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Antioxidant activities of *Daniellia oliveri* (Rolfe) Hutch. & Dalziel and *Daniellia ogea* (Harms) Rolfe ex Holland (Caesalpiniaceae)

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ABSTRACT

Daniellia oliveri and *Daniellia ogea* (Caesalpiniaceae) are medicinal plants used for their various ethnomedicinal uses. Cellular damage induced by free radicals has been implicated in several diseases. Antioxidants possess the ability to protect the body from damage caused by free radical-induced oxidative stress through the inhibition of oxidation directly or indirectly. The aim of this study is to evaluate the *in-vitro* antioxidant activities of the leaves and stem bark extracts of *D. oliveri* and *D. ogea* using different *in vitro* assays including hydroxyl radical scavenging, reducing power, ferrous ion (Fe^{2+}) chelating and lipid peroxidation inhibitory activities. The total polyphenolic contents in the extracts were also determined using standard methods. All the extracts significantly ($p < 0.05$) inhibited hydroxyl radical in a concentration-dependent manner. The reducing power activity of the extracts were in the order; *D. oliveri* stem bark > *D. ogea* stem bark > *D. ogea* leaf > *D. oliveri*. Also, *D. oliveri* leaf had the highest lipid peroxidation inhibitory activity (IC_{50} = 3.71 µg/mL) compared with tocopherol and quercetin (IC_{50} = 4.84 and 26.58 µg/mL). The iron-chelating activity of the extracts was low compared to EDTA. Additionally, total polyphenolic content estimation revealed a considerable amount of phenolics, flavonoids and proanthocyanidins which may be responsible for the antioxidant activity exhibited by the extracts. These results provide the scientific evidence suggesting the potential antioxidant property of *D. oliveri* and *D. ogea* extracts in preventing diseases associated with oxidative stress.

Keywords: *Daniellia ogea*, *Daniellia oliveri*, Caesalpinioideae, antioxidant, total polyphenolic content.

Introduction

Antioxidants are an important class of substances which possess the ability to protect the body from damage caused by free radical-induced oxidative stress through the inhibition of oxidation directly or indirectly.[1] The main attribute of antioxidants is their ability to mop up free radicals.[2] The antioxidants in biological system can either be enzymatic or non-enzymatic. The enzymatic antioxidants include catalase (CAT), superoxide dismutase (SOD), glutathione (GSH) and peroxidase (GPx) systems,[3] while the non-enzymatic antioxidants include reducing agents such as *β*-carotene, vitamin C, vitamin E, selenium and polyphenols; these all catalyze neutralization of many free radicals and therefore exert therapeutic role by being oxidized themselves.[4] Overproduction of free radicals and the unbalanced mechanisms of antioxidant defense result in the onset of numerous chronic clinical disorders such as inflammatory diseases, ageing, asthma, diabetes mellitus, cardiovascular diseases, peptic ulcer, rheumatoid arthritis, cancer and neurodegenerative disorders.[5] Several synthetic antioxidants are available in the market amongst which include butylated hydroxyl toluene (BHT) and butylated Hydroxyl anisol (BHA). However, their use is restricted because of their reported adverse health implications including carcinogenic effects and pathological damage to kidney and other vital organs.[6,7] Therefore, the development of more effective antioxidants and replacement of the synthetic compounds with natural antioxidants from medicinal plants are of research interest. Many scientific reports indicate that the antioxidant potential of medicinal plants may be related to the concentration of their phenolic compounds. These compounds are of great importance in preventing the onset and/or progression of most of the aforementioned human diseases.[8,9]

Daniellia oliveri (Rolfe) Hutch and Dalziel and *Daniellia ogea* (Harms) Rolfe ex Holland belong to the Caesalpiniaceae family. *Daniellia oliveri* is identified by its refined straight trunk and ascending branches. It can be up to a height of 9-25 m, (only a few reaching up to 45 m) with diameter of 150 – 200 cm. On the other hand, *Daniellia ogea* grows into large deciduous trees with altitude of 40-50 m, in the form of cylindrical trees, having a diameter of up to 125 cm with short, rounded buttresses at the base. In Nigeria, it is commonly found in swampy vegetation following the removal of the plantation trees.[10]

