The African Journal of Plant Science and Biotechnology ©2011 Global Science Books

Antibacterial Activities of *Allium sativum*, *Momordica charantia* and *Zingiber officinale* on Food- and Water-Borne Pathogens

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ABSTRACT

The antibacterial activity and phytochemicals of the aqueous, ethanolic and methanolic extracts of *Momordica charantia*, *Zingiber officinale* and *Allium sativum* used traditionally for the treatment of certain food- and water-borne diseases in South Western part of Nigeria was studied. The inhibitory effect of the plant extracts was investigated *in vitro* against clinical isolates of *Escherichia coli*, *Salmonella typhi*, *Shigella dysenteriae*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Bacillus cereus. Momordica charantia* and *A. sativum* showed an inhibitory effect at 20 to 50 mg/ml. The highest zone of growth inhibition of 11.0 mm each was recorded with methanolic extract of *A. sativum* and ethanolic extract of *M. charantia* against *S. aureus* at 50 mg/ml. There was no significant inhibitory effect produced with the extract of *Z. officinale.* The minimum inhibitory concentration of methanol extracts of *M. charantia* and *A. sativum* on all test organisms was 0.01 and 0.0001 mg/ml, respectively. Phytochemistry of the plant extracts revealed the presence of one or more of the following components: alkaloids, tannin, flavonoids, and saponin. The study showed that only the extracts of *M. charantia* and *A. sativum* showed significant antimicrobial activity against the test organisms at above 20 mg/ml and the activity compared favourably with the standard antibiotics-amoxicillin and ciprofloxacin used in the study. The findings therefore, justify the folkloric use of these plants in the treatment of certain ailments of microbial origin, most especially those caused by water- and food-borne pathogens.

Keywords: antimicrobial activity, inhibitory effect, phytochemicals, plant extract, zones of growth inhibition
Abbreviations: MIC, minimum inhibitory concentration

INTRODUCTION

Various medicinal plants have been used for years in daily life to treat diseases all over the world (Akinpelu and Onakoya 2006; Koné *et al.* 2007; Ajayi and Akintola 2010). In view of the ever-increasing prices of antimicrobial agents and the emerging problems of microbial resistance even to newer antibiotics, there is an urgent need to search for alternative cheap drugs from natural sources. *Allium sativum*, *Momordica charantia* and *Zingiber officinale* are among such plants of medicinal value. *A. sativum* L. (garlic) is a multipurpose herb and member of the lily family with proven anti-inflammatory, antihelminthic, antiviral, antitumor, antipyretic and diuretic properties (Schultes 1978; Bluementhal *et al.* 1998; Lawson 1998; Wilson and Demming-Adams 2007). *M. charantia* (bitter lemon), belonging to the family *Cucurbitaceae*, grows in tropical areas including parts of the Amazon, East Africa, Asia and the Caribbean and cultivated throughout South Africa for food and medicine (Taylor 2005). The fruits and leaves contain alkaloids, glycoside, saponin-like substances, resin, an aromatic volatile oil and mucilage and have been reported to have antitumor and anti-HIV activities (Grover and Yadav 2004; Nagasawa *et al*. 2007; Mwambete 2009). The plant has been used for expulsion of intestinal gas, promoting menstruation, antiviral for measles and hepatitis, wounds treatment and has antiprotozoal activity against *Entamoeba histolytica* (Huang 2001). *Z. officinale* (ginger) belongs to the *Zingiberaceae* family which is a familiar dietary spice known for its long standing utility as a flavouring agent, antiemetic and a digestive AID. *Z. officinale* is an excellent remedy for digestive problems such as flatulence, nausea, indigestion, high blood pressure, fever, muscle spasms, convulsion and gastrointestinal disorder (Mascolo *et al*. 1989; Srinivasan *et al.* 2001). *Z. officinale* has also been reported to immunomodulatory properties and found to inhibit various inflammatory mediators such as prostaglandins and pro-inflammatory cytokines (Sharma *et al.* 1994; Grzanna *et al*. 2005).

