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Antimicrobial potential of different plant extracts against *Escherichia coli* Isolated from poultry drinking troughs on farms in Enugu metropolis, Nigeria

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Abstract

Introduction and Objective. The increasing emergence of antibiotic-resistant bacteria, particularly in poultry farming environments, poses a serious threat to both animal and human health. The aim of the study is to evaluate the antimicrobial potential of the aqueous and ethanol plant extracts of Ginger (*Zingiber officinale)*, Garlic *(Allium sativium)* and Scent leaf (*Ocimum gratissimum),* respectively, at different concentrations against *E. coli* isolated from poultry drinking troughs on three farms in Enugu, Nigeria.

Materials and Method. *E. coli* was isolated using standard microbiological techniques. Antimicrobial susceptibility of the bacteria to ethanol and aqueous plant extracts as well as conventional antibiotics was assessed using the agar well diffusion method. The plasmid profiles of the bacterial isolates were determined via agarose gel electrophoresis.

Results. The bacterial counts from the drinking troughs ranged from $2.0 \times 10^4 - 7.9 \times 10^4$ CFU/cm^2. While some differences were observed between farms and sample points, there was a varying degree of antibacterial activity of *Zingiber officinale, Allium sativium* and *Ocimum gratissimum* against *Escherichia coli*. The ethanolic extract of all plants showed higher zones of inhibition than the aqueous extracts. The ethanolic extracts of *Zingiber officinale* (garlic) at higher concentrations of 250 µl exhibited zones of inhibition of 41 mm for EA1 and 37 mm for EA2, surpassing that of the control, Ofloxacin antibiotics (10 µg) (39–41 mm) which was one of the most potent of all the conventional antibiotics used against *E. coli* isolates. All *E. coli* isolates revealed the presence of single plasmids of 10 kbp indicating potential for antibiotic resistance.

Conclusions. Plant extracts, particularly ethanol extracts of *Zingiber officinale* and *Allium sativium*, has promising antimicrobial activity against resistant strains of *E. coli*. Further studies are needed to explore the mechanism of action and optimize plant extract formulations for broader application.

Key words

E. coli, poultry, plant extract, antimicrobial action, *Zingiber officinale*, *Allium sativium*, *Ocimum gratissimum*

INTRODUCTION

Poultry farming is an important source of livelihood in Nigeria, especially in Enugu state, producing meat, eggs and other poultry products for economic purposes as well as enhancing food security. However, one of the major challenges of poultry farming in Nigeria is the emergence of diseases among various types of poultry birds – chickens, ducks, and turkeys. Poultry are particularly vulnerable to a variety of microbial ailments, including pullorum, cholera, chronic respiratory diseases, Newcastle disease, colibacillosis and coccidiosis. Poultry disease emerges from the intricate interactions among birds and their environment, as well as from infectious and non-infectious agents [1, 2]. While the non-infectious agents can be physical and chemical poisons, as well as an abundance or deficiency of minerals and vitamins [1], most avian diseases result from infectious agents, of which the majority are caused by bacteria such as *Salmonella*, *E. coli*, *Pseudomonas*, *Klebsiella, Aeromonas, Clostridium, Enterobacter, Proteus, Citrobacter*, and *Pasteurella* [3]. Poultry birds typically contract *Pasteurella* from animal bites, typically cats or rats [3]. However, some disease-causing bacteria, such as *Staphylococcus aureus, Proteus vulgaris*, *Streptococcus* spp, *Escherichia* spp, *Staphylococcus* spp, *Klebsiella* spp., *Salmonella* spp., *Bacillus* spp., *Lactobacillus* spp., *Corynebacterium* spp. and *Pseudomonas* spp., can be associated with chicken drinking troughs [4].

The management of bacterial infections in poultry involves the use of antibiotics. As poultry production continues to rise to meet the demands of a growing population, so too does the risk of antimicrobial resistance within these settings. Routine sub-therapeutic doses of antibiotics are given to poultry animals in an effort to promote growth and prevent disease but, nevertheless, prolonged exposure frequently leads to the development of bacterial resistance [5]. *E. coli* is one, among some bacteria that have shown resistance to some

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antibiotics as these specific bacterial species have the ability to quickly acquire resistance genes, frequently via horizontal gene transfer [6]. The development of antimicrobial resistance and dissemination constitute an increasing threat to global agricultural and public health systems, necessitating the development of innovative methods to combat bacterial diseases. As such, alternate antimicrobial approaches are necessary in order to protect animal health and welfare, as well as lessen the possibility that humans could also become infected with resistant bacteria through the food chain [7].

