Evaluation of Phytochemical Contents, Proximate Nutritional Composition and Antimicrobial Activity of the Leaves and Rhizome Extracts of *Cyperus rotundus* Linn. in Uyo, Akwa Ibom State, Nigeria

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Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/SAJRM/2020v7i130159
Editor(s):
(1) Dr. Chamari Hettiarachchi, University of Colombo, Sri Lanka.
Reviewers:
(1) Seema Surendran, India.
(2) Aziz Khan, University of Science and Technology, Bannu, Pakistan.
Complete Peer review History: http://www.sdiarticle4.com/review-history/58042

Received 07 April 2020
Accepted 12 June 2020
Published 25 June 2020

ABSTRACT

**Background:** The leaves and rhizome extracts of *Cyperus rotundus* Linn. popularly called “Nut grass” in many Nigerian communities have been extensively used in local food preparation and in treatment purposes.

**Aim:** This study aimed to evaluate the phytochemical contents, proximate nutritional composition and antimicrobial activity of the leaves and rhizome extracts of *C. rotundus*.

**Methodology:** The disease-free plant materials were collected from a farm in Uyo, Akwa Ibom State, Nigeria. Preparation of the plant material, methanolic and aqueous extracts; bacterial culture, isolation, microscopy and biochemical identification; phytochemical screening and
proximate nutritional analysis were done according to standard methods, while screening for antimicrobial activity was done by agar well diffusion technique.

**Results:** The preliminary phytochemical analysis of the plant extracts showed the presence of bioactive compounds at varying amounts such as glycosides, tannins, reducing sugars, alkaloids, flavonoids, polyphenols, terpenoids, saponins and phlobatannins. The proximate nutritional and elemental analysis of *C. rotundus* extracts showed high presence of B-carotene (164.3 ± 0.02), Vitamin A (109.25 ± 0.01) and carbohydrate (59.0 ± 0.01) with moderate content of lipid (24.25 ± 0.02) and moisture (9.10 ± 0.01) as well as contents of some mineral elements such as Ca, K and P occurring in the range literature values in mg per 100 g dry weight of the plant sample. The methanol and aqueous extracts of *C. rotundus* showed varying diameter of zones of inhibition on the test organism. The observable inhibitory effect of the plant extracts on the test organism was more pronounced with methanol extracts as indicated by the diameter of zones of inhibition in mm in the order of 22.0>14.0>13.0 for *P. mirabilis*, *E. coli* and *S. aureus*, respectively compared to the aqueous extract.

**Conclusion:** The results of this study have shown the antimicrobial, therapeutic and nutritional potential of the leaves and rhizome extracts of *C. rotundus*. It could possibly find application as a good alternative antibacterial agent, nutraceuticals and dietary supplements.

**Keywords:** Antimicrobial; *Cyperus rotundus*; methanol; minerals; phytochemicals.

1. INTRODUCTION

*Cyperus rotundus* (*C. rotundus*) Linn. is a sedge of the family Cyperaceae and order Cyperales. This plant which grows naturally in tropical, subtropical and temperate regions is native to Africa, Southern and Central Europe (North of France and Austria) and Southern Asia [1]. *C. rotundus* is a perennial plant that may reach a height of up to 140 cm (55 inches). As in other Cyperaceae, the leaves sprout in ranks from three of the base of the plant, around 5-20 cm (2-8 inches) long [2].

*Cyperus rotundus* Linn. is recognized with many local names and synonyms in many places of its existence. In Nigeria, it is known as Nutgrass, coco-grass, purple nut sedge, yellow nut or red nut sedge. In Iraq, it is known as Soad or Al Saad, while in other areas, it is known as Nagarmotha, Nutsedge and others. The rhizome of *C. rotundus* is cylindrical in shape, scaly creeping, bulbous at the base and appears reddish in colour from inside and blackish outside, with a characteristic odour [3,4].

The leaves and rhizome (root) extracts of *C. rotundus* have been extensively studied over the years by many authors [2,5-7] owing to their traditional, nutritional and medicinal use, especially in the treatment of dental caries and bowel disorders which dates back to 300-400AD [2].

