MALAYSIAN JOURNAL OF ANALYTICAL SCIENCES

Journal homepage: https://mjas.analis.com.my/

Research Article

Phytochemical analysis and non-enzymatic antioxidant activity of *Clerodendrum serratum* Linn. leaves and stems

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Received: 16 March 2025; Revised: 9 June 2025; Accepted: 18 June 2025; Published: 22 August 2025

Abstract
Clerodendrum serratum Linn. is a shrub from the Verbenaceae family with various traditional medicinal uses. This study aims to investigate the phytochemical composition and non-enzymatic antioxidant activity of *C. serratum* leaves and stems. Methanolic crude extracts were prepared and qualitatively screened, revealing the presence of tannins, phenolics, terpenoids, steroids and flavonoids in both plant parts, while alkaloids were detected only in the leaves. Quantitative analysis showed that the total phenolic content (TPC) in leaves and stems was 4.61 ± 0.93 and 2.52 ± 0.75 mg/g.fwt, respectively, with no significant difference between them. Nevertheless, the total flavonoid content (TFC) was higher in leaves (38.77 ± 0.88 mg/g.fwt) than in stems (33.28 ± 2.49 mg/g.fwt). Additionally, non-enzymatic antioxidants such as ascorbic acid (4.80 ± 0.04 mg/g.fwt), α-tocopherol (31.06 ± 6.88 µg/g.fwt), carotenoids (0.64 ± 0.10 mg/g.fwt) and chlorophyll (6.52 ± 0.49 mg/g.fwt) were more abundant in the leaves. The findings suggested that *C. serratum* possesses a rich phytochemical profile and antioxidant properties, supporting its potential application in managing oxidative stress and related diseases.

Keywords: *Clerodendrum serratum L.,* phytochemical, antioxidant activity, phenolics, flavonoids

Introduction

Clerodendrum serratum (Linn.) Moon (**Figure 1**), a shrub from the Verbenaceae family (which is now included in the Lamiaceae family), is widely distributed across India, Sri Lanka, Malaysia, and the Peninsular region. This plant is commonly known by various names, such as glory bower, bag flower and bleeding heart [1]. The leaves and roots of *C. serratum* are highly valued for their medicinal properties. The roots, known for their pungent, bitter, and acrid taste, are used in the treatment of various ailments, including asthma, body aches, bronchitis, cholera, dropsy, eye diseases, inflammation, ophthalmia, rheumatism, malaria, fever, snakebites, tuberculosis, ulcers and wounds [2]. They are recognized for their carminative, depurative, expectorant, anti-spasmodic, stimulant, appetite-enhancing and anthelmintic properties [3]. The root decoction is particularly effective in treating oedema, especially that caused by kaoha and is also used to treat worm infestations. A paste made from the roots is applied to the forehead to relieve headaches. The leaves, when applied externally, help alleviate headaches, eye infections and promote appetite. They also serve as an expectorant. The seeds, when boiled in buttermilk, act as a mild laxative and are used to treat dropsy. Additionally, the young shoots and flowers of the plant are consumed as vegetables. *Clerodendrum serratum* is one of the few plants known to have an antagonistic effect on histamine [4].

In the Konkan region, the leaves are commonly consumed as a vegetable and used to treat malaria fever and hiccups. Externally, the leaves are applied to relieve headaches and eye inflammation, while the pulp reduces glandular swelling and speeds up wound healing. Moreover, the juice from the leaves is used to treat erysipelas lesions [5].

Recent studies have highlighted the plant's potential as a source of bioactive compounds, particularly phytochemicals, which contribute to its medicinal efficacy. Phytochemicals, including alkaloids, flavonoids, phenols, and terpenoids, are secondary metabolites that play a crucial role in the plant's defence mechanisms and exhibit a wide range of biological activities beneficial to human health [6].

