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Phenolic content and antioxidant capacity of *Lagerstroemia speciosa* (Banaba) and *Blumea balsamifera* (Sambong) herbal teas sold on-line in the Philippines: A cost-effectiveness analysis

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ABSTRACT

Herbal teas are widely consumed for their health benefits. In this study, the phenolic content and antioxidant capacity of six commercially available banaba (*Lagerstroemia speciosa*) and sambong (*Blumea balsamifera*) herbal teas were analyzed. The antioxidant activity was measured using DPPH and ABTS assays, with *L. speciosa* teas exhibiting higher activity than *B. balsamifera* teas. The phenolic content was determined using the Folin-Ciocalteu method and showed a direct correlation with antioxidant activity. The market prices based on unit phenolic content and antioxidant activity varied widely with different brands sold online indicating the need for better quality control of the teas analyzed.

Keywords: Herbal tea; Banaba; Sambong; Antioxidant activity; Phenolic; Cost analysis

Introduction

Herbal teas have been used for centuries for their potential health benefits, with their use traced back to ancient civilizations such as China and India. Herbal tea looks like regular tea and is brewed the same way, however, it is generally not considered as such because it does contain caffeine and is not from *Camellia sinensis*. Despite its popularity, interest remains in the use of herbal tea for health promotion and disease prevention. The scoping review by Poswal *et al.* (2019) discussed the range of potential health benefits from different types of herbal teas, such as green tea which is associated with reducing the risk of cardiovascular diseases and some cancers; as well as chamomile tea in alleviating anxiety and improving sleep quality. Moreover, herbal teas offer a multitude of health benefits that result from the intricate interplay of molecular pathways. For instance, green tea polyphenols, particularly the catechins, exhibit antioxidant properties by scavenging free radicals and reducing oxidative stress. These compounds have been demonstrated to influence cell proliferation and differentiation by modulating gene expression and various pathways in inflammation and apoptosis. The modulation by green tea components of some of cellular pathways, i.e., NF-B, JNK, p38 MAPK, Wnt/β-catenin, and PI3K/Akt, are known to play crucial roles in mediating these health benefits (Musial *et al.* 2020).

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Banaba (*L. speciosa*), as is called in the Filipino language, is a deciduous tree native to tropical countries, such as the Philippines, Vietnam, Malaysia, and China. Its leaves are more popularly regarded as a tonic for treating diabetes among the locals (Deocaris *et al.* 2005). Corosolic acid (2 α-hydroxyursolic acid) is the most well-known compound found in *L. speciosa* shown to have anti-diabetic properties (Sivakumar *et al*. 2009). Due to its insulin-like properties, various patents/utility models for food supplements containing *L. speciosa* have been filed (Giampapa, 2006; Gyu and Sun, 2017; Noboru *et al.* 1994). *L. speciosa* has also been reported to have anti-inflammatory and antioxidant effects, which can help prevent chronic diseases such as cancer, cardiovascular disease, and Alzheimer's disease (Klein *et al*. 2007; Tripathi *et al*. 2021). *L. speciosa* has also been found to have potential anti-obesity effects by decreasing lipid accumulation and adipocyte differentiation and by inhibiting adipogenesis and lipogenesis (Karsono *et al*. 2019). With these arrays of benefits and the added cost of extracting the natural products from *L. speciosa*, the wholesale price of corosolic acid is prohibitive costing more than $43 per milligram.