Several pharmacologically active substances have been identified in *C. rotundus* that may scientifically explain the folk and alternative medicinal uses. Previous researchers have detected many phytochemical constituents such as flavonoids, alkaloids, cyperol, fatty oils, furochromones, glycerol, linolenic acid, myristic acid, nootkatone, starch, saponins, sesqui-terpenes, sitosterol, stearic acid, terpenoids, polyphenol and novel sesquiterpenoids in the rhizomes and tubers of *C. rotundus* [3,4]. These substances account for the therapeutic, pesticidal, fungicidal and insecticidal properties of the plant.

The widespread medicinal use of *C. rotundus* have been indicated in treatment of nausea and vomiting, dyspepsia, colic, flatulence, diarrhea, dysentery, intestinal parasites, fever, malaria, cough, bronchitis, renal and vesical calculi, urinary tenesmus, skin diseases, wounds, amenorrhea, dysmenorrhea, deficient lactation, loss of memory, insects bites and food poisoning; while the aromatic oils from the plant are used for perfumes and splash [8]. In many parts of Nigeria, the leaves of *C. rotundus* are used as flavouring agents in food, the tubers and rhizomes are used as natural remedies to cure spasms, diarrhea, dysmenorrhea and menstrual irregularities [9].

There is a growing concern on the health impact of synthetic antioxidants in protecting against free radicals from oxidative DNA damage. This has led to a renewed interest in the use of naturally occurring compounds in plants and herbs with antioxidant properties. Extracts from *C. rotundus* have been shown to possess promising antioxidant potential against free
radical induced oxidative damage [10]. Phytochemical compounds such as polyphenols and flavonoids which are widely distributed in C. rotundus have been used to treat many human diseases such as diabetes, cancers and coronary heart diseases. Moreover, flavonoids have been shown to exhibit antiviral, antimicrobial, antiplatelet and antitoxic activities [11].

Several preliminary investigations have shown that the leaves and rhizome extracts of C. rotundus possess nutritional constituents and grave antimicrobial activity against a number of microorganisms such as Candida albicans, Klebsiella pneumoniae, Staphylococcus aureus, Enterococcus faecalis and Salmonella enteritidis at varying concentrations [12]. At present, a lot of studies have been carried out to unravel the pharmacologically active compounds, phytochemicals, antioxidants and nutritional compounds in the leaves and rhizome extracts of C. rotundus [7,12-14]. However, similar studies have not been replicated here in Nigeria to a larger extent, particularly in Uyo, Akwa Ibom State. Hence, there is a dearth of information on the phytochemical, nutritional and antimicrobial activity of C. rotundus in the region. Therefore, this study was carried out to investigate the phytochemical properties, nutritional composition and antimicrobial activity of C. rotundus collected from a farm in Uyo, Akwa Ibom State, Nigeria.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out between March, 2019 and September, 2019 at the Microbiology Laboratory of Obong University, located at Etim Ekpo Local Government Area. Etim Ekpo, created from the former Abak division is one of the Annang-speaking areas with GPS coordinates 5°1’N 7°37’E and time zone UTC +1 (WAT). According to the National Population Commission of Nigeria (web) and the National Bureau Statistics (web), the population statistics of Etim Ekpo is 148, 800 (2016 population census). It is a town situated in Akwa Ibom State, South-South geopolitical zone of Nigeria.

2.2 Collection (Source) and Identification of Plant Material

The disease-free plant materials were collected from a farm in Uyo Akwa Ibom State, Nigeria. They were kept in a dry polythene bag to reduce decomposition and transported in this form to Calabar, where it was properly identified by the forestry department as Cyperus rotundus Linn.

2.3 Laboratory Preparation of Plant Materials

The leaves and rhizome (root) of C. rotundus were washed to remove sand and other foreign particles which may act as contaminants before they were dried in shade. The dried samples were then pulverized using electric blender to obtain a fine powder. The pulverized sample with characteristic dark green color was sieved (0.2mm) and stored in airtight containers until required for further studies.