Several flavonoid compounds have been previously reported in the *Clerodendrum* genus, including apigenin, 7-hydroxyflavanone, scutellarein, and pectolinarigenin. Other isolated flavonoids, such as cleroflavone and hispidulin, exhibit potent antimicrobial, antioxidant, antitumor, and anti-asthmatic properties [7,8]. An isolated compound from its leaf extract, namely 7,12-dimethylbenzanthracene, has been reported to possess anticarcinogenic activity in the liver and kidneys of mice [9, 10]. Furthermore, four anthraquinones, including aloe-emodin, emodin, chrysophanol and 2,5-dimethoxybenzoquinone, have been identified in the stems of *C. serratum* [1]. Studies on the stems of this plant remain limited. Nevertheless, several compounds have been isolated from the whole plant, including stigmasterol, bis(2-ethylhexyl) phthalate, 5,7,40-trihydroxy-30-methoxyflavone, scutellarein, luteolin and serratin [11,12,13]. Additionally, cis-cinnamic acid, trans-cinnamic acid and p-coumaric acid have been isolated from the aerial parts of *C. serratum* [14].

Major secondary metabolites such as phenolic and flavonoid compounds are commonly found in plants and are known for their antioxidant and other biological activities. These compounds scavenge free radicals, thereby reducing oxidative stress and lowering the risk of chronic diseases such as cancer, cardiovascular and neurodegenerative disorders [15]. Total phenolic contents (TPC), particularly plant polyphenols, have been shown to enhance the oxidant-antioxidant balance, strengthen the body's natural antioxidant defences and reduce oxidative damage. Notably, phenolic compounds isolated from *C. serratum* have demonstrated promising potential in managing type 2 diabetes [16]. Total flavonoid content (TFC) in foods and plant extracts is linked to various health benefits. Flavonoids possess anti-inflammatory, antioxidant, antibacterial and anticancer properties, making them valuable in managing conditions like arthritis, asthma and inflammatory bowel disease [17, 18]. Compounds such as hesperidin and hesperetin that are present in citrus fruits and green plants including *C. serratum*, contribute to these therapeutic effects.