Plants are a source of antibacterial components that are mostly synthesized during secondary metabolism [8]. Since the secondary metabolites in plants have the potential to exhibit antibacterial activities against diseases with reduced chances of having negative effects as observed with synthetic drugs, plant-based antibacterial substances offer enormous therapeutic potentials [9]. Certain plants including ginger, garlic, cinnamon, turmeric, lemon, neem, rosemary, tulsi, thyme and yucca, amongst others, have been reported with antibacterial activities against bacterial infections [10].

Hence, the aim of the study is to assess the antibacterial activities of varying concentrations of *Zingiber officinale* (ginger), *Allium sativum* (garlic), and *Ocimum gratissimum* (scent leaf) extracts against *E. coli* species isolated from poultry drinking troughs on poultry farms in Enugu, southeastern Nigeria.

MATERIALS AND METHOD

Study design and sample collection. The plants were obtained from Abakpa market, a local market located in the eastern region of Enugu (coordinates: 6°29'22.0992''N 7°31'1.7724''E). Identification and selection of these plants were based on documented literature on their antimicrobial properties [11, 12] and the availability of the plant in this region. The plants included *Zingiber officinale* (ginger), *Allium sativum* (garlic), and *Ocimum gratissimum* (scent leaf).

Chicken drinking troughs were sampled in the early hours of the morning from three different farms in the town of Enugu: coordinates: 6°29'20''N 7°29'38''E – Farm A; 6°29'N 7°31'E – Farm B; and 6°28'9.64''N 7°31'35.38''W – Farm C. The trough samples were collected using a pre-moistened sterile swab stick which was rubbed firmly, horizontally and vertically within a space of 20 cm^2 at the bottom of each trough, transferred into a swab container containing 1 ml of phosphate buffered saline, and thoroughly mixed. The specimens were then transported in ice packs to the Microbiology Laboratory at Godfrey Okoye University in Enugu.

Sterilization of materials and preparation of plant extract. The plants were allowed to air dry for 2 weeks before being ground using a sterile blender (model NH 21PCS). The plants were extracted according to the method of Sruthi *et al.* [13]. The fine powder of the plants (*Zingiber officinale* 17 g, *Allium sativum* 12.90 g, and *Ocimum gratissimum* 9.60 g) were soaked in 250 ml each of ethanol and water individually for 66 hours, and stirred twice a day (morning and evening). The mixtures were then filtered and the filtrate, evaporated to dryness in a water bath at 80 °C to obtain the aqueous extract and at 60 °C to obtain the ethanol extract.

Isolation of *E. coli*. The swab samples were individually vortexed to dislodge the cells from the swab, then aseptically introduced into 9 ml of normal saline and a 4-fold serial dilution. The pour plate technique was used for isolation. Nutrient Agar and Eosin Methylene Blue (EMB) were poured aseptically into the plates, swirled, allowed to solidify and incubated at 37 for 24 hours. After 24 h, the colonies on each plate were counted and recorded [Tab. 1]. The plates showing a metallic green sheen on EMB agar were further sub-cultured by streaking distinct colonies on nutrient agar plates to obtain pure cultures.

Table 1. Mean total heterotrophic *E. coli* counts

Sampled Farms	Total bacterial counts (CFU/cm2) (mean ± S.D)				
	Point 1	Point 2	Point 3	Point 4	Point 5
A	5.4×10^4 ± 0.6	5.6×10^4 ± 0.6	2.0×10^4 ± 0.2	3.4×10^4 ± 0.4	3.6×10^4 ±0.3
B	7.9×10^4 ± 0.9	5.1×10^4 ± 0.6	3.2×10^4 ± 0.3	4.8×10^4 ± 0.5	2.3×10^4 ± 0.2

SD – standard deviation

Identification of isolates. The isolates were identified by microscopic assessment, biochemical test (indole, citrate utilization and methyl red tests) of their properties, gram stain and cultural characteristics.