The different parts of both species have been used traditionally for the management of various diseases in Africa. A decoction of the leaves and bark of *D. oliveri* is used for the treatment of gastrointestinal complaint, headaches, and as a mouthwash to treat toothache.[11] *D. oliveri* has been reported to have, among other properties, antinociceptive,[12-14] cytotoxic,[15] hepatoprotective and antioxidant,[16] anti-hyperglycemic,[17] and anthelmintic activities.[18,19] In addition, the antioxidant activity of the seed oil,[11] oleoresin [20] and leaves, stembark and root bark [21] have been reported.

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Ethnobotanically, the stem bark of *D. ogea* is taken in Senegal as an aphrodisiac. A decoction of the root is taken as a treatment of gonorrhea and malaria in Nigeria and Ghana. The gum is used in Nigeria as a purgative agent and for the treatment of snakebite.[10] The plant is also used in Ghana for the treatment of cough and asthma.[10] There are few reports on the pharmacological activity of *D. ogea*. A recent report demonstrated the antimalarial[22] and modulatory potentials[23] of the plant. A study on the chemical constituents revealed the major component in the leaf oil includes caryophyllene oxide (20.1%), humulene oxide (6.9%), *α*-humulene (3.8%) and *β*-selinene (3.8%).[24] In this study, a comparative antioxidant activity of the leaves and bark extracts of *Daniellia oliveri* and *Daniellia ogea* was investigated. The total polyphenolic contents in the extracts were also determined.

Materials and Methods

Collection of plant materials

Fresh leaves and stem bark of *D. oliveri* were collected in July 2010 along Lagos-Ibadan expressway at kilometer 42 while *D. ogea* was collected at Odofin Agbegi, Ikire, Osun State, Nigeria. The plants were identified by Mr. T.K. Odewo of the Herbarium Unit of Botany Department, University of Lagos, Lagos, Nigeria and assigned voucher numbers (*D. oliveri* - LUH 2784 and *D. ogea*- LUH 2783). The samples were then deposited at the Herbarium Unit, Department of Botany, University of Lagos, Nigeria.

Extraction of plant materials

Fresh samples of the leaves and stem bark of *D. oliveri* and *D. ogea* were air dried at room temperature until complete dryness was achieved. The dried samples were then ground to powder using a mechanical grinder (Christy and Norrison, Chelmsford-England, 8000 rev per min, 810 LAB MILL, 50158). The powdered samples (400 g of each) were macerated in 1.5 L of absolute ethanol for 24 hours. The extracts were filtered using muslin cloth and the process was repeated for complete extraction. Each of the combined extracts were filtered and concentrated to dryness using rotary evaporator. The yield of the resultant extracts was calculated and extracts stored at 4^{o}C until use.

Phytochemical analysis

The extracts of *D. oliveri* and *D. ogea* (leaves and stem bark) were analyzed for the presence of secondary metabolites using standard qualitative methods.[25, 26]

Estimation of total phenolic content

Total phenolic content was performed according to the protocol of Amaeze *et al.*[27] Gallic acid was prepared in methanol at five concentrations (0.01-0.05 mg/mL) and the plant extracts were also prepared in methanol at a concentration of 1 mg/mL. From each of the extract solutions, 0.5 mL was mixed with 2.5 mL of a 1 in 10 dilution of Folin-Ciocalteau's reagent and 2 mL of 7.5% sodium carbonate. The mixture was left for 30 min at room temperature and the absorbance was read at 760 nm using a spectrophotometer. All determinations were performed in triplicates. The total phenolic contents were expressed as gallic acid equivalent (GAE) using the following equation based on calibration curve: y = 8.4944x + 0.0767, R^2 = 0.9983, where y is the absorbance and x is the gallic acid equivalent (mg/g).

