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ANTIMICROBIAL ACTIVITIES OF *ZINGIBER OFFICINALE* (GINGER) AND *CURCUMA LONGA* (TURMERIC) ON SOME REFERENCE BACTERIAL STRAINS

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ABSTRACT

The antimicrobial activities of *Zingiber officinale* (Ginger) and *Curcuma longa* (turmeric) were studied on selected pathogens using standard microbiological techniques. Reference strains: *Enterococcus durans* ATCC 11576, *Enterococcus faecalis* ATCC 19433, *Enterococcus faecium* ATCC 35667, *Enterococcus gallinarium* ATCC 49573, *Enterococcus hirae* ATCC 49135, *Pseudomonas aeruginosa* ATCC 27853, *Aeromonas hydrophila* ATCC 7966, *Acinetobacter baumanni* ATCC 19606, *Stenotrophomonas maltophilia* ATCC 13637 and *Escherichia coli* WG5 were obtained from GI-Microbiology/Biotechnology Agriculture Research Council, Irene and Durban University of Technology, South Africa. Crude ethanolic extracts and partitioned fractions; dichloromethane, ethyl acetate, n-hexane and 1-butanol were also investigated. Antimicrobial activities of the ethanolic extracts of *Z. officinale* and *C. longa* showed zones of inhibition that ranged from 9 mm to 13 mm and 10 mm to 18 mm respectively against the test isolates. *Z. officinale* ethanolic extract showed no activities against *Enterococcus gallinarium* ATCC 49573 and *Enterococcus hirae* ATCC 49135 while *C. longa* ethanolic extract showed activities against all the test isolates. Various fractions showed inconsistent antimicrobial activities. The largest zone of inhibition was obtained from n-hexane (ZI= 22 mm) fraction of *C. longa* while *Z.* officinale crude extract showed zone of inhibition (ZI= 13) against all the tested isolates. Partitioned extracts showed 8-22 mm zone of inhibition with turmeric having the largest zone of inhibition. Activities in these extracts can be attributed to repertoire of phytochemical constituents, especially the Alkaloids and Flavonoids detected in them. These activities can be utilized for preservation purposes of food since both turmeric and ginger are edible natural spices.

INTRODUCTION

Antimicrobials are substances that can kill or inhibit the growth of microorganisms. Antibiotics are also known to be one of the most vital tools used in fighting bacterial infections and they have greatly improved the quality of health since their introduction in the fight against infectious disease (Boakye *et al*., 2016). There has been growing interest in researching and developing new antimicrobial agents from different natural sources to combat microbial resistance (Nanasombat and Lohasupthawee, 2005; Balouiri *et al*., 2016). Therefore, a greater attention is being paid to screening for antimicrobial activity in these agents in a quest to develop novel antimicrobials. After the revolution in the "golden era", when almost all groups of important antibiotics (tetracyclines, cephalosporins, aminoglycosides and macrolides) were discovered and the main problems of chemotherapy were solved in the 1960s, history repeated itself again and these exciting compounds are in danger of losing their efficacy because of the increase in microbial resistance (Mayers, *et al*., 2009; Savoia, 2012; Balouiri *et al*., 2016). Its impact is considerable with treatment failures associated with multidrug-resistant bacteria and it has become a global concern to public health lately (Guschin *et al*., 2015; Martin *et al*., 2015). For this reason, discovery of new antibiotics is an exclusively important objective. Natural products are still one of the major sources of new drug molecules today. They are derived from prokaryotic bacteria, eukaryotic microorganisms, plants and various animal organisms. Microbial and plant products occupy a major part of the antimicrobial compounds discovered until now (Berdy, 2005).

Ginger (*Zingiber officinale*) is a commonly used spice that contains polyphenolic compounds, among them the 6-gingerol and its derivatives. These chemical compounds made ginger a potent antioxidant (Stoilova *et al*., 2007). Fresh ginger contain moisture, proteins, fats, fiber, carbohydrates and some minerals like iron or calcium (Govindarajan, 1982). Ginger (*Zingiber officinale*) belongs to Zingerberaceae family. It is a perennial, creeping plant, on thick tuberous rhizome, producing on erect annual stem 60-120 cm (Udoh *et al*., 2005). *Zingiber officinale* has been used as medicine from Vedic period and is called "Maha ausshadi" which means the great medicine. It is used as anti-flatulent and for conditions such as headaches, nausea, rheumatism and colds. *Zingiber officinale* is used as food seasoning, flavouring material in food, raw materials in cosmetics and pharmaceutical industries (Alozie and Sonye, 2015). Research have shown that *Z. officinale* has inhibitory effect on food pathogens due to the effects of phytochemicals (Bukar *et al*., 2010). However, increased resistance in pathogenic strains against chemical food preservatives requires the frantic search for new and more effective antimicrobial agents. In many parts of the world, *Z. officinale* has medicinal and culinary values (Omoya and Akharaiyi, 2012). Many scientists have reported antimicrobial properties of several plants. The antimicrobial, antitumour (Khalil *et al*., 2005 and Akroum *et al*., 2009; Omoya and Akharaiyi, 2012), anti-inflammatory and anti-necrotic (Omoya and Akharaiyi, 2012) activities have been reported from the use of plants extracts. The most well-known member of *Zingiber* (ginger) is *Zingiber officinale*.

Ginger CO_2 extracts have been proven to contain high polyphenol content and found to have an enhanced efficiency as an antioxidant preservative at an earlier stage of fat oxidation. The antioxidant effect of ginger is comparable to BHT, which is a chemical antioxidant, inhibiting peroxidation in the range of temperature from 37°C to 80°C (Stoilova *et al*., 2007). Ginger has been shown

to inhibit the multiplication of colon bacteria (Gupta and Ravishankar, 2005) and other microorganisms such as *Escherichia coli*, *Proteus* sp, *Staphylococci*, *Streptococci* and *Salmonella* (Ernst and Pittler, 2000; White, 2007). Ginger also has antifungal activity against some species, such as *Aspergillus*. The phenolic compounds in ginger are denaturing agents that prevent microbial growth by changing the cell permeability leading to rupture of bacterial cells. Most of the phenolic compounds are metal chelators and attach to active sites of metabolic enzymes reducing enzyme activities and bacterial metabolism and reproduction.

