

Comparative *In Vitro* Antioxidant Activities, Phenolic and Flavonoid Profiles of Different Morphological Parts of *Commiphora africana* (A. Rich.) Engl. (Burseraceae)

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Abstract

Commiphora africana (A. Rich.) Engl. is widely used in African traditional medicine for managing oxidative stress-related disorders, but scientific validation of this part-specific use remains limited. This study evaluated and compared the antioxidant activities and total phenolic and flavonoid contents of leaf, stem bark, and root bark extracts of *C. africana*. Powdered plant materials were macerated in 80% aqueous ethanol for 48 h. Antioxidant capacity was assessed using DPPH, hydrogen peroxide (H₂O₂), phosphomolybdenum, and ferric reducing antioxidant power (FRAP) assays, while total phenolic and flavonoid contents were quantified by the Folin–Ciocalteu and aluminum chloride methods. All extracts showed concentration-dependent antioxidant activity. Initial DPPH screening gave IC₅₀ values of 26.90 ± 0.004 (leaf), 58.27 ± 0.006 (stem bark), and 39.34 ± 0.003 µg/mL (root bark), versus 6.43 ± 0.004 µg/mL for ascorbic acid. In extended testing, stem bark outperformed leaf in H₂O₂ scavenging (155.26 vs. 325.43 µg/mL), phosphomolybdenum reduction (1224.25 vs. 1682.33 µg/mL), and FRAP (658.56 vs. 942.17 µg/mL). Total phenolic content was highest in leaf (2.17 mg GAE/g dw); total flavonoid content was highest in stem bark (0.85 mg QE/g dw); all pairwise differences were significant (p < 0.05). The findings demonstrate that the antioxidant activity of *Commiphora africana* varies among plant parts, with the leaf exhibiting the highest phenolic content and strongest DPPH radical-scavenging activity, while the stem bark showed superior hydrogen peroxide scavenging and reducing power.

Keywords: *C. africana*, antioxidant activity, DPPH, flavonoids, phenolic content, medicinal plants

Introduction

Since antiquity, plants have provided a core reservoir of therapeutic agents, and traditional medicine systems continue to lean heavily on plant-derived remedies for everyday healthcare. By WHO estimates, roughly 80% of people worldwide still rely on traditional medicine as their primary form of healthcare [1], and plant extracts and their bioactive constituents form the backbone of a large share of these interventions [2].

Commiphora africana (A. Rich.) Engl. (Burseraceae) is a widely distributed African medicinal plant used across Nigeria and neighboring countries against conditions including cancer, malaria, wounds, diabetes, snakebite, and inflammation [3-4]. Its extracts display antioxidant, antimicrobial, and anti-inflammatory effects that support this traditional use [3, 5]. Phytochemical screening has identified flavonoids, tannins, anthraquinones, triterpenoids, saponins, and alkaloids in *C. africana* extracts [6-7], including specific compounds such as

quercetin, rutin, kaempferol, and apigenin [5]; stem bark extracts in particular have shown broad-spectrum antimicrobial activity alongside notable antioxidant capacity [6].

Oxidative stress, an imbalance favoring oxidants over antioxidants, is implicated in aging and in diseases including cancer, cardiovascular disease, neurodegeneration, and chronic inflammation [9]. Concerns over the safety of synthetic antioxidants have shifted research attention toward natural, plant-derived alternatives [10], particularly phenolic compounds and flavonoids, which scavenge free radicals and exhibit anticancer, cardioprotective, and anti-inflammatory activity [10-12]. Work on other *Commiphora* species confirms that optimized extraction can yield high concentrations of bioactive phenolics [13].

Traditional healers in Northern Nigeria commonly select particular morphological parts of *C. africana* for specific ailments, suggesting an uneven distribution of bioactive constituents across plant organs [3, 6]. However, prior studies

of *C. africana* antioxidant activity have examined only single plant parts or pooled/polyherbal extracts, without directly comparing morphological parts within one experimental design [3, 5]. The present study addresses this gap by comparatively evaluating antioxidant activity, using four complementary assay models, and quantifying total phenolic and flavonoid content in leaf, stem bark, and root bark extracts of *C. africana*, aiming to provide a scientific rationale for ethnomedicinal plant-part preferences and to identify the most potent natural antioxidant source within this species.

Materials and Methods

Plant collection and identification

Fresh samples of *Commiphora africana* comprising leaves, stem bark, and root bark were harvested from their natural growing site in Zaria, Kaduna State, Nigeria, in November 2022. Identification and authentication of the plant material were carried out by Mal. Namadi Sanusi, Taxonomist, Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria, and voucher specimens were deposited after cross-matching against an existing herbarium sample (voucher number 2848). Each plant part was air-dried separately under shade at ambient temperature for three weeks, then reduced to powder using a mechanical grinder, and the resulting powders were kept in airtight, light-protected containers until extraction began.