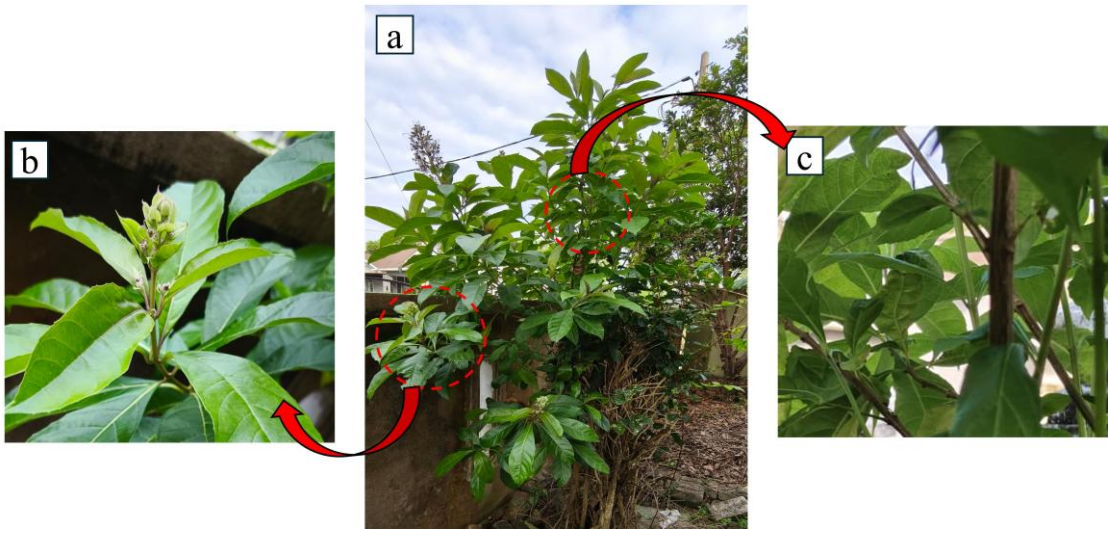

Figure 1. (a) *Clerodendrum serratum* plants; (b) leaves; and (c) stems

In addition to bioactive compounds such as flavonoids and phenolics, non-enzymatic antioxidants found in plants play a crucial role in maintaining cellular health. These compounds help mitigate oxidative stress by neutralizing reactive oxygen species (ROS), which are unstable molecules generated during normal metabolic processes and under environmental stress [19]. Excessive ROS production, if not counteracted by antioxidants, can lead to cellular and molecular damage, including harm to DNA, proteins and lipids, thereby contributing to the progression of various chronic diseases, making *C. serratum* a promising candidate for further pharmacological and nutraceutical exploration. Ascorbic acid, α-tocopherol, carotenoids and chlorophyll are key non-enzymatic antioxidants that complement enzymatic systems in neutralizing reactive oxygen species (ROS). Ascorbic acid helps prevent oxidative stress and cellular damage [20], while α-tocopherol, a fat-soluble antioxidant, protects against lipid peroxidation and also influences gene regulation and protein function [21]. Beyond its antioxidant role, α-tocopherol is involved in regulating cellular processes such as cell proliferation, inflammation, and detoxification [16].

A group of naturally occurring pigments called carotenoids may be found in plants, algae and photosynthetic microorganisms. They are responsible for the red, orange and yellow colours of fruits and vegetables. Additionally, carotenoids take part in photosynthesis, in which they assist in absorbing light energy and transferring it to chlorophyll molecules, enabling plants to transform carbon dioxide and water into sugars and oxygen [22]. Carotenoids also serve as photo protectants, antioxidants, colour attractants and precursors of plant hormones in non-photosynthetic plant organs. In green plants such as *C. serratum*, the carotenoid concentration is very high in leaves. Chlorophyll, a green pigment, may be found in the chloroplasts of plant cells. The conversion of light energy into chemical energy in the form of glucose and oxygen by plants, known as photosynthesis, is based on it. As a natural detoxifier, chlorophyll is frequently marketed as a pharmaceutical or skincare product [23].

This study seeks to investigate the phytochemical composition and non-enzymatic antioxidant activity of *C. serratum* leaves and stems. The primary bioactive compounds were identified using both qualitative and quantitative analyses, and their potential as natural antioxidants was thoroughly assessed. By gaining insight into the chemical constituents and antioxidant properties of this plant, the research aims to highlight its therapeutic potential and contribute to the development of new plant-based remedies.

Materials and Methods

Chemicals and reagents

The chemicals and reagents used in this study were ethanol, ferric chloride ($FeCl_3$), concentrated sulphuric acid, sodium hydroxide (NaOH), quercetin, gallic acid, Folin-Ciocalteu reagent, potassium hydroxide, sodium carbonate, sodium nitrite, aluminium chloride, dimethyl sulfoxide (DMSO), ethyl acetate, chloroform, methanol, hexane, acetone and dichloromethane (DCM).

Plant materials

Fresh leaves and stems of *Clerodendrum serratum* Linn. were collected in April 2021 from Gong Badak, Kuala Nerus, Terengganu, Malaysia. The plant was preserved on an herbarium sheet and assigned the voucher number AACHM5380. The species was identified by Mr. Muhamad Razali Salam from Universiti Malaysia Terengganu (UMT). The plant materials were rinsed with tap water, shade-dried, cut into small pieces, and ground into a fine powder.

Extraction (crude extract)

Approximately 24.0 g of powdered leaf and stem samples were soaked in 100 mL of methanol at room temperature for 72 h. The extracts were then filtered using Whatman No. 1 filter paper and concentrated under reduced pressure, yielding 12.6 g and 4.5 g of crude extracts from leaves and stems, respectively. Both crude extracts were then stored at -20°C until further analysis.

Phytochemical qualitative screening

Phytochemical analysis was carried out for the identification of alkaloids, flavonoids, phenolics, tannins, saponins, terpenoids and steroids according to the standard methods [24, 25].

Alkaloids: One mL of each extract was taken in a test tube. Then, 0.2 mL of dilute HCl was added, followed by 1 mL of Meyer's reagent. A yellowish colouration indicates the presence of alkaloid [24].

Flavonoids: Five drops of concentrated hydrochloric acid (HCl) were added to a small amount of each crude extract. A red formation colour indicates the presence of flavonoids [24].