Studies have shown that ginger extracts at concentrations of 0.4 mg/ml have better antimicrobial activity than commercial antibiotics such as Gentamicin against *Klebsiella pneumonieae*, *Proteus vulgaris*, *Streptococcus pyogenes* and *Staphylococcus aureus* (Ahmed *et al*., 2012). Ginger root extracts have been shown to be more effective than extracts from other parts of the plants, such as leaves and has been able to inhibit the growth of *Staphylococcu*s species with better results than common antibiotics, such as chloramphenicol, ampicillin and tetracycline (Sebiomo *et al*., 2011).

Tumeric (*Curcuma longa*) belongs to the kingdom Plantae, Order Zingiberales, Family Zingiberaceae, Genus *Curcuma* and Specie *longa*. It is a rhizomatous herbaceous perennial plant of the ginger family, Zingiberaceae. It is native in southwest India, and needs temperatures between 20 °C and 30 °C (68 °F and 86 °F) and a considerable amount of annual rainfall to thrive (Prasad *et al.,* 2011).

The most important chemical components of turmeric are a group of compounds called curcuminoids, which include curcumin (diferuloylmethane), demethoxycurcumin, and bisdemethoxycurcumin. The best-studied compound is curcumin, which constitutes 3.14% (on average) of powdered turmeric (Tayyem *et al.,* 2006). In addition, other important volatile oils include turmerone, atlantone, and zingiberene. Some general constituents are sugars, proteins, and resins (Nagpal and Sood, 2013). In fact, it is the curcuminoids that possess all the bio-protective properties of turmeric (Badmaev *et al*., 2004).

Turmeric (*Curcuma longa*) is extensively used as spice, food preservative and colouring material in India, China and South-East Asia. Various sesquiterpenes and curcuminoids have been isolated from the rhizome of *C. longa*, attributing a wide array of biological activities (Tilak *et al*., 2004; Kumar *et al*., 2006) anti-inflammatory (Sandur *et al*., 2007; Aggarwal and Harikumar, 2009), wound healing (Maheshwari *et al*., 2006), anticancer and antibacterial activity (Gupta and Sadhana, 2005; Naz *et al*., 2010). Turmeric has been shown to possess anti-microbial effects against many microorganisms, especially against *Bacillus subtilis*, *Escherichia coli* and *Staphylococcus aureus* (Egan *et al*., 2004). Moreover, it can inhibit the growth of *Salmonella typhi*, and *Bacillus dysenteriae*. Free curcumin in turmeric has a good preservation effect on cooked mutton, bread and bean curd (Yu *et al*., 2002; Jayaprakasha *et al*., 2005; Liang *et al*., 2007).

MATERIALS AND METHODS

Sample Collection and Identification

Reference bacterial strains (*Enterococcus durans* ATCC 11576, *Enterococcus faecalis* ATCC 19433, *Enterococcus faecium* ATCC 35667, *Enterococcus gallinarium* ATCC 49573, *Enterococcus hirae* ATCC 49135, *Pseudomonas aeruginosa* ATCC 27853, *Aeromonas hydrophila* ATCC 7966, *Acinetobacter baumannii* ATCC 19606, *Stenotrophomonas maltophilia* ATCC 13637 and *Escherichia coli* WG5) used for the study were obtained from GI Microbiology and Biotechnology Section, Agricultural Research Council–Animal Production, Irene, South Africa. *Zingiber officinale* (ginger) and *Curcuma longa* (turmeric) were purchased from vendors at Akpan Andem Market, Uyo, Akwa Ibom State, Nigeria.

Preparation of Plants Extracts

Fresh rhizomes of *Z. officinale* and *C. longa* were first examined visually for any sign of disease. The rhizomes were washed, peeled, sliced, air-dried and thereafter pulverized and macerated. The extracts of the rhizomes were prepared in accordance with the description of Basri and Fan (2005). Three hundred (300) gram of ground rhizomes were steeped in separate 1Litre of ethanol and water for ethanolic and aqueous fractions, respectively for 24 h with shaking (Stuart Scientific Orbital Shaker, UK). The resultant extracts were centrifuged at 3000 rpm for 5 min at 4 ºC. The supernatant was then filtered using a Whatman No.1 filter paper while the residue was used for a second extraction with 300 ml of ethanol and water. After the second extraction, the filtrates were concentrated under reduced pressure using a rotary evaporator (Laborota 4000-efficient, Heldolph, Germany) at 50 ˚C. The crude extracts collected were allowed to dry at room temperature to a constant weight of 11.2 g then subjected to phytochemical screening. The resultant dry ethanolic extract was partitioned successfully with n-hexane, dichloromethane, ethyl acetate and butanol solvents to yield their respective fractions (Fig 1).

Phytochemical Analysis of the Extracts

This involves performing simple chemical test to detect the presence or absence of bioactive constituents such as alkaloids, flavonoids, glycosides, saponins, tannins (Trease and Evans 1989; Sofowora ,1993).

Test for Saponins

Half a gramme (0.5 g) of the ethanolic extract was shaken with distilled water in a test tube. Frothing which persisted on standing for 5 minutes was taken as preliminary evidence for the presence of saponin. Thereafter, 0.5 g of the ethanolic extract was reacted with 5% sodium trioxocarbonate solution followed by fehling's solution (1 and 2) and boiled. The presence of a brown precipitate indicated a positive result.

Test for Alkaloids

Half a gramme (0.5 g) of ethanolic extract was stirred with 5 ml of one percent (1%) aqueous hydrochloric acid. One (1) ml of the filtrate each was treated with few drops of mayer's reagent and drangendorff's reagent. Turbidity or precipitation was taken as evidence for the presence of alkaloids in the extract.

Test for Tannins

Five (5) drops of the test solution (extract) was added to 10 ml of distilled water. This was followed by the addition of bromine water. Decolourization of bromine water was an indication of a positive test. Thereafter, half a gramme (0.5 g) of the extract was stirred with 1ml of distilled water and the solution filtered. Ferric chloride reagent was added to the filtrate in a test tube. A blue-black green or blue-green colouration was taken as evidence for the presence of tannins.

Test for Glycosides

A 0.1g of the extract was placed in a small beaker. Next, 15 ml of distilled water and 3 ml of 10% sulphuric acid were boiled for 15 min in a water bath. The boiled mixture was alkalinized by the addition of 10 ml of 5 % potassium hydroxide solution. Finally, 10 ml of freshly prepared fehling's solution was added and boiled for three minutes. A brick red precipitate indicated the presence of reducing sugar and a positive test. Note that the glycosides themselves do not reduce fehling's solution, the simple sugars they produce on hydrolysis produces the precipitation of reduced cuprous oxide (Trease and Evans, 1989).