Chemicals, reagents, and apparatus

All chemicals — Folin–Ciocalteu reagent, monobasic and dibasic sodium phosphate, 2,2-diphenyl-1-picrylhydrazyl (DPPH), gallic acid and quercetin standards, sodium carbonate, potassium hexacyanoferrate, ascorbic acid, ferric chloride, aluminum chloride, sodium nitrite, sodium hydroxide, hydrogen peroxide, ammonium molybdate, and trichloroacetic acid — were sourced from Sigma-Aldrich (St. Louis, MO, USA), while analytical-grade methanol and ethanol came from BDH Chemicals (Poole, England). Absorbance readings were taken on an Agilent Cary 60 UV-Vis spectrophotometer (Agilent Technologies, Santa Clara, CA, USA), with a Buchi rotary evaporator (Switzerland), a Mettler Toledo analytical balance (Switzerland), a Hanna Instruments pH meter (USA), and a Gallenkamp water bath (UK) used as supporting equipment.

Extraction procedure

Each powdered plant part (leaf, stem bark, root bark; 50 g) was macerated separately in 500 mL of 80% aqueous ethanol for 48 h at room temperature, with occasional shaking. Mixtures were then filtered through Whatman No. 1 paper, and the leftover residues were re-macerated twice more under the same conditions to maximize extraction efficiency. Filtrates from each part were pooled and concentrated at 40 °C under reduced pressure on a rotary evaporator, after which the concentrates were moved to pre-weighed bottles and dried to constant weight in a desiccator. Percentage yield was then calculated for each part, and the dried extracts were kept at 4 °C until needed.

Evaluation of antioxidant activities

DPPH free radical scavenging assay

This study made use of two separate DPPH protocols, matching the two evaluation stages reported in the Results section (initial screening and extended evaluation). For the

initial screening across all three plant parts, a modified version of the Hossain et al. method was applied [14]: methanolic stock solutions (15 mg/mL) were serially diluted to give working concentrations of 6.25–100 µg/mL, and 100 µL of each dilution was combined with 3 mL of 0.002% w/v methanolic DPPH solution. Reaction mixtures were vortexed and left to stand in the dark at room temperature for 30 min before absorbance was read at 517 nm against a methanol blank. Ascorbic acid (3.125–50 µg/mL) served as the positive control, and control tubes contained every reagent except the extract; all measurements were run in triplicate. Percentage inhibition was obtained from Equation 1

$$\% \text{ Inhibition} = \left[\frac{(A_{\text{blank}} - A_{\text{sample}})}{A_{\text{blank}}} \right] \times 100, \text{ Equation 1}$$

and IC₅₀ (the concentration scavenging 50% of the radical) was derived by non-linear regression of percentage inhibition against concentration.

When leaf and stem bark extracts were later carried forward into the extended four-assay evaluation, DPPH scavenging was instead measured following Moon and Shobomoto [15]. A 0.135 mM methanolic DPPH solution (1.0 mL) was combined with 1.0 mL of extract or ascorbic acid, each prepared in methanol at 62.5, 125, 250, 500, and 1000 µg/mL; after vortexing, tubes sat in the dark at room temperature for 30 min before absorbance was recorded at 517 nm. Triplicate measurements were used to derive percentage inhibition and IC₅₀ as before. Because this protocol uses a considerably higher DPPH concentration (0.135 mM vs. 0.002% w/v) and a different concentration range than the initial screening, the two resulting data sets cannot be compared directly in absolute terms (discussed further under Results and Discussion).

Hydrogen peroxide radical scavenging assay

Hydrogen peroxide scavenging followed the Ruch et al. procedure [16]. Extract solutions (62.5–1000 µg/mL, in distilled water) were combined at 4 mL with 0.6 mL of 4 mM H₂O₂ in phosphate buffer (0.1 M, pH 7.4), incubated for 10 min at room temperature, and read at 230 nm against a blank containing extract without peroxide. Ascorbic acid was the positive control. Percentage scavenging was computed as (Equation 2)

$$\% \text{ Scavenging} = \left[\frac{(A_{\text{control}} - A_{\text{sample}})}{A_{\text{control}}} \right] \times 100, \text{ Equation 2}$$

and IC₅₀ values were derived as above.

Phosphomolybdenum antioxidant assay

Total antioxidant capacity was assessed by the phosphomolybdenum assay of Prieto et al. [17]: 1 mL of each extract concentration (100–500 µg/mL) was combined with 3 mL distilled water and 1 mL molybdate reagent (0.6 M sulfuric acid, 28 mM sodium phosphate, 4 mM ammonium molybdate), and the capped tubes were held at 95 °C in a water bath for 90 min. Following cooling, absorbance was read at 695 nm against a reagent blank in which distilled water replaced the extract but underwent identical processing; ascorbic acid was the reference standard. Higher absorbance signified stronger total antioxidant capacity, and EC₅₀ (the concentration giving 50% of maximum absorbance) was read from the concentration-response curve.

Ferric reducing antioxidant power (FRAP) assay

Reducing power was assessed using Oyaizu's method [18]. Extract solutions (100–500 µg/mL, 1 mL) were mixed with 2.5 mL phosphate buffer (0.2 M, pH 6.6) and 2.5 mL of 1% w/v potassium ferricyanide, then held at 50 °C for 30 min. After adding 2.5 mL of 10% w/v trichloroacetic acid, the tubes were centrifuged (3000 rpm, 10 min); 2.5 mL of the resulting supernatant was mixed with 2.5 mL distilled water and 0.5 mL of 0.1% w/v ferric chloride, and absorbance was read at 700 nm after 10 min against a reagent blank processed identically but with distilled water in place of extract. Ascorbic acid was used as positive control, higher absorbance reflected greater reducing power, and EC₅₀ values were obtained as for the phosphomolybdenum assay.