Gram staining and microscopic examination. A loopful of suspended culture was placed on a clean slide and gram reaction identified under the microscope, viewing at x100 objective [14].

Biochemical Testing. Three biochemical tests (indole, citrate utilization and methyl red tests) were employed to examine the metabolic capabilities of the bacterial isolates. Each test was performed following standard microbiological procedures as described by Ogodo et al. (2022) [14].

Susceptibility testing using antibiotics. The disc diffusion method of Kirby-Bauer [15] was used. The test cultures were incubated for 24 h at 37 °C after being inoculated into peptone water medium. The inoculated culture was standardized using the McFarland standard then streaked on Muller Hinton agar. Then susceptibility disk of 10 different antibiotics; Levofloxacin (20 µg), Cefotaxim (10 µg), Sparfloxacin (10 µg), Ciprofloxacin (30 µg), Amoxacillin (30 µg), Augumentin (30 µg), Gentamycin (10 µg), Pefloxacin (30 µg), Tarivid (Ofloxacin) (10 µg), and Azithromycin (12 µg) were placed on Muller Hinton agar plates with the aid of a sterile forceps, incubated at 37 °C for 24 h, after which, the zones of inhibition were measured and recorded in millimeters (mm) (Tab. 2).

The multiantibiotic resistance index (MARI), was determined by dividing the total number of antibiotics to which the organism was resistant by the total number of antibiotics to which it was exposed. A MAR index larger than 0.2 indicated that the bacterial strain was multidrug resistant [16].

Bacteria plasmid profile determination. Plasmid DNA was extracted from bacteria isolates using a quick DNA miniprep kit (Zymo research kit) following the manufacturer's protocol. The extracted DNA were electrophoresed in 1% agarose gel

Table 2. Antibiogram activity of antibiotics against *E. coli* isolated from chicken drinking troughs

	ZOI (mm)									
Organism/ Isolate code	LEV	CF	SP	CPX	AM	AU	GN	PEF	OFX	AZ
E. coli EA1	28 ± 2.83	26 ± 4.00	0.0± 0.0	25± 1.0	0.0± 0.0	22±1.0	22±2.0	24±2.12	39±1.0	0.0± 0.0
E. coli EB4	30± 2.12	29 ±1.00	0.0± 0.0	40± 1.0	0.0± 0.0	15±1.0	29±2.0	39±1.0	34±2.0	25±2.0
E. coli EA2	21± 1.00	0.0 ± 0.0	0.0± 0.0	27±2.0	0.0± 0.0	15±1.0	0.0± 0.0	0.0± 0.0	41±1.0	0.0± 0.0

ZOI – Zone of inhibition; **LEV** – Levofloxacin (20 µg); **CF** – Cefotaxim (10 µg); **SP** – Sparfloxacin (10 µg); **CPX** – Ciprofloxacin (30 µg); **AM** – Amoxacillin (30 µg); **AU** – Augumentin (30 µg); **CN** – Gentamicin (10 µg); **PEF** – Pefloxacin (30 µg); **OFX** – Tarivid (Ofloxacin) (10 µg); **Az** – Azithromycin (12 µg)

prepared in 100 ml of 1xTAE buffer and 4 µl of ethidium bromide. The agarose gel was run at 100 volts for 30 minutes and visualized using a UV transilluminator.

Antibacterial potential of plant extract. The antibacterial potential of the plant extract was tested using the Agar well diffusion method [17]. One gram of each extract was dissolved in 5 ml of dimethyl sulfoxide (DMSO). The bacteria isolates were sub-cultured and standardized using 0.5 McFarland standard, as described by [17].

The MHA was streaked with standardized bacteria isolates using a sterile swab stick. A 6 mm diameter sterile cork borer was used to bore wells in each solidified agar. The dissolved extracts were then added into the wells in different plates, which were then incubated at 37 °C for 24 h, after which the zones of inhibition were measured.

Minimum inhibitory concentration and minimum bactericidal concentration of plant extracts. The tube dilution method of Mahat et al., [18] was used for the determination of the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of the extracts. Standardized suspensions of the test organisms were added to a number of sterile nutrient broth tubes that contained different concentrations (100 mg/ml, 50 mg/ml, 25 mg/ml. 12.5 mg/ml and 6.25 mg/ml) of the plant extracts. The tubes were then incubated for a 24 h period at 37 °C. The MIC was recorded as the lowest concentration that inhibited visible growth of the test organisms. The lowest concentration at which no bacterial colony growth was observed on the plates was identified as the MBC.