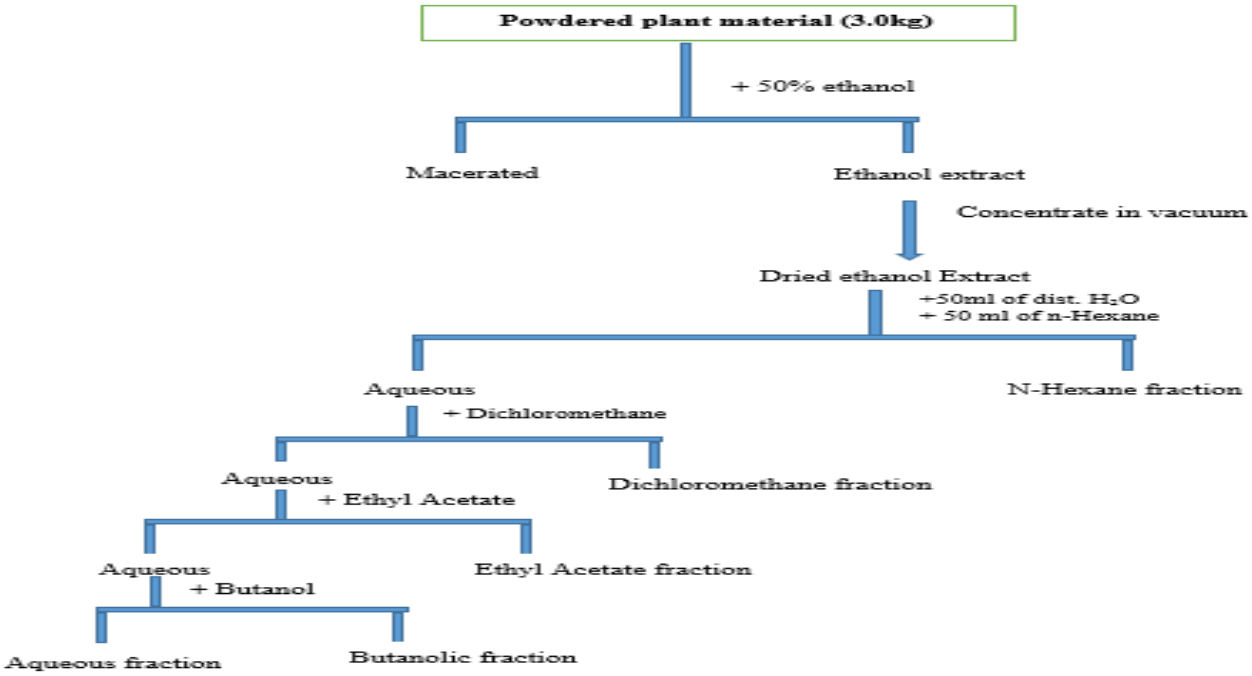

Figure 1: Extraction and Partition tree for *Z. officinale* and *C. longa*

Test for Flavonoids

To 5 ml of extract solution, few pieces of magnesium metal were added followed by few drops of concentrated hydrochloric acid. The formation of orange colour was taken as preliminary evidence for the presence of flavonoids.

Test for Cardiac Glycosides

Liberman's Test

A 0.5 g of the extract was dissolved in 2 ml of acetic anhydride and cooled; followed by sulphuric acid. A colour change from violet to blue or green indicated the presence of a glycone portion of cardiac glycoside (Sofowora, 1993).

Salkowswi Test

A 0.5g of the extract was dissolved in 2 ml of chloroform followed by a careful addition of concentrated sulphuric acid. A reddish-brown colour at the interphase indicated the presence of a steroidal ring (aglycone portion) (Sofowora, 1993).

Keller – Killiani Test

A 0.5 g of the extract was dissolved in 2 ml of glacial acetic acid containing one drop of ferric chloride solution. This was then underplayed with 1 ml of concentrated sulphuric acid. A brown ring obtained at the interphase indicated the presence of a deoxy-sugar characteristics of cardenolides.

Antimicrobial Effect of the Extracts on the Bacterial Isolates

The agar well diffusion technique as described by (CLSI, 2015) and Valgas *et al*., (2007) were employed to determine the effect of various concentrations (12.5 mg/ml, 25 mg/ml, 50 mg/ml and 100 mg/ml) of the extracts on the test isolates. Prior to this test, the test isolates were standardized with slight modification. All the test bacterial isolates were sub-cultured on Muller Hinton agar medium and incubated overnight at 37 ^{o}C and inoculated in 3 ml of Muller Hinton broth to form a

homogenous suspension of the organism which was standardized (0.5 McFarland) using calibrated VITEK 2 Densichek. The surface of the Mueller Hinton agar plate was streaked in three directions by the suspension of the testing organism, using sterile cotton swabs. Plates were allowed to dry for 10 minutes before cutting the wells (5 mm) using sterile cork borer. Wells were then filled with the various extract's concentrations (12.5, 25, 50 and 100 mg/ml). Imipenem (5 µg) discs was used as control. All plates were incubated at 37 ºC for 24 h. After the incubation period, the plates were examined, and the diameter of each zone was measured for inhibition zone formed around the wells for each extract and recorded.

Determination of Minimum Inhibitory Concentration (MIC)

The MIC of *Zingiber officinale* and *Curcuma longa* extracts were carried out as described by Okigbo *et al.* (2009) and CLSI (2017). *Z. officinale* and *C. longa* extracts with different solvents were prepared at 100 mg/ml DMSO. A 100 µl of the extract at the highest concentration (100 mg/ml) was added to the first column in a microtiter plate and 50 µl Mueller Hinton broth to other wells. A 100 µl extract was transferred from the 1st column to the next wells to produce a two-fold dilution series with resultant concentration of 100, 50, 25, 12.5, 6.25 and 3.75 mg/ml of extracted Turmeric and Ginger. The inoculums of the test organisms were prepared according to MacFarland standard. The suspension was then diluted 1:100 by transfer of 0.1 ml of the bacterial suspension to 9.9 ml of sterile nutrient broth before use. 50 µl of 0.5 adjusted McFarland bacterial suspension in Muller Hinton broth were added to dilution series, as well as a positive control well. Mueller Hinton broth only was used as negative control. Plates were incubated without agitation at 37ºC for 24 h. MIC was determined by wells with no visible growth.