Estimation of total flavonoid content

Total flavonoid content were determined using the procedure of Sofidiya *et al.*[28] Quercetin, prepared in methanol at five different concentrations of 0.01-0.05 mg/mL was used as a reference. Ethanol solution of 2% $AlCl_3$ (1.5 mL) was added to 1.5 mL of each extract sample. The mixture was incubated for 1 h at room temperature after which the absorbance was measured at 420 nm. A yellow colour indicated the presence of flavonoids. Extract solutions were prepared in methanol and evaluated at a final concentration of 1 mg/ml. Total flavonoid contents were calculated as quercetin equivalent (mg/g) using the equation based on the calibration curve: y = 8.3558x + 0.2156, R^2 = 0.9593, where y is the absorbance and x is the quercetin equivalent (mg/g).

Estimation of total proanthocyanidin content

Determination of proanthocyanidin content was based on the procedure reported by Asekunowo *et al.*[29] Briefly, 0.5 mL of 1.0 mg/mL of extract solution was mixed with 1.5 mL of 4% vanillin-methanol solution and 0.75 mL concentrated hydrochloric acid. The mixture was left for 15 min at room temperature and the absorbance was measured at 500 nm. Total proanthocyanidin content was calculated with respect to catechin standard curve and results expressed as catechin equivalent (mg/g) following equation: y = 4.9944x + 0.0068, R^2 = 0.9829, where y is the absorbance and x is the catechin equivalent (mg/g).

In vitro antioxidant activity

Each of the plant extracts (10 mg) was dissolved in 10 mL of 95% methanol to make a concentration of 1 mg/mL and then diluted to prepare the different concentrations for antioxidant assays. Tocopherol and quercetin were used as references in all the assays except where otherwise stated. All assays were performed in triplicates.

Hydroxyl radical scavenging assay

Hydroxyl radical scavenging activity of *D. oliveri* and *D. ogea* extracts were assayed by adopting the method described by Shah *et al.*[30] with some modifications. A volume of 0.2 mL of extracts at concentration range of 10-100 µg/mL was added to a reaction mixture containing 0.2 mL of ferric chloride (0.1 M) and 0.2 mL of ethylenediaminetetraacetic acid, EDTA (0.1 M) (ratio 1:1), 0.2 mL of hydrogen peroxide (0.2 M, prepared in 20 mM of phosphate buffer pH 7.4) and 0.2 mL of 2-deoxyribose (3 mM, in 50 mM phosphate buffer, pH 7.4). Ascorbic acid (0.2 mL, 0.3 M) was then added to initiate a Fenton reaction. The reaction mixture was incubated for 1 h at 37^{o}C. After incubation, 0.2 mL of trichloroacetic acid, TCA (2.8% w/v) and 0.2 mL of thiobarbituric acid, TBA (1% w/v prepared in 50 mM NaOH) was added and placed on a boiling water bath for 15 min. After cooling, the absorbance of the reaction mixture was measured at 532 nm and was converted into percentage inhibition of deoxyribose degradation according to the equation;

Scavenging activity (%) = [1- (Sample absorbance)] /Control absorbance x 100

Reducing power

The reducing power capability of each plant extract was determined according to reported procedure by Jing *et al.*[31] In brief, 1.5 mL of *D. oliveri* and *D. ogea* leaves and stem bark extract solutions (10 to 100 mg/mL) were mixed with 1.5 mL of sodium phosphate buffer (0.2 M, pH 6.6) and 1.5 mL of potassium ferricyanide (1%, w/v). The mixture was incubated for 20 min at 50˚C and the mixture was cooled immediately. After incubation, 1.5 mL of trichloroacetic acid, (10%, w/v) was added. After centrifugation at 3000 rpm for 10 min, 1.5 mL of the supernatant was vigorously mixed with 1.5 mL of deionized water and 0.3 mL of ferric chloride (0.1%, w/v). After a 10 min reaction time, the absorbance of the mixture was determined at a wavelength of 700 nm against distilled water. The higher the absorbance, the stronger the reducing power of the sample.

