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Inhibitory Effects of Stem Bark Extract of *Chrysophyllum albidum* (G. Don) against Selected Gastrointestinal Tract Pathogens

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Abstract
This study investigated the inhibitory effects of stem bark extract of Chrysophyllum albidum against selected gastrointestinal tract pathogens. Powdered stem bark was cold extracted using methanol and sterile distilled water in ratio 3:2 (v/v). The mixture obtained was concentrated in vacuo using a rotary evaporator and lyophilized. The stem bark extract was screened for antibacterial, phytochemicals and antioxidant properties using standard method. The antibacterial activities were determined using agar well diffusion method while the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) were determined using agar dilution method. Results obtained indicate that the zones of inhibition shown by the stem bark extract at 10 mg/mL against the bacterial isolates ranged between 10±0.82 mm and 25±0.00 mm. The MICs ranged between 0.31 mg/mL and 5mg/mL while the lowest MIC was 0.31 mg/mL. The MBCs ranged between 0.63 mg/mL and 10 mg/mL while we recorded 0.63 mg/mL as the lowest MBC. The phytochemical screening of the extract revealed the presence of tannins, alkaloids, flavonoids, saponins, steroids, terpenoids, reducing sugar and cardiac glycosides. The antioxidant analysis of stem bark extract showed appreciable antioxidant properties when compared with vitamin C used as control. The stem bark extract exhibited percentage inhibition of 62.80% at a concentration of 15.63 µg/mL while vitamin C exhibited percentage inhibition of 63.53% at the same concentration. This study showed that stem bark extract of Chrysophyllum albidum possessed bioactive compounds that exhibited appreciable antibacterial and antioxidant activities against the gastrointestinal tract pathogens.

Keywords: *Chrysophyllum albidum*, gastrointestinal tract pathogens, phytochemicals, bioactive compounds, inhibitory effects

INTRODUCTION
Gastrointestinal infections are responsible for a high rate of morbidity in the world, although its highest incidence occurs in the developing countries (Sotelo-Coronado *et al.*, 2016). Gastrointestinal infections are a major cause of death claiming about two million lives each year among children less than 5 years of age (Moorin *et al.*, 2010). For this reason, it is

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considered the second leading cause of death in the population at this age, even in developed countries. Gastrointestinal infections also contribute to economic loss in most parts of the world, including high-income countries that have developed surveillance and control programs (Moorin *et al*., 2010). The microorganisms that cause gastrointestinal infections vary with the geographic region, degree of economic development each year, level of sanitation and hygienic standards (Burd and Hinrichs, 2015). Many common gastrointestinal infections are caused by bacteria including *Bacillus cereus*, *Campylobacter jejuni*, *Salmonella typhi*, *Shigella dysenteriae* and *Escherichia coli* (Burd and Hinrichs, 2015). These bacterial pathogens can be readily cultured from freshly collected stool specimens of infected patients using a variety of selective and specialized media (Burd and Hinrichs, 2015). Clinical laboratories generally use a limited set of media to recover the most common bacterial pathogens (Burd and Hinrichs, 2015). For instance, *Salmonella*, *Shigella* and *Campylobacter*.

Gram-negative bacteria are recognized as the most difficult healthcare-associated infections to control and treat (Akasaka *et al*., 2001). For example, resistance to quinolones in Gram-negative bacteria is mainly as a result of genomic mutations which consequently prevent the antibiotic from reaching the site of action (Akasaka *et al*., 2001). To this effect, the search for an innovative antibiotic from natural products is ultimately an important segment of modern medicine to overcome the socio-economic and health impact caused by multidrug-resistant microorganisms (Bakal *et al*., 2017). Natural products of higher plants may possess a new source of antimicrobial agents with possible novel mechanisms of action (Barbour *et al*., 2004; Ahmad and Aqil, 2007).