Phenolics: A small amount of the ethanolic extract was taken with 1 mL of water in a test tube, and 1 to 2 drops of iron III chloride ($FeCl_3$) were added. Blue, green, red or purple color indicates the presence of phenols. [24].

Tannins: Five mL of each extract was placed in a test tube. Then, 2 mL of 5 % of $FeCl_3$ solution was added. A greenish-black precipitate indicates the presence of tannins [24].

Saponins: One mL of each extract was diluted with distilled water to 20 mL and shaken in a graduated cylinder for 15 minutes. The formation of a 1 cm layer of foam indicates the presence of saponins [24].

Terpenoid: Each of the methanolic crude extracts (0.2 g) was mixed with 2 mL of chloroform. 3 mL of concentrated H_2SO_4 was carefully added to form a layer. A reddish-brown interface was formed, which indicated the presence of terpenoid [25].

Steroids: Acetic anhydride (2 mL) was added to 0.5 g of the both extracts in a test tube. Then, 2 mL of sulphuric acid was added. A colour change from violet to blue or green indicates the presence of steroids [25].

Phytochemical quantitative analysis

Determination of total phenolic content

The total phenolic content (TPC) was analysed using the Folin-Ciocalteu reagent [26]. A total of 0.15 mg of extract was combined with 0.5 mL of Folin reagent and allowed to react for five minutes at room temperature. Then, 2 mL of a 7.5% sodium carbonate (Na_2CO_3) solution was added. The mixture was incubated for 30 minutes in the dark to allow for colour development. After incubation, the absorbance was measured at 765 nm using a spectrophotometer. To calculate the TPC, a standard curve was constructed using gallic acid by plotting concentration against absorbance. The total phenolic content was determined using the equation derived from the standard curve, taking into account the sample absorbance and any dilution factors. Results were expressed as milligrams of gallic acid equivalent (GAE) per gram of the sample.

Determination of total flavonoid content

A colorimetric test was used to calculate the total flavonoid concentrations [27]. About 0.3 mL of 5% sodium nitrite and 0.3 mL of 10% aluminium chloride ($AlCl_3$) solution were added to the crude solution, and the mixture was thoroughly combined. The mixture was incubated at room temperature for about 30 minutes. A yellow complex was formed between the flavonoids and aluminium chloride. After incubation, the absorbance of the mixture was measured at 415 nm using a spectrophotometer. A standard curve was created by plotting varying concentrations of quercetin against its absorbance, and the total flavonoid content (TFC) in the sample was calculated using the equation derived from this curve. The results were expressed as milligrams of quercetin equivalent (QE) per gram of the sample.

Determination of α-tocopherol

The tocopherol assay was completed following the method of Jargar et al. [28]. About 0.1 mg of sample was extracted with 1.5 mL of acetone. The mixture was centrifuged (KUBOTA 2420) for 10 min at 10,000 rpm. The obtained supernatant was added with 0.5 mL of hexane and vortexed for 30 s. The top layer was eliminated following centrifugation, and the hexane extraction was repeated twice. The supernatant was added to 0.4 mL of 0.1% (w/v) 3-(2-pyridyl)-5,6-diphenyl-1,2,4-triazine prepared in ethanol), and 0.4 mL of 0.1% (w/v) ferric chloride. The volume was made up to 3.0 mL with absolute ethanol. The mixture was allowed to stand for 4 min for colour development. Then, 0.2 mL of 0.2 M orthophosphoric acid was added, and the mixture was left at room temperature for 30 min. The absorbance was measured at 554 nm. The standard curve was prepared using various concentrations of α-tocopherol (Sigma, type V) at 0-100 µg/mL.

Determination of ascorbic acid

The ascorbic acid concentration was calculated according to Abera et al. [29]. About 0.5 mL of the extract was added to 1.0 mL of 10% trichloroacetic acid (TCA), and the mixture was then centrifuged (Eppendorf 5810R) at 10,000 rpm for 10 min at 4°C. 200 µL of 10% Folin reagent and 300 µL of the supernatant were mixed with 1700 µL of distilled water. After 10 minutes, the absorbance was measured at 760 nm. Ascorbic acid in various concentrations (0-00 µg/mL), was used to create a standard curve.