2.4 Source of Test Bacteria and Method of Identification

Three bacterial isolates namely: Staphylococcus aureus, Proteus mirabilis and Escherichia coli obtained from Microbiology laboratory of Obong University were used for the study. Identity of the isolates was confirmed after sub-culturing microscopically by Gram’s reaction and biochemically by catalase, oxidase, coagulase, citrate, indole, motility and sugar fermentation tests.

2.5 Preparation of Methanolic Plant Extract

Ethanolic extract of C. rotundus was prepared using 75% ethanol. Exactly 10 g of the powdered plant was weighed out into a sterile beaker container containing 100 ml of 75% ethanol, stirred, wrapped with aluminum foil and allowed to stay for 72 hours at room temperature (25°C). After 72 hours, it was filtered and the solvent was heated in a water bath to evaporate completely. The slurry left behind was then stored in McCartney bottles and kept at 4°C until required for use [15,16].

2.6 Preparation of Aqueous Plant Extract

5 g of powdered plant material was soaked in about 50 ml of sterile distilled water, stirred and left overnight. After 24 hours, the suspension was filtered using Whatman No.1 filter and the filtrate was heated in a water bath at 70°C to allow the solvent to evaporate to dryness to eliminate the water. The extract was labeled and stored in the refrigerator until when required for further analysis.
2.7 Preliminary Phytochemical Analysis

Phytochemical tests for the screening and identification of bioactive phytochemical constituents in the extracts of leaves and rhizomes of *C. rotundus* were carried out in two perspectives viz: Qualitative and Quantitative analyses.

2.8 Qualitative Analysis

The extracts were tested for the presence of the following bioactive compounds namely; glycosides, saponins, alkaloids, flavonoids, phenols, phlobatannins, tannins, reducing sugars, anthraquinones and terpenoids using standard methods.

2.8.1 Test for alkaloids (Dragendorff’s test)

About 2 mL of the extract was treated with 3-5 drops of Dragendorff’s reagent and observed for the formation of an orange precipitate to detect the presence of alkaloids.

2.8.2 Test for saponins (Frothing test)

Two milliliter of (Aqueous and ethanolic separately) extracts was shaken vigorously and observed for a stable persistent froth. The frothing was mixed with few drops of olive oil and shaken vigorously after which it was observed for the formation of an emulsion.

2.8.3 Test for glycosides (Keller-Killiani test)

To 5 mL of the extract, 2 mL of glacial acetic acid was added followed by 1 drop of 5% FeCl₃ and then con. H₂SO₄. The appearance of a reddish brown ring at the junction of the two liquid layers indicates the presence of glycosides in the extract.

2.8.4 Test for flavonoids (Alkaline reagent test)

Two milliliter of the extracts was treated with few drops of 20% NaOH solution. Formation of intense yellow colour, which becomes colourless on the addition of dilute HCl, indicates the presence of flavonoids.

2.8.5 Test for polyphenols (Ferric chloride test)

Two milliliter of the extracts were treated with aqueous 5% ferric chloride and observed for formation of deep blue or black colour.

2.8.6 Test for phlobatannins (Precipitate test)

Two milliliter of the extract was boiled with 1 mL of 1% aqueous hydrochloric acid and then shaken. Deposition of a red precipitate was taken as evidence for the presence of phlobatannins.

2.8.7 Test for tannins (Braymer’s test)

Two milliliter of the extract was treated with 10% alcoholic ferric chloride solution and observed for formation of blue or greenish colour solution.

2.8.8 Test for anthraquinones

Two milliliter of the plant extract was shaken with 10 mL benzene, filtered and 5 mL of 10% NH₃OH was added. The mixture was shaken and the presence of pink/red or violet coloration in ammonical (lower) phase indicated the presence of free anthraquinones.

2.8.9 Test for terpenoids (Salkowski’s test)

One milliliter of chloroform was added to 2 mL of the extracts followed by a few drops of concentrated H₂SO₄. Reddish brown precipitate produced immediately indicated the presence of terpenoids.

