

Determination of Flavonoids, Phenolic and Antioxidant Capacity from the Leaves, Stems and Roots of Betel Plants

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Abstract

Betel (*Piper betle* L.) is one of the medicinal plants widely used in traditional medicine for its therapeutic properties. This study aimed to determine the levels of total flavonoids, phenolics, and antioxidants in the leaves, stems, and roots of four betel species, namely, *Piper betle* L., *Piper ornatum* N.E. Br., *Peperomia pellucida* (L.) Kunth, and *Piper aduncum* L. The Total Flavonoid Content (TFC) was measured using the aluminum chloride (AlCl₃) colorimetric method, while Total Phenolic Content (TPC) was determined using the Folin–Ciocalteu method. The antioxidant capacity was assessed by the 2,2-diphenyl-1-picrylhydrazyl (DPPH). The results showed that the highest TFC was found in *Peperomia pellucida* (L.) Kunth leaves (79.27 ± 1.37 mg QE/g DW), whereas the highest TPC was observed in *Piper betle* L. stems (23.97 ± 0.04 mg GAE/g DW). The strongest antioxidant capacity was also observed in *Peperomia pellucida* (L.) Kunth leaves (23.93 ± 0.36 mg AAE/g DW). Correlation analysis revealed a very strong relationship between TFC and antioxidant capacity in leaves ($r = 0.9892$) and a strong correlation between TPC and antioxidant capacity in roots ($r = 0.9745$). These findings suggest that the antioxidant potential of betel species is closely related to their secondary metabolite composition, particularly flavonoids and phenolic compounds.

Keywords

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1. Introduction

Oxidative stress results in cellular damage to proteins, lipids, and DNA when the production of reactive oxygen species (ROS) exceeds the capacity of natural antioxidant defense systems. Persistent oxidative imbalance is associated with numerous chronic and degenerative conditions, including diabetes, cardiovascular disorders, neurodegeneration, and cancer^[1,2]. ROS formation is influenced not only by cellular metabolism but also by external factors such as pollution, cigarette smoke, ultraviolet radiation, and dietary habits^[3].

To prevent oxidative damage, the body requires antioxidant compounds capable of neutralizing free radicals through hydrogen donation, electron transfer, or metal-chelating mechanisms. In recent years, natural antioxidants derived from medicinal plants have received increasing scientific attention due to their safety profile, bioavailability, and multifunctional therapeutic benefits compared to artificial antioxidants like BHA and BHT, which have been linked to toxicological issues after prolonged exposure^[4-6]. Because of their ability to control redox pathways and stabilize free radicals, phenolic and flavonoid compounds are important

bioactive components found in natural sources that contribute to plants' antioxidant potential^[7-9].

The Piperaceae family, particularly betel species including *Piper betle*, *Piper ornatum*, *Peperomia pellucida*, and *Piper aduncum*, is widely utilized in traditional Southeast Asian medicine for wound healing, inflammation, metabolic disorders, gastrointestinal disturbances, and oral health. Phytochemical investigations demonstrate that Piperaceae contains diverse secondary metabolites, including flavonoids, phenolic acids, alkaloids, tannins, essential oils, and terpenoids, many of which exhibit potent antioxidant activity^[10-12]. However, phytochemical composition and antioxidant activity may vary substantially between species and across different plant organs due to environmental stressors, ecological adaptation, anatomical features, and tissue-specific biosynthetic pathways^[8,11,13].

Despite extensive research confirming the antioxidant activity of Piperaceae extracts, comparative quantitative profiling of total flavonoids, total phenolics, and antioxidant activity across multiple organs (leaves, stems, and roots) of different species remains limited. Most previous works focused only on leaf extracts, frac-

tionated solvents, or isolated compounds, leaving uncertainty regarding intra-plant metabolite variation and the relationship between these compounds and functional antioxidant response^[6,12,14]. Understanding such variation is essential to identify optimal plant organs for medicinal, nutraceutical, or industrial utilization and to support targeted extraction strategies.

Therefore, investigating the TFC, TPC, and antioxidant capacity in the leaves, stems, and roots of four Piperaceae species is the aim of this study. Furthermore, correlation analysis is performed to determine the contribution of metabolite content to antioxidant intensity. The findings are expected to provide foundational evidence to support selective Piperaceae utilization and contribute to optimized bioresource development for future phytopharmaceutical applications.