Determination of Carotenoids

The carotenoid content was measured following the method of Gupta et al. [18]. The sample was extracted using 3 mL of 80% (v/v) acetone and was centrifuged (KUBOTA 2420) for 10 minutes at 10,000 rpm. The absorbance of the supernatant was measured at 663.2, 646.8 and 470 nm. Eighty percent of acetone was used as a blank. The following formula was used to determine the carotenoid content:

$$\text{Ca (chlorophyll a, mg/L)} = 12.25A_{663.2} - 2.79A_{646.8} \quad (1)$$

$$\text{Cb (chlorophyll b, mg/L)} = 21.50A_{646.8} - 5.10A_{663.2} \quad (2)$$

$$\text{Cx+c (total carotenoids, mg/L)} = \frac{(1000A_{470} - 1.82C_a - 85.02C_b)}{198} \quad (3)$$

Determination of Chlorophyll

The samples were extracted with 0.5 mL of 80% acetone [30]. The mixture was centrifuged for 10 minutes at 10,000 rpm. Then, the absorbance of the supernatant was measured at 645 and 663 nm. Eighty percent of acetone was used as a blank. The total chlorophyll was calculated using the following equation:

$$\text{Total chlorophyll (mg/g.fwt)} = \frac{[(20.2 \times A_{645}) + (8.02 \times A_{663}) \times V \text{ (volume of the extract, mL)}}{W \text{ (fresh weight of the plant sample, g)}} \quad (4)$$

Statistical analysis

The experiment was conducted in five replicates (n=5), and the data were presented as mean ± standard deviation. The significant differences were determined using a one-way analysis of variance (ANOVA) and tested by Duncan's Multiple Range Test (DMRT) to compare the differences between treatments. An independent T-test was conducted to compare the mean values between leaves and stems. The significance value was set at $p < 0.05$.

Results and Discussion

Phytochemical qualitative screening

The results of the preliminary phytochemical analysis for leaves and stems are presented in **Table 1**. The screening revealed the presence of tannins, phenolics, terpenoids, steroids, and flavonoids in both the methanolic crude extracts of leaves and stems. These findings are in agreement with a recent study by Patel and Bhoya, which reported that the leaves extracts contained tannins, alkaloids, flavonoids, terpenoids and steroids, further highlighting the diverse phytochemical profile of this plant [31]. The earlier work by Singh et al. (2019) revealed the presence of carbohydrates, steroids, saponins, alkaloids, tannins, phenolic compounds and flavonoids in ethanolic crude extract and the presence of alkaloids, deoxysugars, and phytosterols in chloroform crude fraction [32]. A similar observation was also reported by Suple and Hutke, where the leaves of *C. serratum* contains alkaloids, phenolic compounds, tannins, saponins, glycosides, flavonoids, steroids and terpenoids [33].

Phytochemical quantitative analysis

Total phenolic content

Phenolic compounds are the most abundant secondary metabolites in plants, showing a wide range of distinct biological activities and playing important roles as natural antioxidants, antimicrobials, anticarcinogenic and anti-inflammatory activities, thus becoming a hot spot in terms of research and utilization at present. In this current study, the leaves showed a higher mean TPC (4.61 ± 0.93 mg/g fwt) than the stems (2.52 ± 0.75 mg/g fwt), likely due to their direct exposure to light, environmental stress and higher metabolic activity. Since leaves are key sites for photosynthesis and face more oxidative challenges, they tend to accumulate more phenolic compounds as part of their defense mechanisms [34].

In contrast, stems function primarily in structural support and transport and generally require fewer phenolics. Although this trend aligns with findings in species like *Cinnamomum osmophloeum*, where leaves consistently showed higher phenolic content than stems [35], the difference in *C. serratum* was not statistically significant ($p > 0.05$). This outcome could be attributed to sample variation or small sample size. Interestingly, other studies, such as in *Vitis vinifera*, have also reported notable phenolic content in stems, suggesting that phenolic distribution can vary depending on species and environmental factors [36].