Quantification of total phenolic content

Total phenolic content was quantified via a slightly modified Folin–Ciocalteu assay [19–20]. Extract solution (1 mg/mL, 1 mL) was diluted with 9 mL distilled water in a 25 mL volumetric flask, treated with 1 mL Folin–Ciocalteu reagent, and shaken; after 5 min, 10 mL of 7% sodium carbonate was added and the flask made up to volume with distilled water. Following 90 min of incubation at room temperature (25 ± 2 °C), absorbance was read at 550 nm against a reagent blank, with a gallic acid calibration curve (20–100 µg/mL) processed the same way. Content was calculated as (Equation 3)

$$TPC = \frac{(C \times V \times DF)}{M} \quad \text{Equation 3}$$

C being the gallic-acid-equivalent concentration from the calibration curve, V the extract volume, DF the dilution factor, and M the dry extract mass — and expressed in mg GAE/g dw, with all runs in triplicate.

Quantification of total flavonoid content

Total flavonoid content was determined by the aluminum chloride colorimetric method [10, 14]: 1 mL of extract solution (1 mg/mL) was added to 4 mL distilled water in a 10 mL volumetric flask, followed by 0.3 mL of 5% sodium nitrite at time zero and 0.3 mL of 10% aluminum chloride at 5 min; at 6 min, 2 mL of 1 M sodium hydroxide was added and the flask topped up to 10 mL with distilled water. After thorough mixing, absorbance was read at 510 nm against a reagent blank, with quercetin standards (20–100 µg/mL) run in parallel for calibration. Content was calculated analogously to the phenolic assay and expressed in mg QE/g dw, in triplicate.

Statistical methods

Throughout, data are given as mean ± SD from triplicate runs, and IC₅₀/EC₅₀ figures came from non-linear regression performed in Microsoft Excel 2007. To compare phenolic and flavonoid levels across the three plant parts, a one-way ANOVA with Tukey's HSD post-hoc test was applied at the p < 0.05 threshold, with any two groups not sharing a superscript letter treated as significantly different. Pearson's r was then computed to probe relationships between antioxidant activity (IC₅₀/EC₅₀) and phenolic/flavonoid content; because only three morphological parts were available for comparison (n = 3, df = 1), these correlation estimates carry essentially no statistical power and are presented as descriptive trends rather than confirmed associations (see Results, Correlation Analysis).

Results

Extraction yields

Ethanol extraction yields differed by plant part: 8.42% w/w for leaf, 6.37% w/w for stem bark, and 5.91% w/w for root bark, relative to dried starting material.

Initial DPPH screening of leaf, stem bark, and root bark extracts

Table 1 reports the initial-screening DPPH scavenging results for the three ethanol extracts. All three showed the expected concentration-dependent pattern of radical scavenging. Since a lower IC₅₀ signals stronger antioxidant activity, leaf extract emerged as the most potent scavenger in this screening, ahead of root bark and then stem bark.

Extended evaluation of leaf and stem bark extracts across four assay models

Guided by the preliminary DPPH findings and by patterns of traditional use, leaf and stem bark extracts were carried forward for a more thorough four-assay evaluation covering DPPH, hydrogen peroxide scavenging, phosphomolybdenum reduction, and FRAP.

DPPH radical scavenging activity

Applying the Moon and Shobomoto protocol over the 62.5–1000 µg/mL range, both leaf and stem bark extracts showed inhibition climbing steadily as concentration rose (Table 2). As noted in Materials and Methods, the difference in DPPH radical concentration and testing range between this protocol and the initial screening (Table 1) accounts for both the higher absolute IC₅₀ values seen here and the reversal in the leaf/stem-bark ranking — a point taken up further in the Discussion.

Hydrogen peroxide scavenging activity

H₂O₂ scavenging by leaf and stem bark extracts is summarized in Table 3; both followed the familiar concentration-dependent trend, with stem bark roughly twice as active as leaf extract.

Phosphomolybdenum reducing antioxidant capacity

In the phosphomolybdenum assay, absorbance climbed steadily as concentration increased for both extracts (Table 4), and the concentration needed for stem bark to reach half-maximal absorbance was lower than that needed for leaf extract.

Ferric reducing antioxidant power (FRAP)

The FRAP assay showed the same pattern: reducing power climbed as concentration rose for both extracts (Table 5), and stem bark again registered the lower — that is, more potent — EC₅₀.

Comparative antioxidant activity across assay models

Table 6 draws together the IC₅₀/EC₅₀ values for leaf and stem bark extracts across all four assays. Stem bark extract was consistently the more potent of the two — recording lower IC₅₀/EC₅₀ — in the H₂O₂, phosphomolybdenum, and FRAP assays.

Calibration curves for phenolic and flavonoid standards

Quantification of phenolic and flavonoid content relied on calibration curves built with gallic acid and quercetin standards, respectively. Over the 20–100 µg/mL range, the gallic acid curve fit the equation $y = 0.0079x$ ($r^2 = 0.9994$; Figure 1), while

the quercetin curve fit $y = 0.0031x - 0.0111$ ($r^2 = 0.9999$; Figure 2).

