Journal of Medicinal Plants Research Vol. 6(31), pp. 4682-4690, 15 August, 2012
Available online at http://www.academicjournals.org/JMPR
DOI: 10.5897/JMPR12.395
ISSN 1996-0875©2012 Academic Journals

Full Length Research Paper

Antioxidant activities of different solvent extracts of leaves and root of *Flabellaria paniculata* Cav. (Malpighiaceae)

Margaret Oluwatoyin Sofidiya[1]* and Oluwole Familoni[2]

[1]Department of Pharmacognosy, Faculty of Pharmacy, University of Lagos, Nigeria.
[2]Department of Chemistry, Faculty of Science, University of Lagos, Nigeria.

Accepted 24 July, 2012

The antioxidant activities of different solvent extracts of the leaves (ethanol (FLE), aqueous (FLH), chloroform (FLC)) and root (ethanol (FRE), aqueous (FRH) and chloroform (FRC)) of Flabellaria paniculata were screened by different methods using free radical scavenging against DPPH and hydroxyl radicals, *ex vivo* lipid peroxidation, ferrous ion chelating activity, reducing power and total antioxidant capacity in phosphomolybedum assay. The extracts (10 to 100 µg/ml) showed varying degrees of antioxidant activity in different test systems. The leaves and root extracts showed significant inhibition of lipid peroxidation and scavenging of hydroxyl radicals. The extracts also showed moderate chelating property which could explain the affinity of the extracts for iron (Fe), hence their antioxidant capability. However, in DPPH radical scavenging and reducing power assays, FRE extract had higher activity than all the extracts, and the activity is comparable to that of quercetin and tocopherol at higher concentrations (80 to 100 µg/ml) of the extract used in this study. Flavonoid content of different extracts of *F. paniculata* is in the order FLE>FLC>FRE>FRC>FRH>FLH. Ethanol extracted the highest root amount of condensed tannin (216.42 ± 0.018 mg equivalent of catechin/g of extract), while proanthocyanidin contents of leaf extracts varied from 12.7 to 47.9 mg of gallic acid equivalence (GAE)/g extract. No correlation was observed between DPPH, Fe chelating, lipid peroxidation, reducing power, and total phenolic contents of the extracts. However, proanthocyanidin content was moderately correlated with chelating (R^2 = 0.43) and DPPH radical scavenging (R^2 = 0.7811) activities. Hence, these extracts could be considered as natural antioxidants and may be useful for curing diseases arising from oxidative deterioration.

Key words: *Flabellaria paniculata*, antioxidant, polyphenolic content, solvent extraction, leaves, root.

INTRODUCTION

Oxidative stress is a condition in which there is an increased production of oxygen species and diminished levels of antioxidant system resulting in cell damage leading to the pathogenesis of a variety of human diseases (AsokKumar, 2009). The role of exogenous antioxidants in the maintenance of human health, prevention, and treatment of diseases has attracted much attention of the scientists and general public (Niki, 2010).

Exogenous antioxidant compounds may exert beneficial actions upon systems which have been deprived from sufficient amounts of endogenous antioxidants as in some cardiovascular diseases, tumors, inflammation, ulcer, and aging (Hasan et al., 2009). Antioxidants could also attenuate oxidative damage of a tissue indirectly by enhancing natural defenses of cell and/or directly by scavenging the free radical species.

Plant kingdom is a good source of a wide range of natural antioxidants. Many natural antioxidants have been found from various kinds of land plants, such as cereals, vegetables, fruits, and herbs, in which tocopherol, vitamin C, carotenoid, and flavonoid are good

*Corresponding author. E-mail: toyin_sofidiya@yahoo.co.uk. Tel: +234 803 3356 197.

sources of antioxidants (Larson, 1988). *Flabellaria* is a climbing shrub, about 3 to 15 m high. It is indigenous to the tropical West Africa and is locally used for wound healing, sores, and ulcers (Burkill, 1995). Literature on this plant is scare, however, the plant is reported to have antibacterial and wound healing properties (Olugbuyiro et al., 2010). As a part of our ongoing phytochemical and pharmacological investigations on local medicinal plants of Nigeria, this study was designed to examine the antioxidant activity of various solvent extracts of the root and leaves of *Flabellaria paniculata*. This study also seeks to determine the efficiency of different solvents for the extraction of polyphenols from this plant.

MATERIALS AND METHODS

Plant and extract preparation

F. paniculata root and leaves were collected from Egbado in Ogun State, Nigeria in July, 2010. The plant samples were authenticated by Mr T. K. Odewo of the herbarium unit of Botany Department, University of Lagos. Voucher specimen (LUH 2778) was deposited in the herbaria of the Department of Botany and Department of Pharmacognosy, University of Lagos for future reference. The leaves were air dried, while the root was cut into bits and dried in the oven at 45°C. The dried samples were ground to powder, extracted separately with solvents of varying polarity, namely, chloroform, ethanol, and water at room temperature for 24 h. Then, the extracts were filtered over Whatman No. 1 paper and evaporated to dryness under vacuum on a rotary evaporator (Heidolph-Rotacool, Germany) at 38°C. The extracts were expressed as follows: FLE, FLH, and FLC for *Flabellaria* leaf ethanol, aqueous, chloroform extracts and FRE, FRH and FRC for the root ethanol, aqueous and chloroform extracts respectively. Dried residues were subsequently re-dissolved in methanol for antioxidant assay.

Chemicals

1,1-Diphenyl-2-picrylhydrazyl (DPPH), deoxyribose, potassium ferricyanide, catechin, ascorbic acid, catechin, gallic acid, quercetin, Folin-Ciocalteu's phenol reagent, $FeCl_2$, $FeCl_3$, and ferrozine were purchased from Sigma Chemical Co. (St. Louis, MO, USA), while vanillin was from BDH (Poole, England). All the other chemicals used, including the solvents, were of analytical grade.