Total flavonoid content

Total flavonoid content also plays a crucial role in all plants. Flavonoids are known for their antioxidant properties, which help protect the plant from oxidative stress and environmental damage. A low concentration of flavonoids may result in decreased antioxidant activity, making the plant more susceptible to oxidative stress [37]. The total flavonoid contents in the leaves (38.77 ± 0.88 mg/g.fwt) was significantly higher compared to the stems (33.28 ± 2.49 mg/g.fwt) (**Figure 3**).

Table 1. Phytochemical screening of leaves and stems of *Clerodendrum serratum*

Phytochemicals	Plant Parts	
	Leaves	Stems
Tannin	+	+
Saponin	-	-
Phenolic	+	+
Terpenoid	+	+
Steroid	+	+
Flavonoid	+	+
Alkaloid	+	-

Key: Present phytochemicals are represented by the (+) sign, absent phytochemicals are represented by the (-) sign

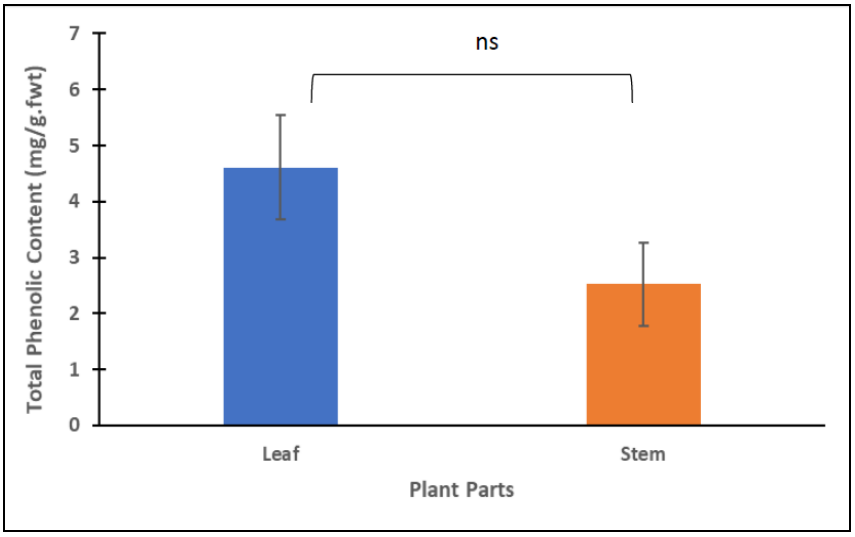

Figure 2. Total phenolic content (mg/g.fwt) in leaves and stems of *C.serratum.* (Values are means ± SD, n=5)

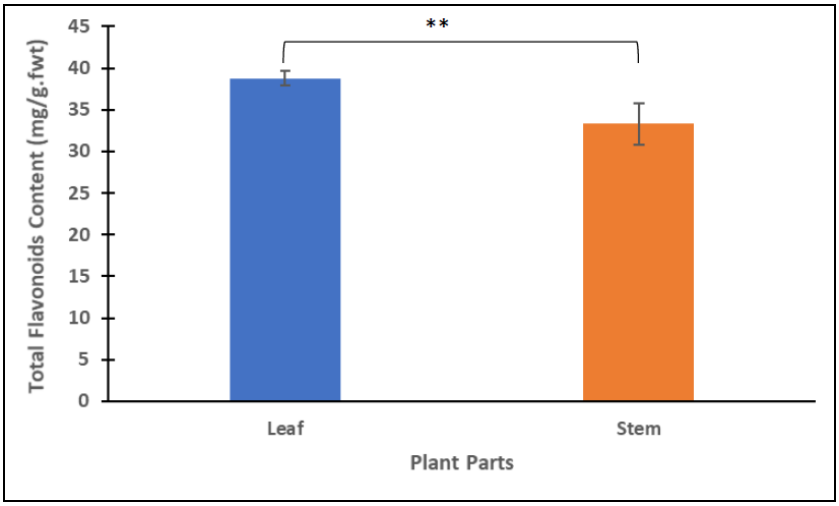

Figure 3. Total flavonoid content (mg/g.fwt) in leaves and stems of *C. serratum.* (Values are means ± SD, n=5)