Among the medicinal plants studied by researchers is *Chrsophyllum albidum*. *Chrysophyllum albidum* is an indigenous plant and an edible tropical fruit (Idowu *et al*., 2006). It is a medicinal herb which belongs to the family Sapotaceae (Idowu *et al*., 2006). It is often called the white star apple or African star apple (Idowu *et al*., 2006). It is widely distributed in Nigeria, Uganda, Niger, Cameroun and Cote d' ivoire (Duyilemi and Lawal, 2009; Adebayo *et al*., 2011). The root, seed and stem bark obtained from this plant exhibited antimicrobial and antioxidant properties (Oputa *et al*., 2016; Dandare *et al*., 2017; George *et al*., 2018). This plant can also be used as anti-inflammatory, anti-spasmodic, anti-analgesic and diuretic properties which can be attributed to their high flavonoids, steroids, glycosides and saponins (Savithramma, 2011). There is paucity of data on the antibacterial potentials of plant extracts against the gastrointestinal tract pathogens. Hence, this study was designed to investigate the inhibitory effects of stem bark extract of *Chrysophyllum albidum* (G. Don) against selected gastrointestinal tract pathogens.

MATERIALS AND METHODS

Collection and Preparation of Bacterial Isolates

The bacterial isolates used in this study include clinical and control strains. The clinical strains were collected from the culture room of Microbiology Laboratory, Aminu Kano Teaching Hospital, Kano, Kano State, Nigeria. The bacterial isolates include *Escherichia coli*, *Shigella dysenteriae* and *Salmonella typhi* from various stool samples while *Escherichia coli* (ATCC 25922), *Shigella dysenteria*e (ATCC 13313) and *Salmonella typhi* (ATCC 14208) were employed as the control strains. The control strains were obtained from American Type Culture Collection (ATCC), Manassas, Virginia, United States of America. The bacterial isolates' identities were confirmed based on cultural, morphological and biochemical laboratory tests and API 20E test. After confirmation, the bacterial isolates were sub-cultured in nutrient broth, incubated at 37 ^{o}C for 18 h and then standardized to 0.5 McFarland standard (10^6 CFU/mL) before use.

Media Employed for Culturing Bacterial Isolates and Sensitivity Testing
Nutrient agar medium was used for sub-culturing the bacterial isolates while Mueller Hinton agar medium was used for the sensitivity testing.

Collection of Plant Material
Fresh stem barks of *Chrysophyllum albidum* (G. Don) were collected in Ile-Ife, Osun State, Nigeria in the month of December, 2020. The stem barks were identified and authenticated at the Herbarium, Plant Biology Department, Bayero University, Kano, Kano State, Nigeria by Mr Baha'uddeen Said Adam. Voucher specimen was prepared and deposited for reference purposes under herbarium accession number BUKHAN 0522.

Preparation of the Plant Extract
The stem barks of *Chrysophyllum albidum* were washed thoroughly under tap water, air dried under a shade, milled into powdery form and sieved using filter to obtain fine ground particles. Exactly, 1500 g of powdered stem barks were extracted using methanol and sterile distilled water in the ratio of 3:2 (v/v) for four days with regular agitation at time intervals. The supernatants collected were filtered using number 1 Whatman filter paper and the filtrate was concentrated *in vacuo* using a rotary evaporator to eliminate the methanol. The aqueous residue left was then lyophilized to obtain a 148.5 g of a dark brown stem bark extract.

Qualitative Phytochemical Tests
The stem bark extract was subjected to phytochemical screening using the methods described by Trease and Evans (2002) and Harborne (2006).

Quantitative Phytochemical Tests
The methods described by Ejikeme *et al*. (2014), Indumathi *et al*. (2014), Obdoni and Ochuko (2001), Makinde and Obih (1985), Boham and Kocipai-Abyazan (1974) were used to determine the quantity of each bioactive constituent present in the stem bark extract.