Experimental animals

The liver for the preparation of homogenate used in this assay was obtained from 3 albino rats which were purchased from Laboratory Animal Centre, Redeemer University, Ogun State and maintained in the Animal House of College of Medicine, University of Lagos, Nigeria. They were housed in cages and placed on standard pellet feed (Livestock Feed PLC, Ikeja, Lagos, Nigeria), and were given free access to clean water. The principles and guidelines for care and use of the laboratory animals in biomedical research (NIH, 1985) were adhered to strictly.

DPPH radical scavenging activity assay

The effect of the extracts on DPPH radicals was estimated according to the method of Liyana-pathirana and Shahidi (2005). A solution of 0.135 mM DPPH in methanol was prepared and 1.0 ml of this solution was mixed with five different concentration of each extract, ranging from 10 to 100 µg/ml. The reactions mixture was shaken thoroughly and left on the bench at room temperature for 30 min. The absorbance of the mixture was measured spectrophotometrically at 517 nm using spectrophotometer. α-tocopherol and quercetin were used as reference. The ability to scavenge DPPH radical was calculated by the following equation:

$$\text{DPPH radical scavenging activity (\%)} = \frac{\text{Absorbance of control} - \text{Absorbance of sample}}{\text{Absorbance of control}} \times 100$$

where absorbance of control is the absorbance of DPPH radical plus methanol.

Ex-vivo lipid peroxidation inhibition assay

Three male rats weighing 180 to 200 g were sacrificed under ethereal anesthesia and their livers were excised. 10% (w/v) liver homogenate was prepared in phosphate buffered saline (PBS) (pH 7.4) and centrifuged at 3000 rpm for 15 min to obtain a clear supernatant. Different concentrations (10 to 100 µg/ml) of the *F. paniculata* extracts and quercetin were incubated with 1 ml of the rat liver homogenate and the reaction initiated by the addition of 0.1 ml of $FeSO_4$ (25 µM), 0.1 ml of ascorbate (100 µM), and 0.1 ml of KH_2PO_4 (10 mM), and the volume was made up to 3 ml with distilled water and incubated at 37°C for 1 h. Then, 1 ml of 5% trichloroacetic acid (TCA) and 1 ml of thiobarbituric acid (TBA) was added to this reaction mixture and the tubes were boiled for 30 min in a boiling water bath. This was then centrifuged at 3500 rpm for 10 min. The extent of lipid peroxidation was evaluated by the estimation of thiobarbituric acid reactive substances (TBARS) level by measuring the absorbance at 532 nm (Ananthi et al., 2010).

Scavenging of hydroxyl radical by deoxyribose method

The hydroxyl radical scavenging activity of the extracts were measured by the deoxyribose method (Halliwell et al., 1987) and compared with that of quercetin and tocopherol. To the reaction mixture containing deoxyribose (3 mM, 0.2 ml), ferric chloride (0.1 mM, 0.2 ml), ethylenediaminetetraacetic acid (EDTA; 0.1 mM, 0.2 ml), ascorbic acid (0.1 mM, 0.2 ml), and hydrogen peroxide (2 mM, 0.2 ml) in phosphate buffer (pH 7.4, 20 mM) were added 0.2 ml of various concentrations of extracts. The solutions were then incubated for 30 min at 37°C. After incubation, TCA (0.2 ml, 15 % w/v) and TBA (0.2 ml, 1% w/v) in 0.25 N HCl were added. The reaction mixture was kept in a boiling water bath for 30 min and then was allowed cool. Thereafter, absorbance was measured at 532 nm and was converted into percentage inhibition of deoxyribose degradation.

Metal chelating activity assay

The chelating activity of the extracts for ferrous ions, Fe^{2+} was measured according to the method of Dinis et al. (1994). To 0.5 ml of the extract, 1.6 ml of deionized water and 0.05 ml of $FeCl_2$ (2 mM) was added. After 30 s, 0.1 ml ferrozine (5 mM) was added. Ferrozine reacted with the divalent iron to form stable magenta complex species that were very soluble in water. After 10 min at room temperature, the absorbance of the Fe^{2+} ferrozine complex was measured at 562 nm. The chelating activity of the extract for Fe^{2+} was calculated as chelating rate (%) = (A0 - A1) / A0 × 100, where A0 was the absorbance of the control (blank, without extract) and A1 was the absorbance in the presence of the extract. EDTA was used as a positive control.

Reducing power

The reducing capacity of the extracts was determined by the method of Oyaizu (1986). Varying concentrations of the solvent extracts (10 to 100 µg/ml) were mixed with phosphate buffer (2.5 ml, 0.2 M, pH 6.6) and potassium ferricyanide [$K_3Fe(CN)_6$] (2.5 ml, 1%). The mixtures were incubated at 50°C for 20 min. Then, aliquots (2.5 ml) of trichloroacetic acid (10%) were added and the mixtures were centrifuged for 10 min at 1000 g. The upper layer of the solution (2.5 ml) was mixed with distilled water (2.5 ml) and $FeCl_3$ (0.5 ml, 0.1%), and the absorbance was measured at 700 nm in a spectrophotometer. Increased absorbance of the reaction mixture is indicative of an increased reducing power.

Total antioxidant capacity by phosphomolybdenum method

The total antioxidant capacity (TAC) of the extracts was evaluated by the method of Prieto et al. (1999). This assay is based on the reduction of Mo (VI) to Mo (V) by the sample and the subsequent formation of a green phosphate/Mo (V) complex at acidic pH. Extract (0.3 ml) solution was mixed with 3 ml of reagent solution (0.6 M sulphuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). For the blank, 0.3 ml methanol was mixed with 3 ml of the reagent. The tubes containing the reaction solution were incubated at 95°C for 90 min, and then the absorbance of the test sample was measured at 695 nm. The antioxidant activity is expressed as the number of equivalents of quercetin.