2.8.10 Test for reducing compounds

Fehling’s Test: 2 mL of the extracts were put in test tubes, 5 mL of Fehling solution added and heated in the water bath for 5 min. The formation of brick-red precipitation or coloration indicated the presence of reducing sugar.

Molisch’s Test: To 5 mL of each extract, 2 drops of alcoholic solution of α-naphthol was added and mixed by vigorous stirring. This was followed by the addition of 1 mL of conc. H₂SO₄. The formation of a violet ring in the test tube within few minutes indicated the presence of carbohydrates.

Benedict’s Test: 1 mL of Benedict’s reagent was added to 2 mL of the extract and heated on a water bath for 2 minutes. The development of a characteristic colored precipitate indicated the presence of sugar.

2.9 Proximate and Nutritional Analyses of *C. rotundus*

Analysis of the proximate compositions of *C. rotundus* was carried out using the official method (dehydration) described by the Association of Analytical Chemists [17] and the DNS colorimetric and Kjeldahl method. Elemental compositions of the plant were
determined by the wet digestion extraction method as described by AOAC [17]. All the calculations were carried out on the dry weight basis of the Nutgrass (C. rotundus) and expressed in mg/100 g dry weight. The proximate nutritional compositions were determined by the spectrometric method [17,18,19]. The amount of vitamins and other nutrients present were expressed as mean values ± standard deviation.

2.10 Screening for Antibacterial Activity of C. rotundus Extracts by Agar Well Diffusion Assay

Screening for antibacterial activity was done by agar well diffusion technique as described by Adeniyi et al. [20]. Plates of Mueller Hinton Agar (MHA) were inoculated with 0.1 mL of a 24 hr broth culture (equivalent to 0.5 MacFarland turbidity standards) of each bacteria isolate in sterile Petri dish. The seeded plates were rocked to obtain homogenous distribution of the isolates and allowed to set. Holes were bored on the plates with the aid of a sterile cork borer of 5mm diameters and equal volumes of 50 µl of extract were introduced in the wells using a micropipette. The plates were allowed to stand for an hour at room temperature to allow for proper diffusion of the extract, before incubation for 24 hr at 37°C. After incubation, the diameter of zones of inhibition was measured, including the 5 mm diameter of the hole using a digital caliper. The experiments were carried out in triplicates and the mean values were calculated and recorded in millimeter. Antibacterial activity was recorded when the zone of inhibition was greater than 5 mm. A solution of only dimethylsulfoxide (DMSO) and water in equal ratios was used as negative control while Ciprofloxacin antibiotics disc was used as positive control.

3. RESULTS

Table 1 shows the result of the phytochemical screening of the leaves and rhizome extracts of C. rotundus. Alkaloids, glycosides, saponin, flavonoids, polyphenols, tannins, terpenoids and reducing compounds were detected in both leaves and rhizome extracts of the solvents. Phlobatannins was detected only in the rhizome extract, while anthraquinones was not detected in any of the plant parts investigated. Comparatively, ethanol extracts of leaves and rhizome yielded more phytochemical compounds than aqueous extracts.

The quantitative phytochemical screening of C. rotundus extracts in mg/100 g dry weight of sample is presented in Table 2. The plant extracts exhibited important quantity of alkaloids, glycosides, flavonoids, polyphenols and reducing compounds. The highest content of these compounds was found in methanol extract, with reducing compounds (451 ± 11 mg/100 g) being the most abundant followed by polyphenols (401 ± 11 mg/100 g). The least compound was saponin in aqueous extract with percentage abundance of 42 ± 11 mg/100 g dry weight.

Table 3 shows the proximate nutritional composition of C. rotundus expressed in mg per 100g dry weight of the sample. The results showed the plant is high in B-carotene (164.3 ± 0.02), Vitamin A (109.25 ± 0.01), carbohydrate (59.0 ± 0.01) and lipid (24.25 ± 0.02) content but low in Vitamin C, protein, moisture and total ash content.