Antioxidant Property of *C. albidum* Stem Bark Extract
The antioxidant of the stem bark extract was investigated on the basis of its ability to reduce the stable 1,1-diphenyl-2-picrylhydrazyl (DPPH) free radical assay as described by Brand-Williams *et al*. (1995). Various concentrations of *C. albidum* stem bark extract were prepared using analytical methanol. Vitamin C (ascorbic acid) was used as an antioxidant standard. Exactly, 1 mL from each extract and 3 mL of methanol was mixed with 0.5 mL of 1.0 Mm DPPH in methanol and allowed to react at room temperature for 30 minutes. The absorbance was measured using a spectrophotometer at a wavelength of 517 nm. The blank solution was prepared using the same amount of methanol and DPPH. The DPPH with solvent (without extract) served as the control. All measurements were made in triplicate and averaged. The ability of the extract to scavenge DPPH radical was calculated using the following equation:

$$\text{DPPH radical scavenging activity (\% inhibition)} = \frac{A_{blank} - A_{sample}}{A_{blank}} \times 100$$

Where A_{blank} = Absorption of the blank, A_{sample} = Absorption of the extract.

Antibiogram of *C. albidum* Stem Bark Extract and the Standard Antibiotics against Bacterial Isolates
The antibiogram of the stem bark extract of *C. albidum* together with the standard antibiotics was determined using agar-well diffusion method (Hugo and Russel, 2015) with some modifications. Exactly, 0.1 mL of the standardized bacterial isolates (0.5 McFarland standard)

was inoculated into molten Mueller Hinton Agar (Oxoid, UK), poured into sterile Petri dishes and allowed to set. The wells were then bored into the agar medium using a sterile cork borer with diameter of 6 mm. The wells were filled with 0.1 mL prepared solutions of the extract at a concentrations of 10, 5, 2.5, 1.2 and 0.63 mg/mL and care was taken not to allow spillage of the solution on the surface of the medium. The plates were allowed to stand on the laboratory bench for about 1 h before incubating the plates in an upright position at 37 ^{o}C for 24 h. The plates were later observed for zones of inhibition and the diameters of zones of inhibition were measured using a sterile ruler and readings were recorded in millimeter. The sensitivity of the bacterial isolates to the extract were compared with that of streptomycin and ampicillin at a concentration of 1 mg/mL each which served as positive control. Exactly, 10% Dimethyl sulfoxide (DMSO) served as negative control and the experiment was carried out in triplicates.

Determination of Minimum Inhibitory Concentrations
The minimum inhibitory concentrations (MICs) of the stem bark extract were determined by agar dilution method following standard procedure (EUCAST, 2000; Akinpelu *et al*., 2015). Two-fold dilutions of the stem bark extract were prepared in sterile distilled water and 2 mL of different concentrations of the solution were added to 18 mL of sterile molten Nutrient agar to give final concentration regimes of 0.16 mg/mL to 10 mg/mL. The medium was then poured into sterile Petri dishes and allowed to set. The surfaces of the media were allowed to dry before streaking with 18 h old standardized bacteria cultures. The plates were later incubated at 37 ^{o}C for up to 48 h after which they were examined for the presence or absence of growth. Sterile agar medium plate without the extract served as control. The MICs were taken as the lowest concentration that prevented the growth of the test bacteria.

Determination of Minimum Bactericidal Concentrations
The minimum bactericidal concentrations (MBCs) of the stem bark extract were determined by using the method reported by Akinpelu *et al*. (2015). Samples for the MBCs were taken from the line of streaks without visible growth on the MIC plates and sub-cultured onto freshly prepared Nutrient agar plates and later incubated at 37 ^{o}C for 48 h. The MBCs were taken as the lowest concentrations of the extract that did not show any growth on a new set of plates.

Statistical Analysis
Data were expressed as mean ± SD (standard deviation) of three replicates and were statistically analysed using descriptive analysis. Values were considered significant at $p \leq 0.05$.