Determination of total phenolics, flavonoids, and proanthocyanidins

Total phenol contents in the extracts were determined by the modified Folin-Ciocalteu method and as reported by Wolfe et al. (2003). An aliquot of the extract was mixed with 5 ml Folin-Ciocalteu reagent (previously diluted with water 1:10 v/v) and 4 ml (75 g/L) of sodium carbonate. The tubes were vortexed for 15 s and allowed to stand for 30 min at 40°C for color development. Absorbance was then measured at 760 nm. Samples of extract were evaluated at a final concentration of 1 mg/ml. Total phenolic contents were expressed as mg gallic acid equivalent (GAE)/g dry extract using the following equation based on the calibration curve: $y = 8.4794x + 0.078$, $R^2 = 0.9984$, where x is the absorbance and y is the GAE (mg/g).

Total flavonoids were determined using the method of Ordonez et al. (2006). To 0.5 ml of the sample, 0.5 ml of 2% $AlCl_3$ ethanol solution was added. After 1 h at room temperature, the absorbance was measured at 420 nm. A yellow color indicated the presence of flavonoids. Extract samples were evaluated at a final concentration of 1 mg/ml. Total flavonoid contents were calculated as quercetin (mg/g) using the following equation based on the calibration curve: $y = 8.3558x + 0.2156$, $R^2 = 0.9593$, where x is the absorbance and y is the quercetin equivalent (mg/g). Determination of proanthocyanidin was based on the procedure reported by Sun et al. (1998). A volume of 0.5 ml of 1 mg/ml extract solution was mixed with 3 ml of 4% vanillin-methanol solution and 1.5 ml hydrochloric acid; the mixture was allowed to stand for 15 min. The absorbance was measured at 500 nm. Total proanthocyanidin contents were expressed as catechin equivalents (mg/g) using the following equation based on the calibration curve: $y = 4.9944x + 0.0068$, $R^2 = 0.9829$, where x is the absorbance and y is the catechin equivalent (mg/g).

Statistical analysis

Values were expressed as mean ± standard deviation of three parallel determinations. Microsoft Office Excel 2007 (Microsoft Corporation, USA) was employed to determine the correlation between polyphenol contents and antioxidant activity. Where applicable, the data were subjected to one-way analysis of variance (ANOVA) and differences between samples were determined by Tukey's comparison test using GraphPad Prism 5.

RESULTS AND DISCUSSION

The antioxidant activity of putative antioxidants have been attributed to various mechanisms, including the prevention of chain initiation, binding of transition metal ion catalysts, decomposition of peroxides, prevention of continued hydrogen abstraction, reductive capacity, and radical scavenging (Diplock, 1997). In this study, the antioxidant activities of the extracts obtained from *F. paniculata* leaves and root with different solvents of varying polarity were screened using different methods, including free radical scavenging against DPPH and hydroxyl radicals, *ex vivo* lipid peroxidation, ferrous ion chelating activity, reducing power and total antioxidant capacity in phosphomolybdenum assay. The polyphenolic contents of these extracts were also determined.

DPPH is a stable free radical which has commonly been used in antioxidant activity analysis. Figure 1 shows the scavenging activity against DPPH radicals of the different solvent extracts of leaves and root of *F. paniculata*. At 80 µg/ml, the scavenging abilities on DPPH radicals were 79.12, 32.19, 4.64, 7.43, 10.43, and 7.56% for FRE, FRH, FRC, FLE, FLH, and FLC extracts, respectively. FRE demonstrated an antiradical activity several times greater than all the other extracts with activity comparable to that of quercetin and tocopherol at 80 µg/ml. The activity of the root extracts is better than the leaf, with chloroform being the least solvent to extract antioxidant components from the root. The observed differential scavenging activities of the extracts against the DPPH system could be due to the presence of different compounds in the extracts (Sahreen et al., 2010). Type of solvent and polarity may also affect the single electron transfer and the hydrogen atom transfer which are key aspects in the measurements of antioxidant capacity (Pe´rez-Jime´nez and Saura-Calixto, 2006).

In living systems, biomembranes are composed of lipids, including unsaturated fatty acids that react easily to form lipid peroxides and free radicals. The accumulation of lipid peroxides in living systems induces functional anomalies and pathological changes (Halliwell, 2000). In the present study, all the extracts significantly inhibited the formation of TBARS generated by ferrous sulphate in a dose-dependent manner (Figure 2). At 100 µg/ml, FRE was found to be the most active with 95% inhibition, followed by FRC (92%), while FLH had the least (79%). Although, all the extracts inhibited the accumulation of lipid peroxides; the leaf extracts however, was less