Contemporary research has shown that 80% of available medicine in many developing countries is obtained from medicinal plants while in the developed countries; plants constitute mainly raw materials for industrial preparation of pure chemical derivatives (Schultes 1978). The occurrence in ethnomedicinal plants of several antimicrobial compounds; phenolics and polyphenols, quinines (Vamos-Vigyazo 2001), flavones (Borris 1996), lectins and polypeptides (Balls *et al.* 2002), tannins and alkaloids (Trease and Evans 1989) has been widely reported.

More than 250 different diseases and syndromes have been associated with contaminated foods or drinks (Desta 1993). The majority of the food-and water-borne diseases, although self-limiting can also be life threatening needing antibiotic therapy. But most of the etiologic agents in many countries have already developed resistance to common antibiotics (Asherbir and Ashenafi 1999); hence, a need for alternative therapy. The epidemiology of food- and water-borne diseases is changing and reports from different parts of the world indicate that strains of resistant food-borne pathogens have as public health problem. The illness as a result of eating food and water contaminated with bacteria and/or their toxins range from stomach upset to more serious symptoms such as diarrhea, fever, vomiting, abdominal cramps and dehydration (Adak *et al*. 2002; Karmegam *et al*. 2008). Food-borne diseases associated with *S. enteritidis*, *S. aureus*, *B. cereus*, and *E. coli* have been reported in Australia, Canada, Japan, United States, European countries, Nigeria and South Africa with increased resistance to antibiotics in practical use (Akinyemi *et al.* 2000; Farzana and Hameed 2006).

Received: 2 December, 2010. Accepted: 24 May, 2011.

Original Research Paper

In Nigeria, therapy with medicinal plants is of great importance in conjunction with western medicine in the health care. Presently, there is increasing evidence for the antimicrobial properties of various plants. The plants reported here have been used for traditional treatment and relief of urinary tract infection suspected to be caused by *Pseudomonas aeruginosa* and *Staphylococcus aureus* (Azu and Onyeagha 2007). Ayogu and Amadi (2009) reported the antibacterial activities of *A. sativum*, *Z. officinale* and *Moringa oleifera* leaves extracts against *Salmonella typhi*, the causative agent of typhoid fever. The potential of some plants as a source of new drugs is still largely unemployed. Considering the vast potentiality of plant as a source of new therapeutic agents, the present study therefore investigated and compared the antibacterial activities of aqueous, ethanolic and methanolic extracts of *A. sativum*, *Z. officinale* and *M. charantia* on some pathogens associated with food- and water-borne diseases.

MATERIALS AND METHODS

Sample collection

Fresh leaves of *Z. officinale*, *M. charantia* and seed of *A. sativum* were either collected from home gardens or purchased from the central market in Ado-Ekiti, Nigeria. Plants specimens were identified and voucher specimens deposited at the Herbarium Unit, Department of Plant Science, University of Ado-Ekiti State, Nigeria.

Isolation of test microorganisms

The test microorganisms, *Escherichia coli* (ATCC2592), *Staphylococcus aureus* LIO, *Salmonella typhi* (LIO), *Shigella dysenteriae* (LIO), *Klebsiella pneumoniae* (LIO), and *Bacillus cereus* (LIO) were all clinical strains obtained from the stock culture collection of the Department of Microbiology, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. All the bacteria used as test organisms with the exception of *E. coli* (ATCC2592) were locally isolated organisms recovered from food and water samples at the Microbiology laboratory of Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. *E. coli* (ATCC2592) was a type isolate of American Type Culture Collection unit.

Preparation of extracts

Collected plant materials were washed with sterile water and allowed to drain. They were air dried at room temperature for two days and ground into fine powder using an electric blender. 200 g of the powdered plant were extracted separately with 250 ml of water (aqueous extraction), 70% ethanol (ethanolic extraction) and 60% methanol (methanolic extraction). Obtained extracts were filtered through Whatman No. 1 filter paper and evaporated to dryness under vacuum at 45°C. The ethanol and methanol reagents were both product of Oxoid Ltd, Wade Rd, Basingstoke, Hants, RG248PW, UK.

