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Antioxidative and Nutraceutical Properties of *Crossopteryx febrifuga* (Afzel. ex G. Don) Benth.

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ABSTRACT: Over years, *Crossopteryx febrifuga* leaf has been used as curative without knowing its antioxidant and nutritional properties. Antioxidant properties were determined using some standard methods. Proximate analysis of carbohydrates, protein, crude fibres and crude fat as well as some mineral and vitamin compositions were also determined using standard methods in Association of Official Analytical Chemists. It was found that the plant exhibited significant free radical scavenging activity and have significant phenol and flavonoid contents. Carbohydrate, protein, crude fibres and crude fat and calcium, magnesium, potassium, sodium, zinc were found. In addition, riboflavin, thiamine, niacinamide, folic acid, ascorbic acid and pyridoxine were contained in relative quantity. It was clearly evident that *Crossopteryx febrifuga* leaf sample has antioxidants, nutrients and so could be considered as a potential source of all these nutritional values which were discovered in the plant leaf. Therefore, it could be a possible agent for health maintenance and prophylaxis.

Keywords: Antioxidant; Nutrients; Nutraceutical; Properties; *Crossopteryx febrifuga*

Introduction

Several plants were already tested for antioxidant and nutraceutical properties, however, a lot of others are yet to be assessed for the same properties and *C. febrifuga* is among them. In the past few decades, there have been rise in the researchers' desires to investigate and acknowledge the role of free radicals such as reactive nitrogen species (RNS), reactive oxygen species (ROS), superoxide (O_2^o-), hydrogen peroxide (H_2O_2) and hypochlorus (HOCl) and their implication in various disease situations (Talla *et al*., 2017, Forman and Zhang, 2021). Formic and Regelson (1995reported that phenolic compounds of plant origin especially the flavonoids are scavengers of free radicals. In neurodegenerative disorders such as Alzheimer disease, Parkinson's disease, it has been reported that nitric oxide generates neurotoxin resulting to nerve cell damage and subsequent death (Lokman *et al*., 2016).

Antioxidants prevent the destructive impact of oxidative reaction normally induced by reactive oxygen species in a living body (Ozsoy *et al*., 2008). There are usually two types of antioxidants in living body: enzymatic type such as glutathione, catalase, superoxide dismutase and non-enzymatic type such as vitamin E, Vitamin C, Selenium and Carotenoid (Jacob, 1995). To protect biological system from the oxidative destruction of free radicals, the key antioxidants in high demand is natural type such as polyphenols (Silva *et al*., 2005). Some natural antioxidants which include tocopherol, ascorbic acid, b-carotene and even plant phenolics have been known to be very viable in providing sound protective impact in biological system (Soobrattee *et al*., 2005). Human disorders such as cardiovascular diseases, diabetes, and malnutrition attributed to nutritional and

nutraceutical deficiency or imbalance are managed or treated with plants having higher concentration of the required nutritional supplement in the form of minerals, vitamins, amino acid, good fat or carbohydrates (Ghafar *et al*., 2010).

The normal biochemical reactions taking place in human body, exposure to xenobiotic of various kinds and environmental pollutants consequently lead to generation of free radicals as reactive oxygen species (ROS) and reactive nitrogen species (RNS) (Bealem *et al.*, 2021; Ozsoy *et al*, 2008). Some of the factors or conditions that usually necessitate the production and release of reactive species include mental or emotional stress, smoking, radiation, viral toxin, alcohol intake Lokman *et al*., 2016. These free radicals cause oxidative stress in different pathophysiological conditions which eventually results in oxidative damage and of course cellular damage. It has been known that the body and dietary antioxidants aid in preventing aging and diseases by attenuating or attacking the free radicals in a version described as one-electron reaction (Lokman *et al*., 2016, Oyaizu *et al*., 1986). The in balance between the body content of free radicals and antioxidants lead to disease setting and subsequent complication in ill or degenerative conditions such as cancer, diabetes, atherosclerosis, arthritis, aging (Silva *et al*., 2005).