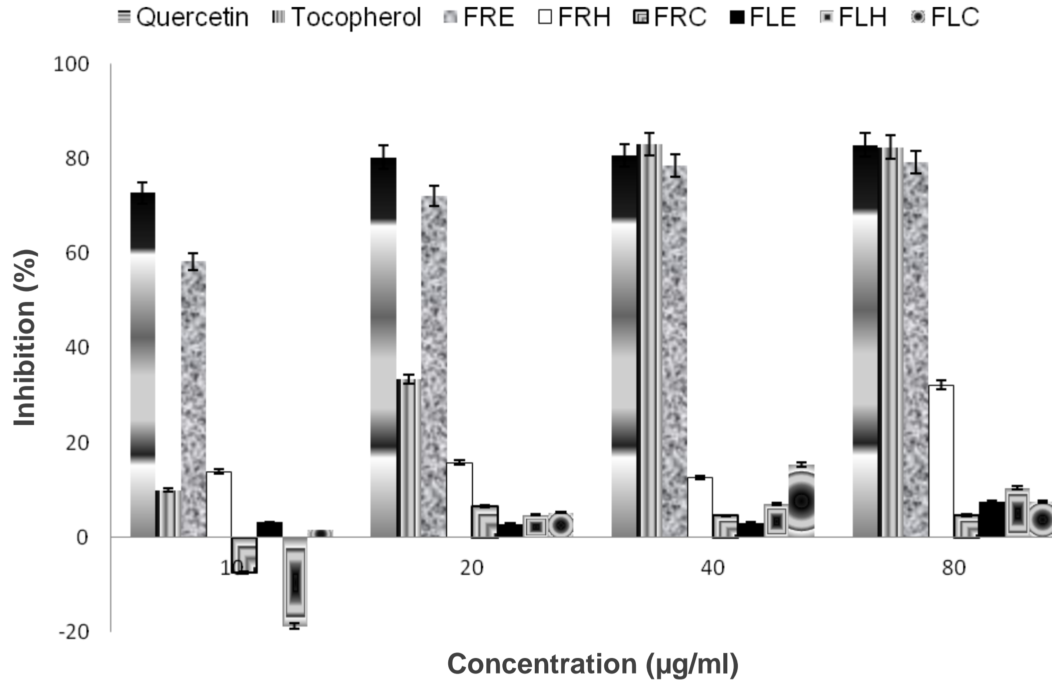

Figure 1. DPPH radical scavenging activity of the different solvent extracts of *F. paniculata* root and leaf. Data are expressed in mean ± SD (n = 3). FRE, FRH and FRC are *Flabellaria* root ethanol, aqueous and chloroform extracts while FLE, FLH and FLC are *Flabellaria* leaf ethanol, aqueous and chloroform extracts respectively.

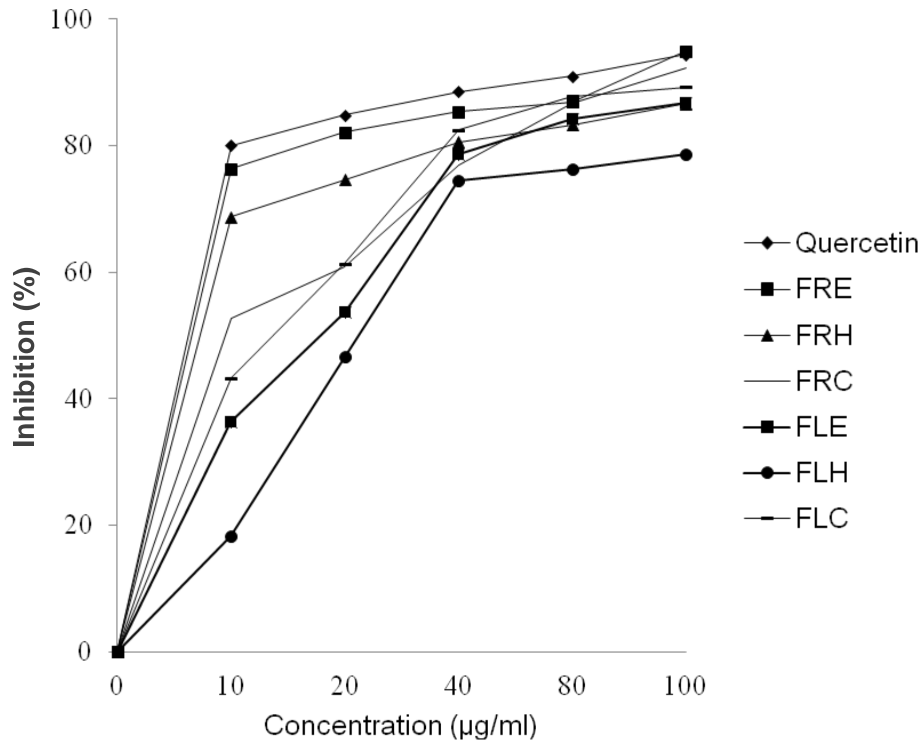

Figure 2. Fe^{2+}-Ascorbate induced lipid peroxidation of the different solvent extracts of *F. paniculata* root and leaf. Data are expressed in mean ± SD (n = 3). FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively.