RESULTS
The stem bark extract exhibited appreciable antibacterial potentials against the bacterial isolates at different concentrations. The zones of inhibition exhibited by the stem bark extract against the bacterial isolates ranged between 10±0.82 mm and 25±0.00 mm (Table 1). The zones of inhibition exhibited by *Escherichia coli* at different concentrations ranged between 10±0.82 mm and 25±0.00 mm, *Salmomella typhi* (10±0.00 mm and 22±1.63 mm) and *Shigella dysenteriae* (10±1.63 mm and 20±082 mm). The highest zone of inhibition 25±0.00 mm was expressed against *Escherichia coli* at a concentration of 10 mg/mL. Some bacterial isolates were resistant to the standard antibiotics used in this study while some were susceptible at a concentration of 1 mg/mL. *Escherichia coli and Shigella dysenteriae* demonstrated 45.4% resistance to ampicillin while *Salmonella typhi* expressed 36.4% resistance to ampicillin. Streptomycin at a concentration of 1 mg/mL inhibited the growth of 19 bacterial isolates while ampicillin at the same concentration inhibited the growth of 14 bacterial isolates out of the 28 bacterial isolates used in this study. The zones of inhibition expressed by the standard antibiotics used as a

positive control ranged between 10±0.00 mm and 28±0.82 mm. The stem bark extract at a concentrations of 5 mg/mL and 10 mg/mL inhibited the growth of all the bacterial isolates (Table 1).

Table 1: Sensitivity patterns exhibited by the stem bark extract of *Chrysophyllum albidum* against bacterial isolates

	Zones of inhibition (mm)**							
Bacterial isolates	**10 mg/mL**	**5 mg/mL**	**2.5 mg/mL**	**1.25 mg/mL**	**0.63 mg/mL**	**STP 1 mg/mL**	**AMP 1 mg/mL**	**DMSO (10%)**
EC1	22±0.82	18±0.82	16±1.63	14±0.00	12±0.82	10±0.82	0	0
EC2	20±0.82	18±0.00	16±0.82	14±1.63	12±0.00	0	18±1.63	0
EC3	20±1.63	17±0.82	14±0.82	11±1.63	0	24±0.82	22±0.00	0
EC4	22±0.00	18±1.63	14±0.00	12±0.00	0	23±0.82	0	0
EC5	13±0.82	11±0.00	0	0	0	24±1.63	12±0.00	0
EC6	20±0.00	16±0.82	12±0.00	10±1.63	0	0	20±0.82	0
EC7	25±0.00	22±0.82	18±0.82	16±0.00	13±0.82	26±0.82	28±0.82	0
EC8	22±1.63	18±1.63	14±0.00	12±0.82	10±0.82	22±0.82	26±0.00	0
EC9	25±0.00	23±0.82	18±0.82	14±0.00	12±0.82	0	0	0
EC10	20±1.63	16±0.82	14±0.00	10±0.82	0	16±0.82	0	0
EC11	21±1.63	18±0.00	16±0.82	14±0.82	12±0.00	24±0.82	22±0.00	0
ST1	12±0.00	10±1.63	0	0	0	13±0.82	0	0
ST2	16±0.82	12±0.82	10±0.82	0	0	20±0.82	0	0
ST3	13±0.00	11±0.82	0	0	0	10±0.00	20±0.82	0
ST4	20±0.82	16±0.00	12±0.82	10±0.82	0	13±0.82	22±0.82	0
ST5	12±0.00	10±1.63	0	0	0	0	0	0
ST6	20±0.82	16±0.82	12±1.63	10±0.00	0	12±0.00	20±1.63	0
ST7	17±0.82	14±0.00	12±0.82	10±1.63	0	24±0.82	26±0.00	0
ST8	18±0.00	14±1.63	12±1.63	10±0.82	0	0	22±0.82	0
ST9	20±1.63	17±0.82	14±0.00	11±1.63	0	0	0	0
ST10	22±1.63	18±0.00	14±0.82	11±0.82	0	23±0.82	21±0.82	0
ST11	12±1.63	10±0.82	0	0	0	0	0	0
SD1	18±0.00	14±1.63	11±1.63	0	0	0	0	0
SD2	20±1.63	16±0.00	12±0.82	0	0	21±0.82	19±0.82	0
SD3	13±1.63	10±1.63	0	0	0	25±0.00	0	0
SD4	20±0.82	18±0.82	15±0.82	12±1.63	0	18±0.00	0	0
SD5	12±0.82	10±1.63	0	0	0	26±0.00	0	0
SD6	13±0.82	11±0.82	0	0	0	0	0	0