We studied another popular herbal tea, sambong (*B. balsamifera*), a perennial herb widely distributed in India, Pakistan, Burma, Indo-China Peninsula, Malaysia, Indonesia, and the Philippines. It is also known as ainaxiang (China), sembung (Malaysia), sambong (Philippines), and naat (Thailand). In Asian traditional medicine, *B. balsamifera* is used for the treatment of urinary tract infections, kidney stones, and hypertension (Pang *et al.* 2014). From the recent review by Wang *et al*. (2023), *B. balsamifera* has more than 150 volatile or non-volatile constituents, including monoterpenes, sesquiterpenes, diterpenes, flavonoids, organic acids, esters, alcohols, dihydroflavone and sterols. Its two main phytochemicals are L-borneol and oleum which are the main components of many Chinese medicines such as Yinlishuang pills, Yankang tablets, Jinhoujian Spray and Xinwei Zhitong. *B. balsamifera* extracts have various pharmacological activities including antioxidant, antibacterial, antitumor, hepatoprotective, anti-inflammatory, analgesic, and wound healing promotion.

In general, herbal teas can provide health benefits for the general population at a lower cost than regular food supplements. However, to our knowledge, there are no published reports that assess their cost-effectiveness based on antioxidant activities that can inform consumers of the potential health benefits. Thus, our present study assessed the phenolic and antioxidant activities of selected commercial brands of *B. balsamifera* and *L. speciosa* sold online in the Philippines. We found that polyphenols are the main antioxidant constituents of *L. speciosa* and *B. balsamifera* and their functional activities, i.e., the level of phenolics and antioxidant property, are not associated with the selling price.

Materials and methods

Reagents and materials

The chemicals used in this study were purchased from various sources. Folin-Ciocalteu phenol reagent, anhydrous sodium carbonate, 2,2-diphenyl-1-bicrylhydrazyl, 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt, potassium persulfate, and methanol were obtained from Sigma Aldrich (St. Louis, MO). The ethanol solvent, composed of 90% ethanol with 5% methanol and 5% isopropyl alcohol, was sourced from Fisher Chemical (Waltham, MA). Gallic acid was procured from Acros Organics (Geel, Belgium). Commercial herbal tea samples were purchased from online marketplaces in the Philippines. Market prices were noted (Table I).

Table I. Sources of commercial herbal leaf tea samples

Brand ID	Market Price (USD per 2g)
B1	0.106
B2	0.128
B3	0.085
S1	0.125
S2	0.456
S3	0.128

L. speciosa (B1-3) and B. balsamifera (S1-3) tea samples were purchased from online sellers in the Philippines. Market price was based on average price from online marketplaces in the Philippines. One tea bag is approximately two grams. The brand names are not shown.

Sample Extraction

The tea samples were prepared by dipping the tea bags into 200 ml of freshly boiled water for 5 minutes. The resulting tea infusion was then cooled and assayed for phenol content and antioxidant activity using DPPH and ABTS assays. The samples were blinded prior to analysis to ensure unbiased results.

Phenolic content

The phenolic content of the tea infusions was determined using the Folin-Ciocalteu assay (Charland *et al*. 2021). A 10% concentration of the Folin-Ciocalteu reagent and 1.0 M Na_2CO_3 were prepared. In a 96-well microplate, 20 ml of each tea infusion was mixed with 100 ml of the Folin-Ciocalteu reagent and incubated for 4 minutes. After incubation, 100 ml of 1 M Na_2CO_3 was added. The absorbance was measured at 645 nm after 2 hours of incubation in the dark. Distilled water was used as a negative control, while gallic acid served as both the positive control and the standard for generating a calibration curve to express the total phenolic content (TPC) in mg/ml gallic acid equivalents (GAE).

Antioxidant activities

The antioxidant activities of each tea infusion extract were determined using DPPH and ABTS assays (Vinci *et al*. 2022). Both assays were performed on a 96-well microplate using serial dilutions of the tea infusions mixed with the respective reagents. Each extract (0.1 g/ml) was diluted 10-fold three times to give concentrations ranging from 0.01 to 1 x 10-4 g/ml. Gallic acid (2.5-100.0 ug/ml) was used as a standard. For the DPPH assay, 10 ml of the extract or standard was mixed with 200 µl of 0.2 mM DPPH. After 30 minutes, the absorbance at 519 nm was measured. The antioxidant activity was calculated using the given formula below, and IC_{50} values were derived to express the antioxidant activity.

