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Nutritional, phytochemical, and antimicrobial properties of *Senna siamea* leaves

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ABSTRACT

Senna siamea is a medicinal plant with numerous benefits in different parts of the world. This study evaluated the leaf's nutritional composition, mineral composition, phytochemical constituents, antioxidant properties and antimicrobial properties, and high-performance liquid chromatography (HPLC) using standard methods. The proximate analysis revealed the presence of moisture content (12.14 ± 0.01), ash content (1.05 ± 0.07), crude fat (4.21 ± 0.10), crude protein at (9.78 ± 0.11), crude fiber (2.70 ± 0.32), and carbohydrate content (70.12 ± 0.37). Mineral analysis showed an abundance of potassium (125.18 ± 0.04), followed by magnesium (32.62 ± 0.01), and phosphorus (18.30 ± 0.02). The phytochemical screening revealed the presence of saponins, flavonoids, phenolics, steroids, and alkaloids with 13.25 ± 0.03 mg GAE/g total phenolics and 3.99 ± 0.01 mg QE/g flavonoid contents, respectively. IC_{50} values of the scavenging abilities of DPPH, NO radicals, and TBARS were 206.01 μg/mL, 347.66 μg/mL, and 394.92 μg/mL, respectively while the IC_{50} value for FRAP was 145.01 μg/mL. *Salmonella typhimurium* 14028 and *Pseudomonas aeruginosa* 27853 were most susceptible. At 100 mg/mL, their average zone of inhibition was 18 and 16 mm for ethyl acetate and 15 and 12 mm for methanol, respectively. The minimum inhibitory concentration (MIC) for both isolates was 25 and 50 mg/mL while the leaves were rich in chlorogenic acid, p-coumaric acid, friedelin, quercetin, emodin, cassiarin A, and kaempferol. These results reveal the leaf as a good source of nutrients and also confirm its phenolic antioxidant activity and antimicrobial properties.

1. Introduction

Humans, animals, and plants are inseparable. This is because plants are used all over the world for different purposes. Before the advent of science, our forefathers used these plants either in the form of food for nutritional purposes, animal feed, or therapeutic use. People still depend on these plants in some parts of the world where access to healthcare is still limited. The response of these plants can be due to the nutrients, antioxidants, or phytochemicals present in the plant. There is a growing recognition and development of financial and medicinal help for these plants in developed and developing countries [1]. These plants are important because they can synthesize compounds with physiological value [2]. *Cassia* (now *Senna*) comes from Greek meaning spice, while *siamea* originated from Siam, now Thailand [3]. This plant is a native of Southeast Asia and belongs to the family Caesalpiniaceae. Traditionally, they are used to treat different ailments, and their seeds, pods, and leaves are edible. Some parts of the plant such as the leaves and flowers are used as vegetables in Thai curry recipes. In addition, it is considered a plant of economic significance and a nutritious food [4]. In Nigeria, the leaves of the pawpaw (*Carica papaya*), lime (*Citrus lemonum*), and lemon (*Cymbopogon citratus)* are combined with the dried leaves and simmered whereas, the tea is sipped to combat malaria fever [5]. According to reports, the herb has been used in ethnomedicine for treating constipation, asthma, typhoid fever, diabetes, and hypertension [6]. The average-sized ornamental plant, which can reach a height of 20 m, is known as Odan in Yoruba, Cassia tree in English, and Bakin raskata in Hausa [7].

According to data from the World Health Organization [8], 80 % of people depend primarily on traditional medicine, and a significant portion of these treatments rely on plant extracts and their components

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[9]. Medicinal plants benefit from treating and curing human illnesses since they contain phytochemical elements [10]. Terpenoids, flavonoids, steroids, alkaloids, and phenolic compounds are some of the naturally occurring compounds in medicinal plants. During cell metabolism in living organisms, oxidant substances like reactive oxygen species and reactive nitrogen species are normally produced, and they participate in different cell-protecting mechanisms. At times, oxidative stress can be provoked due to an imbalance between endogenous antioxidants and free radicals [11,12]). This may result in autoimmune and neurodegenerative diseases, arthritis, cardiovascular dysfunction, asthma, diabetes, and cancer [13,14]. These medicinal plants' natural compounds help protect the human body from chronic diseases due to antioxidant and radical scavenging properties. These antioxidants are free radical scavengers that can make radicals harmless.

Since new diseases keep emerging, antimicrobial resistance is also on the rise, there is a need to find an alternative and continue producing new drugs to complement the existing ones to reduce the menace of antimicrobial resistance. Antibiotic-resistant microbial pathogens are predicted to be susceptible to the activity of plant extracts that display target locations different from those used by antibiotics [15]. However, little information exists on the use of this plant on clinical isolates of gastrointestinal origin. Since the plant is useful for several purposes, studying the nutritional composition, phytochemical constituents, antioxidants, and antimicrobial properties is important. This will strengthen existing information and likely help to formulate new dietary supplements and drugs. The purpose of the study was to evaluate the nutritional, antioxidant, and phytochemical properties of *Senna siamea* leaves. In addition, the antimicrobial activity of the methanol and ethyl acetate extract of *Senna siamea* leaves against some selected pathogens as well as the HPLC in identifying different components were studied.