RESULTS AND DISCUSSION

Phytochemical Constituents of the Extracts

The Phytochemical analysis revealed that *Curcuma longa* extracts alkaloids, flavonoids, saponins and cardiac glycosides were present in varied proportions while *Zingiber officinale* extract had only alkaloids and flavonoids present (Table 1).

Table 1: Phytochemical Properties of the Ethanolic Extracts of *Curcuma longa* and *Zingiber officinale*

Physiochemical Components	Plant Extracts	
	Curcuma longa	*Zingiber officinale*
Alkaloids	++	++
Flavonoids	+++	++
Saponins	++	-
Tannins	+	-
Cardiac Glycosides	+	-

Key: (+++): Present in high concentration; (++): Present in moderate concentration; (+): Present in low concentration and (-): Not detected

Antimicrobial Activities of the *Z. officinale* Ethanolic Crude Extract on the Bacterial Isolates

The antimicrobial effect of the various concentrations (12.5, 25, 50 and 100 mg/ml) of ethanolic extracts of *Z. officinale* on the various reference bacterial strains are presented in Figure 2. The analysis revealed that ethanolic crude extract had varying antimicrobial properties on most of the isolates. However, the extract had no antimicrobial effect on *Enterococcus faecalis ATCC 19433, Enterococcus gallinarium ATCC 49573* and *Enterococcus hirae ATCC 49135*.

Antimicrobial Activities of the *C. longa* Ethanolic Crude Extracts on the Bacterial Isolates

The antimicrobial property of *C. longa* extracts on the reference bacterial isolates is presented in Figure 3. The analysis revealed that although the tested concentrations of the extract had antimicrobial effect on the test isolates, *E. coil* WG5 was susceptible to only 100 mg/ml concentration of the extracts.

Antimicrobial Activities of Partitioned Fraction of the extracts on Bacterial Isolates

The antimicrobial activities of the four different concentrations (12.5 mg/ml, 25 mg/ml, 50 mg/ml and 100 mg/ml) of different fractions (Dichloromethane, Ethyl acetate, n-Hexane and Butanol) of the extracts on the test bacterial isolates are presented in Figures 4 to 12 showing varying susceptibilities.

Antimicrobial Activities of Dichloromethane Extracts of *Z. officinale*.

Analysis of the antimicrobial activities of the dichloromethane soluble fraction of extracts of *Z. officinale* on the reference bacterial strains is presented in Figure 5. The analysis revealed that although the dichloromomethane soluble fraction of the *Z. offocinale* extract had varying antimicrobial effect on the bacterial isolates, it had no inhibitory effect on some reference strains (*E. gallinarium* ATCC 49573, *E. hirae* ATCC 49135, *P. aeruginosa* ATCC 27853 and *S. maltophilia* ATCC 13637).

Antimicrobial Activities of the Dichloromethane Extracts of *C. longa*.

The dichloromomethane soluble fraction of the *C. longa* extracts had inhibitory effect on all the bacterial isolates except *E. durans* ATCC 11576 and *E. hirae* ATCC 49135 of the reference bacterial stains. Similarly, Imipenem, which served as control had effect on all the isolates except *S. maltophilia* ATCC 13637 (Figure 5).

Antimicrobial Activities of Ethyl Acetate Extracts of *Z. officinale*

The antimicrobial activities of the ethyl acetate soluble fraction of extracts of *Z. officinale* on the reference bacterial strains showed that all the test bacterial isolates were susceptible to the extract except two reference strains (*E. durans* ATCC 11576 and *P. aeruginosa* ATCC 27853). The control drug (imipenem) likewise did not have any inhibitory effect on *S. maltophilia ATCC 13637* (Figure 6).

Antimicrobial Activities of Ethyl Acetate Extracts of *C. longa*

The ethyl acetate soluble fraction of *C. longa* showed a strong inhibitory effect on all the reference bacterial strains except *E. faecalis* ATCC 19433 (Figure 7). Susceptibilities increase with increasing concentration.

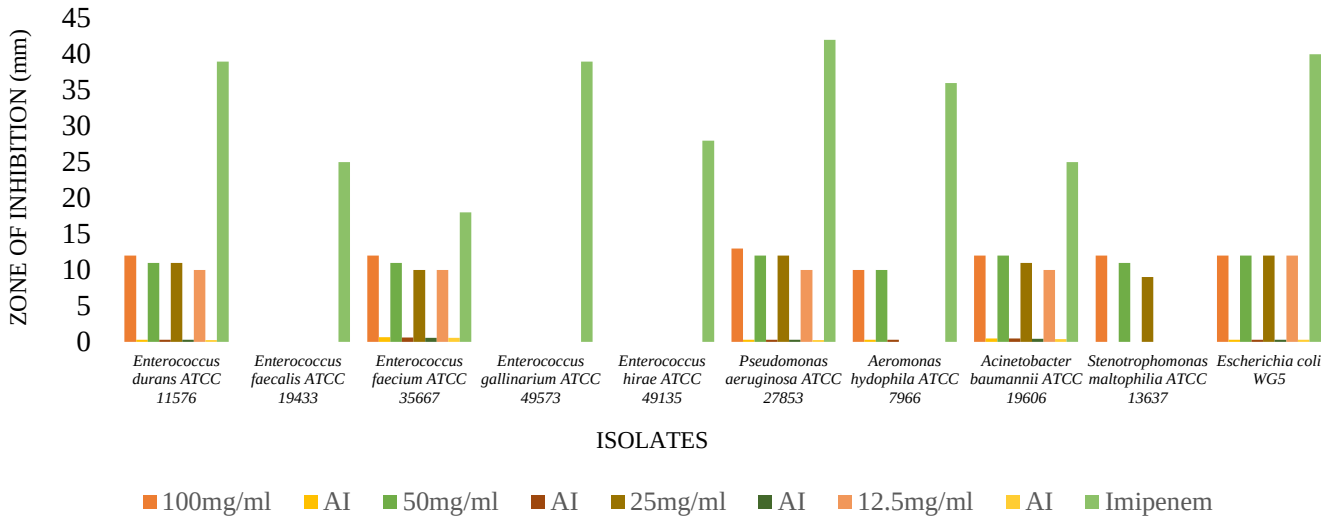

Figure 2: Antimicrobial Activities of Ethanolic Extracts of *Z. officinale* on Reference Bacterial Isolates