Metal chelating activity assay

The chelating activity of the extracts was measured following a previous study reported by Sofidiya and Familoni.[32] In this method, ferrozine reacts with Fe^{2+} ions to form a purple complex that strongly absorbs at a wavelength of 562 nm, the intensity of which decreases in the presence of Fe^{2+} chelating agents. Concisely, an aliquot of 1.6 mL of deionized water and 0.05 mL of $FeCl_2$ (2 mM) was added to 0.5 mL of each of the extracts. Thereafter, 0.1 mL of ferrozine (5 mM, dissolved in methanol) was added after 30 s to initiate the reaction. The mixture was then shaken thoroughly and left for 10 min at room temperature. The absorbance of the Fe^{2+} ferrozine complex formed was measured at 562 nm. Ethylenediaminetetraacetic acid (EDTA) was used as a positive control. The chelating activity of the extract for Fe^{2+} was calculated as;

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chelating rate (%) = $(A_0 – A_1)/ A_0$ x 100

where A_0 was the absorbance of the control (blank, without extract) and A_1 was the absorbance in the presence of the extract.

Determination of Fe^{2+} ascorbate-induced lipid peroxidation

Inhibition of lipid peroxidation was estimated as illustrated by Ananthi *et al*.[33] with slight modifications. This assay is based on the reaction of the product of lipid peroxidation malondialdehyde (MDA) with thiobarbituric acid reactive species (TBARS), which strongly absorbs at a wavelength of 532 nm. For this assay, liver homogenate which was prepared in Tris-HCl buffer, pH 7.4, with 10% w/v rat liver and centrifuged for 15 min at 3000 rpm producing a colourless supernatant served as the lipid-rich media. Each extract sample (0.5 mL) at varying concentration (10-100 µg/mL) was mixed with 1 mL of liver homogenate. Peroxidation was induced upon the addition of 0.05 mL of $FeSO_4$ (0.03 M), 0.1 mL of ascorbic acid (0.1 M) and 0.1 mL of KH_2PO_4 (0.01 M). The volume of the mixture was raised by adding distilled water up to 3 mL and was incubated at 37°C for 1 h. Thereafter, to each sample tubes, 1 mL each of trichloroacetic acid (5% w/v) and thiobarbituric acid (0.8% w/v) was added. The mixture was then centrifuged at 3500 rpm for 10 min and absorbance of the supernatant was measured at 532 nm. The percentage inhibition of lipid peroxidation was calculated using the equation;

% inhibition of lipid peroxidation = $(A_{control} - A_{test})/(A_{control})$ x 100

Where $A_{control}$ is the absorbance of the control reaction and A_{test} is the absorbance in the presence of the sample extracts.

Statistical analysis

All results are expressed as mean ± SEM and differences between means were statistically analyzed using one-way analysis of variance (ANOVA) followed by Tukey's multiple range post-hoc test. Differences were considered significant at $p < 0.05$. The IC_{50} values were calculated using AAT Bioquest® – EC50 calculator.[34]

Results and Discussion

Phenolic compounds have been recognised to possess a wide range of biological activities, including antioxidant activity. In this study, the total polyphenolic contents and antioxidant activity of the ethanol extracts from the leaves and stem bark of *D. oliveri* and *D. ogea* were evaluated. Four different *in-vitro* antioxidant assays were employed, including hydroxyl radical scavenging, reducing power, metal chelating and lipid peroxidation assays.