Antibacterial assay

The disc diffusion method of Oluma *et al.* (2004) was used. An overnight broth culture of each test organism (10^6 cfu/ml) was seeded onto cooled sterile Mueller-Hinton agar purchased from Himedia (Mumbai, India). Sterile filter paper discs (2 mm diameter), each impregnated with the respective concentrations of the extract (ranging from 10-50 mg/ml) were placed firmly on the seeded nutrient agar. Sterile paper discs containing physiological saline alone served as control. Amoxicillin (20 µg/ml/disc) and ciprofloxacin (20 µg/ml/disc) which were product of Oxoid Ltd. (Basingstoke, UK), were used as an antibiotic reference standard. The plates were incubated at 37°C for 24 hrs. Zones of growth inhibition were measured in mm. Each test was carried out in triplicate. The minimum inhibitory concentration (MIC) was carried out by using the agar dilution method (Bauer *et al*. 1966).

Statistical analysis

Data from three independent replicate on the antimicrobial activities of *A. sativum*, *M. charantia* and *Z. officinale* were subjected to one-way analysis of variance at 0.01 level of significance for comparison of the activities. The Statistical Package for Social Sciences (SPSS) version 10 was employed in the statistical analysis of the data.

RESULTS AND DISCUSSION

The antimicrobial activity of all the extracts (aqueous, ethanolic and methanolic) of *M. charantia*, *A. sativum*, and *Z. officinale* varied greatly, with the extracts of *A. sativum* showing greater inhibitory effect on the test organisms. *Momordica charantia* and *Z. officinale* produced little or no inhibitory effect. This confirms that the plants studied possessed antibacterial properties in varying proportion. Mohana *et al.* (2008) reported the antimicrobial activity of 8 higher medicinal plants against 11 human pathogenic bacteria. All the aqueous, ethanolic, and methanolic extracts of *M. charantia* and *A. sativum* possess an appreciable antimicrobial activity against the test bacteria. The result confirms the earlier findings of Karmegam *et al*. (2008) who reported the antibacterial potency and synergistic effect of certain plant extracts against food-borne diarrheagenic bacteria.

The antimicrobial activities observed in *M. charantia* and *A. sativum* extracts may be due to the presence of some phytochemical components in the plants (Oshodi *et al*. 2004). The test organisms were susceptible to the aqueous extract of *M. charantia* at concentration of 20 mg/ml and above with zones of growth inhibition ranging from 5.0 to 11.0 mm. This infers that *M. charantia* extract is only effective at concentration of 20 mg/ml; hence, the antimicrobial activity is concentration dependent. Azu and Onyeagha (2007) reported that the efficacy of most plant extracts is concentration dependent. The susceptibility of the test organisms increased with increasing extract concentration particularly aqueous and ethanol extracts, though, the increase was not significant ($P > 0.01$) (**Table 1**). *Salmonella typhi* was only sensitive to *M. charantia* at a concentration equal or above 20 mg/ml with higher sensitivity being recorded with aqueous extract. Similarly, *S. aureus* and *Kl. pneumoniae* followed the same trends as these organisms were only susceptible to *M. charantia* at 20 mg/ml and above of the extracts. A zone of growth inhibition of 5.0 mm each was recorded against *Staphylococcus aureus* and *S. dysenteriae* at both 20 mg/ml and 30 mg/ml of methanolic extract of *M. charantia*. Similarly, *E. coli* showed similar susceptibility at these concentrations with zone of growth inhibition of 7.0 mm (**Table 1**).

The inhibitory effects of the extracts of *M. charantia* on *S. aureus*, *Aeromonas hydrophila*, *Sh. Sonnei*, and *Pseudomonas aeruginosa* have been reported (Perumal and Ignacimuthu 2000). Similarly, Omoregbe *et al*. (1996) reported the antibacterial activities of aqueous, ethanol and methanol extracts of the leaves against various bacterial species.

In the present study, the susceptibility of the test pathogens to the extracts of *M. charantia* justified the folkloric uses of this plant in the traditional medicine practice as a cure for stomach pains, diarrhea and gonorrhea (Egwari 1999; Oluma *et al*. 2004).

The methanolic extract of *M. charantia* showed low activity against *Kl. pneumoniae* compared to considerable activities observed with the aqueous and ethanolic extracts at all concentrations tested. This shows that the bioactive components of *M. charantia* are best extracted with either water or ethanol solvent. The study is in concurrence with the findings of Brantner and Grein (1994) and Obiukwu and Nwanekwu (2010) who both reported the efficacy of antibacterial properties of *M. charantia* against the tested organisms.