2. Materials and Methods

2.1. Materials

The leaves, stems, and roots of four betel species, *Piper betle* L., *Piper ornatum* N.E. Br., *Peperomia pellucida* (L.) Kunth, and *Piper aduncum* L., were employed as plant materials in this investigation.

The analytical reagents used were distilled water, gallic acid (Merck), sodium carbonate (Merck), Folin-Ciocalteu reagent (Sigma), quercetin (Sigma), sodium nitrite (Merck), aluminum chloride (Merck), sodium hydroxide (Merck), ascorbic acid (Merck), methanol (Merck), and DPPH (Sigma).

2.2. Instruments

The instruments used included UV-Vis spectrophotometer (Thermo Scientific Genesys 10S), analytical balance (KERN), desiccator, oven (Mettler), hot plate (Maspion), and thermometer.

2.3. Procedures

2.3.1. Sample Identification

Samples of *Piper betle* L., *Piper ornatum* N.E. Br., *Peperomia pellucida* (L.) Kunth, and *Piper aduncum* L. were collected from areas around Padang City in Indonesia. The leaves, stems, and roots were separated from each plant and identified at the Andalas University Herbarium Laboratory.

2.3.2. Sample Preparation

After being thoroughly washed with distilled water and let to air dry at room temperature, each sample was separated into leaves, stems, and roots. Prior to

examination, the dry materials were ground into tiny pieces and homogenized using a grinder.

2.3.3. Determination of Moisture Content

After being cleaned, a porcelain crucible was dried in an oven at 105 °C for an hour, cooled in a desiccator for fifteen minutes, and then weighed. Following that, around 2 g of the homogenized material was placed in the crucible and dried at 105 °C for three hours. The sample was weighed once again after chilling in a desiccator for fifteen minutes. The moisture content was determined in accordance with AOAC (2019) after this procedure was repeated until a steady weight was achieved.

2.3.4. Sample Extraction^[15]

The homogenized material (about 5 g) was extracted by boiling it for 15 minutes at 90 °C with frequent stirring in 30 mL of distilled water. The extract was filtered and diluted to a final volume of 30 mL in order to produce the aqueous extract. Each sample was removed three times.

2.3.5. Determination of TFC

2.3.5.1. Preparing the Quercetin Standard Calibration Curve

Ten milligrams of quercetin were dissolved in ten milliliters of methanol to create a quercetin stock solution (1,000 mg/L). Next, successive dilutions were used to create solutions with concentrations of 50, 100, 150, 200, and 250 mg/L. One milliliter of each standard solution was mixed with 0.3 milliliters of 5% NaNO₂. Five minutes later, 0.3 mL of 10% AlCl₃ was added, and the mixture was let to stand for six minutes. The mixture was then well mixed with 2.4 mL of distilled water and 2 mL of 1 M NaOH. A UV-Vis spectrophotometer was used to measure the absorbance at 450 nm. The same reagents were used to create a reagent blank without quercetin. An absorbance versus concentration calibration curve was created.

2.3.5.2. Determination of TFC in Samples

One milliliter of the plant extract was diluted to ten milliliters using distilled water. The standard's color creation process was adhered to. TFC was reported as milligrams of quercetin equivalents per gram of dry weight (mg QE/g DW) using absorbance measured at 450 nm. It was carried out three times.

2.3.6. Determination of TPC^[16]

2.3.6.1. Preparation of the Gallic Acid Standard Calibration Curve

A stock of 1,000 mg/L gallic acid was made and diluted to standards of 10–50 mg/L. Folin-Ciocalteu reagent was added to each 1 mL aliquot, left for five minutes, and then diluted with water and Na₂CO₃ to make 10 mL. In order to create a calibration curve, absorbance at 750 nm was measured after two hours, along with a blank.

2.3.6.2. Determination of TPC in samples

Distilled water was used to dilute one milliliter of extract to ten milliliters. The standard's color creation process was adhered to. TPC was expressed as gallic acid equivalents per gram of dry weight (mg GAE/g DW). Three distinct analyses were carried out.

2.3.7. Determination of Antioxidant Capacity

2.3.7.1. Preparing the Ascorbic Acid Calibration Curve

A stock of 1,000 mg/L of ascorbic acid was made and diluted to standards of 5–25 mg/L. After mixing each 1 mL aliquot with 2.5 mL of 0.1 mM DPPH, the mixture was left in the dark for half an hour. The calibration curve was plotted using the absorbance at 516 nm.