Key: EC1-EC10=Strains of *Escherichia coli*, EC11 = *Escherichia coli* (ATCC 25922), ST1-ST10 = Strains of *Salmonella typhi*, ST11 = *Salmonella typhi* (ATCC 14028), SD1-SD5 = Strains of *Shigella dysenteriae*, SD6 = *Shigella dysenteriae* (ATCC 13313), ATCC=American type culture collection, STP= Streptomycin, AMP = Ampicillin, 0= Not sensitive, mm* = mean of three replicates, P≤ 0.05, DMSO = Dimethyl sulfoxide

The minimum inhibitory concentrations (MICs) and minimum bactericidal concentrations (MBCs) exhibited by the stem bark extract against the bacterial isolates are shown in Table 2. The MICs exhibited by the stem bark extract against the bacterial isolates ranged between 0.31 and 5 mg/mL while the lowest MIC (0.31 mg/mL) was exhibited against *Escherichia coli*. The MBCs of the stem bark extract against the test isolates ranged between 0.63 and 10 mg/mL while the lowest MBC (0.63 mg/mL) was observed against *Escherichia coli*.

Table 2: The minimum inhibitory and minimum bactericidal concentrations exhibited by the stem bark extract against bacterial isolates

Isolates Code	MIC (mg/mL)	MBC (mg/mL)
EC1	0.63	1.25

EC2	0.63	1.25
EC3	1.25	2.5
EC4	1.25	1.25
EC5	5	10
EC6	1.25	2.5
EC7	0.31	0.63
EC8	0.63	1.25
EC9	0.63	1.25
EC10	1.25	2.5
EC11	0.63	1.25
ST1	5	10
ST2	2.5	5
ST3	5	10
ST4	1.25	1.25
ST5	5	10
ST6	1.25	2.5
ST7	1.25	1.25
ST8	1.25	2.5
ST9	1.25	2.5
ST10	1.25	2.5
ST11	5	10
SD1	2.5	5
SD2	2.5	2.5
SD3	5	10
SD4	1.25	2.5
SD5	5	10
SD6	5	10

Key: EC1-EC10 = Strains of *Escherichia coli*, EC11= *Escherichia coli* (ATCC 25922), ST1-ST10 =Strains of *Salmonella typhi*, ST11=*Salmonella typhi* (ATCC 14028), SD1-SD5=Strains of Shigella *dysenteriae*, SD6 = *Shigella dysenteriae* (ATCC 13313), ATCC=American type culture collection, ND = Not determined

The qualitative phytochemical screening of the stem bark extract of *Chrysophyllum albidum* revealed the presence of alkaloids, tannins, flavonoids, saponins, steroids, terpenoids, reducing sugar and cardiac glycosides (Table 3).

Table 3: Qualitative phytochemical composition of the *Chrysophyllum albidum* stem bark extract

Chemical test	Test reaction
Tannins	Positive
Alkaloids	Positive
Flavonoids	Positive
Saponins	Positive
Steroids	Positive
Terpenoids	Positive
Reducing sugar	Positive
Cardiac glycosides	Positive

Quantitative phytochemical analysis of the plant indicated that the stem bark extract contained the phytochemicals in varying concentrations. The bioactive constituent with the highest quantity was flavonoids followed by saponins, alkaloids, tannins, phenols and terpenoids respectively as shown in Table 4.