Total phenolic and flavonoid contents

Table 7 gives total phenolic and flavonoid contents for the three ethanol extracts. Phenolic content ranked leaf > stem bark > root bark, with every pairwise comparison reaching significance (one-way ANOVA, Tukey's HSD, $p < 0.05$). Flavonoid content told a different story, running stem bark > leaf > root bark, and here too every pairwise comparison was significant ($p < 0.05$).

Correlation analysis

Relationships between antioxidant activity and phytochemical content varied by assay and compound class. Initial-screening

DPPH IC_{50} correlated moderately, negatively with total phenolic content ($r = -0.62$) and only weakly, negatively with total flavonoid content ($r = -0.38$), while H_2O_2 -scavenging activity showed a stronger negative correlation with flavonoid content ($r = -0.71$). None of these reached statistical significance ($p > 0.05$ throughout) — unsurprising given that only three morphological parts were available for comparison ($n = 3$, $df = 1$), a sample size at which Pearson's r carries almost no statistical power. These figures are best read as descriptive trends rather than confirmed relationships, pending replication in studies with more independent samples or accessions.

Table 1: IC_{50} Values of *C. africana* Extracts and Ascorbic Acid in the Initial DPPH Screening

Sample	IC_{50} Value ($\mu\text{g/mL}$)
Leaf extract	26.90 ± 0.004
Stem bark extract	58.27 ± 0.006
Root bark extract	39.34 ± 0.003
Ascorbic acid	6.43 ± 0.004

Values are expressed as mean $\pm$ SD ($n = 3$).

Table 2: DPPH Radical Scavenging Activity of *C. africana* Extracts (Extended Evaluation)

Sample	Concentration ($\mu\text{g/mL}$)	% Inhibition	IC_{50} ($\mu\text{g/mL}$)	r^2
Leaf extract	62.5	17.67 ± 0.838	613.55	0.9357
	125	23.07 ± 0.176		
	250	25.48 ± 0.320		
	500	32.22 ± 0.147		
	1000	79.47 ± 0.337		
Stem bark extract	62.5	17.43 ± 0.017	385.51	0.8177
	125	22.78 ± 0.127		
	250	28.28 ± 0.683		
	500	86.38 ± 1.503		
	1000	91.69 ± 0.279		
Ascorbic acid	62.5	19.02 ± 0.032	87.94	0.9663
	125	35.95 ± 0.026		
	250	60.04 ± 0.037		
	500	88.59 ± 0.055		
	1000	97.04 ± 0.043		

Values are expressed as mean $\pm$ SD ($n = 3$).

Table 3: Hydrogen Peroxide Scavenging Activity of *C. africana* Extracts

Sample	Concentration ($\mu\text{g/mL}$)	% Inhibition	IC_{50} ($\mu\text{g/mL}$)	r^2
Leaf extract	62.5	11.76 ± 2.183	325.43	0.7351
	125	29.71 ± 0.123		
	250	63.05 ± 2.096		
	500	79.80 ± 0.587		
	1000	88.57 ± 0.300		
Stem bark extract	62.5	33.59 ± 0.111	155.26	0.8088
	125	45.53 ± 0.829		
	250	61.91 ± 0.252		
	500	86.19 ± 0.238		
	1000	91.71 ± 0.182		
Ascorbic acid	62.5	32.60	105.78	0.7809
	125	48.35		
	250	73.26		
	500	85.14		
	1000	97.06		

Values are expressed as mean $\pm$ SD ($n = 3$).

Table 4: Phosphomolybdenum Reducing Activity of *C. africana* Extracts

Sample	Concentration (µg/mL)	Absorbance (695 nm)	EC ₅₀ (µg/mL)	r ²
Leaf extract	100	0.276 ± 0.029	1682.33	0.9986
	200	0.675 ± 0.019		
	300	1.008 ± 0.008		
	400	1.347 ± 0.003		
	500	1.679 ± 0.023		
Stem bark extract	100	0.453 ± 0.014	1224.25	0.9924
	200	0.941 ± 0.003		
	300	1.290 ± 0.038		
	400	1.759 ± 0.007		
	500	2.030 ± 0.030		
Ascorbic acid	100	0.802 ± 0.011	936.40	0.9933
	200	1.263 ± 0.102		
	300	1.678 ± 0.220		
	400	2.083 ± 0.044		
	500	2.705 ± 0.015		

Values are expressed as mean ± SD (n = 3).

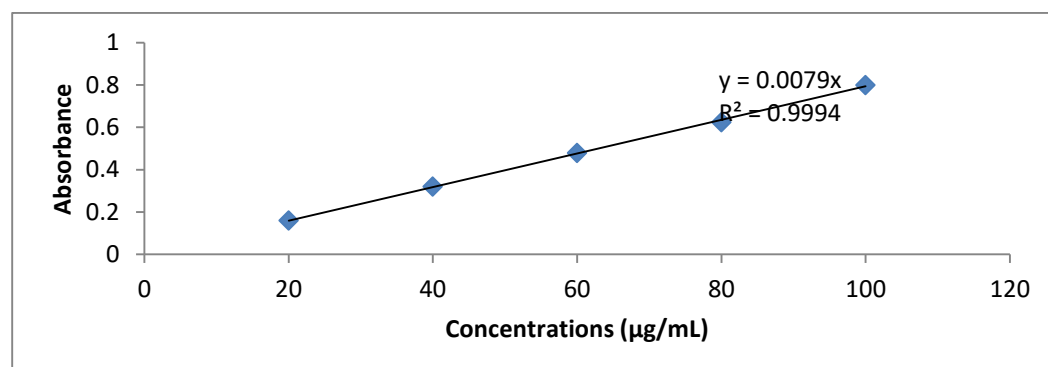
Table 5: FRAP Activity of *C. africana* Extracts