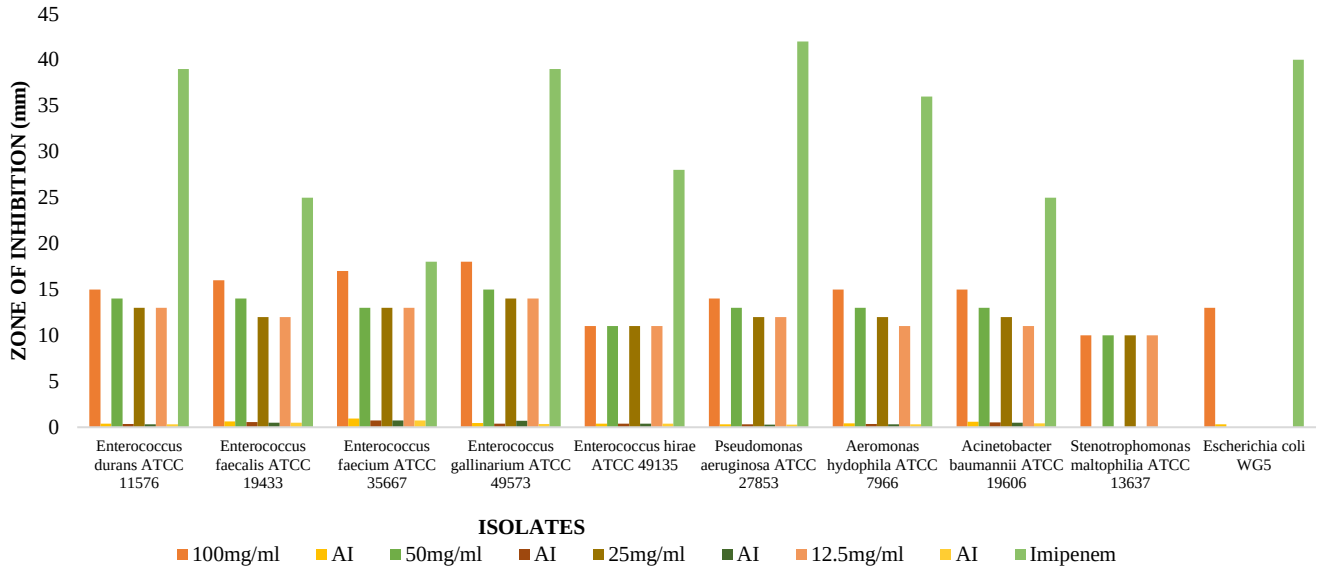

Figure 3: Antimicrobial Activities of Ethanolic extract of *C. longa* on Reference Bacterial Isolates

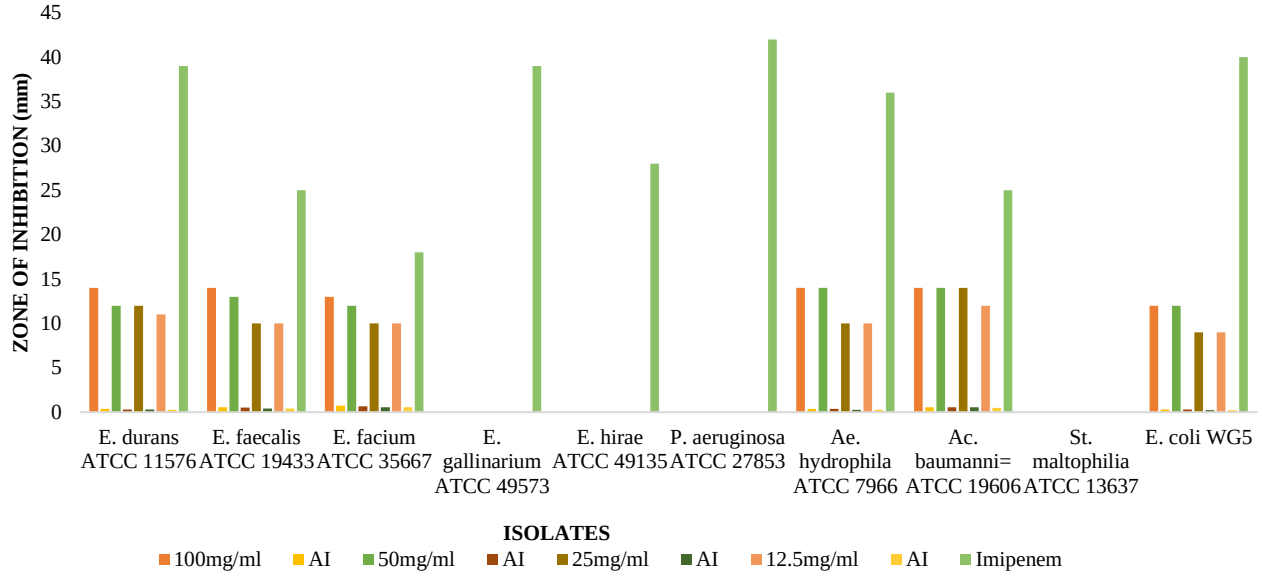

Figure 4: Antimicrobial Activities of Dichomomethane Extract of *Z. officinale* on ReferenceBacterial Isolates