### Table 1. Preliminary phytochemical screening of the leaves and rhizome extracts of C. rotundus

| Phytochemical constituent | Test                     | Leaves extracts | Rhizome extracts |
|--------------------------|--------------------------|------------------|------------------|
|                          |                          | Aqueous          | Ethanol          | Aqueous          | Ethanol          |
| Alkaloids                | Dragendorff’s test       | +                | ++               | +                |       |
| Glycosides               | Keller-Killiani test     | ++               | ++               | -                |       |
| Saponin                  | Frothing test            | +                | ++               | +                |       |
| Flavonoids               | Alkaline reagent test    | +                | ++               | -                |       |
| Polyphenols              | Ferric chloride test     | ++               | +++              | +                |       |
| Phlobatannins            | Precipitate test         | -                | -                | +                |       |
| Tannins                  | Brayer’s test            | +                | +                | +                |       |
| Anthraquinones           | NH₃OH test               | -                | -                | -                |       |
| Terpenoids               | Salkowski’s test         | -                | +                | +                |       |
| Reducing compounds       | Fehling’s test           | -                | -                | +                |       |
|                          | Molisch’s test           | +                | ++               | +                |       |
|                          | Benedict’s test          | +                | +                | -                |       |

**Key:** - = Absent; + = Present; ++ = Present in moderate amount; +++ = Present in excess
of which potassium was the most abundant (K = 561.5 mg/100 g dry weight) followed by phosphorus (P = 234.6 mg/100 g dry weight). The least abundant mineral element was copper (Cu = 0.46 mg/100 g dry weight).

Table 5 shows the antimicrobial activity of ethanol and leaves extracts of *C. rotundus* on the test organisms. The results showed the diameter of inhibition zones in mm of extracts for *P. mirabilis*, *E. coli* and *S. aureus* to be 22.0>14.0>13.0 for methanol extract and 19.0>12.0>10.0 for aqueous extract, respectively. However, the diameter of zones of inhibition for the positive control with Ciprofloxacin antibiotics was comparatively higher than that obtained from the two extracts against the test organisms.

### 4. DISCUSSION

*Cyperus rotundus* Linn. is a sedge of the family Cyperaceae and order Cyperales that is widely distributed in the Mediterranean basin areas and grows naturally in tropical, sub-tropical and temperate regions. It is widely regarded as a traditional medicine plant due to its potent pharmacological, antioxidant, hepatoprotective and antimicrobial properties; and as a good source of nutraceuticals [6,24]. Increasing trend in antimicrobial resistance of some pathogenic microorganisms such as *S. aureus*, *P. mirabilis* and *E. coli* to commonly used antibiotics has prompted a rapid search for the use of medicinal plant as alternative source for the development of therapeutics and nutraceuticals [2]. In this study, evaluation of the phytochemical potentials of *C. rotundus* revealed that its aqueous and methanolic extracts contains a number of bioactive compounds such as alkaloids, glycosides, saponin, flavonoids, polyphenols, tannins, terpenoids, reducing compounds and phlobatannins but with iteration in the type of solvent used (Table 1). This result is in accordance with that reported by Karzan et al. [6], Omeman et al. [7], Okuda and Ito [25], but slightly differs from the results of Wangila [12] and Arumugam and Vijisaral [26] who reported the presence of similar phytochemical compounds except flavonoids. The observed difference may be due to the methods adopted for the preliminary screening as the former used Shinoda test while the later used alkaline reagents, as used in this study.

The phytochemical compounds in *C. rotundus* possess excellent medicinal values and have been reported to demonstrate good anti-cancer, anti-malarial, hepatoprotective, hypolipidaemic,

### Table 2. Quantitative phytochemical screening (mg/100 g dry weight) of extracts from *C. rotundus*

| Phytochemical compounds | Aqueous | Methanol |
|-------------------------|---------|----------|
| Alkaloids               | 274 ± 11| 320 ± 11 |
| Glycosides              | 252 ± 14.5| 301 ± 14.5|
| Saponins                | 42 ± 8.5 | 85 ± 8.5 |
| Tannins                 | 46 ± 11  | 98 ± 11  |
| Flavonoids              | 280 ± 11 | 337 ± 11 |
| Polyphenols             | 381 ± 11 | 401 ± 11 |
| Reducing compounds      | 395 ± 11 | 451 ± 11 |