All the extracts (aqueous, ethanolic and methanolic) of *A. sativum* showed an appreciable inhibitory effect on all

Table 1 Antibacterial activity of aqueous, ethanolic and methanolic extracts of *Momordica charantia* against the test organisms.

Test organisms	Zones of inhibition (mm)														
	Concentration of extracts (mg/ml)														
	Aqueous extract					Ethanolic extract					Methanolic extract				
	10	20	30	40	50	10	20	30	40	50	10	20	30	40	50
E. coli	0.0	6.0	6.6	7.0	8.0	6.0	6.0	6.0	7.0	8.0	5.0	5.0	7.0	7.0	8.0
S. aureus	0.0	6.0	6.6	7.0	8.0	0.0	7.0	7.0	10.0	11.0	0.0	3.0	5.0	5.0	5.0
S. typhi	0.0	7.0	7.4	10.0	11.0	0.0	0.0	5.0	6.0	6.0	0.0	5.0	5.0	6.0	8.0
Sh. dysenteriae	0.0	5.0	5.3	6.6	6.9	5.0	6.0	6.0	10.0	10.0	0.0	0.0	5.0	5.0	9.0
Kl. pneumoniae	0.0	5.0	5.2	5.6	8.0	0.0	3.0	5.0	8.0	8.0	0.0	3.0	3.0	5.0	5.0
B. cereus	0.0	4.5	5.0	5.2	6.8	0.0	3.2	4.6	7.2	7.8	0.0	3.1	3.5	4.6	4.6

Table 2 Antibacterial activity of aqueous, ethanolic and methanolic extracts of *Allium sativum* against the test organisms.

Test organisms	Zone of inhibition (mm)														
	Concentration of extract (mg/ml)														
	Aqueous extract					Ethanolic extract					Methanolic extract				
	10	20	30	40	50	10	20	30	40	50	10	20	30	40	50
E. coli	7.5	7.7	8.4	9.8	9.9	7.5	7.7	8.4	9.8	9.9	7.8	8.2	9.0	9.0	10.3
S. aureus	8.0	8.0	8.9	9.3	10.2	8.2	8.2	8.9	8.9	10.0	8.8	8.8	10.2	10.2	11.0
S. typhi	4.0	4.5	4.5	4.7	5.0	4.0	4.5	4.7	4.7	5.0	4.8	4.8	5.6	5.9	6.3
Sh. dysenteriae	6.3	4.5	4.5	4.8	5.0	4.0	4.8	5.0	5.0	6.2	4.8	4.8	4.9	4.9	4.9
Kl. pneumoniae	6.3	6.8	6.8	7.8	8.5	6.3	6.7	7.0	7.0	8.2	6.8	6.9	6.9	8.6	9.0
B. cereus	7.5	7.8	7.9	9.3	9.8	7.4	7.9	9.3	9.3	9.8	7.8	8.4	8.8	9.4	10.0

Table 3 Antibacterial activity of aqueous, ethanolic and methanolic extracts of *Zingiber officinale* against the test organisms.

Test organisms	Zones of inhibition (mm)														
	Concentration of extracts (mg/ml)														
	Aqueous extract					Ethanolic extract					Methanolic extract				
	10	20	30	40	50	10	20	30	40	50	10	20	30	40	50
E .coli	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S. aureus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S. typhi	0.0	0.0	0.0	0.0	4.5	0.0	0.0	0.0	0.0	5.0	0.0	0.0	0.0	0.0	5.4
Sh. dysenteriae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kl. pneumoniae	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	2.0
B. cereus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

the organisms, even at concentration of 10 g/ml (**Table 2**). This confirms the effectiveness and usefulness of *A. sativum* in the treatment of diseases and the need to enhance its exploitation in this regard. This is of particular interest, considering the alarming rate of emergence of multi-drug resistant strains of microorganisms worldwide. Ayogu and Amadi (2009) reported similar inhibitory activity of *A. sativum* against *S. typhi*. The antimicrobial activity of the plant against *S. typhi* has also been reported by other workers (Arora and Kaur 1999; Iwlokun *et al.* 2004; Ekwenye and Elegalam 2005).