The abilities of the extracts to inhibit hydroxyl radical-mediated deoxyribose degradation in a $FeCl_3$-EDTA-ascorbic acid and H_2O_2 reaction mixture is presented in Figure 1. All the extracts, tocopherol, and quercetin significantly ($p < 0.05$) inhibited hydroxyl radical in a concentration dependent manner. The scavenging ability of *D. oliveri* stem bark reached 40.84% at the lowest concentration of 10 µg/mL. The order of activity is; *D. oliveri* stem bark > *D. ogea* stem bark > *D. oliveri* leaf > *D. ogea* leaf. The hydroxyl radical attacks deoxyribose, which subsequently results in thiobarbituric acid reacting substance (TBARS) formation.[35] This extremely reactive free radical formed in biological system has been implicated as a major active oxygen centered radical formed from the reaction of various hydroperoxides with transition metal ions, which is capable of damaging almost every molecule found in living system causing lipid peroxidation and biological damage.[36] The results suggest the quenching ability of hydroxyl radicals and significant scavenger of active oxygen species of the extracts thus reducing the rate of chain reaction.

The reducing power assay is often used to determine the ability of an antioxidant to donate an electron or hydrogen. The reducing power of ethanol extracts of *D. oliveri* and *D. ogea* at different concentrations compared with that of tocopherol and quercetin as standards are presented in Figure 2. The increase in absorbance at 700 nm indicated better reducing power of the extracts. Among all the extracts, the highest reducing power activity was shown by *D. oliveri* stem bark followed by *D. ogea* stem bark, *D. ogea* leaf and *D. oliveri* leaf. The effect of the stem bark extract of *D. oliveri* (0.81) was higher than that of tocopherol (0.40) but less than quercetin (1.09). Studies revealed that there is a direct correlation between antioxidant activities and reducing power of certain bioactive compounds.[37] The presence of antioxidants in the extracts resulted in reduction of the Fe^{3+}/ferric cyanide complex to the ferrous form, Fe^{2+} estimated by measuring the formation of Perl's Prussian blue at the wavelength of 700 nm. These results indicate that the extracts could donate an electron and neutralize free radicals and ROS.

The iron-chelating activity of the extracts of *D. oliveri* and *D. ogea* is presented in Figure 3. All the extracts showed lower activity in this assay. The iron chelating capacity of the extracts at the highest concentration of 100 µg/mL was significantly lower ($p < 0.05$) compared to EDTA. Studies have proven that metal chelation is an important antioxidant property owing to the iron binding ability of chelating agents in reducing metal-catalyzed oxidation leading to inhibition of reactive oxygen species generation.[38] The formation of the ferrozine – Fe^{2+} complex was only interrupted by the extracts at the highest concentration, indicating chelating activity.

Lipid peroxidation causes damage to biological membranes, enzymes and proteins resulting in series of complications to human health.[39] Changes in the absorbance of reaction mixture at the 532 nm resulting from inhibition of lipid peroxidation activities of *D. oliveri* and *D. ogea* extracts are presented in Figure 4. The extracts and the standards showed high inhibitory activity of lipid peroxidation. At 100 µg/mL, the percentage inhibition obtained for the stem bark and leaf of *D. ogea* was 67.75% and 68.46%, respectively. On the other hand, the % inhibitory effect of *D. oliveri* stem bark and *D. oliveri* leaf at this concentration was 71.30% and 67.14%, respectively. Judging from the IC_{50} values (the concentration of an inhibitor that is required for 50% inhibition of its target -TBARS/lipid peroxidation), the inhibitory activity of the extracts is in the order *D. oliveri* leaf (3.71 µg/mL) > *D. ogea* stem bark (8.673 µg/mL) > *D. ogea* leaf (40 µg/mL) > and *D. oliveri* stem bark (43 µg/mL). Several studies have reported inhibitory effect of medicinal plants in lipid-rich thiobarbituric acid reactive species complex, indicating that the inhibition of lipid peroxidation by the samples could afford protection against oxidative damage.[30,32,40] In general, our results corroborate the previous reports on substantial antioxidant activities of *D. oliveri* in 2,2-diphenyl-1-picrylhydrazyl (DPPH) and phosphomolybdenum assays.[14,16,21,41]