2. Materials and methods

2.1. Collection and identification of plant material

The *Senna siamea* leaves were collected from a *Senna siamea* tree growing inside Ekiti State University, Ado Ekiti, Ekiti State, Nigeria. The plant was identified and authenticated in the Department of Plant Science and Biotechnology herbarium unit by Mr. Omotayo Felix Olorunfemi with voucher number (UHAE2023056). The leaves were washed with clean tap water before being air-dried and pulverized using an electric blender. The powdered samples were kept in a clean bag until ready for use.

2.2. Proximate analysis and elemental composition

The proximate analysis, namely moisture content, ash content, fat content, crude protein, crude fiber, carbohydrate, and mineral composition of the leaves was determined as described by AOAC [16].

2.3. Preparation of the extract

The plant samples were air-dried and ground to a mesh size (2 mm). About 200 g of sample was extracted in 2000 mL distilled water, placed in a fitted conical flask, and stirred for 48 hours using a shaker at medium speed. The mixture was decanted and filtered using sterile Whatman paper No. 1. The filtrate measured up to 600 mL and evaporated to dryness. The crude extract was then subjected to bioassay analysis. The extracts were filtered and kept for further use.

2.4. Phytochemicals

2.4.1. Determination of qualitative phytochemicals

The presence of tannins, saponins, flavonoids, terpenoids, and steroids in the leaves was carried out as described by Gul et al., [17].

3. Determination of quantitative phytochemicals

The total phenol and flavonoid content was obtained using the method of Seidu and Otutu., [18].

3.1. Determination of Antioxidant Properties

3.1.1. 2,2-Diphenyl-1-picrylhydrazyl (DPPH) Scavenging Assay

This was carried out as described by Patil et al., [19] and Pandey and Barve., [20], with minor modifications. The percentage inhibition of the DPPH free radical scavenging activity was calculated using the following equation. DPPH radical scavenging activity (%) = [(Abs control – Abs sample)]/(Abs control) ×100 where Abs control is the absorbance of DPPH radicals + methanol; Abs sample is the absorbance of DPPH radical + sample or standard.

3.1.2. Nitric oxide scavenging activity

This was carried out as stated by Boora et al., [21]. Gallic acid was used as the positive control and the nitric oxide scavenged (%) was calculated as = *A*control − *A*test *A*control × 100, (1) where *A*control = absorbance of the control sample and *A*test = absorbance in the presence of the samples of extracts or standards

3.1.3. Determination of thiobarbituric acid reactive species

Lipid peroxidation was estimated colorimetrically by thiobarbituric acid reactive substances (TBARS) using the modification method of Niehaus and Samuelsson [22]. The percentage inhibition was calculatedusing the equation: % lipids inhibition = {Ao- A1}/Ao × 100, where Ao is the absorbance of the control and A1 is the absorbance of the sample extract.

3.1.4. Ferric reducing antioxidant power (FRAP) assay

The ability to reduce ferric ions was measured using the methods described by Benzie and Strain [23] and Oyaizu et al., [24].

3.2. Antimicrobial susceptibility testing of Senna siamea

3.2.1. Preparation of Senna siamea leave extract

Fresh leaves were air-dried and ground with a blender. 1200 mL of methanol and ethyl acetate were used to extract 250 g of dried plant material. After mixing and giving it sporadic shakes, it was left to stand for 48 hours. Then, the sample was filtered and concentrated using a rotary vacuum evaporator. The resulting extract was weighed and kept until when needed.

3.2.2. Microorganisms

In this investigation, four Gram-negative bacterial type strains, *Escherichia coli* (*E. coli* 25922), *Klebsiella pneumoniae* (KPN 700303), *Salmonella typhimurium* (14028) and *Pseudomonas aeruginosa* (27853), were used. The bacterial isolates were acquired from the Molecular Laboratory, Department of Pharmaceutical Microbiology, University of Ibadan, Oyo State.

3.2.3. Antibacterial activity of the methanolic and ethyl acetate extract of Senna siamea

3.2.3.1. Susceptibility testing of test organisms. The antibacterial properties were determined using the agar well diffusion technique of Dauda et al., [25]. The logarithmic phase of each bacterial suspension was separated into an aliquot of 100 µL and placed using a sterile swab stick on a 20 mL molten Mueller-Hinton agar (Oxoid) medium. The wells were drilled at equal distances on the agar using a sterilized 6 mm cork borer and 100 µL of various amounts of reconstituted extract were added. Then, the extracts were allowed to diffuse into the seeded media for 30 minutes before incubating between 18 and 24 hours at 37 ° C.

After incubation, the widths of the inhibitory zones (mm) were determined on bacterial plates [26].