Sample	Concentration (µg/mL)	Absorbance (700 nm)	EC ₅₀ (µg/mL)	r ²
Leaf extract	100	0.233 ± 0.058	942.17	0.9068
	200	0.267 ± 0.058		
	300	0.667 ± 0.058		
	400	1.733 ± 0.153		
	500	2.333 ± 0.158		
Stem bark extract	100	0.367 ± 0.153	658.56	0.9497
	200	0.667 ± 0.058		
	300	1.467 ± 0.322		
	400	2.600 ± 0.436		
	500	3.967 ± 0.586		
Ascorbic acid	100	34.221 ± 0.011*	199.71	0.9864
	200	49.651 ± 0.220*		
	300	67.763 ± 0.120*		
	400	81.562 ± 0.320*		
	500	91.432 ± 0.203*		

Values are expressed as mean ± SD (n = 3); *For ascorbic acid, values represent % inhibition.

Table 6: Comparative IC₅₀/EC₅₀ Values (µg/mL) of *C. africana* Extracts Across Antioxidant Assays

Assay Model	Leaf Extract	Stem Bark Extract	Ascorbic Acid
DPPH	613.55	385.51	87.94
H ₂ O ₂	325.43	155.26	105.78
Phosphomolybdenum	1682.33	1224.25	936.40
FRAP	942.17	658.56	199.71

**Figure 1: Calibration curve for the Standard Gallic acid powder**

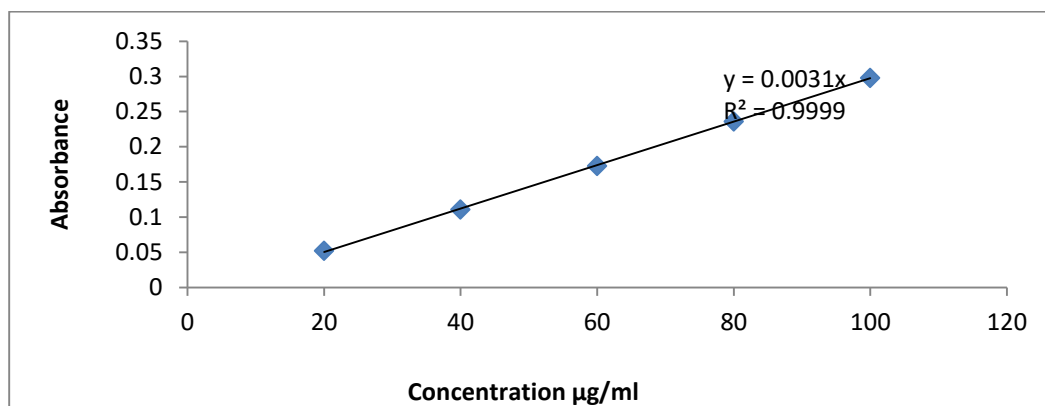


Figure 2: Calibration curve for the standard Quercetin powder

Table 7: Total Phenolic and Flavonoid Contents of *C. africana* Extracts

Sample	Total Phenolics (mg GAE/g dw)	Total Flavonoids (mg QE/g dw)
Leaf	2.17 ± 0.041 ^a	0.62 ± 0.064 ^b
Stem bark	1.14 ± 0.045 ^b	0.85 ± 0.043 ^a
Root bark	0.88 ± 0.054 ^c	0.41 ± 0.044 ^c

Values are expressed as mean ± SD ($n = 3$). GAE = gallic acid equivalents; QE = quercetin equivalents; dw = dry weight. Entries in a given column that do not share a superscript letter (^a, ^b, ^c) differ significantly (one-way ANOVA, Tukey's HSD, $p < 0.05$).

Discussion

This investigation aimed to characterize the antioxidant potential and phytochemical profile of the different morphological parts of *Commiphora africana*, an important plant in African traditional medicine. Every plant part examined showed measurable antioxidant activity, albeit of differing strength, lending scientific context to the ethnomedicinal use of this species and adding to recent reports on its biological properties [3, 6].

In the initial DPPH screening (Table 1), leaf extract came out as the strongest radical scavenger ($IC_{50} = 26.90 \mu\text{g/mL}$), ahead of root bark ($39.34 \mu\text{g/mL}$) and stem bark ($58.27 \mu\text{g/mL}$). Because leaves are the plant's main photosynthetic organ and sit directly exposed to UV light and other environmental stressors, they tend to build up higher levels of protective antioxidant metabolites [22] — a pattern that fits both this result and recent reports on the antioxidant capacity of *C. africana* leaves [5].