The results obtained in this current study might be due to the plant's natural distribution of flavonoids in different parts. Other factors that may contribute to this result are that actively growing tissues on leaves may accumulate higher levels of flavonoids than older, lignified tissues [17]. Flavonoids are known for their antioxidant and other biological activities. Research on other plants, such as *Dryopteris erythrosora* and *Buddleja davidii*, has shown that the TFC can vary significantly between different parts of the same plant, with leaves often containing a higher concentration of flavonoids compared to the stems [38]. This natural variation in flavonoid distribution within the plant may be attributed to the plant's defense mechanisms, environmental factors, and specific biological functions of the different plant parts. When compared to other medicinal plants with similar ecological and morphological characteristics, the TFC values of *C. serratum* are within a comparable range. For example, *Ocimum spp.*, widely used in traditional medicine, exhibits TFC values ranging from 32.86 ± 2.2 to 54.51 ± 3.5 mg quercetin equivalents/g extract [39]. Similarly, *Andrographis paniculata*, another medicinal herb known for its anti-inflammatory effects, shows flavonoid contents between 37.81 ± 0.73 to 61.37 ±1.10 mg/g [40]. These comparisons suggest that *C. serratum* contains flavonoid levels consistent with other plants known for their health benefits, supporting its potential use in pharmaceutical and nutraceutical applications. Nevertheless, variations in TFC may arise from differences in extraction methods, plant parts analyzed and environmental factors [40].

Non-enzymatic antioxidant and pigment concentrations in *C. serratum*

Ascorbic acid, α-tocopherol, carotenoids and phenolic compounds are antioxidants that work both singly and synergistically to prevent or delay oxidative reactions that lead to degenerative diseases [39, 40]. The non-enzymatic antioxidants vary between the plant species, possibly due to variety, maturity at harvest, growing conditions, soil state and condition of post-harvest storage [41]. In this study, the antioxidant activity in the leaves and stems of *C. serratum* was determined, and the results are summarized in **Table 2**.

Ascorbic acid is a cofactor for enzymes involved in regulating hormone biosynthesis, which helps in maintaining the balance of plant hormones and overall plant health. Therefore, ascorbic acid has a critical function in plant growth and development [42]. In addition to being known as a substrate of many peroxidases, ascorbic acid is one of the main components of the ascorbate-glutathione and/or water–water cycle that effectively eliminates ROS. Higher production of ROS during the photosynthetic activities in the leaf leads to higher ascorbic acid production in plants [43]. The ascorbic acid in the leaves and stems ranged from 2.99 ± 0.07 to 4.80 ± 0.04 mg/g. fwt. The leaves contained higher ascorbic acid than the stems of *C. serratum.* The results correlate well with the study of Smirnoff (2018) [44]. They proposed that the ascorbic acid concentration in plants varied between tissues, with the highest concentrations found in leaves and flowers, and lower concentrations in less photosynthetically active tissues, such as stems. Moreover, high metabolic activity in leaves may contribute to a slightly higher accumulation of ascorbic acid compared to stems [21]. The ascorbic acid content in this current study was significantly lower than the total ascorbic acid in 10 selected Malaysian ulam [41], of 19 selected Malaysian ulam studied by Sumazian et al. and of 43 edible plant species from eight families that are widely consumed in Thailand [45, 46].

α-Tocopherol, in cooperation with other antioxidants, plays a part in reducing ROS levels (mainly singlet oxygen, $^1O_2$ and hydroxyl radical, $OH^{\cdot}$) in photosynthetic membranes and limiting the extent of lipid peroxidation by reducing the lipid peroxyl radicals to the corresponding hydroperoxides. The reaction between α-tocopherol and lipid radical occurs in the membrane-water interphase, where α-tocopherol donates a hydrogen ion to lipid radical with consequent tocopheroxyl formation [47, 48]. The α-tocopherol concentration in *C. serratum* was in the range of 13.87 ± 5.88 to 31.06 ± 6.88 µg/g.fwt, lower than the ascorbic acid concentrations. This outcome might be due to the function of both antioxidants, which work cooperatively with each other. Zandi and Schnug reported the utilization of ascorbic acid as a reducing agent in the regeneration of α-tocopherol, aiming to safeguard membranes against oxidative stress [43]. Additionally, it is noteworthy that when combined with α-tocopherol, ascorbic acid effectively scavenges lipid peroxyl radicals, thereby halting the propagation of lipid peroxidation within membranes. The result was comparable to the α-tocopherol obtained in 43 vegetables in Thailand [46] and lower than to those studied by Norhayati et al. [41]. The increased tocopherol content in the leaf could be attributed to the common synthesis in green tissues, where photosynthetic organelles and pigments are concentrated [43].