The antioxidant activity of plants may be due to the presence of phytochemicals like polyphenolics, steroids, and triterpenes. In this study, the qualitative phytochemical screening of the extracts of *D. oliveri* and *D. ogea* revealed the presence of flavonoids, saponins, terpenoids and cardiac glycosides. In addition, alkaloids were detected in *D. ogea* stem bark and *D. oliveri* leaf extracts. However, anthraquinones were not detected in any of the extracts (Table 1). This observation is at variance with previous preliminary phytochemical reports, especially on *D. oliveri*.[42,43] The variation in results may be due to some factors such as difference in geographical location of the plant, time of collection as well as solvent used for extraction. Furthermore, quantification of the polyphenolic contents of the plant extracts revealed that *D. oliveri* stem bark had the highest phenolic content (396.71 ± 0.04 mg gallic acid equivalent/g extract) while *D. ogea* leaf contained the least phenolic content (85.94 ± 0.06 mg gallic acid equivalent/g extract) (Table 2). In the estimation of flavonoid content, the leaves of *D. ogea* recorded the highest flavonoid content (99.82 ± 0.16 mg quercetin equivalent/g of dried extract). The content of proantocyanidins were 419.11 ± 0.16, 163.29 ± 0.03, 107.56 ± 0.04, 90.00 ± 0.02 mg catechin equivalent/g of dried extracts for *D. oliveri* stem bark, *D. ogea* stem bark, *D. oliveri* leaf and *D. ogea* leaf, respectively.

Phenolic compounds are very important plant constituents because of their scavenging ability on free radicals due to their hydroxyl groups.[44] The hydroxyl donating groups in phenolics react with free radicals within the biological system resulting in antioxidant activities which may include radical scavenging, iron chelating, inhibition of lipid peroxidation and reducing power.[45]

Flavonoids are phenolic compounds with important roles in scavenging free radicals and they are valuable in preventing oxidative

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stress associated disorders.[46] Proanthocyanidins have been reported to reduce intracellular reactive oxygen species thereby playing vital role as natural antioxidant.[47]

The presence of these phytochemicals may be accountable for the varying degree of antioxidant activity observed for the extracts. Furthermore, these results corroborate many reported studies revealing significant correlation between polyphenolic content and antioxidant capacity.[48-50]

Table 1: Yield (%) and phytochemical analysis of ethanol extract of *D. ogea* and *D. oliveri*

Extract	Yield (w/w %)	Alkaloids	Anthraquinones	Flavonoids	Saponins	Terpenoids	Cardiac glycosides
Dog B	30%	+	-	+	+	+	+
Dog L	7.5%	-	-	+	+	+	+
Dol B	5%	-	-	+	+	+	+
Dol L	10%	+	-	+	+	+	+

Dog B - *D. ogea* stem bark, Dog L - *D. ogea* leaves, Dol B - *D. oliveri* stem bark, Dol L - *D. oliveri* leaves. + Detected; - Not detected

Table 2: Polyphenolic content of *D. ogea* and D. *oliveri* extracts

Plant Extract	Total phenolics (mg gallic acid equivalent/g dry extract)	Total flavonoids (mg quercetin equivalent/g dry extract)	proanthocyanidins (mg catechin equivalent/g dry extract)
Dog B	$285.26 \pm 0.04^{a,b,d}$	$16.72 \pm 0.02^{a,b,d}$	$163.29 \pm 0.03^{a,b,d}$
Dog L	$85.94 \pm 0.06^{a,b,c}$	$99.82 \pm 0.16^{a,b,c}$	$90.01 \pm 0.02^{a,b,c}$
Dol B	$396.71 \pm 0.01^{b,c,d}$	$16.64 \pm 0.01^{b,c,d}$	$419.11 \pm 0.16^{b,c,d}$
Dol L	$123.46 \pm 0.06^{a,c,d}$	$70.82 \pm 0.04^{a,b,c}$	$107.56 \pm 0.04^{a,c}$

Data are expressed as mean ± SEM, n = 3. Dog B - *D. ogea* stem bark, Dog L - *D. ogea* leaves, Dol B - *D. oliveri* stem bark, Dol L - *D. oliveri* leaves. Means with superscripts with different letters in the columns are significantly ($p < 0.05$) different from each other where $^{a}p < 0.05$- versus Dol B, $^{b}p < 0.05$ -versus Dol L, $^{c}p < 0.05$- versus Dog B and $^{d}p < 0.05$- versus Dog L.