Table 4: Quantitative phytochemical composition of the *Chrysophyllum albidum* stem bark extract

Chemical test	Concentrations (%)
Tannins	0.94±0.01

Alkaloids	10.37±0.04
Flavonoids	31.00±0.01
Saponins	26.01±0.01
Phenols	0.51±0.01
Terpenoids	0.2±0.10

The antioxidant property of *Chrysophyllum albidum* stem bark extract was measured by the ability to scavenge DPPH free radicals comparing with vitamin C (ascorbic acid). The scavenging effects of the extracts and the standard on the DPPH radical are shown in Figure 1. It can be seen that stem bark extract showed appreciable antioxidant activity compared to vitamin C (ascorbic acid) used as control. The stem bark extract expressed percentage inhibition of 62.80% at a concentration of 15.63 µg/mL while vitamin C exhibited percentage inhibition of 63.53% at the same concentration.

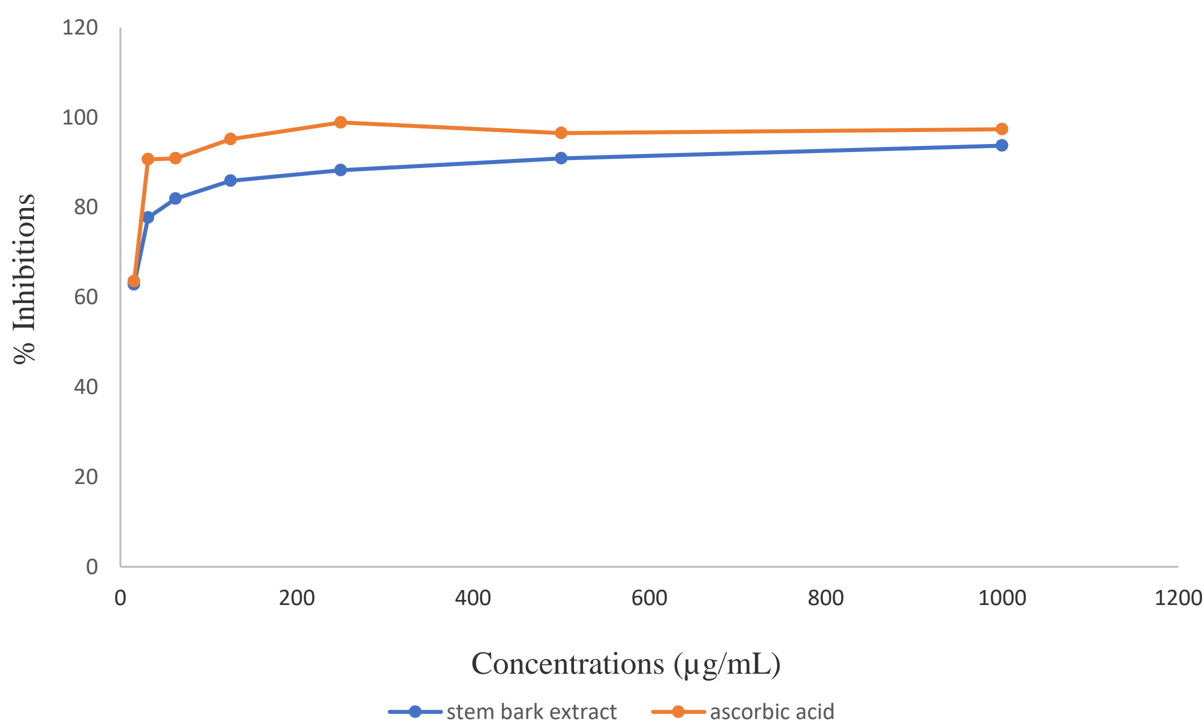

Figure 1: Antioxidant activity of stem bark extract of *Chrysophyllum albidum*

DISCUSSION

The inhibitory effects of stem bark extract of *Chrysophyllum albidum* was assessed against various strains of gastrointestinal tract pathogens. These bacteria include *Salmonella typhi*, *Escherichia coli* and *Shigella dysenteriae*. The stem bark extract exhibited appreciable antibacterial potential against the bacterial isolates. The stem bark extract at a concentrations of 5 and 10 mg/mL inhibited the growth of all the test bacterial isolates. The zones of inhibition exhibited by the stem bark extract against the bacterial isolates ranged between 10±0.82 and 25±0.00 mm (Table 1). The zones of inhibition observed by *Escherichia coli* at different concentrations ranged between 10±0.82 and 25±0.00 mm, *Salmomella typhi* (10±0.0 and 22±1.63 mm) and *Shigella dysenteriae* (10±1.63 and 20±082 mm). This was consistent with the previous studies on the antibacterial activities of this plant (Duyilemi and Lawal, 2009; Adeleye *et al*., 2016; George *et al*., 2018). The stem bark extract compared favourably with the two standard antibiotics namely streptomycin and ampicillin used as positive control. This is an indication that the stem bark extract could serve as a pointer towards the development of

drugs of natural origin to treat gastrointestinal infections caused by these pathogens. Also, the sensitivity of these pathogens to the extract further affirms its efficacy in the management of diarrhoea and dysentery by the people of Southern part of Nigeria as earlier reported by Laurent *et al*. (2012). The inhibitory effects of the plant extract of the plant were found to be concentration dependent as the highest activity was at the highest concentration (10 mg/mL) followed by 5, 2.5, 1.25 and 0.63 mg/mL (Table 1). On the other hand, streptomycin and ampicillin at 1 mg/mL inhibited the growth of 19 and 14 out of 28 bacterial isolates respectively. The zones of inhibition expressed by the standard antibiotics ranged between 10±0.00 and 28±0.82 mm.