If a sound health condition, an index for human development and productivity is actually desired as being proclaimed among human population, the health maintaining and immune boosting type of foods need to be further embraced by all. Foods like vegetables, fruits, nuts, cereals and others that are chiefly rich in vitamins, minerals and some essential amino acids are required to attain this fit. Such food or part of food for maintaining health is called nutraceutical (Michels & Frei, 2012). A nutraceutical is a whole food or food components or dietary supplements with nutritive and functional roles for which reason they are considered to help in ensuring that good health is maintained. They usually occur in the form of dietary fibre, vitamins, oils, proteins, peptides, amino acids, keto acids, antioxidants that serve as agents which strive to prevent a living individual from getting infections or diseases established in the body (Liu, 2003).

Dietary fibre as an essential macronutrient under nutraceutical is important for diet as it alters the constituents of the gastrointestinal system, by influencing nutrients assimilation and chemicals to the target region through bulking and viscosity (Eastwood & Kritchevsky, 2005).

From the various studies conducted on some diseases and reported by Bazzano *et al*. (2001) and Liu *et al*. (2003), an inverse relationship was repeatedly observed between the individuals feeding on nutraceuticals such as fruits and vegetables and being susceptible to degenerative diseases like cancer and cardiovascular diseases.

The aim of the research was to evaluate the antioxidants, nutrients and nutraceutical composition in dried sample and methanol extract of *C. febrifuga*.

Materials and methods

In-vitro antioxidant assays of *Crossopteryx febrifuga*

Collection of plant sample: Disease free sample of *Crossopteryx febrifuga* leaves were collected in Zango Daji, Adavi Local Government Area of Kogi State, Nigeria during an ethnobotanical survey in November, 2018. The plant was identified and authenticated with the voucher number UBHdt/217 assigned, by taxonomists in the Herbarium Unit of the Department of Plant Biology and Biotechnology, University of Benin, Benin City, Nigeria.

Preparation of extracts: The leaf plant sample was dried under shade and powdered. The powdered sample (200 g) was packed in thimble and placed in a Soxhlet apparatus. Extraction was performed using one litre of methanol (98%) for 48 hours at a temperature not exceeding the boiling point (64.7 °C) of the solvent in the round bottom flask. The resulting solution was concentrated in vacuum to dryness to give dried sample of methanol extract of 20 g. The dried extract was finally stored in a refrigerator at 5 °C in order to preserve it till the time of use.

DPPH free radical scavenging assay: *In vitro* assay of antioxidant property of *C. febrifuga* methanol extract using 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) photometric assay. The free radical scavenging activity of the extract was determined using DPPH assay and spectrophotometer. Each of the test extracts (2 mL) at different concentrations (20, 40, 80, 160, and 320 µg/mL) was mixed with 0.5 mM DPPH (in 1 ml of methanol) in a cuvette. The absorbance at 517 nm was taken after 30 minutes of incubation in the dark at room temperature. The concentrations were prepared in triplicates and the percentage antioxidant activity calculated as follows:

Percentage inhibition = % scavenging = Ac – As/Ac x 100%.

One millilitre of methanol plus 2.0 mL of the extract was used as the blank, while 1.0 mL of the 0.5 mM DPPH solution plus 2.0 mL of methanol was used as the negative control. Ascorbic acid (vitamin C) was used as reference standard (Sadhu *et al*., 2003).

ABTS radical scavenging activity: The antioxidant activity of *C. febrifuga* was determined according to the modified method of Bajpai *et al*. (2005) in triplicate. In this method, the solution constituted from 5 ml of 7 mM ABTS and 80 µl of 140 mM potassium sulphate was left to stand in a dark condition at room temperature for a range of 12–16 h period prior to use. Thereafter, about 1 ml of ABTS was added to a test tube of 50 µl extract and mixed for about 30 s. After 3 min, the absorbance was measured at 734 nm. The percentage of radical scavenging activity was calculated by comparing the absorbance values of control with the extract.

Hydrogen peroxide assay: Antioxidant activity by hydrogen peroxide scavenging assay was determined according to the method of Nabavi *et al.* (2008). In this method, 40 mM hydrogen peroxide solution was prepared in phosphate buffer of pH 7.4. Methanol extract of *C. febrifuga* leaf (100 µg) already dissolved in distilled water was added to 0.6 mL of the hydrogen peroxide. Absorbance of sample and standard at 230 nm were determined using a spectrophotometer (Cary 50 Bio UV-VIS Spectrophotometer, Varian) 10 minutes later against a blank solution containing the phosphate buffer without hydrogen peroxide. The percentage scavenging property of the methanol extract and standard compound were calculated as such:

$$H_2O_2\ \%\ \text{scavenging} = Ac - As/Ac \times 100\%.$$

where Ac is control absorbance while As is extract absorbance.