2.3.7.2. Determination Antioxidant Capacity in Samples

The same color development procedure used for the standard was followed. The antioxidant capacity was then expressed in milligrams of ascorbic acid equivalents per gram of dry weight (mg AAE/g DW). Each measurement was performed three times.

2.3.8. Data Analysis

Total contents of flavonoids, phenolics, and antioxidants were calculated using the regression equations obtained from their respective standard calibration curves. Pearson's correlation coefficient (*r*) was used to assess the relationships between the TFC and antioxidant contents as well as between the TPC and antioxidant levels. The data was examined using Duncan's multiple range test and two-way ANOVA to look for significant differences (*p* < 0.05).

3. Results and Discussion

3.1. Sample Identification

Sample identification was conducted at the Herbarium of Andalas University (ANDA), as stated in

Identification Letter No. 230/K.ID/ANDA/III/2023. The collected samples were identified based on morphological characteristics and taxonomic verification, as listed in Table 1.

Table 1. Identification results of betel plant samples

Family	Genus	Species
Piperaceae	<i>Piper</i>	<i>Piper betle</i> L.
Piperaceae	<i>Piper</i>	<i>Piper ornatum</i> N.E. Br.
Piperaceae	<i>Peperomia</i>	<i>Peperomia pellucida</i> (L.) Kunth
Piperaceae	<i>Piper</i>	<i>Piper aduncum</i> L.

All four species belong to the aromatic Piperaceae family. This family of plants has a variety of bioactive secondary metabolites in their leaves and stems, including flavonoids, phenolic compounds, and essential oils.. These morphological and chemical similarities explain why they have traditionally been used as medicinal plants.

3.2 Moisture Content

The proportion of water in a sample is known as its moisture content. It is a crucial factor in figuring out the concentration and stability of bioactive substances. The gravimetric approach was employed in this investigation to ascertain the moisture content. This technique uses heating to remove moisture. the sample at a constant temperature until a stable mass is obtained. Fresh samples were oven-dried at 105°C until all the water evaporated. Before being weighed, they were chilled in a desiccator using silica gel to stop ambient moisture from reabsorbing. According to AOAC (2019), the moisture percentage was determined using the weight loss both before and after drying. This procedure ensures accurate determination of moisture content, which is essential for subsequent quantification of total flavonoids, phenolics, and antioxidants on a dry-weight basis.

According to Figure 1, the stem of *Peperomia pellucida* (L.) Kunth had the maximum moisture content (96.59% ± 0.12%), while the leaf of *Piper aduncum* L. had the lowest moisture content (73.15% ± 0.07%). Previous studies have reported the following moisture content percentages: 77.25% for *Piper betle* L. leaves^[17]; and 95.45% for *P. pellucida* leaves. Variations in moisture content among the samples may be impacted throughout growth by environmental elements as temperature, humidity, and light exposure. Determining moisture content is

essential to obtaining the dry weight of each sample, which is the basis for calculating total flavonoid, phenolic, and antioxidant capacity.

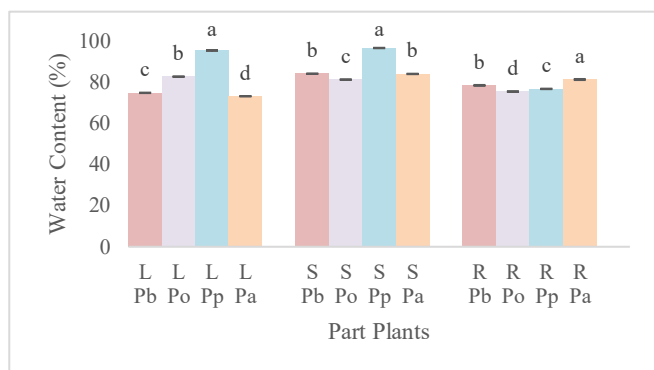


Figure 1. Moisture content (%) of different parts of Betel plant

Results are expressed as the mean $\pm$ standard deviation ($n = 3$). Different letters above each bar indicate significant differences among plant parts according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$. L = Leaf; S = Stem; R = Root; Pb = *Piper betle* L.; Po = *Piper ornatum* N.E.Br, Pp = *Peperomia pellucida* (L.) Kunth; Pa = *Piper aduncum* L.