In this study, the carotenoid content (0.64 ± 0.10 mg/g fwt) was 10.2 times lower than the total chlorophyll content (6.52 ± 0.49 mg/g fwt) in the leaf tissues. This result is expected, as chlorophylls are the primary pigments responsible for capturing light energy during photosynthesis, while carotenoids serve as accessory pigments. Although present in smaller amounts, carotenoids play vital roles in photoprotection, antioxidant defense, and supporting light absorption by covering spectral regions not absorbed by chlorophyll. Their specific distribution and localization within chloroplasts reflect their specialized functions. Carotenoids also contribute to the structural integrity of photosystems and help protect against photooxidative damage. A lower carotenoid concentration compared to chlorophyll is typical, especially in leaves, which are highly photosynthetically active. Nevertheless, carotenoid levels can vary across plant tissues, with studies showing higher concentrations in leaves than in stems or roots [47–49]. Insufficient carotenoid levels may increase plant vulnerability to photodamage and oxidative stress.

Higher chlorophyll content in the leaves of *C. serratum* is crucial for efficient photosynthesis, enabling the plant to absorb light, especially in the blue and red wavelengths, and convert it into chemical energy necessary for growth and metabolic functions [50]. Chlorophyll not only drives energy production but also supports the synthesis of bioactive compounds such as phenolics, flavonoids, and alkaloids, which are linked to the plant's medicinal value. Its abundance reflects a healthy, metabolically active plant capable of producing secondary metabolites with antioxidant and therapeutic properties, contributing to both plant vitality and potential pharmacological applications.

Table 2. The non-enzymatic antioxidant activities and pigment concentrations in *C. Serratum*

Plant Parts	Non-Enzymatic Antioxidants			
	Ascorbic Acid	**α-Tocopherol (µg/g.fwt)**	**Carotenoids (mg/g.fwt)**	**Total Chlorophyll (mg/g.fwt)**
Leaf	4.80 ± 0.04^{a}	31.06 ± 6.88^{a}	0.64 ± 0.10^{a}	6.52 ± 0.49^{a}
Stem	2.99 ± 0.07^{b}	13.87 ± 5.88^{b}	0.29 ± 0.02^{b}	0.56 ± 0.07^{b}

Conclusion

The results of this study revealed that the methanolic crude extracts of *Clerodendrum serratum* Linn. contained various phytochemicals, including tannins, phenolics, terpenoids, steroids, and flavonoids. Total phenolic content (TPC) and total flavonoid content (TFC) were higher in the leaves than in the stems, highlighting the leaves as a potential source of antioxidants. Non-enzymatic antioxidants and pigments such as ascorbic acid and α-tocopherol, carotenoids, and chlorophyll were also present in both plant parts, particularly the leaves, contributing to the antioxidant potential of this species. These findings support the traditional use of *C. serratum* Linn. as a medicinal plant and suggest its potential in managing oxidative stress-related diseases. Given the rich antioxidant profile, especially in the leaves, *C. serratum* holds promise for applications in the pharmaceutical and nutraceutical industries, where natural antioxidants are in demand for the development of supplements, functional foods and therapeutic agents. Further studies are recommended to isolate and identify individual bioactive compounds, particularly from the leaves, and evaluate their biological activities.

Acknowledgement

A sincere thanks to the Faculty of Science and Marine Environment, Universiti Malaysia Terengganu (UMT) for providing the space and facilities.

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