Evaluation of total phenolic constituent: Total phenolic content of *C. febrifuga* was quantified using the Folin-Ciocalteu's method (Govindarajan, 2013), with gallic acid as a standard. Twenty microliter of freshly prepared *C. febrifuga* was added to 1.55 ml of double deionized water and 100 µl Folin-Ciocalteu reagent thoroughly mixed and incubated for 5 min at room temperature. Following incubation, 300 µl of the Na_2CO_3 (2%, W/V) solution was added and the mixture was allowed to stand at room temperature for an additional 2 h and the absorbance was measured at 765 nm. The total phenolic content was expressed as gallic acid equivalents of the plant (GAE mg/g extract). All determinations were performed three times.

Evaluation of total flavonoids constituent: Total flavonoids content found in the *C. febrifuga* extract was determined using the method of Kim *et al*. (2003), Timothy *et al*. (2019). In this method, 1 ml of extract at 100 µg/ml was mixed with 4 ml distilled water and then added was 300 µl $NaNO_3$ and again 300 µl $AlCl_3$ was added to the mixture. At room temperature, the mixture was thereafter incubated for 5 min. At the end of incubation, 2 ml of sodium hydroxide (1 M) was added and the volume of the solution was raised to 10 ml by further addition of distilled water. The sample absorbance and blank were taken at 510 nm using UV-VIS spectrophotometer. It showed yellow colour on UV light of spectrophotometer. The flavonoid composition in total was then expressed as rutin equivalents in mg/g of dry sample.

Nutraceutical evaluation

Determination of mineral composition of Crossopteryx febrifuga leaf: Mineral elements such as Na, Mg, Ca, K, Zn, P were determined using Atomic Absorption Spectrophotometer (AAS) based on Association of Official Analytical Chemist (AOAC, 2000, 2005). Digestion of the plant leaf sample for mineral analysis was done as followed. About 3 g of the sample was measured into a digestion flask. Then, 5 ml of nitric acid with 1.2 ml of perchloric acid were added. The mixture was heated on a digester in a fume cupboard until a colourless mixture was obtained. The volume was made up to 100 ml. Atomic absorption spectrophotometer (AAS) was used for quantitative analysis of each of the minerals after acid digestion as described in the official method of the Association of Official Analytical Chemists.

Proximate analysis: Determination of protein, crude fibre, crude fat and carbohydrate was carried out using the modified methods of (Rangana, 1999), (AOAC, 2005) and (Raghuramulu *et al*., 2005) respectively.

Determination of protein in C. febrifuga leaf: Protein in the sample was determined using Kjeldahl method. In this method, 0.5 - 1.0 g of dried sample was taken into digestion flask. About 10 - 15 ml of concentrated H_2SO_4 and 8 g of digestion mixture i.e. K_2SO_4: CuSO (8: 1) were added. The flask was swirled in order to mix the contents thoroughly, then placed on heater to start digestion till the mixture become blue green in colour. The digest was cooled and transferred to 100 ml volumetric flask and volume was made up to mark by the addition of distilled water. The digest was distilled in Markam Still Distillation Apparatus. Ten millilitres of digest was introduced in the distillation tube, then 10 ml of 0.5 N NaOH was gradually added via the same way. Distillation continued for at least 10 minutes and ammonia (NH_3) produced was collected as NH_4OH in a conical flask containing 20 ml of 4% boric acid solution with few drops of modified methyl red indicator. While distilling, yellow colouration appeared due to the emergence of NH_4OH. The distillate was then titrated against standard 0.1 N HCl solution till the appearance of pink colour. A blank was also run through all steps as above. Percent crude protein content of the sample was calculated by using the following formula:

$$\%\ \text{Crude protein} = 6.25^* \times N\ (^*\ \text{Correction factor})$$

$$\%\ N = (S\text{-}B) \times N \times 0.014 \times D \times 100/\text{Wt of sample} \times V$$

where S = Sample titration reading, B = Blank titration reading, N = Normality of HCl, D = Dilution of sample after digestion, V = Volume taken for distillation 0.014 = milli equivalent weight of Nitrogen