Each value represents the mean of 3 determination ± SD

### Table 3. Proximate nutritional composition of *C. rotundus* (mg/100 g dry weight)

| Parameter                | Amount (Mean ± SD) in mg/100 g |
|--------------------------|---------------------------------|
| Moisture content         | 9.10 ± 0.01                     |
| Total ash content        | 3.40 ± 0.01                     |
| Lipid content            | 24.25 ± 0.02                    |
| Protein content          | 4.71 ± 0.02                     |
| Carbohydrate content     | 59.0 ± 0.01                     |
| B-carotene               | 164.3 ± 0.02                    |
| XSEREAWE                 | 109.25 ± 0.01                   |
| Vitamin A                | 3.25 ± 0.02                     |
| Vitamin C                | 164.3 ± 0.02 |

### Table 4. Mineral composition of the leaves of *C. rotundus* in mg/100 g dry weight

| Mineral | Composition | Range of reported literature values |
|---------|-------------|-------------------------------------|
| Sodium (Na) | 6.4 | 7.2-14.9 [21] |
| Potassium (K) | 561.5 | 556.9-845.8 [22] |
| Calcium (Ca) | 22.78 | 19.09-32.27 [22] |
| Magnesium | 102.7 | 105.5-112.3 [22] |
| (Mg) | Iron (Fe) | 10.12 | 13.57-15.44 [21] |
| Zinc (Zn) | 1.22 | 1.88-2.7 [22] |
| Copper (Cu) | 0.46 | 0.43-0.71 [23] |
| Phosphorus (P) | 234.6 | 229.6-283.7 [23] |

Table 4 shows the mineral composition of the leaves of *C. rotundus* in mg/100 g dry weight. A total of eight (8) mineral elements were detected of which potassium was the most abundant (K = 561.5 mg/100 g dry weight) followed by phosphorus (P = 234.6 mg/100 g dry weight). The least abundant mineral element was copper (Cu = 0.46 mg/100 g dry weight).
The proximate nutrient composition in leaves extract of *C. rotundus* was carried out to determine the mean level of food constituents and vitamins as well as the mineral composition in mg/100 g dry weight of the sample (Table 3). Analysis of the proximate nutritional composition of the extract clearly showed that the plant is high in B-carotene (164.3 ± 0.02), Vitamin A (109.25 ± 0.01), carbohydrate (59.0 ± 0.01) and lipid (24.25 ± 0.02). However, the moisture content as well as Vitamin C, protein and total ash contents is considerably low. This result is consistent with the report of Ibrahim et al. [31]. The moisture content of foods and food products to a large extent determines the level of microorganisms and also the degree of spoilage in foods. This perhaps has a direct influence on the physical, chemical, stability and freshness of the food product during long storage. The low moisture content in *C. rotundus* is desirable in terms of durability and edibility of the plant product. This study reports low moisture content of 9.10±0.01 mg/100 g in dry leaves sample of *C. rotundus* which is a little bit higher to the 5.19% moisture content reported by Kabbashi et al. [32].

This study also shows that, *C. rotundus* is rich in protein (4.71 ± 0.02), ash (3.40 ± 0.01), carbohydrate (59.0 ± 0.01), lipid (24.25 ± 0.02) and B-carotene (164.3 ± 0.02). This suggest that the plant contains a high source of energy and its food product such as the tiger nut could serve as excellent food supplement with high nutritive value. These food classes possess satiety values and could help in delays emptying of the stomach [22]. Studies have shown that the presence of beneficial protein in plant can function in lowering blood sugar levels, thus serving as a good nutraceutical for diabetes. The low lipid content in *C. rotundus* could possibly improves blood cholesterol levels, decrease the