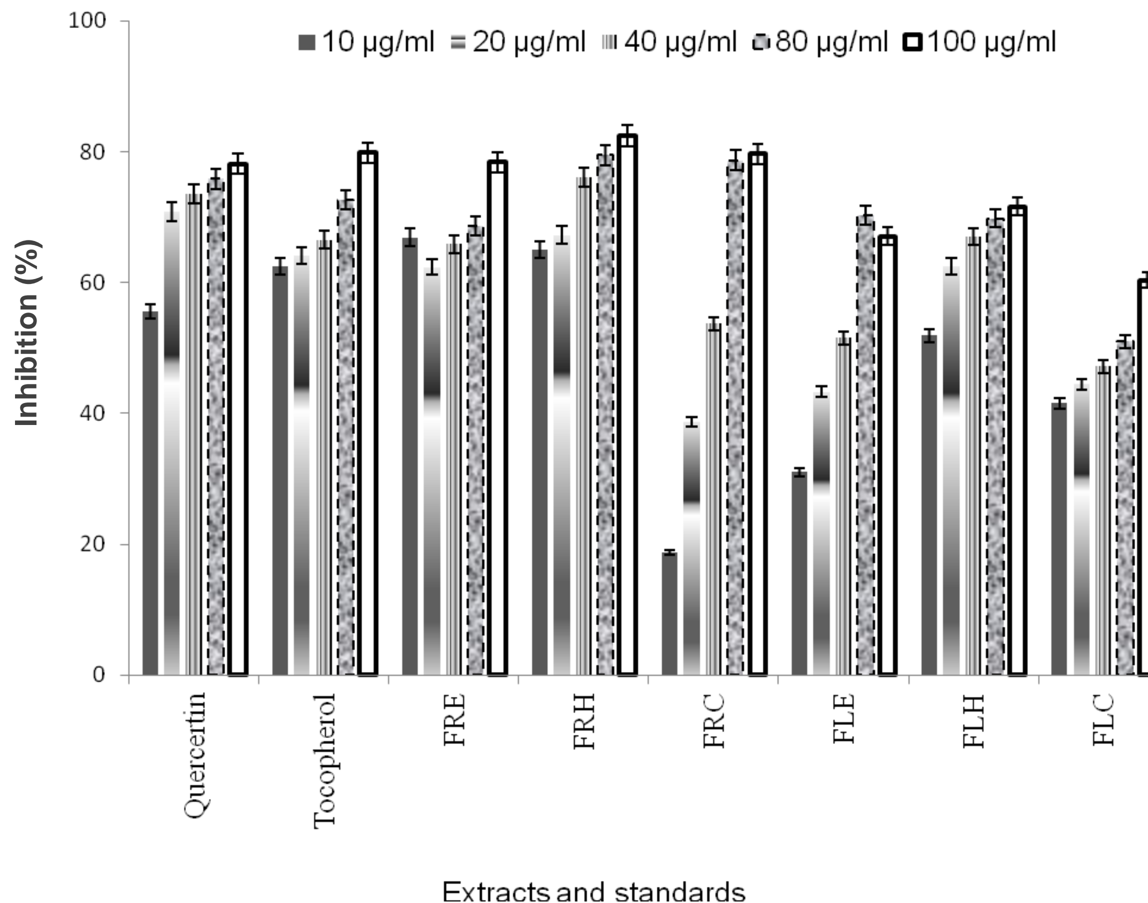

Figure 3. Hydroxyl radical scavenging effect of different solvents extract of *F. paniculata* in comparison with standard quercetin and tocopherol. Data are expressed in mean ± SD (n = 3). FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively.

efficient at lower doses. The inhibitory effects demonstrated by the extracts could be due to the presence of antioxidant compounds.

Hydroxyl radicals are highly reactive oxygen centered radicals causing lipid oxidation and enormous biological damage. They attack all proteins, DNA, polyunsaturated fatty acids in membranes, and almost any biological molecules it touches (AsokKumar, 2009). All the extracts showed more than 60% inhibition of hydroxyl radicals at a concentration of 100 µg/ml (Figure 3). The root extracts (FRE, FRH, and FRC) showed higher activity than the leaf (FLE, FLH, and FLC) extracts with percentage inhibition of 78, 82, and 80, respectively at 100 µg/ml. The levels of hydroxyl radical scavenging activities of root extracts are also comparable or greater than that of quercetin (78%) and tocopherol (80%). These results suggest that *F. paniculata* extracts are excellent scavengers of hydroxyl radical.

The ability of antioxidants to chelate and deactivate transition metals prevents such metals from participating in the initiation of lipid peroxidation and oxidative stress through metal-catalyzed reaction, and this action is considered to be due to an antioxidant mechanism (Adefegha and Oboh, 2011). Ferrous ion chelating capacity of the various solvent extracts of leaves and root of *F. paniculata* is as shown in Figure 4. The chelating ability of FLC (51.9%) and FRE (47.7%) at 10 µg/ml was comparable to that of EDTA (46.1%) at this concentration. Although, a dose-dependent ferrous ion chelating capacity was observed for EDTA, the activity of these extracts decreased with increased concentration. FRC on the other hand, showed dose-dependent chelating capacity with 50% activity at 100 µg/ml. All other extracts showed relatively low ferrous ion chelating capacity. The mechanism through which these extracts inhibited Fe^{2+} induced lipid peroxidation could be explained by their moderate Fe chelating properties and significant scavenging of ^{-}OH radicals.

Fe^{2+} can catalyze one-electron transfer reactions that generate reactive oxygen species, such as the reactive hydroxyl radical ($OH^{\cdot}$), which is formed from H_2O_2 through the Fenton reaction. Iron also accelerates peroxidation by