3.2.3.2. Determination of minimum inhibitory concentration (MIC) and maximum bactericidal concentration (MBC). The tube dilution method was used to evaluate the extracts' minimum bactericidal concentration (MBC) and minimum inhibitory concentration (MIC) against test organisms. To overcome the challenges of observing turbidity for each of the 96 wells, the inhibition of bacteria was visualized by monitoring the color response with p-iodonitrotetrazolium violet (Bio Medicals Inc.) rather than the conventional method of measuring turbidity [27].

3.3. Characterization of bioactive compounds using HPLC analysis

The qualitative-quantitative analysis of the phenolic contents of the leaf of *Senna siamea* was determined using the method reported by Dastmalchi et al., [28]. The concentration of the sample was calculated as:

$$\text{Concentrationofthesample} = \frac{\text{PeakareaofthesamplexStandardconcentration}}{\text{Thepeakareaofthestandard}}$$

3.4. Statistical analysis

The averages of the results were calculated and presented as mean ± standard deviation using Excel. The IC50 was evaluated using linear regression analysis.

4. Results

4.1. Proximate analysis and elemental composition

The nutritional information of *Senna siamea* leaves is presented in Table 1. The values of the various parameters tested varied between 1.05 ± 0.07 (ash content) and 70.12 ± 0.37 (carbohydrate), which is relatively high. Other ingredients include crude fiber (2.70 ± 0.32), crude fat (4.21 ± 0.10), crude protein (9.78 ± 0.11), and moisture content (12.14 ± 0.01). The percentage composition of the elemental nutrient in the leaf is presented in Table 2. Micronutrients such as zinc, manganese, and cadmium were in minute quantities. Among macro-elements, potassium (125.18 ± 0.04) has the highest nutritional value, followed by magnesium (32.62 ± 0.01). In total, sodium (0.02 ± 0.01), manganese (0.02 ± 0.00), and cadmium (0.01 ± 0.00) had the lowest nutritional composition.

4.2. Qualitative and quantitative phytochemical screening of Senna siamea leaves

The qualitative phytochemical analysis of *Senna siamea* leaves, denoting whether specific phytochemical compounds were detected.

Table 1
Proximate composition of *Senna siamea* leaves.

S/N	Parameters (%)	Values
1	Crude fat	4.21 ± 0.10
2	Crude fibre	2.70 ± 0.32
3	Moisture content	12.14 ± 0.01
4	Crude Protein	9.78 ± 0.11
5	Ash content	1.05 ± 0.07
6	Carbohydrate	70.12 ± 0.37

Values are mean ± standard deviation of triplicate readings.

Table 2
Elemental composition of *Senna siamea* leaves (μg/g).

S/N	Parameters	Values
1	Sodium	0.02 ± 0.01
2	Magnesium	32.62 ± 0.01
3	Potassium	125.18 ± 0.04
4	Calcium	11.06 ± 0.00
5	Phosphorus	18.30 ± 0.02
6	Chloride	0.05 ± 0.00
7	Zinc	0.42 ± 0.03
8	Manganese	0.02 ± 0.00
9	Lead	ND
10	Cadmium	0.01 ± 0.00

Values are mean ± standard deviation of duplicate readings.

Saponins (+), alkaloids (+), total flavonoids (+), total phenolics (+), and steroids (+) were present while tannins were not detected (-). For quantitative screening, the leaf aqueous extract exhibited a high content of total phenolics, quantified at 13.25 ± 0.03 mg GAE/g, and total flavonoids, which were quantified at 3.99 ± 0.01 mg QE/g.

4.3. Antioxidant activities of Senna siamea leaves

The DPPH, NO radicals scavenging ability, and FRAP of the *S. siamea* leaf are presented in Fig. 1. In this study, varying levels of antioxidant activity, with IC_{50} values were observed for different assays. Specifically, the IC_{50} values for DPPH radical scavenging ability are 206.01 μg/mL, for nitric oxide (NO) is 347.66 μg/mL, FRAP (Ferric Reducing Antioxidant Power) is 145.01 μg/mL, and for inhibition of TBARS (Thiobarbituric acid reactive substances) at 394.92 μg/mL.

4.4. Antibacterial activities of ethyl acetate and methanolic extract of Senna siamea leaves

The antibacterial properties of *Senna siamea* methanolic and ethyl acetate extract against four (4) clinical pathogens, using the microtube dilution method are represented in Tables 3 and 4. The study showed that distinct doses of plant extract had varied antibacterial activities against the tested types of bacteria in a dose-dependent way. From the outcome displayed in Table 4, ethyl acetate extract of *S. siamea* at all four concentrations, i.e. 100, 50, 25, and 12.5 mg/mL demonstrated a better inhibitory effect against pathogens except *E. coli* ATCC 25922 which is resistant at 12.5 mg/mL concentration. However, Table 5 shows that *E. coli* ATCC 25922 is also resistant to methanolic extract at 25 mg/mL and 12.5 mg/mL, *Klebsiella* ATCC 70030 and *P. aeruginosa* ATCC 27853 were resistant to the inhibitory effect of methanolic extract of *S. siamea* at a concentration of 12.5 mg/mL.