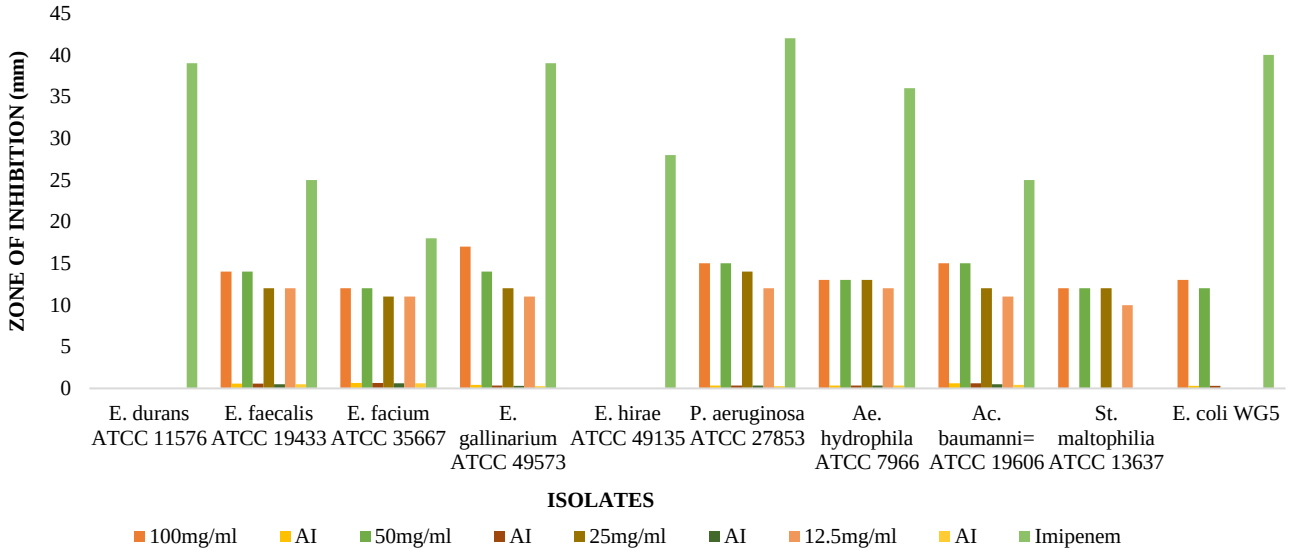

Figure 5: Antimicrobial Activities of Dichloromomethane Extract of *C. longa* Reference Bacterial Isolates

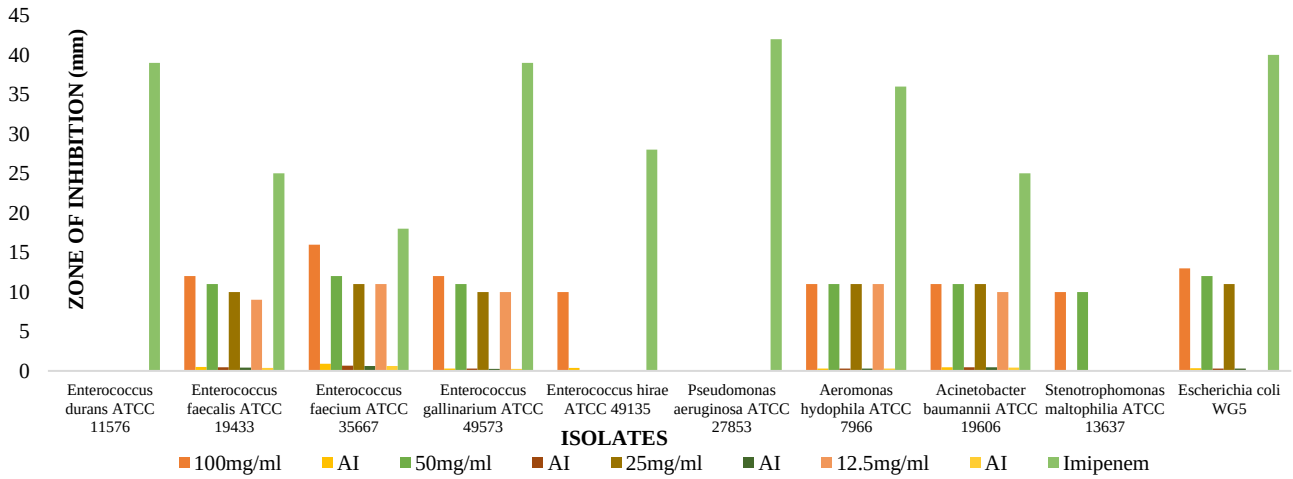

Figure 6: Antimicrobial Activities of Ethyl Acetate Extract of *Z. officinale* on Reference Bacterial Isolates

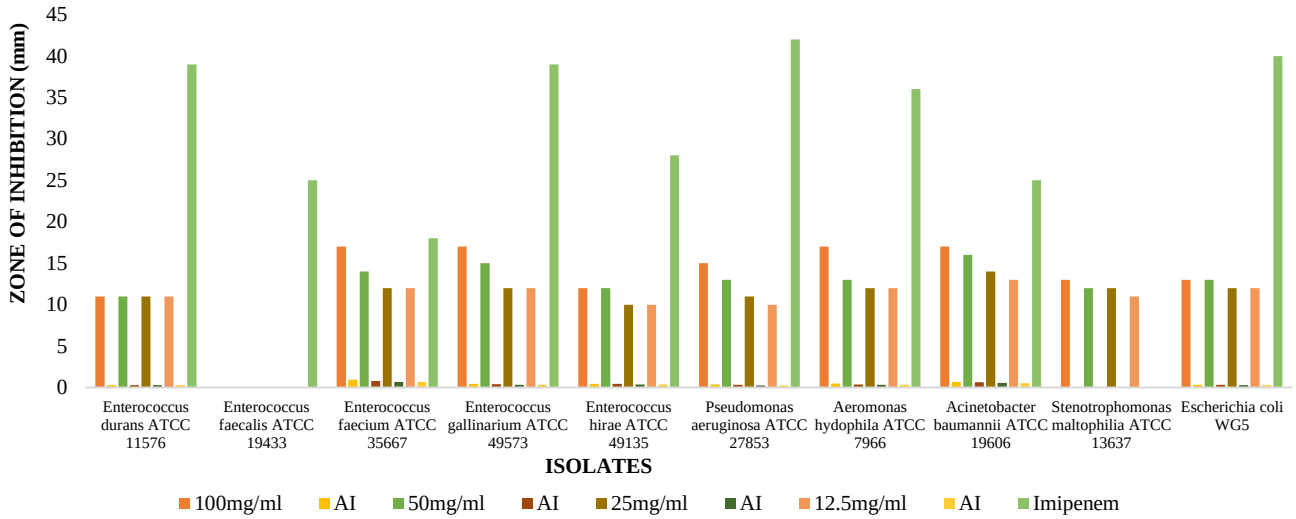

Figure 7: Antimicrobial Activities of Ethyl Acetate Extract of *C. longa* on Reference Bacterial Isolates

Antimicrobial Activities of n-Hexane Extracts of *Z. Officinale*

The antimicrobial activities of n-Hexane soluble fraction of *Z. officinale* on the bacterial isolates from fish, meat and chicken samples, reference bacterial strains and clinical bacterial isolates are illustrated in Figure 8. Besides the standard antibiotic (imipenem) which showed prominent zone, far beyond the zones created by the extract, there were just little or no differences in the zones of inhibition across various concentration gradients.

Antimicrobial Activities of n-Hexane Extracts of *C. longa*

The antimicrobial effect of n-hexane soluble fraction of *C. longa* on the reference bacterial strains are illustrated in Figure 9. Same little or no differences in zones across varying concentrations was observed as the effect of n-Hexane fraction of the extracts of *c. longa*.