Determination of crude fibre in C. febrifuga leaf: A moisture free and ether extracted sample of crude fibre made of cellulose was first digested with dilute H_2SO_4 and then with dilute KOH solution. The undigested

residue collected after digestion was ignited and the weight loss due to ignition was measured and designated as crude fibre. Sample of 0.153 g (W_0) was transferred to porous crucible. The crucible was later placed into Dosi-fiber unit and the valve was switched off. After that added was 150 ml of preheated H_2SO_4 solution and then some drops of foam-suppresser to each column. The cooling circuit was opened and the heating elements turned on (power at 90%). While it started boiling, the power was reduced to 30% and left for 30 minutes. Valves were opened for drainage of acid and rinsed with distilled water thrice to completely ensure the removal of acid from sample.

The same procedure was used for alkali digestion by using KOH instead of H_2SO_4. The sample was dried in an oven at 150 °C for 1 h. The sample was cooled in a desiccator and weighed (W_1). The sample was kept in crucibles in muffle furnace at 55 °C for 3 - 4 h. The sample was thereafter cooled in a desiccator and its weight determined again (W_2). Calculations were done by using the following formula:

$$\%\text{Crude fibre} = W_1\text{-}W_2\text{x}100\%/W_{O.}$$

Determination of crude fat in C. febrifuga leaf: Dry extraction method was applied for fat determination. It consisted of extracting dry sample with some organic solvent, since all the fat materials e.g. fats, phospholipids, sterols, fatty acids, carotenoids, pigments, chlorophyll etc. are extracted together therefore, the results are frequently referred to as crude fat. Fats were determined by intermittent Soxhlet extraction. Crude fat was determined by ether extract method using Soxhlet apparatus. About 1 g of moisture free sample was wrapped in filter paper, placed in fat free thimble and then introduced in extraction tube. The receiving beaker cleaned, dried, weighed and was filled with petroleum ether and fitted into the apparatus. The water and heater were turned on to start extraction. After 4 - 6 siphoning, the ether was made to evaporate and then the beaker disconnected before last siphoning. The extract was transferred into clean glass dish with ether evaporated with the aid of water bath. The dish was thereafter placed in an oven set at 105 ^{o}C for 2 h and thereafter cooled in a desiccator. The percent crude fat was determined by using the following formula:

$$\%\text{ Crude fat} = \text{Wt of ether extract /Wt.of sample x } 100\%.$$

Determination of carbohydrate in C. febrifuga leaf: Carbohydrate was determined using the method described by James (1995). In this method, 5 ml of each of the sample extracts was diluted to 450 ml with distilled water. Using pipette, 1 ml of each diluted filtrate of the sample was added to three different test tubes, 1 ml of water was added to a test tube as a blank and 1 ml of glucose added to a test tube to serve as standard. To each of the test tubes, 5 ml of freshly prepared 0.10% Anthrone reagent was added, stoppered and gently shook to ensure proper mixing. The test tubes were differently labelled and placed in a test tube rack. Both the test tubes and the rack were placed in water bath (30 °C) and allowed to stand for 12 minutes. Then they were removed and cooled to initial temperature. The absorbance at 620 nm of the samples and standard against the blank were determined from a spectrophotometer. The green colour which showed the presence of glucose was stable for about 2 hours. Total available carbohydrate as percentage of glucose was calculated as follows:

$$\text{Glucose (\%)} = 25A_1/\text{X}\text{x}A_2\text{x}100\%.$$

where X = Weight of sample (g),

A_1 = Absorbance of diluted sample,

A_2 = Absorbance of diluted standard.

Vitamins determination: Digestion of plant sample for Vitamins: About 5 g of dried sample was weighed into beaker, 100 ml of hot distilled water was added and allowed to stand for one hour. This was filtered with Whatman filter paper. Thereafter, 25 ml of the sample was measured into conical flask. Three drops of 5% starch solution added. The iodine solution titrated until the blue black colour appears at the end point. The same process was repeated for standard vitamin C. Concentration of Vitamin C = Volume of the sample x {Concentration of standard Vitamin C/volume of vitamin C}. Similar procedure was utilized in determining other vitamins (Atasie *et al.*, 2009, Kumar *et al*., 2014).