4.5. Minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of ethyl acetate and methanolic extract of Senna siamea leaves

The MIC of the *S. siamea* ethyl acetate and methanolic extracts needed to stop the growth of each test pathogenic isolate was calculated using the tube dilution method. The findings are displayed in Tables 3 and 4. As shown in the tables, the methanol and ethyl acetate extract of the leaves inhibited the development of all pathogens tested at a very high dose of 50 mg/mL, except *Salmonella typhimurium* ATCC 14028,

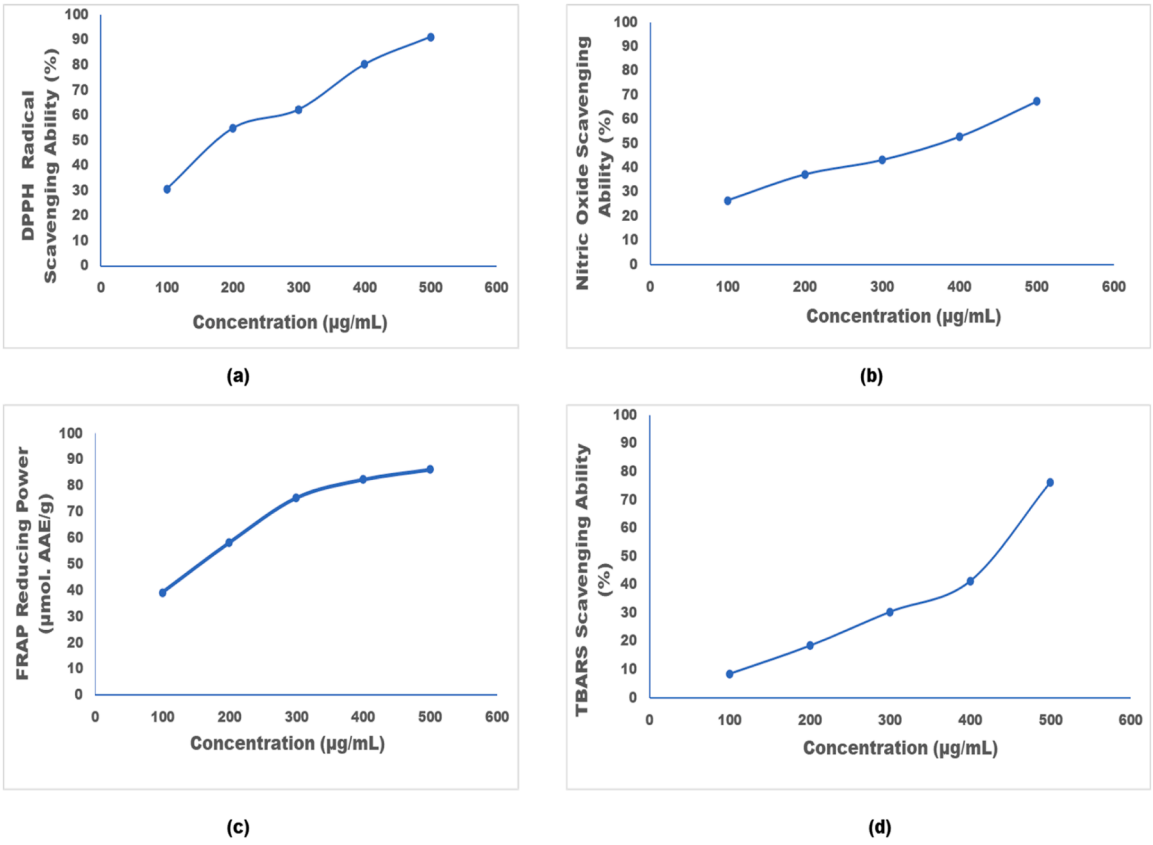

Fig. 1. Showing the (a) Radical Scavenging Ability of DPPH (%) (b) NO Radical Scavenging Ability (%) (c) FRAP Reducing Power and Radical Scavenging Ability of TBARS (%) of aqueous extract *Senna siamea* Leaves.

Table 3
Antibacterial activity of the ethyl acetate extract of *Senna siamea* leaves.

Isolates	Conc. (mg/mL)/Zone of Inhibition (mm)						
	100	50	25	12.5	Gent	MIC	MBC
E. coli 25922	12	8	6	-	15	50	100
K. pneumoniae 700303	12	10	8	5	16	50	100
S. typhimurium 14028	18	16	13	10	12	50	100
P. aeruginosa 27853	16	14	12	10	16	50	100

Table 4
Antibacterial activity of the methanolic extract of *Senna siamea* leaves.