Notably, the DPPH IC_{50} values obtained for leaf and stem bark in the extended evaluation (613.55 and $385.51 \mu\text{g/mL}$, respectively; Table 2) are far higher than and reverse the order seen in the initial screening (Table 1). The explanation lies in the assay conditions themselves: the initial screening used a comparatively dilute DPPH radical (0.002% w/v) over a lower extract range (6.25–100 $\mu\text{g/mL}$), following Hossain et al. [14], whereas the extended evaluation used a far more concentrated radical (0.135 mM) across a higher extract range (62.5–1000 $\mu\text{g/mL}$), following Moon and Shobomoto [15]. A more concentrated radical demands proportionally more antioxidant to reach 50% scavenging, which alone would push IC_{50} upward; it is also plausible that the two protocols engage different constituents of the leaf and stem bark extracts to different degrees, which would help explain the ranking reversal. Assay-to-assay differences of the kind discussed below (DPPH versus H_2O_2 versus reducing-power assays) can independently produce divergent rankings, but it bears emphasizing that the Table 1 and Table 2 DPPH figures come from two distinct

protocols rather than a single repeated measurement, and so are not interchangeable. Adopting one harmonized DPPH protocol across all plant parts and evaluation stages in future work would permit a cleaner, protocol-independent comparison.

Across the four-assay extended evaluation, stem bark consistently outperformed leaf extract in H_2O_2 scavenging, phosphomolybdenum reduction, and FRAP. The likely reason is that each assay probes a different antioxidant mechanism. DPPH scavenging chiefly reflects an antioxidant's ability to donate a hydrogen atom or electron to a stable radical [21]; the H_2O_2 assay instead captures the capacity to break down hydrogen peroxide itself, a reactive oxygen species that can spawn highly damaging hydroxyl radicals via Fenton chemistry [16]; the phosphomolybdenum assay tracks the antioxidant-driven reduction of Mo(VI) to Mo(V), visible as a green phosphate/Mo(V) complex absorbing maximally at 695 nm [17]; and FRAP follows the reduction of ferricyanide (Fe^{3+}) to ferrocyanide (Fe^{2+}), which then forms a Prussian-blue complex with ferric chloride absorbing at 700 nm [18]. The phosphomolybdenum and FRAP assays, taken together, essentially gauge electron-donating (reducing) capacity. Stem bark's edge in these reducing-power assays, paired with its solid H_2O_2 -scavenging performance ($IC_{50} = 155.26 \mu\text{g/mL}$), points to constituents that are especially good both at donating electrons and at neutralizing reactive oxygen species — a combination with real clinical relevance given H_2O_2 's role in inflammation, neurodegeneration, and carcinogenesis [23]. This lines up with Ahmad et al.'s recent report of strong H_2O_2 -scavenging and reducing-power activity in *C. africana* extracts [3], as well as with Jimoh et al.'s observations on the reducing power of this species [6].

Total phenolic and flavonoid contents were distributed unevenly across the plant parts. Leaf extract held the highest phenolic content (2.17 mg GAE/g dw), which fits both the established view that phenolics are major drivers of radical-scavenging capacity [24] and the leaf extract's strong showing in

the initial DPPH screening. Phenolics act through several overlapping mechanisms — direct radical scavenging, metal chelation, and enzyme modulation among them [10] — and the phenolic levels measured here sit within the range reported for other African traditional medicinal plants [3, 19].

Flavonoid content told a different story: stem bark extract had the highest level (0.85 mg QE/g dw), consistent with its stronger performance in the H₂O₂-scavenging and reducing-power assays. Their benzopyrone core, studded with hydroxyl groups, makes flavonoids effective antioxidants through hydrogen- and electron-donation, resonance stabilization of radical intermediates, and metal chelation [12, 25]. One caveat is worth flagging: the aluminum chloride colorimetric method used here selectively detects flavones and flavonols bearing free 3- or 5-hydroxyl groups via their 4-keto complex, and is less sensitive to other subclasses such as flavanones, flavan-3-ols, and anthocyanidins — so the values reported should be read as an index of flavonoid content rather than a complete measure of it. Recent HPLC-MS work on *C. africana* extracts has identified quercetin, isoquercitrin, rutin, and kaempferol among its flavonoids [5] — compounds with well-documented antioxidant activity through the mechanisms just described, offering a plausible chemical explanation for stem bark's reducing-power advantage. Root bark, meanwhile, had the lowest phenolic and flavonoid content of the three parts, in line with the broader observation that underground organs tend to carry fewer phenolic antioxidants than aerial ones, even if they may store other bioactive compound classes instead [26].

Interestingly, the stem bark exhibited greater activity than the leaf extract in several assays despite its lower total phenolic content: it suggests composition matters more than sheer quantity — the specific phenolic compounds present, their structures, and any synergy between them may drive antioxidant activity more than total phenolic content alone does [10]. The correlation data point the same way: although not statistically significant given the small number of plant parts, the negative association between H₂O₂-scavenging activity and flavonoid content ($r = -0.71$) was numerically stronger than that between DPPH activity and flavonoid content ($r = -0.38$), hinting descriptively that flavonoids in this species matter more for reducing/H₂O₂-scavenging mechanisms than for direct DPPH radical scavenging.