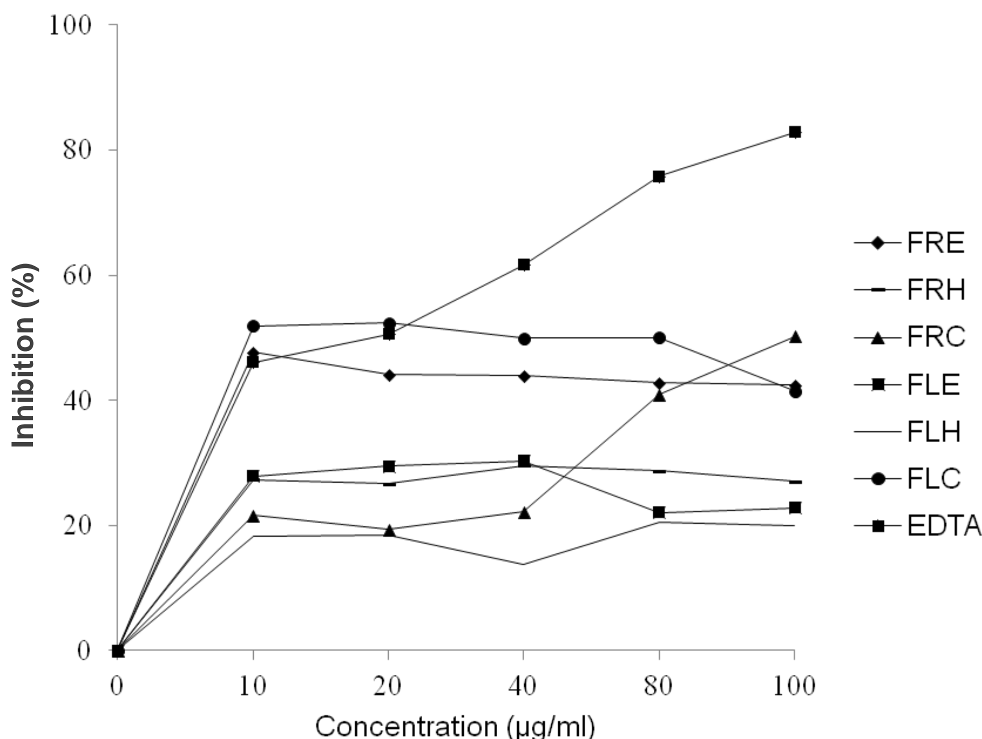

Figure 4. Metal chelating effect of different solvent extracts of *F. paniculata* root and leaf in comparison with EDTA. Data are expressed in mean ± SD (n = 3). FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively.

decomposing lipid hydro-peroxides into peroxyl and alkoxyl radicals (Zago et al., 2000; Nagulendran et al., 2007). Thus, when complexes are formed between the extract and Fe^{2+}, it reduces the concentration of free Fe^{2+}, Fe^{2+-} -induced lipid peroxidation could then be prevented or reduced (Costa et al., 2011).

The reducing power of the extracts is as shown in Figure 5. All the extracts exhibited a concentration-dependent reducing power activity, though, very low. Among the extracts, FRE showed better reducing power with activity comparable to that of tocopherol at all the concentrations. Quercetin, however, showed significant reductive capability than tocopherol and all the extracts. The activity of the remaining extracts was not different at all the concentrations tested. The data from this assay suggest that the extracts are able to donate electrons, thereby, reducing Fe^{3+} to Fe^{2+}, an indication of their antioxidant potential (Pin-Der-Duh, 1998; Dorman et al., 2003).

Figure 6 illustrates the TAC of different solvent extracts of *F. paniculata* measured spectrophotometrically at 695 nm, which was based on the reduction of Mo (VI) to Mo (V) by the extract and subsequent formation of green phosphate/Mo (V) complex at acidic pH. In this method, a higher TAC value corresponds to a higher antioxidant activity (Prieto et al., 1999). FRE showed the highest activity with value of 80.67 mg quercetin/g dry extract, while there is no significant difference between the activity of FRH and FRC; FLH and FLC, respectively.

Polyphenolic compounds such as flavonoid and proanthocyanidin are widely found in plant source and have been proven to possess significant anti-oxidant activities (McDonald et al., 2001), and are responsible for many pharmacological properties observed in plants. The total flavonoid content of the extracts varied from 4.64 to 97.46 mg quercetin/g dry extract (Table 1). The flavonoid content is in the order: FLE>FLC>FRE>FRC>FRH>FLH. The ethanol extract of the leaf (FLE) showed maximum flavonoid content (97.46 mg quercetin/g extract), however, the high amount recorded for the leaf chloroform (FLC) (90.48 mg quercetin/g extract) is also noted. Chloroform extract has been found to be rich in flavonoids. This observation is similar to the results of many authors (Hossain and Shah, 2011).

Proanthocyanidin content exhibited significant variations depending on the extraction solvent (Table 1). Ethanol extracted the highest root amount of condensed tannin (216.42 ± 0.018 mg catechin/g extract). Water appeared to be the least solvent to extract condensed tannin from *F. paniculata* root (12.99 mg catechin/g extract). The data from Table 1 also showed that proanthocyanidin content of leaf extracts varied from 12.7

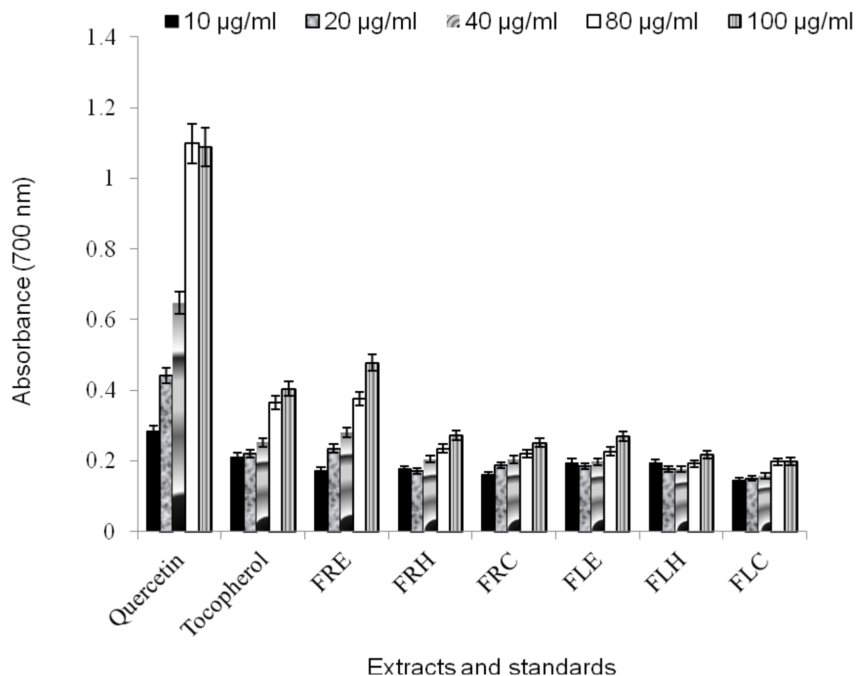

Figure 5. Reducing power of different solvents extract of *F. paniculata* in comparison with standard quercetin and tocopherol. Data are expressed in mean ± SD (n = 3). FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively.