Results

In vitro antioxidant property of methanol extract (ME) of Crossopteryx febrifuga leaf scavenging activity of Crossopteryx febrifuga leaf on DPPH radical: The ability of *C. febrifuga* methanol extract to scavenge free radicals was done using radical 2, 2-Diphenyl-1-picrylhydrazyl (DPPH). In scavenging assay of DPPH, the methanol extract of 5.30 µg/ml displayed the best scavenging activity at 94.20% when compared to the standard ascorbic acid 90%. The methanol extract (ME) at graded concentration elicited a competitive DPPH radical scavenging activity at 94.20% against the reference compound, ascorbic acid at 90 % (Figure 1). By this result, the scavenging property of the extract was seen slightly higher than that of the standard scavenging agent, ascorbic acid.

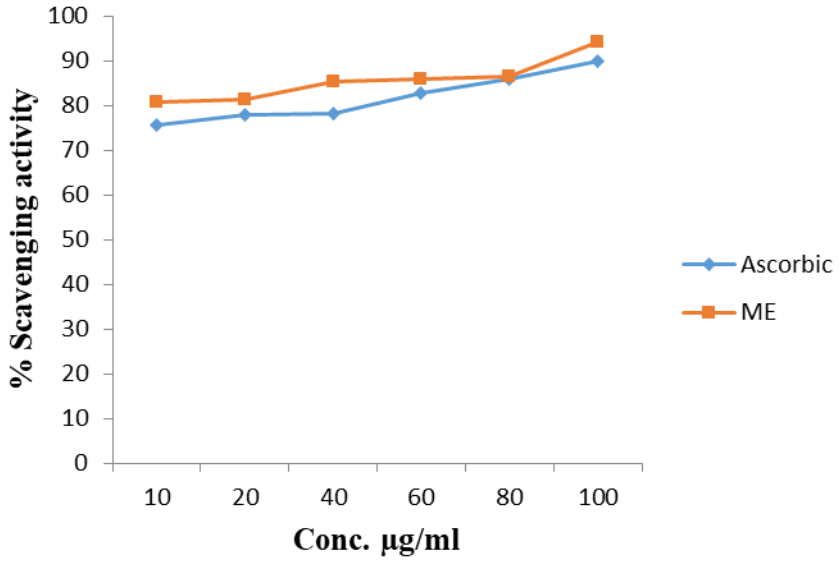

Figure 1: Scavenging property of methanol extract of *Crossopteryx febrifuga* on DPPH radical

Scavenging activity of Crossopteryx febrifuga leaf on ABTS cation free radicals: The result of antioxidant property of *C. febrifuga* methanol extract was measured using a radical cation 2,2-azino-di-(3ethylbenzthiazoline sulfonate (6) (ABTS). The methanol extract revealed the best activity at graded concentration (5.20 µg/ml). It showed a competitive but still better ABTS radical scavenging activity at 99.8% as against the reference compound, ascorbic acid at 98.6 % (Figure 2). By this observation, it was evident that *C. febrifuga* methanol extract has very high scavenging activity which could perhaps be attributed to its high antioxidant content.