The antimicrobial activity of *M. charantia* and *A. sativum* appeared to be broad spectrum since these plant extracts inhibited both the Gram-positive and Gram-negative bacteria tested in the study. *A. sativum* produced greater inhibitory effect on the test organisms than *M. charantia* at all concentrations of the extracts ($P > 0.01$) with methanolic extract being the most active against the test bacteria. It is particularly interesting that *A. sativum* extract produced considerable inhibitory effect at concentration of 10 mg/ml compared to other plant extracts investigated in the study.

Alanis and Ceballos (2005) screened several plants among which *A. sativum* was found to possess a high activity against enteric pathogens. The finding in this study further agrees with other works (Ross *et al*. 2001; Gomaa and Hashish 2003). *Zingiber officinale* did not show any inhibitory effect on *E. coli*, *S. dysenteriae* and *B. cereus* at all con-centrations (10-50 mg/ml) of the extracts. However, the extracts showed low inhibitory effect on *S. typhi* and *Kl. pneumoniae* with zone of growth inhibition of 4.5 mm in aqueous extract, 5.0 mm in ethanolic extract and 5.4 mm in methanolic extract at 50 mg/ml (**Table 3**). The absence of activity in *Z. officinale* against *E. coli*, *S. aureus*, *Sh. dysenteriae*, and *B. cereus* may suggest that the concentration of active constituents in the extract may be too low for any appreciable antimicrobial activity. In addition, a low concentration of diffusible water-soluble active constituents or excessive heating, which often affect biologically active substances such as flavonoids, essential oils and other heterogeneous phyto-constituents present in the extracts might also influence their respective activities (Oshodi *et al*. 2004). Furthermore, it may also be due to number of factors such as time of collection of plant materials, method of extraction, solvent used for extraction, difference in the sensitivity of the target bacteria to the plant extract, or difference in concentration of extract used and climate, which might in turn, affect the quantity of active components in the plants (Ashebir and Ashenafi 1999). The findings from the study agree with the previous studies of Onyeagba *et al.* (2004), who reported the absence of antibacterial activity in *Z. officinale* against the tested bacteria. Poonam *et al.* (2010) similarly reported in his findings that *Z. officinale* did not showed antibacterial activity against diarrhoeal pathogens but only exhibited its antidiarrhoeal activity by inhibiting the production of cholera toxin, thus affecting bacterial and host cell metabolism. However, this study is in contrast to Akoachere *et al.* (2002), who reported the antibacterial effect of *Z. officinale* and *Garcinia kola* on respiratory tract pathogens, and Obiukwu and Nwanekwu (2010) who reported antibacterial properties of *Z. officinale* against a diarrhoeal-causing *Vibro cholerae*. These studies however elucidate the major problem with this type of research, namely the lack of uniformity in the criteria selected to study the activity. This has in the past lead to relevant contradictions between the results obtained by different groups and even for the same. Authors study the same sample with different methods. To try to solve this problem, Ríos and Recio (2005) published a review of the experimental methods used for studying the activity of both plant extracts and essential oils to date. They proposed the use of diffusion methods for studying polar compounds of small or medium molecular size and for determining the antimicro-

Table 4 Minimum inhibitory concentrations of aqueous, ethanolic and methanolic extracts of *Momordica charantia*, *Zingiber officinale* and *Allium sativum* on the test organisms.

Test organisms	Minimum Inhibitory concentration(mg/ml)								
	Concentration of extracts (mg/ml)								
	M. charantia			*A. sativum*			*Z. officinale*		
	A	E	M	A	E	M	A	E	M
E. coli	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	0.0	0.0
S. aureus	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	0.0	0.0
S. typhi	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	1.0	1.0
Sh. dysenteriae	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	0.0	0.0
Kl. pneumonia	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	0.0	0.0
B. cereus	0.1	0.02	0.01	0.001	0.0001	0.0001	0.0	0.0	0.0

A: aqueous extract, E: ethanolic extract, M: methanolic extract

Table 5 Susceptibility of the test organisms to standard antibiotics as positive control.