3.3 Total Flavonoid Content (TFC)

TFC is expressed in milligrams of quercetin equivalent per gram of dry weight (mg QE/g DW). This value was determined using the aluminum chloride (AlCl_3) colorimetric technique. Because quercetin is a flavonol that easily forms a stable yellow complex with AlCl_3 through its hydroxyl groups at certain places on the aromatic rings, it was chosen as the reference standard. The TFC content in the extract is accurately measured by this process. A standard calibration curve for quercetin was used to calculate TFC. With an R^2 value of 0.9959, the regression equation that results is $y = 0.0018x + 0.0046$. Good linearity of the calibration curve is indicated by an R^2 value approaching 1.

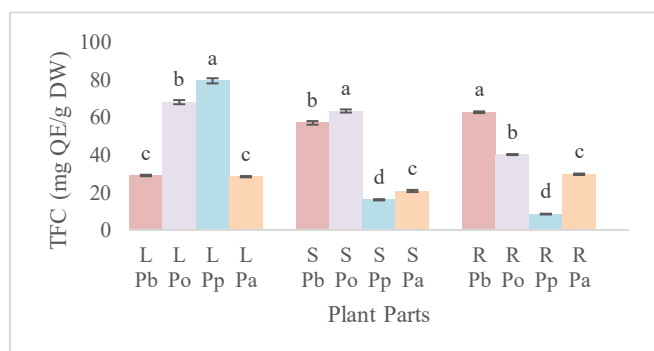


Figure 2. TFC of different parts of Betel plant

Figure 2 shows the TFC (TFC) of the samples. Among the four betel species analyzed, the leaves of *Peperomia pellucida* (L.) Kunth had the highest flavonoid concentration (79.27 ± 1.37 mg QE/g DW), while the roots of the same species had the lowest concentration (8.45 ± 0.20 mg QE/g DW). These findings are consistent with a prior work by Kunth that discovered 70.36 ± 0.01 mg QE/g of total flavonoids in the ethanol extract of *P. pellucida* leaves^[18]. Additionally, leaves of *Piper aduncum* L. and *P. ornatum* N.E. Br. extracted with ethanol showed higher TFCs than those extracted with hexane^[19]. This variation suggests that the yield of flavonoid compounds is strongly influenced by the kind of solvent employed during extraction. Because polar solvents like ethanol include hydroxyl groups in their structures that improve solubility and interaction with the solvent matrix, they often extract more flavonoids.

3.4 Total Phenolic Content (TPC)

Gallic acid was used as the reference standard for determining the TPC using the Folin–Ciocalteu colorimetric technique. Because it is a straightforward, stable phenolic molecule that belongs to the hydroxybenzoic acid group and produces reliable, repeatable absorbance readings, gallic acid was selected. When phenolics and the Folin–Ciocalteu reagent combine in an alkaline environment, a blue complex with a wavelength of 750 nm is formed. Using a gallic acid calibration curve, TPC was represented as mg GAE/g DW, resulting in the regression equation $y = 0.0161x + 0.0198$ ($R^2 = 0.9993$).

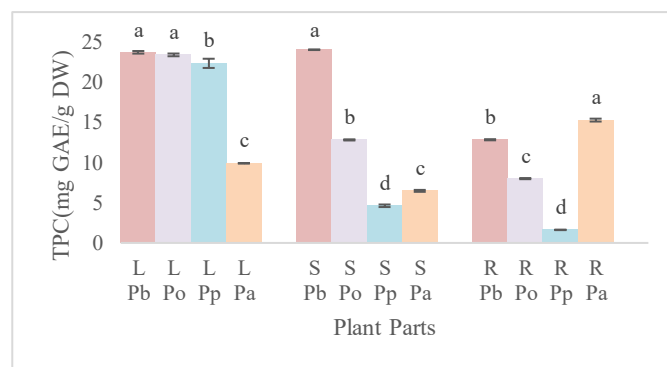


Figure 3. TPC of different parts of Betel plant

As shown in Figure 3, *Piper betle* L. stems had the highest TPC content, while *Peperomia pellucida* (L.) Kunth roots had the lowest, with values of 23.97 ± 0.04 and 1.62 ± 0.03 mg GAE/g DW, respectively. Previous studies have reported variations in the TPC of different Piperaceae species. Indirayati (2020) found that the ethanol extract of *P. aduncum* leaves contained $57.53 \pm$