Antimicrobial Activities of Butanol Extracts of *Z. officinale*.

The antimicrobial activities of butanol soluble fraction of *Z. officinale* on the reference bacterial strains are illustrated in Figure 10. This also showed little or no differences in zones across varying concentrations.

Antimicrobial Activities of Butanol Extracts of *C. longa*

The antimicrobial effect of butanol soluble fraction of *C. longa* on the reference bacterial strains are illustrated in Figure 11. There were definite increase in zones of inhibition with increasing concentration of the extract against *E. faecium* and *E. coli* WGS

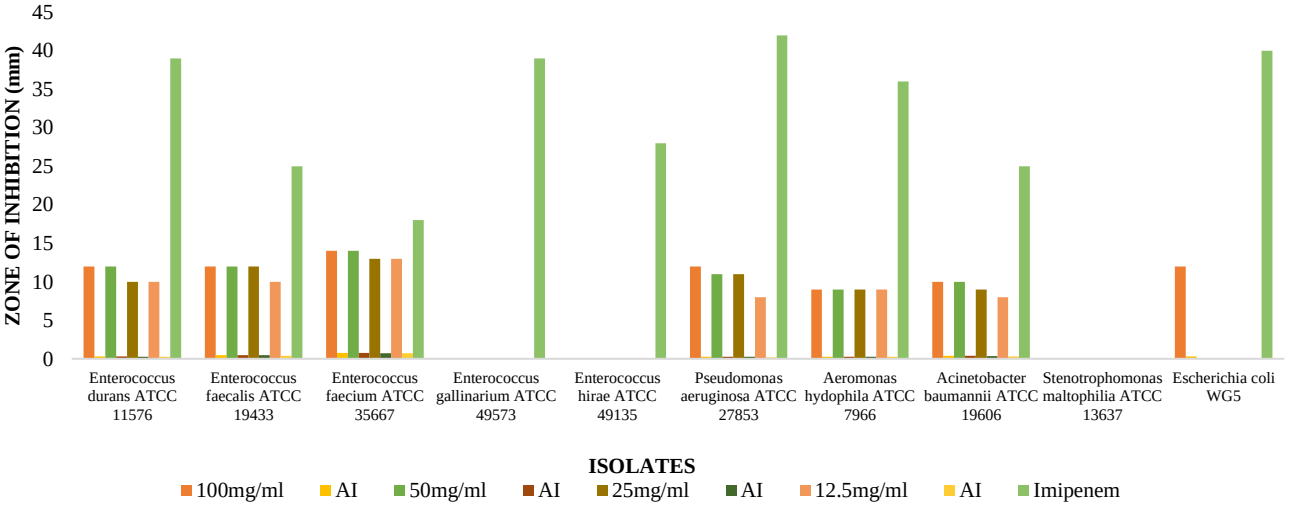

Figure 8: Antimicrobial Activities of n-hexane Extract of *Z. officinale* on Reference Bacterial Isolates

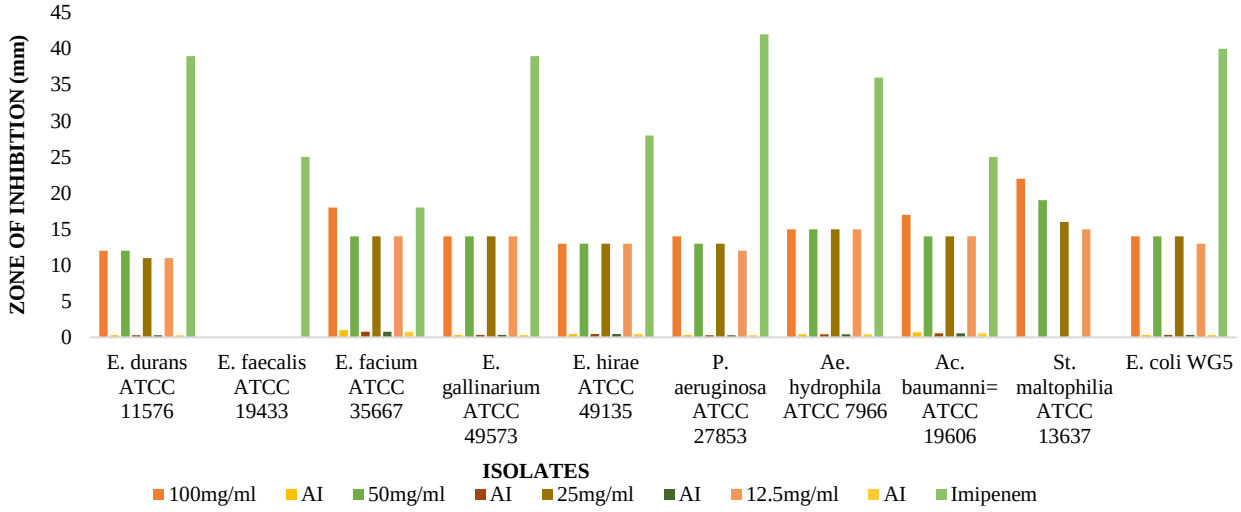

Figure 9: Antimicrobial Activities of n-hexane Extract of *C. longa* on Reference Bacterial Isolates

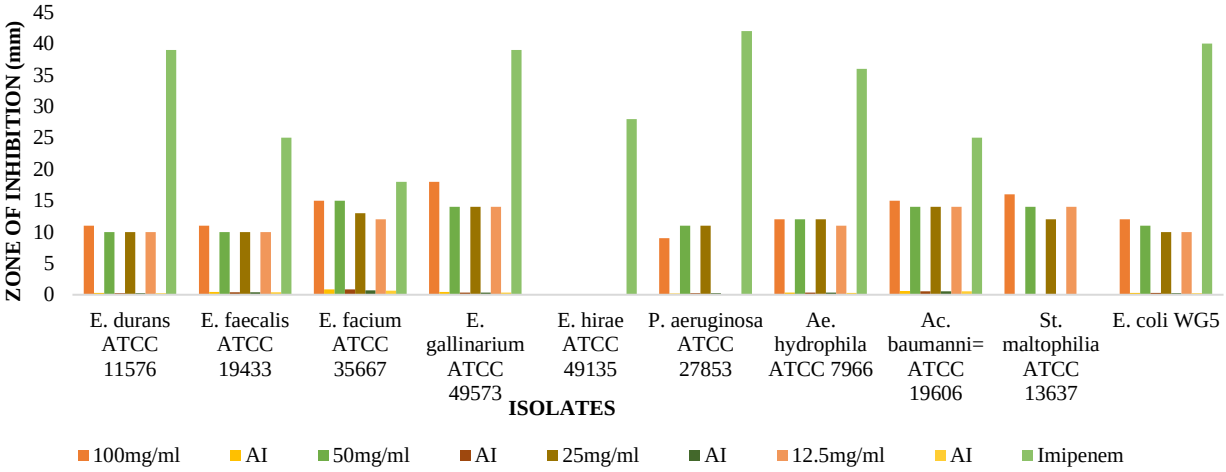

Figure 10: Antimicrobial Activities of butanol Extract of *Z. officinale* on Reference Bacterial Isolates