Test organisms	Antibiotics Diameter of Zones of Inhibition (mm)	
	Amoxicillin (20 µg/ml/disc)	Ciprofloxacin (20 µg/ml/disc)
E. coli ATCC2592	15	24
S. aureus LIO	12	23
S. typhi LIO	18	36
Sh. dysenteriae LIO	13	*20*
Kl. pneumoniae LIO	15	31
B. cereus LIO	13	27

ATCC: American type culture collection, LIO: Locally isolated organism

bial spectrum because this method allows researchers to test different compound against one microorganism. The solid dilution method was recommended for studying polar and non-polar substances as well as all types of complex extracts. This method is especially good for determining the relative potency of extracts or essential oils and for establishing their antimicrobial spectrum as it facilitates the use of different strains against the extracts on the same plate.

The MIC of *M. charantia* extracts ranged from 0.02-0.1 mg/ml. The MICs obtained for all the plants extracts showed that *A. sativum* which had the MIC of 0.0001 mg/ml was generally more active than the other extracts. Meanwhile, *A. sativum* showed comparable activity with the extracts of *Z. officinale* with MIC of 1.0 mg/ml (**Table 4**). In the comparative studies with standard antibiotics, the extracts of *A. sativum* and *M. momordica* compared favourably with amoxicillin while ciprofloxacin showed greater bacteriocidal effect on the test organisms (**Table 5**).

The antibacterial activity of the plants studied varied with the test bacteria, reason being likely to be due to the differences in their phytochemical constituents. Previous studies have revealed major chemical constituents, which are likely to be responsible for the antimicrobial properties of some of the plants studied. These phytochemicals have been reported to possess antimicrobial properties thus making them to be relevant in clinical practice (Oshodi *et al*. 2004). *A. sativum* has been reported to contain enzymes such as alliinase, myrosinase, peroxidase and a volatile oil of about 0.1-0.4% containing sulphur compounds, including allicin, diallyl disulphide, dially trisulphide, ajoene and others such as allyl cystane sulfoxide, mythul allyl thiosulfinate and related compounds (Lawson 1998; Dirsch *et al*. 1998). *M. charantia* has been reported to contain an array of biologically active chemical components including triterpenes, steroids, alkaloids, charatin, cucurbitins, cucurbitacins, cucurbitanes, oleic acid, oleanolic acid, cucurbittacin B1, hydroxytryptamenes and proteins (Kohlert *et al*. 2000; Oliff 2007) α- and β-momorcharin and cucurbitacin B, have been tested for possible anticancerous effects (Dong 1993). It is speculated that the antimicrobial activities of triterpenes depend on interactions between their lipid components with the net surface charge of microbial membranes; also, the compound may penetrate into the interior of the cell by crossing the cell membranes thus interacting with intracellular sites important for antibacterial activity (Trombetta *et al*. 2005). *Z. officinale* have been reported to contain both volatile oils and non volatile pungent compounds. The volatile oil components in *Z. officinale* consist mainly of sesquiterpene hydrocarbons, predominantly zingeberene (35%), curcumene (18%) and farnesene (10%), with lesser amount of bisabolene and β-sesquiphellandrene (Govidarajan 1987). A sesquiterpene alcohol known as zingiberol has also been isolated. Many of these volatile oil constituents have been reportedly contributed to the distinctive aroma and taste of ginger, but most are not unique to ginger (Govidarajan 1987). Some of the nonvolatile pungent compounds which give *Z. officinale* its characteristic pungent flavor as well as being responsible for many of its pharmacological actions include gingerols and paradol with 6-gingerol being the most common. In addition to the extractable oleoresins, *Z. officinale* have been further reported to contain many fats, waxes, carbohydrates, vitamins, minerals and a potent proteolytic enzyme called zingibain which constitutes the *Z. officinale* rhizomes (Govidarajan 1987).

The use of plants for disease treatment, including infectious ones, has been extensively applied by people, particularly in rural areas of Nigeria. This study reveals the great potential of these plants for therapeutic treatment of diseases particularly food- and water-borne related diseases. Thus, this study has justified the folklore use of the plant studied in the treatment of certain ailments caused by the test organisms. Future research on this study should however concentrate more on isolation and characterization of the bioactive components of these plants which can further be chemically synthesized for clinical trials.

ACKNOWLEDGEMENTS

I wish to acknowledge Mr. T. Omotayo of the Department of Plant Science, University of Ado-Ekiti for identifying the plant materials used. The supportive role played by the technical staff of the Department of Microbiology, University of Ado- Ekiti, Nigeria is also acknowledged.

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