Isolates	Conc. (mg/mL)/Zone of Inhibition (mm)						
	100	50	25	12.5	Gent	MIC	MBC
E. coli 25922	10	8	-	-	15	50	100
K. pneumoniae 700303	10	8	6	-	16	50	100
S. typhimurium 14028	15	12	10	8	13	25	50
P. aeruginosa 27853	12	10	8	-	15	50	100

where inhibition was noticed at 25 mg/mL. The findings demonstrated that a minimum bactericidal dose of 50 mg/mL to 100 mg/mL of *S. siamea* extract can stop the growth of the test strains. At a higher MBC of 100 mg/mL, the extract showed greater effectiveness as a bactericidal agent against the isolates; however, its MBC against *Salmonella typhimurium* ATCC 14028 was only 50 mg/mL.

4.6. HPLC analysis

The HPLC chromatogram and the chemical compound of the crude extract of *Senna siamea* are shown in Fig. 2 and Table 5, respectively. HPLC characterization revealed some phenolic compounds with known

Table 5
HPLC-DAD evaluation of chemical compound of crude extract of *Senna siamea*.

S/N	Compound	Concentration (mg/g)	Retention time
1	Chlorogenic Acid	922.723602	1.266
2	P-Coumaric Acid	2042.499566	2.75
3	Emodin	426.9047332	4.45
4	Betulin	90.65266358	5.466
5	Beta-Sitosterol	126.1824479	6.483
6	Stigmasterol	93.39781555	7.333
7	Barakol	116.53284	7.95
8	Anhydrobarakol	93.75206545	8.416
9	Piperidine	91.61289724	9.05
10	Siameanin	118.4419167	9.35
11	Quercetin	53730.30229	11.05
12	Kaempferol	2013.297869	12.166
13	Cassiarin A	474.2785383	13.7
14	Luteolin	199.7286002	14.816
15	Cassiamin A	187.6539182	15.716
16	Chrysophanol	117.6405829	16.25
17	Apigenin	135.5814609	17.233
18	Friedelin	548.1373646	17.616
19	Chrobisiamone	112.8616264	19.25
20	Siameadin	132.6819653	19.766

potential as antioxidants, anti-inflammatory, antimicrobial, and antidiabetic, among other pharmacological properties. Chlorogenic acid, p-coumaric acid, friedelin, quercetin, emodin, cassiarin A, and kaempferol were most prominent in the leaves of *Senna siamea*. The most notable compound, quercetin, was eluted at 11.05 min, while all eluted compounds were detected between 1.27 and 20.3 min.