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**Table 5. Antimicrobial activity of ethanol and leaves extracts of *C. rotundus***

| Test organism        | Aqueous | Ethanol | -ve control | +ve control |
|----------------------|---------|---------|-------------|-------------|
| *Escherichia coli*   | 12.0    | 14.0    | -           | 23.0        |
| *Staphylococcus aureus* | 10.0    | 13.0    | -           | 17.0        |
| *Proteus mirabilis*  | 19.0    | 22.0    | -           | 25.0        |

Each value is expressed as mean of three experiments in mm; - indicates no activity

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anti-diarrhoeal, analgesic and anti-inflammatory activities [2,24,27]. For instance, polyphenols and flavonoids widely distributed in this plant and present in considerable amounts in leaves and rhizomes (Table 2) have been used to treat human diseases, such as diabetes, cancer and coronary heart diseases [28]. Also, flavonoids have also been shown to exhibit antiviral, antimicrobial, antiplatelet, antitoxin, antioxidative and antigenotoxic activities. These activities are believed to be due to their redox properties. In fact, polyphenols can play important roles in absorbing and neutralizing free radicals, quenching singlet and triplet oxygens, or decomposing peroxides [28]. Other bioactive compounds also detected in the plant extracts such as saponins have been shown to possess hypotensive and cardio depressant properties, while glycosides have been used naturally as cardioactive drugs in the treatment of congestive heart failure and cardiac arrhythmia [29].

Quantitative extraction of the phytochemical compounds in *C. rotundus* was performed in two solvents, with reducing compounds, polyphenols, flavonoids alkaloids and glycidoses present in much higher amount in methanol solvent than in aqueous solvent, each value expressed in mg per 100 g dry weight of the sample (Table 2). The only secondary metabolite not detected in both solvents was anthraquinones, while terpenoids was detected only in methanol solvent. This result was in agreement with reports from previous literature [5,6,7,30]. The quantitative estimation may be useful in determining the level of these compounds in the plant sample which may subsequently lead to its deployment by humans either in medicinal formulation or in other areas of relative traditional importance. For instance, *in vivo* studies of the effect of the methanolic extracts of flavonoids and terpenoids in albino rats have indicated their effectiveness in the treatment of inflammatory diseases. Additionally, terpenoids have been found to possess significant antipyretic and analgesic effects similar to salicylic acid [27]. Also, cytoprotective effects of *C. rotundus* have been indicated in case of ethanol induced gastric damage in albino rats, as well as its significant antidiarrhoel, haemodynamic and hypolipidaemic activities [24].
risk of cardiovascular disease and promote weight loss. The presence of some vitamins such as Vitamin A, Vitamin C and B-carotene is an indication that C. rotundus may play a part in the regulation of bodily functions, because some vitamins require fat for their dissolution into the blood stream and provide nutrients. Also, vitamin A is necessary for enhancement of good vision that can be gotten from C. rotundus [33,34].

In this study, the mineral composition of C. rotundus include both essential and trace elements such as sodium, potassium, calcium, phosphorus, magnesium, iron, zinc and copper in varying amounts (Table 4). This result is close to that obtained by Ekeanyanwu and Ononogbu [22], Adejuyitan [35] who reported the presence of similar elemental composition in addition to cobalt. Studies have shown the involvement of these elements in the regulation of certain activities in human cells, tissues and organs. The strengthening of heart muscle contraction is aided by increase in Ca$^{2+}$ concentration in cells while Fe$^{3+}$ plays a role in blood circulation. Also, minerals in diets are solely required for metabolic reactions, transmission of nerve impulses, rigid bone formation and regulation of salt and water balance in the body. These elements are important in proper biochemical function and their presence could improve immunological and physiological processes that can mitigate certain diseases in the body [33]. Previous studies have shown that the leaves and rhizome of C. rotundus are edible and have some nutritional value. The Rhizome (root) and tubers are known to contain high amount of carbohydrates and are also good nutritional source of mineral and trace elements [2].