$$\%\ \text{Scavenging Activity} = \frac{\text{blank absorbance} - \text{sample absorbance}}{\text{blank absorbance}}\ x\ 100$$

The ABTS radical cation was prepared by mixing ABTS and potassium persulfate in a 1:1 ratio 18 hours before use. On a 96-well plate, 200 µl of the mixed ABTS radical reagent was added to different volumes of tea extracts (10, 5, 2 and 1 µl). Water was used as a negative control. The samples were incubated at room temperature for 10 minutes in the dark, and the absorbance was measured at 750 nm. The ABTS assay was performed in triplicate. The antioxidant activity was expressed as an IC_{50} (mg/ml), the half-maximal inhibition concentration. The IC_{50} value was generated by plotting the measured absorbance of the different volumes of tea extracts using their specific concentrations, based on the mass of tea materials divided by the initial volume. This plot generates a sigmoidal curve, from which the point of 50% effectiveness can be determined using the logarithmic equation. All absorbance readings were obtained using a Biotek Cytation 5 Image Reader. Both assays were replicated at least three times.

Statistical analysis

Experimental data (phenolic content and IC_{50} values from DPPH and ABTS assays) from the tea samples were analyzed using student's ANOVA with Tukey's Test ($p < 0.05$) to compare their differences.

Results and discussion

This study aims to determine the phenolic content and antioxidant capacity of the widely marketed herbal teas derived from *L. speciosa* and *B. balsamifera* in the Philippines and analyze their respective cost-effectiveness. As shown in Table II, our analyses indicate that *L. speciosa* tea samples (range: 60.61 - 530.16 mg gallic acid/g) generally displayed a higher phenolic content than *B. balsamifera* tea samples (range: 50.69 - 115.16 mg gallic acid/g). The values observed in *L. speciosa* leaves is within the range reported for ethanolic extract of *L. speciosa* petals (446 mg gallic/g) as reported

Table II. Phenolic content and antioxidant activities of the herbal leaf tea samples

Brand ID	Phenolic content (mg gallic acid/g)	Antioxidant Activities, IC_{50} (µg/mL)	
		DPPH	ABTS
B1	60.61 ± 16.05	19.95 ± 4.28	8.51 ± 3.37
B2	530.16 ± 48.58	0.42 ± 0.14	0.14 ± 0.04
B3	170.59 ± 21.24	89.11 ± 9.39	97.30 ± 5.82
S1	50.69 ± 19.29	5071.89 ± 356.29	192.49 ± 12.62
S2	115.16 ± 28.17	198.03 ± 39.63	75.01 ± 6.15
S3	69.77 ± 19.60	788.85 ± 110.03	387.50 ± 54.02

Means with the different superscript letters are significantly different using Tukeys' HSD test at p < 0.05.

by Tiwary *et al*. (2017) and higher than the 9.63 µg gallic acid/g reported by Junaid *et al*. (2012) for methanolic seed extracts. In addition to this, *L. speciosa* teas consistently showed lower IC_{50} values than *B. balsamifera* teas based on DPPH and ABTS assays. This is indicative of a strong antioxidant activity of *L. speciosa* tea which can be directly connected to a higher phenolic content. Phenolic compounds are secondary metabolites that are widely distributed in plant sources, including herbal teas. Our study is consistent with results from some studies of herbal teas that exhibit an association between phenolic content and antioxidant activity. For instance, reported, that the phenolic content of different kinds of herbal teas have a positive relationship with their antioxidant activity. Similarly, observed that the phenolic content of herbal teas is related to their ability to scavenge free radicals. According to Fazilatun *et al*. (2005), the antioxidant activity of *B. balsamifera* flavonoids is related to the number of hydroxyl groups, with flavonoids containing one free hydroxyl group having higher antioxidant activity than methylated ones. Hu *et al*. (2018) used a DPPH radical scavenging experiment to assess the high antioxidant activity of flavonoids in *B. balsamifera* leaves.