5. Discussion

The proximate analysis reveals the nutritional composition of any

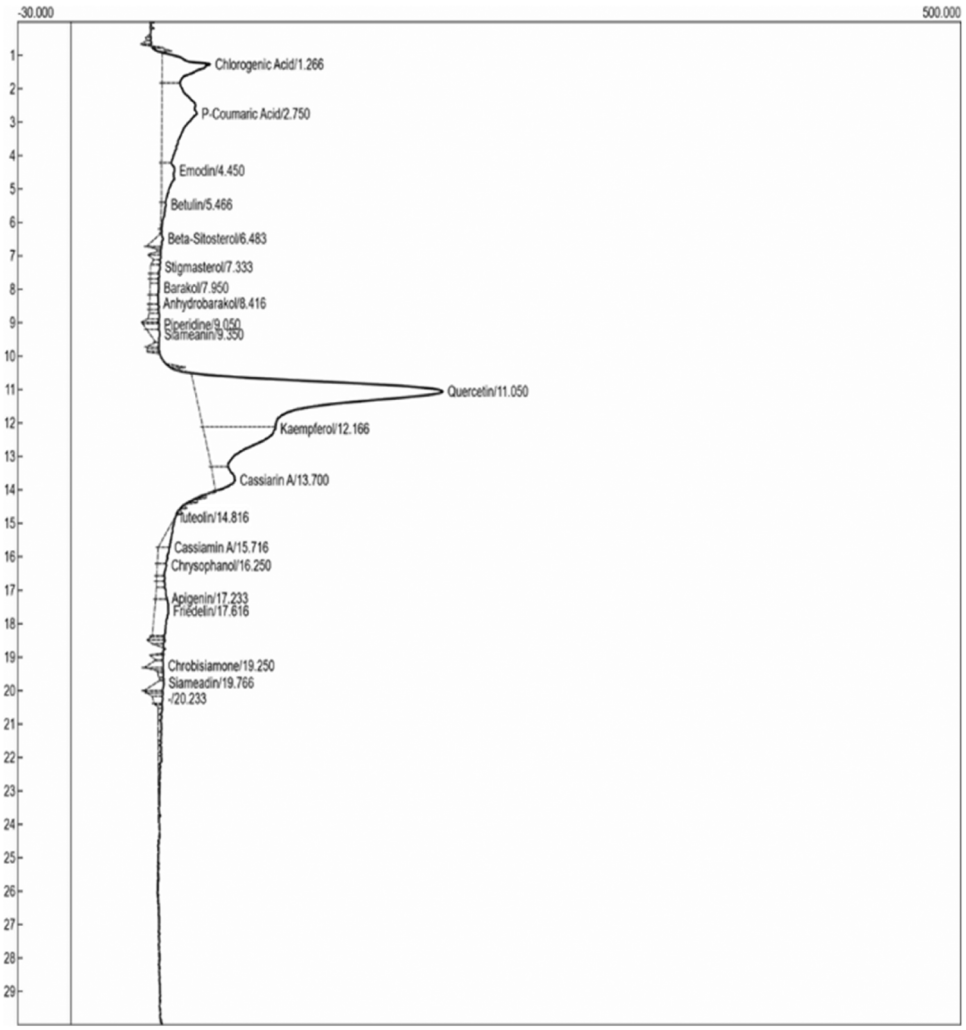

Fig. 2. HPLC Chromatogram of the Crude Extract of *Senna siamea* leaves.

given food. In plants, it reveals the accumulation of nutrients in any part of the plant. This study reported a crude fat value higher than the 3.00 % reported for *S. siamea* [29], 2.02 ± 0.82 for *Cassia tora,* and 1.76 ± 0.5 for *Celtis integrifolia* [30]. On the contrary, Ali-Smith et al., [2] reported higher values of 12.02 ± 0.05 in *Senna siamea* and 9.67±0.191 was reported for *Senna alata* leaves [31]. This suggests that the crude fat content in the leaves can aid the body in storing and transporting metabolic fuel [2]. The crude fiber content obtained was low compared to 17.42 ± 0.714 reported in *Senna alata* leaves [31] and 27.07 + 0.10 accumulated in *Cassia tora* leaves [30]. Some diseases have been associated with a low fiber diet intake [32,33]. Fiber intake helps reduce the occurrence of breast cancer, diabetes, colon cancer, coronary heart disease, hypertension, and serum cholesterol levels [34]. Therefore, *Senna siamea* leaves can serve as a good source of dietary fiber that will enhance body metabolism.

The moisture content of the leaf is far lower than the 46.01 % obtained for the *Senna siamea* leaf which was reported by Ali-Smith et al., [2]. However, Kubmarawa et al., [30] reported a moisture content of 12.82 + 0.15 for *Cassia tora* leaves. The moisture content obtained in the study was not more than 14 %, which is required for crude drugs. This suggests that *Senna siamea* leaf would have a longer shelf life because of its low water content. The activity of some enzymes can degrade some important constituents because of high moisture content, and this action may lead to microbial growth during storage since high moisture content in the plant leaf indicates higher chances of microbial degradation [35]. The protein content obtained in this study is higher than the 4.01 % reported for *Senna siamea* [2] and 8.20 + 0.05 found in the leaves of *Celtis Integrifolia* [30]. Differences in values may be attributed to geographical locations. In this study, the protein content obtained from the leaves can supplement protein from other sources. Incorporating proteins in our diet is necessary to maintain and regulate various functions and structures of organs and tissues in the body [36]. This includes synthesizing hormones for some body functions such as maintenance of body protein, repair, and growth [37]. The ash content obtained was lower than 20.62 % [29]; 9.86 + 2.1 [30] and 5.95 ± 0.078 [31] reported for the leaves of *S. siamea*, *Cassia tora* and *Senna alata*, respectively. The normal complexes of inorganic and organic compounds are revealed by the total value of the ash in a plant [38]. The ash content gives insight or information on the minerals present in the plant. Although it was present in small amounts, the ash in the leaves of *Senna siamea* can still be used as a supplement. A high carbohydrate value was recorded compared to the 33.81±0.827 *Senna alata* leaves reported by Okeke et al., [31]. This suggests that the leaves can serve as a good energy source, and help to assimilate and digest other foods [2].

Minerals are inorganic substances necessary for maintaining physicochemical processes and can be found in body fluids and tissues. The disease and health states in humans and domestic animals are significantly influenced by mineral elements [39]. While some minerals are needed for the metabolic and physiological functions of the body, others are not important. In this study, Mg, K, Ca, and P were present in appreciable amounts. The values obtained here are higher compared to the sodium (0.07 ± 0.01) and potassium (1.44 ± 0.01) values found in

C. integrifolia leaf as stated by [30]. Potassium is a constituent of important enzymes, while sodium is one of the major electrolytes in the blood. Sodium and potassium help regulate the balance of acid and base [40]. In humans, there is a relationship between hypertension and the rate of sodium intake and this makes diets that are high in potassium and low in sodium content important [41]. The magnesium accumulated in *Senna siamea* leaves in this study is higher when compared to those found in the leaves of *Cassia arereh* Del. (0.34 %) reported by Olusola et al., [42]. In this study, a calcium value that was higher than *Cassia tora* (3.52 ± 0.40) and *C. Integrifolia* (3.70 ± 0.30), as reported by Kubmarawa et al., [30] was obtained. Dietary intake of magnesium has been proven to be necessary since studies have reported a relationship between type 2 diabetes and low levels of magnesium in the body [43]. Magnesium is important for bone strengthening, maintaining a steady heartbeat, maintaining proper functioning of the normal nerves and muscles, and also helping to build a strong and healthy immune system [44]. Calcium is an important mineral that is needed for strong bone formation. It also helps prevent osteoporosis, a calcium deficiency-related disease [45]. Therefore, the concentration of magnesium and calcium found in *S. siamea* may be of benefit. The phosphorus content in *Senna siamea* leaves is high compared to the phosphorus content obtained in *Cassia arereh* Del. [42] but lower than the 67.89 mg/100 g in *Launea taraxacifolia* leaves [46]. It suggests that it can be used as a component of ATP, nucleic acid, phosphorylated metabolic intermediates, teeth, and bones. An inadequate amount of this mineral can cause osteomalacia in adults, while rickets are common among children [39].

