, E. H. and Komaitis, M. (2016) 'Antioxidant and antimicrobial properties of tea and aromatic plant extracts against bacterial foodborne pathogens: A comparative evaluation', *Current Topics in Nutraceutical Research*, 14 (2), pp. 133–142
- Kowalska, J., Marzec, A., Domian, E., Galus, S., Ciurzyńska, A., Brzezińska, R., and Kowalska, H. (2021) 'Influence of tea brewing parameters on the antioxidant potential of infusions and extracts depending on the degree of processing of the leaves of Camellia sinensis', *Molecules*, 26 (16), pp. 1-17

- Kunhachan, P., Banchonglikitkul, C., Kajsongkram, T., Khayungarnnawee, A., and Leelamanit, W. (2012)
  'Chemical composition, toxicity and vasodilatation effect of the flowers extract of *Jasminum sambac* (L.) Ait. 'G. Duke of Tuscany'', *Evidence-Based Complementary and Alternative Medicine*, 2012, pp. 1-7
- Lee, L. S., Kim, S. H., Kim, Y. B., and Kim, Y. C. (2014) 'Quantitative analysis of major constituents in green tea with different plucking periods and their antioxidant activity', *Molecules*, 19 (7), pp. 9173–9186
- Li, H., Luo, L., Ma, M., and Zeng, L. (2018) 'Characterization of volatile compounds and sensory analysis of jasmine scented black tea produced by different scenting processes', *Journal* of Food Science, 83 (11), pp. 2718–2732
- Lorenzo, J. M., and Munekata, P. E. S. (2016) 'Phenolic compounds of green tea: Health benefits and technological application in food', Asian Pacific Journal of Tropical Biomedicines, 6 (8), pp. 709– 719
- Luo, Q., Zhang, J. R., Li, H. Bin, Wu, D. T., Geng, F., Corke, H., Wei, X. L., and gan, R. Y. (2020) 'Green extraction of antioxidant polyphenols from green tea (*Camellia sinensis*)', *Antioxidants* (*Basel*), 9 (9), pp. 1-15
- Mancin, E., Beglinger, C., Drewe, J., Zanchi, D., Lang, U. E., and Borgwardt, S. (2017) 'Green tea effects on cognition, mood and human brain function: A systematic review', *Phytomedicine*, 34, pp. 26–37
- Molan, A. L., De, S., and Meagher, L. (2009) 'Antioxidant activity and polyphenol content of green tea flavan-3-ols and oligomeric proanthocyanidins', *International Journal of Food Sciences and Nutrition*, 60 (6), pp. 497–506
- Narbona, E., Del-Valle, J. C., Arista, M., Buide, M. L., and Ortiz, P. L. (2021) 'Major flower pigments originate different colour signals to pollinators', *Frontiers in Ecology and Evolution*, 9, pp. 1-14
- Ohishi, T., Goto, S., Monira, P., Isemura, M., and Nakamura, Y. (2016) 'Anti-inflammatory action of green tea', Anti-Inflammatory & Anti-Allergy Agents in Medicinal Chemistry, 15 (2), pp. 74–90
- Paiva, L., Lima, E., Motta, M., Marcone, M., and Baptista, J. (2020) 'Variability of antioxidant properties, catechins, caffeine, L-theanine and other amino acids in different plant parts of Azorean Camellia sinensis', *Current Research in Food Science*, 3, pp. 227–234
- Panpan, L., Xiaoyu, Z., and Yongquan, X. (2013) 'Study on organic acids contents in tea leaves and its extracting characteristics', *Journal of Tea Science*, 33 (5), pp. 405–410
- Pisoschi, A. M., Pop, A., Cimpeanu, C., and Predoi, G. (2016) 'Antioxidant capacity determination in plants and plant-derived products: A review', *Oxidative Medicine and Cellular Longevity*, 2016, pp. 1-36
- Prasanth, M. I., Sivamaruthi, B. S., Chaiyasut, C., and Tencomnao, T. (2019) 'A review of the role of

green tea (*Camellia sinensis*) in antiphotoaging, stress resistance, neuroprotection, and autophagy', *Nutrients*, 11 (2), pp 1-24