The MICs exhibited by the stem bark extract against the bacterial isolates ranged between 0.31 and 5 mg/mL while 0.31 mg/mL was the lowest MIC recorded in this study. The MBCs of the stem bark extract against the bacterial isolates ranged between 0.63 and 10 mg/mL while the lowest MBC was 0.63 mg/mL (Table 2). Medicinal plant extract with very low MIC and MBC is known to possess high antimicrobial potency (Achinto and Munirrudin, 2009). The assertion of these authors supports the aforementioned finding. According to Shammughapriya *et al*. (2008), the plant extracts with MIC index which is equal or less than 2 mg/mL is considered as bactericidal while those above 2 mg/mL but less than 16 mg/mL are said to be bacteriostatic. This observation showed that the stem bark extract of *C. albidum* was bactericidal in action. Hence, this plant extract could be a good source of potent antimicrobial drug of natural origin that can be used to treat gastrointestinal infections that are killer disease especially among the children less than 5 years of age.

The results of phytochemical analysis of stem bark extract revealed the presence of tannins, alkaloids, flavonoids, saponins, steroids, reducing sugars, terpenoids and cardiac glycosides (Table 3). Previous studies reported the presence of these phytochemicals in the crude extracts of *Chrysophyllum albidum* (Oladipupo, 2014; Ushie *et al*., 2014; Ojemeleke *et al*., 2018). The quantitative phytochemical analysis also showed the presence of these phytochemicals in varying concentrations in the stem bark extract of *C. albidum* (Table 4). The phytochemical with the highest quantity was flavonoids, followed by saponins, alkaloids, tannins, phenols and terpenoids respectively (Table 4). The detection of these phytochemicals in the stem bark extract is consistent with the work of past researchers (Okoli and Okere, 2010; Owolabi *et al*., 2017; Akanji, 2020) who reported the presence of these phytochemicals in large quantities in the leaves, stem bark and root extracts of *Chrysophyllum albidum*. These phytochemical compounds are known to be biologically active and contributed to the antimicrobial and antioxidant activities of medicinal plants (Trease and Evans, 2002). This is an indication that these phytochemicals contributed to the inhibitory effects of the stem bark extract against bacterial isolates used in this study. For example, presence of tannins in a medicinal plant suggests the ability of the plant to play major roles as antimicrobial, antidiarrheal, antioxidant and antihemorrhoidal agents (Banso and Adeyemo, 2007). Tannin was found to be present in stem bark extract of *Chrysophyllum albidum*.