The zinc content in this leave is slightly higher 0.04 ± 0.03 than the zinc content in *Cassia tora* and 0.02 ± 0.01 in *C. integrifolia* [30] but low compared to 21.3 ± 0.05 in *Cassia nigricans* leaves [40] and 0.57±0.021 in *Senna alata* leaves [31] Since zinc is needed in a small amount for the human body, the value obtained in this study is still sufficient. Zinc deficiency and its consequences such as stunted growth and acute diarrhea in children can be prevented and treated by incorporating zinc in dietary formulation. The body's immunity and strength are enhanced when zinc is adequately present [47]. Although Mn recorded here is low, its deficiency rarely occurs and is required in small quantities because excess of this can lead to diseases such as Parkinson's [48,49]. They are involved in synthesizing cholesterol and fatty acids and are used as catalysts and cofactors in many enzymatic processes. They are also an important cofactor for mucopolysaccharide and glycoprotein synthesis [50]. The cadmium content here is lower (0.01 ± 0.00) than 0.07 % in *Senna siamea* [29] and 0.106 ± 0.03 in *Cassia nigricans* leaves [40]. Though the value is very minute compared to previous works, it is usually needed in small quantities for body functions. If the concentration of cadmium is too high, it is likely to affect the vascular system, kidneys, liver, and immune systems, and also acute and chronic poisoning [51]. In humans, the lack of intake of these minerals and nutrients can affect overall health and performance [52].

Studies have shown that saponins exert biological roles such as antibacterial [53], antifungal [54], anti-oxidant, anti-inflammatory, and anti-cancer effects [55,56]. Alkaloids, which are secondary metabolites have been reported to possess both antimicrobial and antioxidant properties [57,58] while steroids possess insecticidal and antibacterial properties [59]. This might have contributed to both the antioxidant and antimicrobial activities obtained in this study.

The growing interest in antioxidants comes from their known health benefits, mainly due to natural compounds that help prevent diseases related to oxidative stress caused by free radicals attacking important biomolecules [60]. There are different ways to measure how effective an antioxidant is, which vary in how they create the molecules or radicals being targeted and how they measure the end results. Because antioxidants work in many different ways inside our bodies, it is important to choose the right tests to understand their activity. No single method can fully assess how powerful an antioxidant is [61]. Therefore, this study used four different tests - DPPH, FRAP, NO radical scavenging ability, and inhibition of TBARS - to see the antioxidant activities of *S. siamea* leaves. Using a DPPH radical scavenging assay to test the antioxidant potential of aqueous extracts of *S. siamea* measures how well compounds can neutralize the stable purple DPPH radical by donating hydrogen ions or electrons, which causes a color change from purple to yellow [62]. Concentration-dependent antioxidant activity was observed in all extracts, showing they can effectively neutralize DPPH radicals. The extracts had an IC50 value of 206.01, indicating their strong ability to scavenge free radicals.

Nitric oxide (NO) is important for cell communication but can also contribute to oxidative stress when it reacts with superoxide radicals. This leads to the formation of highly reactive peroxynitrite anions. High levels of NO have been associated with increased production of pro-inflammatory substances, making inflammatory conditions worse in diseases such as ulcerative colitis, diabetes, multiple sclerosis, and arthritis [63]. *S. siamea* extracts showed concentration-dependent cytotoxic effects and were able to inhibit nitric oxide production effectively. They had an IC50 value of 347.66 for this inhibition, suggesting their potential to reduce oxidative stress and inflammation in disease. These anti-inflammatory effects could be due to the natural chemicals (phytochemicals) present in the plant. Ferric reducing antioxidant power (FRAP) measures how well an antioxidant can convert Fe^{3+} (ferric) to Fe^{2+} (ferrous) through the action of phenolic compounds that can donate hydrogen [64]. Higher FRAP values indicate stronger antioxidant activity. The FRAP values of the extracts showed significant differences ($p < 0.05$) based on the dosage used. This means that the effectiveness of the extracts in reducing Fe^{3+} varied depending on how much was used. In all cases, the extract showed greater efficacy in reducing Fe^{3+}. The IC50 value for FRAP, which represents the concentration of antioxidant compounds in the extract required to reduce Fe^{3+} by 50 %, was determined to be 145.01 μg/mL. These results highlight the potential of both extracts as a source of natural antioxidants, with higher FRAP values indicating stronger antioxidant activity. The synthesis of malondialdehyde or lipid peroxidation might activate cycles of toxicological cascades or surges in free radical-impaired cells, which is believed to be a powerful signal. If this is monitored, it would break biomembranes and cause havoc [65].