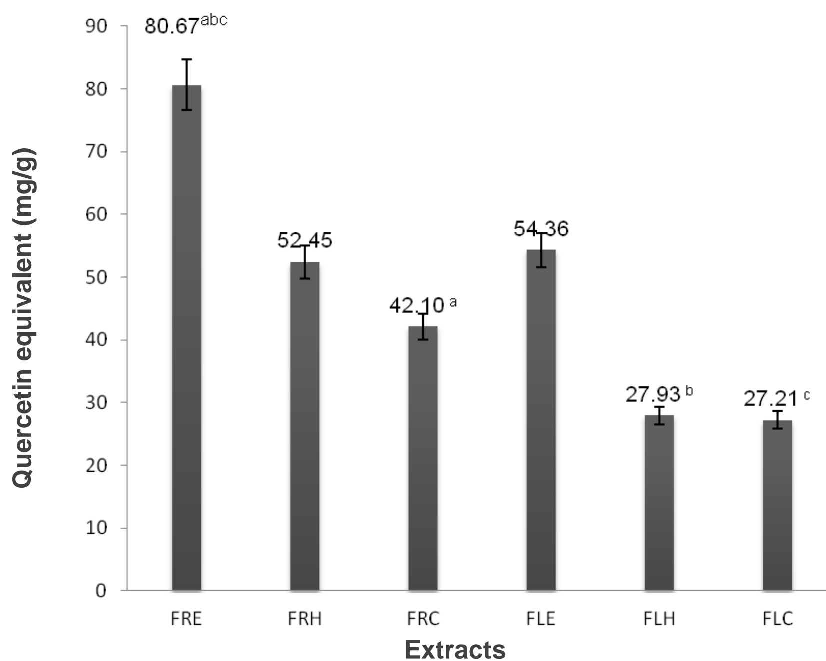

Figure 6. Total antioxidant capacity of different solvents extract of *F. paniculata* at the extract concentration of 100 µg/ml. The antioxidant activity is expressed as the number of equivalents of quercetin/g extract. Data are expressed in mean ± SD (n = 3). FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively. Bars with the same superscripts are statistically different, $P < 0.05$.

Table 1. Total polyphenolic content of different extracts of *F. paniculata* root and leaf.

Plant extract	Total proanthocyanidins (mg catechin/g extract)	Total phenolics (mg garlic acid/g extract)	Total flavonoids (mg quercetin/g extract)
FRE	216.42 ± 0.02[a]	59.96 ± 0.00[a]	33.08 ± 0.05[a]
FRH	12.99 ± 0.00[b]	18.68 ± 0.01[b]	13.21 ± 0.01[b]
FRC	24.47 ± 0.00[c]	101.75 ± 0.06[c]	25.42 ± 0.00[b]
FLE	47.89 ± 0.00[d]	91.23 ± 0.03[c]	97.46 ± 0.13[c]
FLH	12.72 ± 0.00[b e]	33.23 ± 0.06[b]	4.64 ± 0.07[d]
FLC	44.36 ± 0.01[d f]	54.78 ± 0.05[ad]	90.48 ± 0.04[ce]

FRE, FRH, and FRC are *Flabellaria* root ethanol, aqueous, and chloroform extracts, while FLE, FLH, and FLC are *Flabellaria* leaf ethanol, aqueous, and chloroform extracts, respectively. Analyses were mean of three replicates ± standard deviations. Means along the same column with different superscripts are significantly different, $P < 0.05$.

to 47.9 mg catechin/g extract. Proanthocyanidin content of leaf extracts were in descending order: FLE>FLC>FLH.

Variations in the quantity of total phenolics in different solvent extracts of the leaves and root of *F. paniculata* are presented in Table 1. Maximum phenolic content was recorded in root chloroform extract (FRC) (101.75 ± 0.062 mg GAE/g extract) and the lowest by water extracts of the root (FRH) and leaf (FLH). Correlation analysis between all parameters showed no significant positive correlation with total phenolic, flavonoid, and proanthocyanidins, with the exception of proanthocyanidin content which were weakly correlated with chelating ($R^2 = 0.43$) and DPPH radical scavenging ($R^2 = 0.7811$) activities. Moderate correlation ($R^2 = 0.6114$) was also observed with flavonoid content and hydroxyl scavenging activity. Our observation is similar to the report of many authors (Lim et al., 2002; Lin et al., 2011) that there is no direct correlation between phenolic content and antioxidant activity.

Conclusively, this study demonstrated that the solvent extracts of leaf and root of *F. paniculata* have good antioxidant activity, with strong hydroxyl radical scavenging, and inhibition of lipid peroxidation. The observed antioxidant activity of the extracts depended on both the solvent used for extraction and the assay method. Moreover, the antioxidant capacity may be a contributing factor to the reported medicinal uses of the leaf as mentioned in earlier publication by other authors.

ACKNOWLEDGEMENTS

The authors wish to thank University of Lagos for the financial support (CRC NO. M2010/03). The technical assistance of Mr Olawale Lasore is also acknowledged.

REFERENCES

Adefegha SA, Oboh G (2011). Water extractable phytochemicals from some Nigerian spices inhibit Fe^{2+}- induced lipid peroxidation in rat's brain – *in vitro*. J. Food. Proc. Technol. 2:104.