Antimicrobial activity of C. rotundus extracts was tested on Gram-negative bacteria, E. coli and P. mirabilis and Gram-positive bacterium, S. aureus using agar well diffusion technique (Table 5). The antimicrobial potential of C. rotundus extracts showed their ability to inhibit the growth of these organisms in vitro as indicated by the diameter of zones of inhibition in mm of methanol extract in the order of 22.0>14.0>13.0 for P. mirabilis, E. coli and S. aureus, respectively. There was remarkable iteration in the antimicrobial efficacy of the different extracts on the test organisms. In aqueous extract, the diameter of zones of inhibition was found to be in the order of 19.0 mm>12.0 mm>10.0 mm for P. mirabilis, E. coli and S. aureus, respectively. The highest antimicrobial activity of methanol extract was found at 22.0 mm against P. mirabilis and lowest at 13.0 mm against S. aureus. On aqueous extract, maximum antimicrobial activity was equally recorded for P. mirabilis at 19.0 mm and minimum at 10.0 mm for S. aureus. This result was similar to that obtained from previous studies [5,7,31]. This may be due to variation in the polarity of the two solvents and the differences in the level of resistance of the test organism vis-à-vis their virulence nature. The Ciprofloxacin (5 µg) disc used as positive control showed greater antimicrobial activity to the test organisms in comparison to the plant extracts with diameter of zones of inhibition at the range of 17– 25 mm. This indicates increased efficacy of the fluoroquinolone antibiotic and confirms the rationale for its widespread use in the treatment of bacterial infections caused by these pathogens in both community and hospital settings [6].

The observable inhibitory effect of the plant extracts on the test organism is not surprising because the active extracts contain flavonoids and other polyphenolic compounds. These families of compound have been reported to play significant role in the prevention of colonization of epithelial, mucosal and enteric surfaces by parasites, bacteria and fungi [7,36]. Preliminary screening for antimicrobial activity of C. rotundus and the tested bacteria revealed such activity with methanol and aqueous extracts. The methanol extract contains higher quantities of flavonoids, tannins and polyphenols than the aqueous extract. Thus, their antimicrobial activity is somewhat different [37]. We deduced that, the polyphenolic composition in methanol extract is somewhat different from that of aqueous extract since they are solvents with dissimilar polarities. Phytochemical compounds such as tannins, flavonoids and polyphenols have been reported to contribute to the antimicrobial activity of C. rotundus extracts [6,7]. Interestingly, it is known that these phytochemicals can form heavy soluble complexes with proteins, bind to bacterial adhesions and block the activity of certain receptors on the cell surface [38]. Also, tannins which are active compounds in several medicinal plants have been shown to form irreversible complexes with proline-rich proteins resulting in the inhibition of cell wall proteins. This property could elucidate the antimicrobial mechanisms of plant extracts. This explanation also goes further to corroborates reports of several in vitro assays demonstrating potentially significant interactions of these bioactive compounds with biological systems such as viruses,
bacteria and molluscs as well as enzyme inhibiting, antioxidant and radical-scavenging properties. Their tendency to interfere with biological systems is partly due to a characteristic ability to form complexes with macromolecules combined with a polyphenolic nature [14,39].

5. CONCLUSION

This study revealed the presence of certain phytochemical compounds and nutritional composition in rhizome and leaves extracts of C. rotundus indicating that the plant possesses excellent pharmaceutical and nutraceutical potentials. Antimicrobial activity of the plant extracts on the test organism showed that it has inhibitory effect on some bacterial pathogens which could be exploited as alternative treatment option for certain bacterial infections and in the development of drug in future. The proximate nutritional and mineral composition of the plant extracts is also an indication that it could serve as a good source of food supplement supplying the body with essential elements, vitamins, carbohydrates and proteins.

ACKNOWLEDGEMENTS

The authors would wish to acknowledge the management, staff and students of the Department of Microbiology, Obong University, Etim Ekpo, Akwa Ibom State – Nigeria for providing research facilities, technical assistance and encouragement. Our thanks are also due to Mr. Sunday Michael Ekpo of Biochemistry Department, University of Calabar, Calabar – Nigeria for providing useful information about the plant and identification of the plant sample as Cyperus rotundus.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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