These part-to-part differences in antioxidant activity give a plausible scientific grounding for the selective way traditional medicine deploys different plant parts. Healers across Northern Nigeria and elsewhere in Africa routinely favor particular morphological parts of *C. africana* for particular complaints, which suggests an empirical grasp of how bioactive constituents are unevenly distributed through the plant [6]. Stem bark's H₂O₂-scavenging and reducing-power activity could well underlie its traditional application to oxidative-stress- and inflammation-related conditions such as wounds, inflammatory disorders, and snakebite [3, 7], and the antioxidant activity documented here may also feed into the reported anti-inflammatory, antiparasitic, and hepatoprotective effects of *C. africana* [3-4], since oxidative stress contributes to the pathology of these conditions and antioxidants can slow disease progression by lowering inflammatory mediators, limiting cellular damage, and supporting immune function [23]. Ahmad and colleagues recently reported hepatoprotective and nephroprotective effects for *C. africana* extracts in a carbon-tetrachloride toxicity model, where biochemical and histological

parameters were significantly restored — further evidence of this species' therapeutic promise [3].

Work on other *Commiphora* species adds further perspective on phytochemical diversity within the genus. Bin Mokaizh and colleagues optimized extraction conditions for *Commiphora gileadensis* bark and, under optimized conditions, reported total phenolic content of 77.21 mg GAE/g dw and total flavonoid content of 23.12 mg QE/g dw [13] — figures well above those found here, a gap more likely explained by species differences, geographic origin, and extraction methodology than by any shortfall in bioactive potential in *C. africana*.

Limitations of the Study

This study was limited by the use of crude extracts, which prevented identification of the specific bioactive compounds responsible for the observed antioxidant effects. The *in vitro* assays used cannot fully predict *in vivo* efficacy because of pharmacokinetic factors. Total phenolic and flavonoid contents were measured as aggregate values rather than individual compounds, and the small sample size for correlation analysis limits the strength of statistical inferences. In addition, the use of different DPPH protocols restricted direct comparison of results across evaluation stages. Future studies should include bioassay-guided isolation of active constituents, comprehensive phytochemical profiling, *in vivo* validation, and assessment of seasonal, geographical, and synergistic influences on antioxidant activity.

Conclusion

The findings demonstrate that the antioxidant activity of *Commiphora africana* varies among plant parts, with the leaf exhibiting the highest phenolic content and strongest DPPH radical-scavenging activity, while the stem bark showed superior hydrogen peroxide scavenging and reducing power. These results provide scientific support for the traditional use of specific plant parts and highlight *C. africana* as a promising natural source of antioxidants for phytomedicinal and functional food applications. Further studies should focus on isolating the active compounds, elucidating their mechanisms of action, and confirming their efficacy and safety *in vivo*.

Declarations

Ethical approval

Ethical approval was not required for this study, as it did not involve human participants, human materials, or animals. The plant material used was collected and identified in accordance with institutional guidelines, and a voucher specimen (No. 2848) was deposited at the Herbarium, Department of Botany, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria.

Informed consent

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Competing interests / Conflict of interest

The authors declare that they have no competing interests.

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Authors' Contributions

AZA: Methodology, laboratory investigations, formal analysis, writing – original draft. UFS: Conceptualization, supervision, methodology, writing – review and editing. AA: Supervision, resources, writing – review and editing. All authors read and approved the final manuscript.

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Artificial Intelligence (AI) Disclosure

The authors used an AI-based writing and editing assistant (Claude, Anthropic) to assist with manuscript restructuring, reference formatting, and language editing in accordance with journal guidelines, and to perform the statistical calculations (ANOVA, Tukey's HSD, and correlation significance testing) reported herein from the authors' summary data. The authors reviewed all AI-assisted content and calculations and take full responsibility for the final manuscript.