Ananthi S, Raghavendran HRB, Sunil AG, Gayathri V, Ramakrishnan G, Vasanthi Hannah R (2010). *In vitro* antioxidant and *in vivo* anti-inflammatory potential of crude polysaccharide from *Turbinaria ornata* (Marine Brown Alga). Food Chem. Toxicol. 48:187–192.

AsokKumar K, UmaMaheswari M, Sivashanmugam AT, SubhadraDevi V, Subhashini N, Ravi TK (2009). Free radical scavenging and antioxidant activities of *Glinus oppositifolius* (carpetweed) using different *in vitro* assay systems. Pharm. Biol. 47(6):474–482.

Burkill HM (1995). The useful plants of West Tropical Africa, Royal Botanical Gardens, Kew, 2nd ed. 3:3.

Costa P, Goncalves S, Andrade PB, Valentao P, Romano A (2011). Inhibitory effect of *Lavandula viridis* on Fe^{2+}-induced lipid peroxidation, antioxidant and anti-cholinesterase properties. Food Chem. 126:1779–1786.

Dinis TP, Madeira VMC, Almeida LM (1994). Action of phenolic derivates (acetaminophen, salycilate and 5-aminosalycilate) as inhibitors of membrane lipid peroxidation and as peroxyl radical scavengers. Arch. Biochem. Biophy. 315:161–169.

Diplock AT (1997). Will the "good fairies" please prove to us that vitamin E lessens human degenerative disease? Free Radic. Res. 27:511-532.

Dorman HJD, Peltoketo A, Hiltunen R, Tikkanen MJ (2003). Characterization of the antioxidant properties of de-odourised aqueous extracts from selected Lamiaceae herbs. Food Chem. 83:255−262.

Halliwell B (2000) .The antioxidant paradox. Lancet. 355:1179-1180.

Halliwell B, Gutteridge JMC, Aruoma OI (1987). The deoxyribose method: a simple 'test-tube' assay for determination of rate constants for reactions of hydroxyl radicals. Anal. Biochem. 165:215–219.

Hasan SMR, Jamila M, Majumder MM, Akter R, Hossain M, Mazumder EH, Alam A, Jahangir R, Rana S, Arif, Rahman S (2009). Analgesic and antioxidant activity of the hydromethanolic extract of *Mikania scandens (*L.) Willd. leaves. Am. J. Pharmacol. Toxicol. 4(1):1-7.

Hossain MA, Shah MD (2011). A study on the total phenols content and antioxidant activity of essential oil and different solvent extracts of endemic plant *Merremia borneensis*. Arabian J. Chem. DOI 10.1016/j.arabjc.2011.01.007.

Larson RA (1988). The antioxidants of higher plants. Phytochemistry. 27:969-978.

Lim SN, Cheung PCK, Ooi VEC, Ang PO (2002). Evaluation of antioxidative activity of extracts from brown seaweed, *Sargassum siliquastrum*. J. Agric. Food Chem. 50:3862–3866.

Lin L, Cui C, Wen L, Yang B, Luo W, Zhao M (2011). Assessment of *in vitro* antioxidant capacity of stem and leaf extracts of *Rabdosia serra* (MAXIM.) HARA and identification of the major compound. Food Chem. 126:54–59.

Liyana-Pathirana CM, Shahidi F (2005). Antioxidant activity of commercial soft and hard wheat (*Triticum aestivum L*) as affected by gastric pH conditions. J. Agric Food Chem. 53:2433-2440.

McDonald S, Prenzler PD, Antolovich M, Robards K (2001). Phenolic content and antioxidant activity of olive extracts. Food Chem. 73:73–84.

Nagulendran KR, Velavan S, Mahesh R, Hazeena-Begum V (2007). *In vitro* antioxidant activity and total polyphenolic content of *Cyperus rotundus* rhizomes. E-J Chem. 4(3):440-449.

NIH (1985). Guide for the Use of Laboratory Animals DHHS, PHS. NIH Publication No. 85-23 (1985 Revised).

Niki E (2010). Assessment of antioxidant capacity *in vitro* and *in vivo*. Free Radic. Biol. Med. 49:503–515.

Olugbuyiro JAO, Abo KA, Leigh OO (2010). Wound healing effect of *Flabellaria paniculata* leaf extract. J. Ethnopharmacol. 127:786–788.

Ordonez AAL, Gomez V, Vattuone MA, Isla MI (2006). Antioxidant activities of *Sechium edule* (Jacq.) Swartz extracts. Food Chem. 97:452–458.

Oyaizu M (1986). Studies on products of browning reaction prepared from glucoseamine. Jpn J. Nutr. 44:307–315.

Pe´rez-Jime´nez J, Saura-Calixto F (2006). Effect of solvent and certain food constituents on different antioxidant capacity assays. Food Res. Int. 39:791–800.

Pin-Der-Duh X (1998). Antioxidant activity of burdock (*Arctium lappa* Linne): its scavenging effect on free radical and active oxygen. J. Am. Oil Chem. Soc. 75:455–456.

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. Anal. Biochem. 269:337–341.

Sahreen S, Khan WR, Khan RA (2010). Evaluation of antioxidant activities of various solvent extracts of *Carissa opaca* fruits. Food Chem. 122:1205–1211.

Sun JS, Tsuang YW, Chen IJ, Huang WC, Hang YS, Lu FJ (1998). An ultra-weak chemiluminescence study on oxidative stress in rabbits following acute thermal injury. Burns 24:225–256.

Wolfe K, Wu X, Liu RH (2003). Antioxidant activity of apple peels. J. Agric. Food Chem. 51:609–614.

Zago MP, Verstraeten SV, Oteiza PI (2000). Zinc in the prevention of Fe^{2+} initiated lipid and protein oxidation. Biol. Res. 33:143-150.