- Rofida, S., and Hartanti, D. (2021) 'Phytochemistry profile, efficacy, and safety of green tea (*Camellia* sinensis (L.) Kuntze) for breast cancer chemoprevention: A systematic review', Jurnal Tumbuhan Obat Indonesia, 14 (2), pp. 164–173
- Roshanak, S., Rahimmalek, M., and Goli, S. A. H. (2016) 'Evaluation of seven different drying treatments in respect to total flavonoid, phenolic, vitamin C content, chlorophyll, antioxidant activity and color of green tea (*Camellia sinensis* or *C. assamica*) leaves', *Journal of Food and Science Technology*, 53 (1), pp. 721–729
- Sakamoto, Y. (1971) 'Color of tea infusion', Japan Agricultural Research Quarterly, 6 (2), pp. 102– 105
- Samadi, S., and Fard, F. R. (2020) 'Phytochemical properties, antioxidant activity and mineral content (Fe, Zn and Cu) in Iranian produced black tea, green tea and roselle calyces', *Biocatalysis and Agricultural Biotechnology*, 23, pp. 1-6
- Santos-Sánchez, N. F., Salas-Coronado, R., Villanueva-Cañongo, C., and Hernández-Carlos, B. (2019)
  'Antioxidant compounds and their antioxidant mechanism' in Shalaby, E. (eds.) Antioxidant. London: IntechOpen, pp. 1–28.
- Schoeneck, M., and Iggman, D. (2021) 'The effects of foods on LDL cholesterol levels: A systematic review of the accumulated evidence from systematic reviews and meta-analyses of randomized controlled trials', *Nutrition, Metabolism & Cardiovascular Diseases*, 31 (5), pp. 1325–1338
- Sirichaiwetchakoon, K., Lowe, G.M. and Eumkeb, G. (2020), 'The free radical scavenging and antiisolated human ldl oxidation activities of Pluchea indica (L.) Less. tea compared to green tea (Camellia sinensis)', BioMed Research International, 2020, pp. 1-12
- Thaipong, K., Boonprakob, U., Crosby, K., Cisneros-Zevallos, L., and Byrne, D. H. (2006) 'Comparison of ABTS, DPPH, FRAP, and ORAC assays for estimating antioxidant activity from guava fruit extracts', *Journal of Food Composition and Analysis*, 19, pp. 669–675
- Tsai, T. H., Tsai, T. H., Chien, Y. C., Lee, C. W., and Tsai, P. J. (2008) 'In vitro antimicrobial activities against cariogenic Streptococci and their antioxidant capacities: A comparative study of green tea versus different herbs', *Food Chemistry*, 110 (4), pp. 859–864
- Widowati, W., Janeva, W., Nadya, S., Amalia, A., Arumwardana, S., Kusuma, H. S. W., and Arinta, Y. (2018) 'Antioxidant and antiaging activities of *Jasminum sambac* extract, and its compounds', *Journal of Reports in Pharmaceutical Sciences*, 7 (3), pp. 270–285
- Wu, L. C., Lin, C. L., Peng, C. C., Huang, T. L., Tsai, T.H., Kuan, Y. E., and Chung, Y. C. (2021)

'Development from *Jasminum sambac* flower extracts of products with floral fragrance and multiple physiological activities', *Evidence-Based Complementary and Alternative Medicine*, 2021, pp 1-12

- Zhang, H., Li, Y., Lv, Y., Jiang, Y., Pan, J., Duan, Y., Zhu, Y. (2017) 'Influence of brewing conditions on taste components in Fuding white tea infusions', *Journal of Science in Food and Agriculture*, 97 (9), pp. 2826–2833
- Zhao, C. N., Tang, G. Y., Cao, S. Y., Xu, X. Y., Gan, R. Y., Liu, Q., Mao, Q. Q. and Shang, A., and Li, H. (2019), 'Phenolic profiles and antioxidant activities of 30 tea infusions from green, black, oolong, white, yellow and dark teas', *Antioxidant*, 8, pp. 1-14