References

- World Health Organization (WHO), 2022. WHO establishes the Global Centre for Traditional Medicine in India. Available: <https://www.who.int/initiatives/who-global-centre-for-traditional-medicine> [Accessed 28 July 2026].
- Elujoba AA, 2005. Medicinal plants and herbal medicines in the treatment and management of diseases: The Nigerian experience. *Nigerian Journal of Natural Products and Medicine*, 9: 5-10.
- Ahmad SM, Adamu J, Alhassan I, Muhammad IU, 2025. Comparative and combined evaluation of *Mitracarpus hirtus* and *Commiphora africana* extracts for antioxidant, antimicrobial, hepatoprotective, and nephroprotective activity. *Sokoto Journal of Medical Laboratory Science*, 10(3). <https://doi.org/10.4314/sjmls.v10i3>
- Jansen O, Angenot L, Tits M, Nicolas JP, De Mol P, Nikiema JB, Frederich M, 2010. Evaluation of 13 selected medicinal plants from Burkina Faso for their antiparasitocidal properties. *Journal of Ethnopharmacology*, 130(1): 143-150. <https://doi.org/10.1016/j.jep.2010.04.021>
- Compaore M, Meda RNT, Kiendrebeogo M, 2024. Antioxidative, anti-inflammatory potentials and phytochemical profile of *Commiphora africana* (A. Rich.) Engl. (Burseraceae) and *Loeseneriella africana* (Willd.) (Celastraceae) stem leaves extracts. *Carta Evidence*. Available: <https://carta-evidence.org/paper/221530e50f766ae5527ae15568c9b9969a6d47777cd5f6b3b493db57b472357d/>
- Jimoh I, Alhassan I, Asipita PO, Evinemi PA, Musa LA, 2024. An investigation of the phytochemical composition and antimicrobial activities of *Commiphora africana* stem bark extract. *International Journal of Global Sustainable Research*, 2(8): 523-530. <https://doi.org/10.59890/ijgsr.v2i8.2868>
- Ezekiel I, Mabrouk MA, Ayo JO, 2010. Study of the effect of hydroethanolic extract of *Commiphora africana* (stem-bark) on inflammation and pain in rodents. *Asian Journal of Medical Sciences*, 2(3): 81-84.
- Ma J, Jones SH, Hecht SM, 2005. A dihydroflavonol glucoside from *Commiphora africana* that mediates DNA strand scission. *Journal of Natural Products*, 68(1): 115-117. <https://doi.org/10.1021/np0497000>
- Sies H, 1997. Oxidative stress: Oxidants and antioxidants. *Experimental Physiology*, 82(2): 291-295. <https://doi.org/10.1113/expphysiol.1997.sp004024>
- Shahidi F, Ambigaipalan P, 2015. Phenolics and polyphenolics in foods, beverages and spices: Antioxidant activity and health effects - A review. *Journal of Functional Foods*, 18: 820-897. <https://doi.org/10.1016/j.jff.2015.06.018>
- Khenouf S, Amira S, Arrar L, Baghiani A, 2010. Effect of some phenolic compounds and Quercus tannins on lipid peroxidation. *World Applied Sciences Journal*, 8(9): 1144-1149.
- Spencer JPE, 2012. Flavonoids: Modulators of brain function? *British Journal of Nutrition*, 108(S1): S12-S20. <https://doi.org/10.1017/S0007114512005875>
- Bin Mokaizh AA, Nour AH, Aini Mahata S, Ukaegbu CI, Elnour AAM, AL-Farga A, 2025. Evaluation of soxhlet extraction parameters for the recovery of improved bioactive compounds from *Commiphora gileadensis* bark. *Grasas y Aceites*, 76(2): 2261. <https://doi.org/10.3989/gya.1101242.2261>
- Hossain MA, Al-Raqmi KAS, Al-Mijazy ZH, Weli AM, Al-Riyami Q, 2015. Study of total phenol, flavonoids contents and phytochemical screening of various crude extracts of locally grown *Myrtus communis*. *Asian Pacific Journal of Tropical Biomedicine*, 5(8): 676-680. <https://doi.org/10.1016/j.apjtb.2015.05.001>
- Moon, J.K., Shibamoto, T. (2009). Antioxidant assays for plant and food components. *Journal of Agricultural and Food Chemistry*, 57(5), 1655–1666.
- Ruch RJ, Cheng SJ, Klaunig JE, 1989. Prevention of cytotoxicity and inhibition of intercellular communication by antioxidant catechins isolated from Chinese green tea. *Carcinogenesis*, 10(6): 1003-1008. <https://doi.org/10.1093/carcin/10.6.1003>
- Prieto P, Pineda M, Aguilar M, 1999. Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: Specific application to the determination of vitamin E. *Analytical Biochemistry*, 269(2): 337-341. <https://doi.org/10.1006/abio.1999.4019>

18. Oyaizu M, 1986. Studies on products of browning reaction: Antioxidative activities of products of browning reaction prepared from glucosamine. Japanese Journal of Nutrition, 44(6): 307-315. <https://doi.org/10.5264/eiyogakuzashi.44.307>
19. Compaore M, Lamien-Meda A, Mogosan C, Lamien CE, Kiendrebeogo M, Vostinaru O, Kiendrebeogo M, 2011. Antioxidant, diuretic activities and polyphenol content of *Stereospermum kunthianum* Cham. (Bignoniaceae). Natural Product Research, 25(19): 1777-1788. <https://doi.org/10.1080/14786419.2010.529546>
20. Makkar HPS, 2003. Quantification of Tannins in Tree and Shrub Foliage: A Laboratory Manual. Kluwer Academic Publishers: Dordrecht.
21. Brand-Williams W, Cuvelier ME, Berset C, 1995. Use of a free radical method to evaluate antioxidant activity. LWT - Food Science and Technology, 28(1): 25-30. [https://doi.org/10.1016/S0023-6438\(95\)80008-5](https://doi.org/10.1016/S0023-6438(95)80008-5)
22. Close DC, McArthur C, 2002. Rethinking the role of many plant phenolics - protection from photodamage not herbivores? Oikos, 99(1): 166-172. <https://doi.org/10.1034/j.1600-0706.2002.990117.x>
23. Halliwell B, Gutteridge JMC, 2015. Free Radicals in Biology and Medicine, 5th ed. Oxford University Press: Oxford.
24. Rice-Evans CA, Miller NJ, Paganga G, 1996. Structure-antioxidant activity relationships of flavonoids and phenolic acids. Free Radical Biology and Medicine, 20(7): 933-956. [https://doi.org/10.1016/0891-5849\(95\)02227-9](https://doi.org/10.1016/0891-5849(95)02227-9)
25. Pietta PG, 2000. Flavonoids as antioxidants. Journal of Natural Products, 63(7): 1035-1042. <https://doi.org/10.1021/np9904509>
26. Foti MC, 2022. Antioxidant properties of phenols. Journal of Pharmacy and Pharmacology, 74(2): 167-181. <https://doi.org/10.1093/jpp/rgab060>