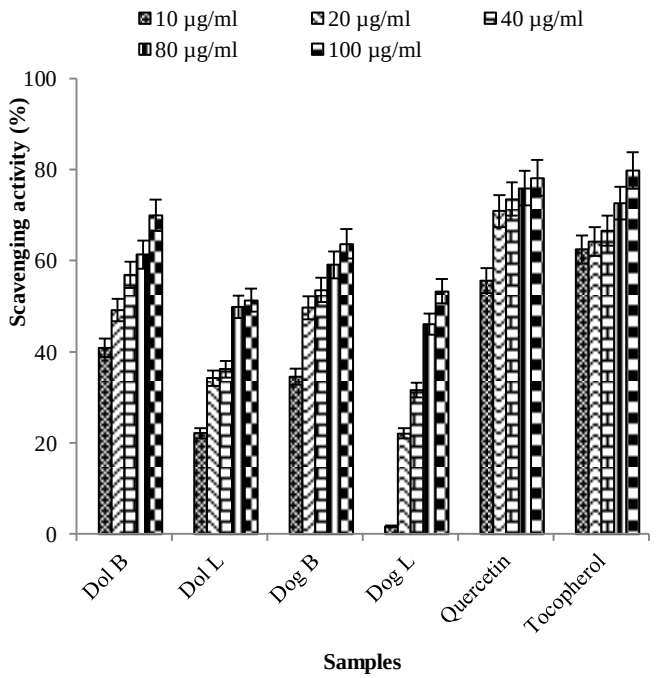

Figure 1: Hydroxyl radical scavenging of *D. oliveri* and *D. ogea* extracts.
Data are expressed as mean ± SEM, n = 3. Dol B - *D. oliveri* stem bark, Dol L - *D. oliveri* leaves, Dog B - *D. ogea* stem bark, Dog L - *D. ogea* leaves.

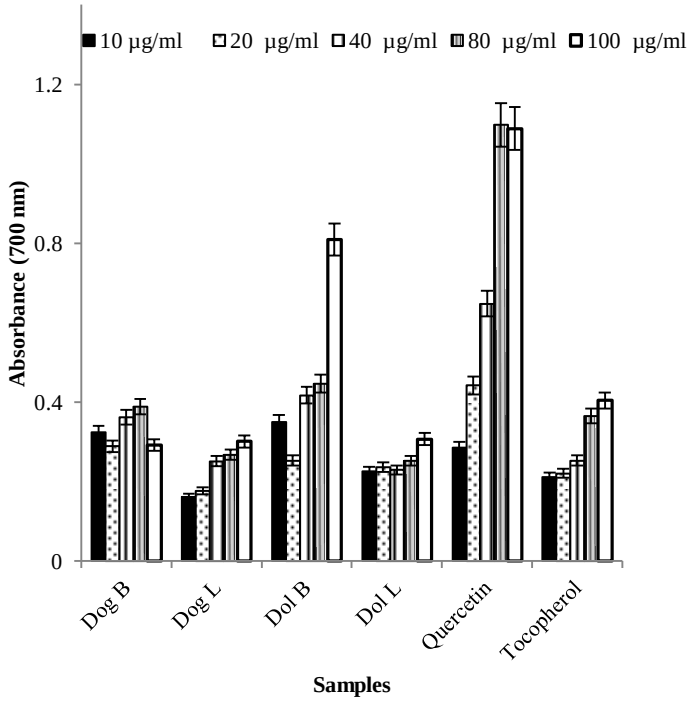

Figure 2: Reducing power of *D. ogea* and *D. oliveri* extracts.
Data are expressed as mean ± SEM, n = 3. Dog B- *D. ogea* stem bark, Dog L - *D. ogea* leaves, Dol B- *D. oliveri* stem bark, Dol L - *D. oliveri* leaves