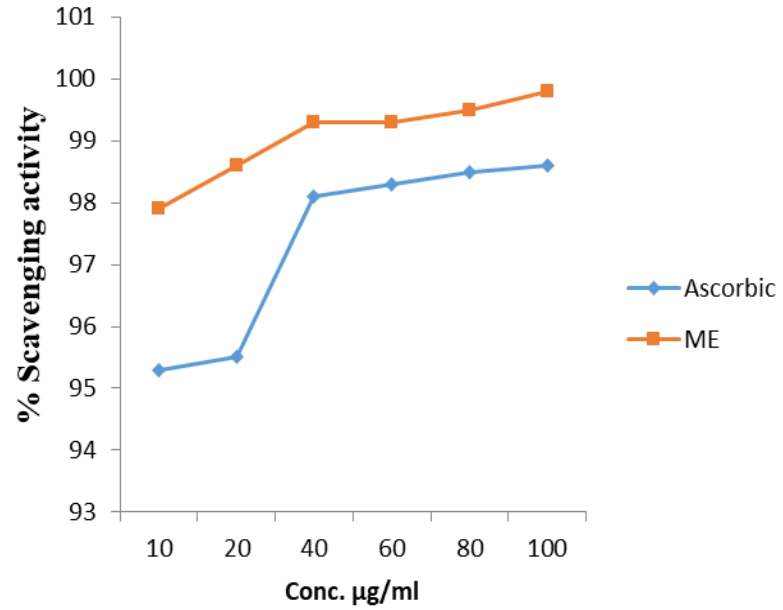

Figure 2: Scavenging property of *Crossopteryx febrifuga* leaf on ABTS radicals

Hydrogen peroxide assay: The result of antioxidant properties of *C. febrifuga* methanol extract was measured using hydrogen peroxide assay. The methanol extract at graded concentration of 5.00 µg/ml exhibited H_2O_2 radical scavenging property. It was observed to display the best activity at (53.1 %) when compared with the reference antioxidant, ascorbic acid of 74.1 % (Figure 3). Contrary to what were obtained in DPPH and ABTS scavenging activities, the hydrogen peroxide assay showed that *C. febrifuga* methanol extract demonstrated less antioxidant activity when compared to the standard compound, ascorbic acid.

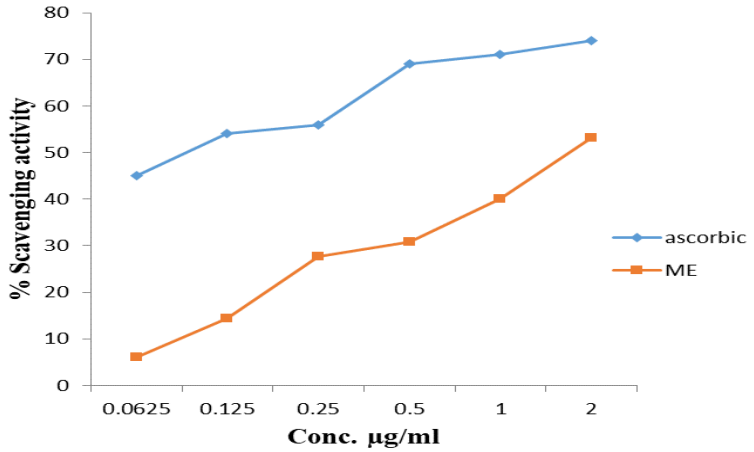

Figure 3: Scavenging property of *Crossopteryx febrifuga* leaf on hydrogen peroxide radical

Total phenols and flavonoids content in Crossopteryx febrifuga leaf extract: Phenols and flavonoids are very essential bioactive constituents which exist in plants and are very important for their antioxidant properties. Total phenolic content of *C. febrifuga* was quantified using the Folin-Ciocalteu reagent with gallic acid and quercetin as standards. The investigation of the total phenol contents of the extract showed that it has significant value of 63 GAE/g as against 80 GAE/g reference antioxidant, gallic acid. Similarly, the total flavonoid content of *C. febrifuga* revealed a significant value of 28 QE/g as against 58 QE/g reference antioxidant, quercetin (Figures 4 and 5). Furthermore, the total phenol and flavonoid in *C. febrifuga* were seen to be lower than what were obtained in gallic acid and quercetin respectively.