0.14 mg GAE/g DW^[20]. The TPC of *P. pellucida* leaves extracted with ethanol was 37.18 ± 0.01 mg GAE/g. A comparative study across six regions in India found that the methanolic extract of *P. betle* leaves had the highest TPC in samples collected from the Desibagla region. Additionally, the TPC of ethanol-extracted *P. ornatum* leaves was 0.949 ± 0.003 mg GAE/g DW. These findings suggest that the TPC of plant samples is influenced by solvent polarity and environmental factors. Polar solvents, such as ethanol and methanol, generally extract phenolic compounds more effectively due to their ability to dissolve hydroxylated aromatic structures. Environmental parameters, including temperature, sunlight exposure, soil nutrients, and altitude, also play a crucial role in modulating phenolic compounds. Phenolic biosynthesis occurs within plant tissues. This analysis is based on the Folin–Ciocalteu colorimetric reaction. The Folin–Ciocalteu reagent is yellow and contains phosphomolybdic–phosphotungstic acid complexes. A blue molybdenum–tungsten complex is formed when the reagent is reduced under alkaline conditions (supplied by Na_2CO_3) in the presence of phenolic chemicals. The concentration of phenolic chemicals directly correlates with the blue color's intensity.

3.5 Antioxidant Capacity

The sample's antioxidant capacity was evaluated using a standard solution of ascorbic acid. The regression equation obtained from the standard calibration curve is $y = -0.0312x + 0.8606$, with an R^2 value of 0.9986. Figure 4 shows the antioxidant capacity of the samples. The data are expressed as the mean $\pm$ standard deviation from three measurements ($n = 3$). Duncan's multiple range test (DMRT) at $p < 0.05$ indicates significant differences across plant portions with different letters above the bars.

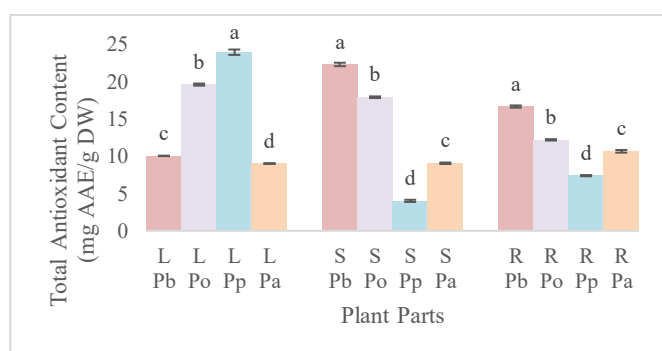


Figure 4. Antioxidant capacity of Betel plant samples

The antioxidant capacity as determined by the DPPH technique is displayed in Figure 4. At 23.93 ± 0.36 mg

AAE/g DW, the leaves of *Peperomia pellucida* (L.) Kunth showed the greatest antioxidant capacity. On the other hand, with a value of 4.01 ± 0.15 mg AAE/g DW, the stems of the same species showed the lowest capacity. Because DPPH radicals are photosensitive and break down in the presence of light, the DPPH assay was carried out in the dark. For the DPPH radicals and antioxidant chemicals to fully interact, the reaction mixture was incubated for thirty minutes. A UV-Vis spectrophotometer was then used to measure the absorption. The purple-colored DPPH radicals are reduced to their non-radical state when they interact with extracts that may donate hydrogen atoms. This causes the hue to shift from deep violet to yellow, signifying the scavenging of free radicals^[21]. When ascorbic acid and gallic acid were utilized as standards, the boiling extract of *Piper betle* L. leaves showed total antioxidant capacities of 0.443 mg AAE/g and 0.115 mg GAE/g, respectively, according to a research by Dasgupta and De (2004)^[22]. Additionally, at 63.56 ± 0.89 mg CE/g, the methanol extract of *Piper betle* L. leaves taken from the Banaras Sahasthradhara area showed the greatest antioxidant capacity^[23]. Likewise, *Piper aduncum* L. leaf methanolic extract showed an antioxidant capacity of 0.790 ± 0.50 $\mu\text{mol TEAC/g}$. These findings imply that the type of standard chemical utilized, solvent polarity, and geographic origin can all have a substantial effect on the observed antioxidant capacity. Variations in environmental conditions and extraction efficiency are closely associated with differences in antioxidant capacity among Piperaceae species.