Overall, this study highlights how the anti-inflammatory and antioxidant properties of *S. siamea* extracts become stronger as their concentration increases. The study's findings on the antibacterial activity of several *Senna siamea* leaf extracts showed that these extracts exhibit varying degrees of sensitivity and broad-spectrum antibacterial activity against the tested bacterial species. According to Abo et al., [66], the chemical characteristics of *Senna siamea* leaves may be responsible for the antibacterial activity of extracts made from the leaves. The antibacterial activity of both extracts obtained in this study conforms with the report of Ahmed-Alizaga and Olayanju [67] where *Senna siamea* leaf extracts were active against certain bacteria in their investigation. This study's findings corroborated the report of Bukar et al., [68] who documented *Senna siamea* leaf extracts' antipseudomonal effectiveness against pathogenic *Pseudomonas aeruginosa*.

The MIC and MBC of the extracts demonstrated that the isolates can be inhibited and/or killed by different dilutions of the methanol and ethyl acetate extracts of *Senna siamea* at varied doses. The extract has an MBC ranging from 50 to 100 mg/mL. According to this study, leaf extracts from *Senna siamea* have antibacterial activity and therapeutic qualities that prevent the formation of germs. The current study's findings demonstrate the effectiveness of *Senna siamea* leaf extracts against every tested bacterium. The extracts' antibacterial properties probably stem from the presence of bioactive substances. The findings of this investigation have supported the use of *S. siamea* leaves for both therapeutic and medicinal purposes.

The study involved the use of HPLC with diode array detection (HPLC-DAD) to determine how the chemical components of this plant relate to its medicinal properties. Twenty (20) different compounds were analyzed and most of them had phenolic characteristics. These

phenolic compounds have hydrogen atoms in their structure, allowing them to effectively neutralize free radicals. Additional evidence of the potential ability of the plant to treat conditions associated with oxidative stress was also provided.

The most prominent biological molecule revealed by HPLC is quercetin which has been reported to have strong antioxidant and antimicrobial properties. Quercetin scavenges ROS, thereby protecting the cell against oxidative stress. In addition, it helps in regulating glutathione levels and maintaining oxidative balance [69]. Its in-vitro mechanism of action includes inhibition of lipid peroxidation, metal ions chelation, and scavenging of the free radicals [70]. Studies have shown that quercetin has antimicrobial activity against bacteria and fungi [70]. For instance, Wang et al., [71] confirmed the antimicrobial effect of quercetin against Gram-positive and Gram-negative bacteria along with some antibiotic-resistant strains. The growth of *Proteus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Salmonella enteritidis*, *Aspergillus flavus*, and *Escherichia coli* was reported to be inhibited by quercetin [71,72].

The mechanisms by which quercetin exerts its antimicrobial activity include inhibition of enzyme activities, inhibition of protein and nucleic acid synthesis, and interference with cell wall synthesis cell permeability [70]. In addition, p-coumaric has been reported to have antibacterial, anti-inflammatory, antioxidant, antidiabetic, and anticancer properties [73–76]. p-coumaric can exert this antioxidant property because it can give or donate electrons or hydrogen due to the presence of the phenyl hydroxyl group [77]. Their antimicrobial activity against pathogenic microorganisms is due to binding with the DNA, thereby inhibiting cellular activity [78]. This suggests that these compounds could have contributed to the antioxidant and antimicrobial properties of the leaves.

6. Conclusion

In summary, the nutritional composition analysis of *S. siamea* leaves reveals that it can be a significant contributor to fulfilling the body's nutritional requirements for healthy growth. Furthermore, the study on the mineral content and proximate composition suggests that *Senna siamea* leaves may be a natural source of essential minerals needed in the human diet, which can help prevent diseases such as anemia. This research provides valuable information on the potential use of *Senna siamea* leaves in the food and pharmaceutical sectors.

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CRediT authorship contribution statement

Oluwasegun Sodiq Dauda: Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Adefunke Oluwaseun Ogunniran:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Data curation, Conceptualization. **Precious Oluwaseun Adekunle:** Investigation, Data curation. **Deborah Joy Falodun:** Investigation, Data curation. **Foluso Christopher Jegede:** Investigation, Data curation. **Damilare Rotimi:** Writing – review & editing, Writing – original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Author Agreement Statement

We the undersigned declare that this manuscript is original, has not been published before, and is not currently being considered for publication elsewhere. We confirm that the manuscript has been approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. We understand that the corresponding author is the sole contact for the editorial process. She will be responsible for communicating with the other authors about progress, submissions of revisions, and final approval of proofs.

Data availability

Data will be made available on request.

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