The capacity of phenolic and flavonoid compounds to transfer hydrogen ions or electrons to free radicals and mitigate oxidative damage has been attributed to their antioxidant activity. The chemical structure of these compounds influences their antioxidant activity and dictates the capacity to scavenge different kinds of free radicals (Prior and Cao, 2000). The degree of antioxidative activity of functional food and tea for human health is significant since chronic illnesses, such as cardiovascular disease, cancer, and neurological disorders, are linked with oxidative stress (Liguori *et al*. 2018). Thus, the anti-oxidative constituents in herbal teas can help in the prevention, if not, management of disease risk by countering oxidative stressors.

Finally, our study evaluated the unit cost of the herbal teas in relation to their food functionality. Based on our work, *L. speciosa* Brand 2 tea was found to be the most cost-effective source of phenolics and had highest levels of antioxidant, while *B. balsamifera* Brand 2 tea had the highest per unit cost relative to its phenolic and antioxidant activities (Figure 1). Our straightforward cost analysis emphasizes the need for a cost-benefit analysis to discover the best source of phenolics and antioxidants for therapeutic and health purposes. This is especially important in developing nations like the Philippines, where herbal medicines are extensively utilized as alternative therapies due to their ease of availability and low cost.

Our work sheds light on the phenolic composition and antioxidant capacity of some herbal teas sold online in the Philippines. As a disclaimer, the limited sample size of six commercially available herbal teas is a major drawback of this study. To give a more thorough investigation of the phenolic content and antioxidant activity of herbal teas, future research could broaden both the sample size and plant species. Another limitation is the lack of information on geographic sourcing, processing, and storage methods by the manufacturers, which may affect the chemical composition of the tea batches analyzed. In addition, our study merely

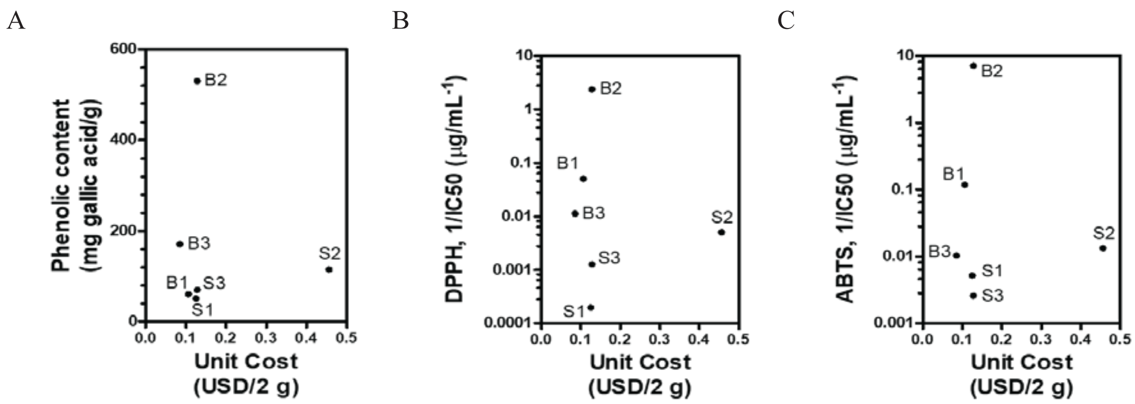

Fig. 1. Cost analysis of the different commercial herbal teas based on (A) phenolic content and antioxidant activities, (B) DPPH and (C) ABTS

compared the cost-effectiveness of the herbal teas based on their phenolic content and antioxidant activity. Despite the limitations, our work highlights the economic feasibility of herbal medicine as an alternative treatment option in resource-constrained settings and provides as guide to consumers in making informed decisions in choosing their beverage options.

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