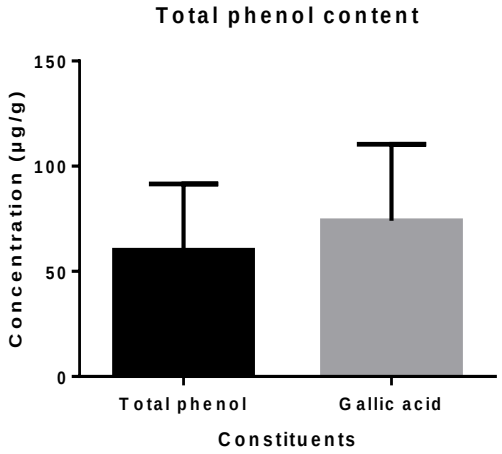

Figure 4: Total phenol in *Crossopteryx febrifuga* leaf extract

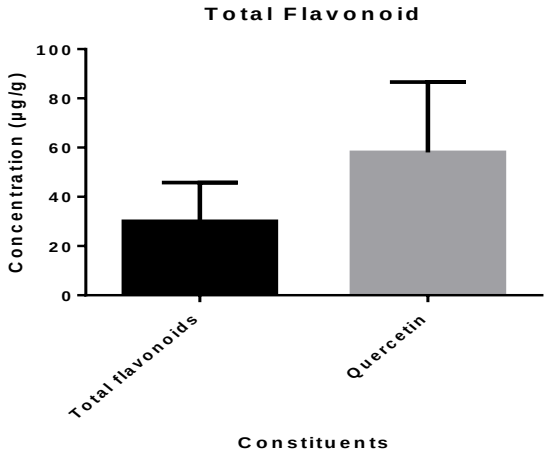

Figure 5: Total flavonoid in *Crossopteryx febrifuga* leaf extract

Nutraceutical composition of Crossopteryx febrifuga: Mineral salts such as calcium, magnessium, potassium, sodium and zinc were noted in relative amount in *C. febrifuga* leaf sample with Phosphorus been absent (Table 1). Some classes of food such as carbohydrate, protein, fat including fibre were found in relative quantities in the leaf sample of *C. febrifuga* (Table 2). Some vitamins such as ascorbic acid, thiamine (B1), folic acid (B9), pyridoxine (B6), niacinamide (B3), niacinamide (B3) and panthothenic acid (B5) were discovered in relative quantities in the leaf sample of *C. febrifuga* (Table 3).

Table 1: Mineral constituents of *Crossopteryx febrifuga* leaf

S/N	Minerals	mg/g
1	Ca	0.122
2	Mg	0.465
3	K	0.764
4	Na	0.427
5	Zn	15.38
6	P	ND

Table 2: Vitamin constituents of *Crossopteryx febrifuga* leaf

S/N	Vitamins	mg/g
1	Ascorbic acid (Vitamin C)	0.241
2	Riboflavin (B2)	0.427
3	Thiamine (B1)	1.127
4	Folic acid (B9)	0.121
5	Pyridoxine (B6)	0.263
6	Niacinamide (B3)	0.135
7	Panthothenic acid (B5)	0.254

Table 3: Proximate composition of *Crossopteryx febrifuga* leaf

S/N	Nutrients	% Composition
1	Carbohydrate	8.76
2	Protein	9.89
3	Fat	2.03
4	Fibre	20.76

Discussion

Antioxidant Activity of Crossopteryx febrifuga leaf: The use of methanol during the extraction was based on the fact that it is a solvent of high polarity and so easily dissolve and separate phenolic compounds from plant material and hence phenolic constituents are readily extractable in methanol (Alara *et al*., 2021).

The presence of phenol and flavonoid in plants are known to confer antioxidant properties on them. Researchers' interest and attention on medicinal plants as well as their phenolic compounds has been on the rise over the years because of their diverse therapeutic applications. The most famous bioactivity of phenolic compounds is antioxidant activity and capacity to prevent or reduce oxidative stress associated diseases (Alfred *et al*., 2022).

The scavenging effects demonstrated by the plant leaf extract on free radicals showed that it has significant property of removing free radicals. The generation of free radicals such as O_2, OH and non-free radical species such as H_2O_2 which are always deleterious to cells within the affected tissue through either direct or indirect oxidizing action induced lipid peroxidation with subsequent cell membrane damage and death (Cheeseman & Holley, 1993). *C. febrifuga* may bear similar pattern of action.

The decrease in absorbance of the DPPH radical caused by antioxidant was due to the scavenging of the radicals through hydrogen donation. This scavenging action was visually noticeable as a colour changed from purple to yellow and this observation is in agreement with some previously reported works (Piao *et al*., 2004; Yu *et al*., 2002). The plant extracts elicited DPPH radical scavenging activity at graded concentration (concentration–dependent). Most likely, the plant leaf methanol extract exhibited its antioxidant property via scavenging at 94.2% percentages against the standard, ascorbic acid at 90%.

ABTS {2, 2-azino-bis (3-ethyl benzothiazoline-6sulphonic acid)} free radical caused by oxidative stress was scavenged through hydrogen donation. The plant extract showed ABTS radical scavenging activity at graded concentration. It exhibited its scavenging property in percentage at 99.8% against the standard, ascorbic acid at 98.6%. In addition, the extract exhibited competitive scavenging property against hydrogen peroxide radical scavenging activity when compared with the reference antioxidant ascorbic acid 74.1 % and 53.1%.