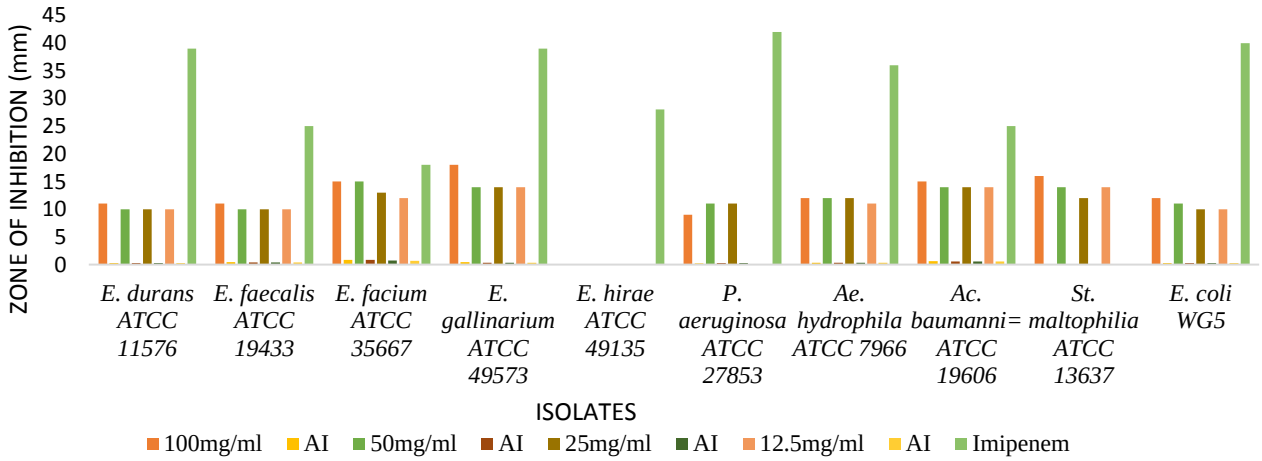

Figure 11: Antimicrobial Activities of butanol Extract of *C. longa* on Reference Bacterial Isolates

DISCUSSION

The assessment of antimicrobial effect of the various concentrations (12.5, 25, 50 and 100 mg/ml) of ethanolic extracts of both *Zingiber officinale* and *Curcuma longa* showed appreciable inhibition of the various reference bacterial strains.

Antimicrobial activities of the ethanolic extracts of *Z. officinale* and *C. longa* showed zones of inhibition that ranged from 9 mm to 16 mm and 10 mm to 16 mm respectively.

This observation corroborated the antibacterial effects reported by Pillay *et al*. (2019), though the researchers observed lower zones of inhibition. Similar to the observation in this study, Revati *et al*. (2015) reported that *Zingiber officinale* (ginger) extracts was found to have activities against all the isolates, zone of inhibition that ranged from 27 to 30 mm. Pillay *et al*. (2019) reported that the *Curcuma longa* at 100 mg/ml was effective in inhibiting the three pathogenic bacteria with zone of inhibition of ≤ 9 mm while *Zingiber officinale* showed ≤ 10 mm on the bacterial pathogens. It is also possible that higher concentration of the extracts may be effective against the resistant *Bacillus* sp.

It is interesting that the ethanolic extracts of both *Zingiber officinale* and *Curcuma longa* inhibited all the reference strains used as test isolates, with the exception of nalidixic resistant *E. coli* WG5 which was only susceptible to 100 mg/ml concentration of the extracts. There was also appreciable but with so much varying extent of antibacterial effects by all the various fractions (Dichloromomethane, ethyl acetate, n-Hexane and butanol) that it is difficult to state the best fraction. Indu *et al*. (2006) studied the antimicrobial effects of 5 spice extracts on 20 serogroups of *E. coli*, 8 serotypes of *Salmonella* species, *L. monocytogenes* and *A. hydrophila*. Panpatil *et al*. (2013) also reported on antimicrobial activities of species of ginger, turmeric and garlic.

The antimicrobial potential shown by both *Zingiber officinale* and *Curcuma longa* can be a result of the observed phytochemical constituents. It was observed that the *Curcuma longa* contained alkaloids, flavonoids, saponins, tannins cardiac glycosides while *Zingiber officinale* contained alkaloids and flavonoids.

Alkaloids are reported to have antibacterial activity where it inhibits transcription, toxin production etc. (Cushnie *et al*., 2014; Mabhiza *et al*., 2016). Flavonoids are found to have antibacterial activity by inhibiting enzymes and interfering in metabolism (Cushnie and Lamb, 2005). Alkaloids are a big and structurally diverse group of secondary metabolites that have microbial, plant, or animal origins. They can be found in around 300 plant families. However, some compounds are limited to specific families, such as hyoscyamine in Solanaceae (Cushnie *et al*., 2014). Though they are present in different parts of the plant, certain compounds are limited to a specific part, such as quinine in cinchona tree bark. Alkaloids are also found in terrestrial and in some marine animals. There are more than 18,000 alkaloids from different sources (Dembitsky, 2005). There are two broad divisions in the classification according to the chemical structure. The first division contains the non-heterocyclic or atypical alkaloids, also called protoalkaloids or biological amines, such as hordenine or N-methyltyramine, colchicine, and erythomycin (an antibiotic) (Evans, 2009). All other phytochemical constituents must have also participated in the antibacterial activities.

CONCLUSION

Ethanolic extracts of *Zingiber officinale* and *Curcuma longa* as well as their fractions showed appreciable antibacterial effects. No conclusive verdict could be made about which of the two spices were better as they inhibited the reference strains in varying patterns. Based on the results obtained in this study, *Zingiber officinale* and *Curcuma longa* have proven to be spices with sufficient antibacterial effects and thus its use is highly recommended as a natural antimicrobial.

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