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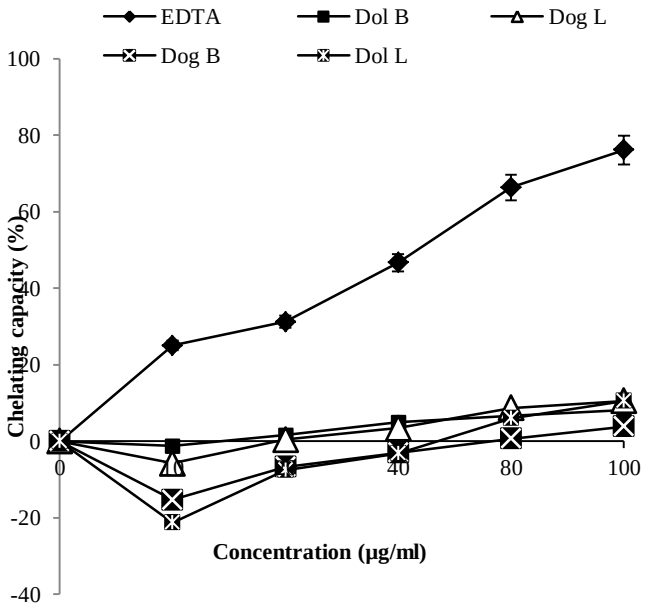

Figure 3: Fe^{2+} chelating effect of *D. ogea* and D. *oliveri* extracts in comparison with EDTA. Data are expressed as mean ± SEM, n = 3. Dog B - *D. ogea* stem bark, Dog L - *D. ogea* leaves, Dol B - *D. oliveri* stem bark, Dol L - *D. oliveri* leaf.

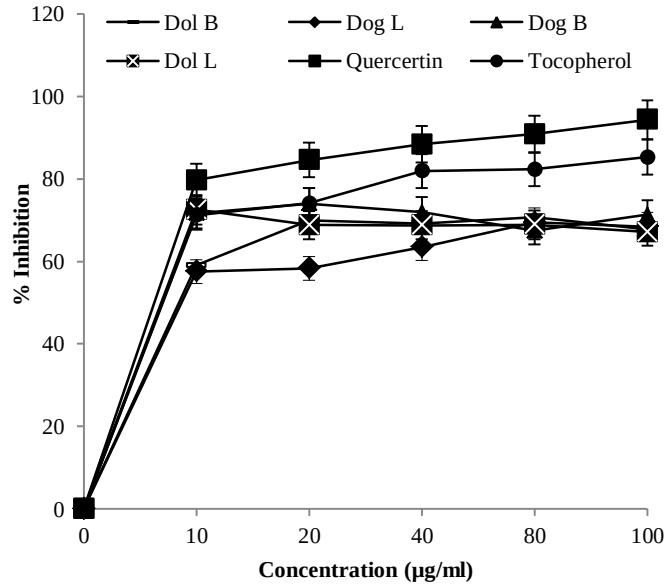

Figure 4: Inhibition of lipid peroxidation by *D. ogea* and D. *oliveri* extracts. Data are expressed as mean ± SEM, n = 3. Dog B - *D. ogea* stem bark, Dog L - *D. ogea* leaf, Dol B - *D. oliveri* stem bark, Dol L - *D. oliveri* leaf

Conclusion

The study demonstrated significant variations in the antioxidant activities of the leaves and stem bark of *D. oliveri* and *D. ogea*. The stem bark extracts of the two plants were found to have better *in vitro* antioxidant activities as demonstrated in this study. They also possessed significant total phenolic and proanthocyanidin contents. The isolation and characterization of bioactive compounds from these plants as natural antioxidant could provide valuable therapeutic agents for oxidative-stress induced disorders.

Conflict of interest

The authors declare no conflict of interest.

Authors' Declaration

The authors hereby declare that the work presented in this article is original and that any liability for claims relating to the content of this article will be borne by them.

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