Saponin which has been ascertained to be responsible for most of the observed biological effects in medicinal plants was also present in the stem bark extract. Saponins are considered a key ingredient in traditional Chinese medicine (Liu and Henkel, 2002). The pharmacological activities of the saponins include antioxidant, anticancer, anti-inflammatory, antifungal and antibacterial (Ramachandran *et al*., 2014; Mboweni, 2018; Mapiye, 2019). In addition, interactions of saponins with cell show lysing of the membrane (Van and Wink, 2015). Alkaloids which were detected in this plant extract have been found to have antidiarrheal,

antimicrobial, antifungal, antiviral, antimalarial, antihypertensive, anti-inflammatory and antifibrogenic effects (Ghosal *et al*., 1996; Namadina *et al*., 2019; Thawabteh *et al*., 2019; Casciaro *et al*., 2020). Kamba and Hassan (2011)) also reported the presence of alkaloids in leaves and stem bark extract of this plant. Terpenoids also found in the extract are known to facilitate membrane disruption using lipophilic compounds and they possess a quite number of medicinal properties such as anti-carcinogenic, antimalarial, antihypertensive, insecticidal, antiviral and anti-ulcer (Saxena *et al*., 2013; Kabera *et al*., 2014; Ndongo, 2017). All these confirm the therapeutic potential of this plant extract and therefore can be used for the treatment of various diseases caused by test bacteria employed in this study.

Flavonoids exhibit a wide range of biological activities which include antimicrobial, anti-inflammatory, antitumor, anti-carcinogenic, anti-aging, analgesic, anti-allergic effects, antiviral and antioxidant properties (Hodek *et al*., 2002; Saxena *et al*., 2013; Ndongo, 2017). Flavonoids, one of the phytochemicals detected in stem bark extract are potent water-soluble super antioxidants and free radical scavengers which prevent oxidative cell damage (Okoli and Okere, 2010). Thus, this plant could serve as a major source of natural flavonoids that could be used to scavenge free radicals produced in human system.

The stability of DPPH free radical method is a sensitive way of determining the antioxidant property of plant extract (Kumar *et al*., 2008). The stem bark extract of *C. albidum* exhibited antioxidant activity and thus compared favourably with vitamin C used as standard (Figure 1). Results obtained in this study support the work reported by George *et al*. (2018) in which the methanolic leaf and fruit extracts of *C. albidum* had high antioxidant properties similar to vitamins C and E. The stem bark extract inhibited hydroxyl radicals produced by DPPH in this study and could serve as a free radical's inhibitor or scavenger using its proton donating ability. This finding further supports the usefulness of the *Chrysophyllum albidum* in scavenging hydroxyl radicals (OH^-) formed in the biological systems of humans which has been recognized as inhibitory and extremely damaging (Rajeev *et al*., 2011). Plants that exhibit antioxidant properties are known to possess free radical scavenging ability (Atawodi, 2005) and this antioxidant potential in plants is majorly due to the phenolics components present in them (Pourmorad *et al*., 2006).

CONCLUSION

The inhibitory effects expressed by the stem bark extract against the gastrointestinal tract pathogens employed in this study validate the use of the plant by the people of South Western part of Nigeria as antidiarrhoeal agent. This has further strengthened its application in herbal medicine. It was observed that the stem bark extract of *C. albidum* was rich with phytochemical compounds such as tannins, saponins, flavonoids, alkaloids, terpenoids, steroids and reducing sugars which are known to be biologically active. Hence, the presence of these secondary metabolites in this plant is responsible for its antibacterial and antioxidant potential witnessed in this study. Further studies are ongoing in our laboratory to determine the mode of action of this plant against the gastrointestinal tract pathogens.

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