3.5. Correlation of Flavonoids and Total Phenolics to Antioxidant Capacity

The correlation results suggest that the link between antioxidants, flavonoids (TFC), and phenolic content (TPC) differs by plant section (Table 2). While TPC shows a strong correlation ($r = 0.611$), TFC shows a very strong correlation ($r = 0.9892$) with antioxidant capacity in leaves. Thus, it seems that flavonoids are the main source of antioxidant capacity in leaves. This result is consistent with earlier research showing that plants use light exposure to boost flavonoid production as a defense against oxidative stress^[24,25]. TPC and TFC, on the other hand, demonstrated minimal correlations in stems ($r = 0.3890$ and $r = 0.0775$, respectively), suggesting that stems are not a significant source of antioxidant metabolites due to their low polyphenol content and predominance of structural components like cellulose and lignin^[26]. The pattern of relationships is

reversed in the roots: TPC shows a strong correlation with antioxidant capacity ($r = 0.9745$), while TFC shows a moderate correlation ($r = 0.5748$). This suggests that non-flavonoid phenolic compounds, including gallic, caffeic, and ferulic acids, contribute more significantly to antioxidant capacity in roots. The roots of many plants have been shown to contain large levels of polymerized tannins and phenolic acids, which are important components of the system that scavenges free radicals^[27, 28]. Overall, these patterns confirm that flavonoids play a greater role in leaves, non-flavonoid phenolics play a greater role in roots, and stems contribute minimally to total antioxidant capacity.

Table 2. Correlation of total phenolics and flavonoids to antioxidant capacity

Part of Plant	Correlation Between	
	TFC-Antioxidant	TPC-Antioxidant
Leaves	$r = 0,9892$	$r = 0,611$
Stem	$r = 0,0775$	$r = 0,3890$
Root	$r = 0,5748$	$r = 0,9745$

4. Conclusions

The study's findings indicate that the four Piperaceae species under investigation had distinct total flavonoid, phenolic, and antioxidant contents in their leaves, stems, and roots. *Piper betle* L. stems showed the greatest TPC (23.97 ± 0.04 mg GAE/g DW), whereas *Peperomia pellucida* (L.) Kunth leaves had the highest TFC (79.27 ± 1.37 mg QE/g DW). *Peperomia pellucida* (L.) Kunth leaves also had the highest total antioxidant capacity (DPPH method) (23.93 ± 0.36 mg AAE/g DW). Total phenolics and antioxidant capacity in roots had a moderate correlation ($r = 0.9745$), whereas total flavonoids and antioxidant capacity in leaves had a substantial correlation ($r = 0.9892$). These results suggest that flavonoids and phenolic compounds primarily contribute to the antioxidant capacity of Betel plants (Piperaceae).

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Validation: Y.Y., R.R.

Visualization: W.D.H.

Writing – original draft: W.D.H.

Writing – review & editing: Y.Y.

Conflict of interest

The authors declare no conflict of interest.

References

- [1] Zhang H, Tsao R. Dietary polyphenols, oxidative stress and antioxidant and anti-inflammatory effects. *Curr Opin Food Sci.* 2020;33:87–93.
- [2] Liguori I, Russo G, Curcio F, Bulli G, Aran L, Della-Morte D, et al. Oxidative stress, aging, and diseases. *Clin Interv Aging.* 2018;13:757–72.
- [3] Birben E, Sahiner UM, Sackesen C, Erzurum S, Kalayci O. Oxidative stress and antioxidant defense. *World Allergy Organ J.* 2012;5(1):9–19.
- [4] Mustafa RA, Hamid AA, Mohamed S, Bakar FA. Total phenolics, flavonoids and antioxidant capacity of selected tropical medicinal plants. *Food Chem.* 2021;348:129129.
- [5] Shahidi F, Ambigaipalan P. Phenolics and polyphenolics in foods, nutraceuticals and health. *J Funct Foods.* 2015;18:820–97.
- [6] Ramos-Escudero F, Marrufo-Curtido A, Requena-Fuentes M, et al. Toxicological concerns on chronic intake of synthetic antioxidants. *J Food Sci Technol.* 2022;59(1):45–54.
- [7] Vuolo MM, Lima VS, Maróstica MR. Phenolic composition and antioxidant correlations in tropical plants. *Plant Foods Hum Nutr.* 2019;74:421–7.
- [8] Phuyal N, Jha PK, Raturi PP, Rajbhandary S. Phenolic content and antioxidant activity of medicinal plants. *Sci World J.* 2020;2020:1–7.
- [9] Dai J, Mumper RJ. Plant phenolics: extraction, analysis and their antioxidant and anticancer properties. *Molecules.* 2010;15(10):7313–52.
- [10] Herrera-Calderón O, et al. Antioxidant potential of *Piper aduncum*. *Toxics.* 2019;7(2):38.
- [11] Ibrahim M, Abd-Rashid A. Systematic analysis of phenolic-driven antioxidant activity in medicinal plant roots. *J Ethnopharmacol.* 2021;271:113890.
- [12] Men TT, et al. Antioxidant and antidiabetic properties of *Peperomia pellucida*. *Vet Integr Sci.* 2022;20(3):683–93.