The low phenol and flavonoid contents discovered in *C. febrifuga* if compared with quercetin concurs with the reports of some other researchers (Ouedraogo, *et al*., 2019). Flavonoid is one of the largest groups of phenolic metabolites which has greatly fascinated researchers interest (Su *et al*., 2021). According to many researchers, phenolic compounds have interesting bioactivities and so, more research is still required in order to comprehend their main actions in living organisms and improve their bioavailability, sustainable extraction methods, refine modification, and procedures of stability to increase the fields of application (Albuquerque *et al*., 2021).

The total phenol and flavonoid contents in *C. febrifuga* were low and this could be attributed to fact that the plant is usually rich in triterpene and saponins instead (Kayangar *et al*., 2019). The low amounts of phenolic compounds and flavonoids detected in *C. febrifuga* is in agreement with the works of some researchers (Ouedraogo, *et al*., 2019).

Previously, some phenolic compounds were reported in *C. febrifuga* using GC-MS (Nma *et al*., 2018) and this supports the identification of phenol in the present study. Nevertheless, the class of phenolic compounds that have been isolated from *C. febrifuga* are mostly flavonoids (Tomas-Barbera and Hostettmann, 1988). The antioxidant activity is in agreement with the findings reported elsewhere in which the extracts of *Parkia. biglobosa* showed better antioxidant activities that the standards trolox and quercetin used in the assay (Windmi *et al*., 2021).

The outcome of this study concur with other reports in which and *C. febrifuga* and *P. biglobosa* showed outstanding inhibition of lipid peroxidation, reactive oxygen species and scavenging capacities on ABTS and DPPH (Alfred *et al*., 2022, Komolafe *et al*., 2014; Oyedemi *et al*., 2021). The antioxidant activity exhibited by *C. febrifuga* was moderate with respect to some previous studies on a-tocopherol in the CUPRAC, ABTS and DPPH (Alfred *et al*., 2022). However, in some other studies, *C. febrifuga* showed higher antioxidant activity than quercetin though with relatively low phenolic and flavonoid (Ouedraogo *et al*., 2019). The *in vitro* antioxidant properties demonstrated by *C. febrifuga* leaf in this study also concurs with the report of Bealem *et al*. (2021) on the leaf of the same plant.

Nutraceutical properties of Crossopteryx febrifuga: The values of Ca, Mg, K, Na and Zn obtained in this study are lower but numerically comparable to those reported by Brice *et al*., (2016). However, phosphorus which was detected in *C. febrifuga* by Brice *et al*. (2016) was not detected in the present work. In addition, the result of proximate analysis showed that the value of crude protein was lower than that reported by Brice *et al*. (2016). These quantitative and qualitative disparities could probably be attributed to the difference in time of harvesting the plants, methodology or geographical location of the plant. On vitamins, to the best of my knowledge till date, no report on vitamin composition of *C. febrifuga* was found. However, results obtained from the plant are of comparative values with those reported on the leaf, bark and root of *Morinda lucida* (Adeleye *et al*. 2018)

which share the same family, Rubiaceae with *C. febrifuga*. The difference in values could be due to the fact that the two plants come from different genera.
The results of the water soluble vitamins obtained from *C. febrifuga* in the present study are also comparable to those reported by Datta *et al*. (2019) on *Oldenlandia corymbosa* which incidentally come from the same family Rubiaceae. However, two vitamins; Panthothenic acid (B5) and Pyridoxine (B6) which were detected in *C. febrifuga* were not detected in *Oldenlandia corymbosa* (Datta *et al*., 2019). Probably, this variation in vitamin constituents could be due to their difference in generic origin.

Conclusion

C. febrifuga leaf exhibited antioxidant properties and contains nutrients such as fat, carbohydrate, protein, fibre as well as nutraceutical elements such Ca, K, Zn, Mg, Na and vitamins such as vitamin C, thiamine, riboflavin, niacinamide, folic acid, pyridoxine and panthothenic acid in significant quantity. This clearly showed that the plant leaf could serve as a good source of supplements in a situation of their deficiency in man.

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