- [13] Arif T, Bhosale JD, Kumar N, et al. Natural antioxidants from Piperaceae. *J Nat Prod Res.* 2022;36(8):2089–97.
- [14] Setzer WN. Antioxidant activity variation in Piper species. *Plants.* 2021;10(9):1756.
- [15] Ervina M, Nawu YE, Esar SY. Comparison of antioxidant capacity of decoction, extract and fractions of *Cinnamomum burmannii* bark. *Int Food Res J.* 2016;23(3):1346–50.
- [16] Musdalipah M, Tee SA, Karmilah, Sahidin, Fristiohady A, Yodha AWM. TPC and flavonoid content of *Meistera chinensis* (Lour.) Skornick. & A.D. Poulsen roots. *Borneo J Pharm.* 2021;4(3):232–240.
- [17] Prastyowati A, Purwijantiningsih L, Pranata F. Kualitas kimia dan mikrobiologi permen keras daun sirih hijau (Piper betle L.). *J Sains Vet.* 2014;32(2):191–8.
- [18] Kunth PL. Evaluation of antimicrobial activity and antioxidant capacity of *Peperomia pellucida* L. Kunth. *Myanmar Korea Conf Res J.* 2020;3(3):1614–21.
- [19] Insanu M, Marliani L, Dinilah NP. Comparison of antioxidant activities from four Piper species. *Pharmaciana.* 2017;7(2):305.
- [20] Indirayati N, Nisa K, Kurang RY, Tarmo NC, Adang KTP. Radical scavenging activity and TPCof seven tropical plants. *IOP Conf Ser Earth Environ Sci.* 2020;462(1).
- [21] Ismail NH, Amira NH, Latip SNHM, Zain WZWM, Aani SNA, Aziman NA. Phytochemical screening and antioxidant capacity of *Melastoma malabathricum* and *Chromolaena odorata*. *Food Res.* 2021;5:30–7.
- [22] Su Lay Yee TTM. Preliminary phytochemical screening, antibacterial and antioxidant activities of Piper betle L. *J Myanmar Acad Arts Sci.* 2020;XVIII(1B):262–7.
- [23] Jaiswal SG, Patel M, Saxena DK, Naik SN. Antioxidant properties of Piper betel leaf extracts from different regions of India. *J Bioresour Eng Technol.* 2014;2(2):12–20.
- [24] Mustafa RA, Hamid AA, Mohamed S, Bakar FA. TPC compounds, flavonoids, and radical scavenging activity of 21 selected tropical plants. *Food Chem.* 2021;348:129–148.
- [25] Noreen H, Semmar N, Farman M, McCullagh JS. Measurement of TPCand antioxidant capacity of Iranian propolis. *Food Sci Nutr.* 2017;5(4):1039–1045.
- [26] Vuolo MM, Lima VS, Maróstica MR. Phenolic composition and antioxidant correlations in tropical plant parts. *Plant Foods Hum Nutr.* 2019;74(4):421–427.
- [27] Zhang H, Tsao R. Dietary polyphenols, oxidative stress and antioxidant and anti-inflammatory effects. *Curr Opin Food Sci.* 2020;33:87–93.
- [28] Ibrahim M, Abd-Rashid A. Correlation between phenolic content and antioxidant capacity in medicinal plant roots: a systematic review. *J Ethnopharmacol.* 2021;271:113–890.