Statistical analysis. Statistical package for social sciences (SPSS) software version 16.0 was used for data analysis. One-way analysis of variance (ANOVA) was performed to compare differences between continuous variables for various groups. A p-value ≤ 0.05 was considered statistically significant.

RESULTS

Total bacterial counts. Table 1 shows mean total heterotrophic *E. coli* counts, with total counts ranging from 2.0×10^4 CFU/cm^2 to 7.9×10^4 CFU/cm^2. However, the p-value of 0.05 indicates that there is evidence of a difference in bacterial counts across the different points (Point 1–5).

Identification of bacteria isolates. *E. coli* was identified based on the morphological and biochemical characteristics.

Antibiogram activity of antibiotics against test isolates. Table 2 shows the susceptibility pattern of antibiotics on various antibiotics. The zone of inhibition ranged from 0 – 41 mm. Ofloxacin showed the largest zone of inhibition (ZOI) of 41mm against *E. coli* EA2, followed by Ciprofloxacin with a ZOI of 40 mm against *E. coli* EB4. Pefloxacin, Gentamicin, Cefotaxim, Sparfloxacin, Amoxicillin and Azithromycin had no ZOI (0 mm) against *E. coli* EA2. Sparfloxacin, Amoxicillin and Azithromycin also had no ZOI (0 mm) against *E. coli* EA1. Sparfloxacin and Amoxicillin had no ZOI (0 mm) against *E. coli* EB4. Thus, the sensitivity of antibiotics ranged from 0% – 100% (Tab. 3). All isolates were sensitive (100%) to Augmentin, Ofloxacin, Ciprofloxacin and Levofloxacin. MARI of each isolate to the antibiotics ranged from 0.2 – 0.6 (Tab. 3).

Table 3. Percentage resistance (%MARI) of *E. coli* isolated from chicken drinking troughs to conventional antibiotics

Organism / Isolate code	LEV	CF	SP	CPX	AM	AU	GN	PEF	OFX	AZ	MARI	%
E. coli EA1	S	S	R	S	R	S	S	S	S	R	**0.3**	30
E. coli EB4	S	S	R	S	R	S	S	S	S	S	**0.2**	20
E. coli EA2	S	R	R	S	R	S	R	R	S	R	**0.6**	60
% Antibiotic sensitivity	100	67	0	100	0	100	67	67	100	33		

MARI – Multiantibiotic resistance index; **S** – Sensitivity; R: Resistance; Legend: **LEV** – Levofloxacin (20 µg); **CF** – Cefotaxim (10 µg); **SP** – Sparfloxacin (10 µg); **CPX** – Ciprofloxacin (30 µg); **AM** – Amoxacillin (30 µg); **AU** – Augumentin (30 µg); **CN** – Gentamicin (10 µg); **PEF** – Pefloxacin (30 µg); **OFX** – Tarivid (Ofloxacin) (10 µg); **Az** – Azithromycin (12 µg) Sensitivity is denoted by a zone of inhibition (mm)

Plasmid profile. Agarose gel electrophoresis showed the presence of a single DNA band of 10 kbp, confirming the presence of plasmid in all isolates. All isolates showed a single plasmid weight of 10 kbp. None of the isolates had multiple plasmids.

Antimicrobial Activity of plant extract on the isolates. The antimicrobial activity of the plant extracts on the isolates is summarized in Table 4, 5 and 6. The various plants extract concentrations showed antimicrobial potential against the isolates with zones of inhibition ranging from 15 – 41 mm. *E. coli* EA4 had the highest zone of inhibitions for both aqueous extract of *Allium sativum* (garlic) and *Ocimum gratissimum* (scent leaf).

Minimum inhibitory concentration and minimum bactericidal concentration. Table 7 shows the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) of different concentrations of the known plants extracts on the isolates. The MIC for ethanol extract of all plants was 50 mg/ml, while the aqueous extract ranged from 25 mg/ml – 100 mg/ml. The MIC for the aqueous ginger extract against *E. coli* EA2 was 50 mg/ml. For aqueous

Table 4. Antimicrobial activity of the different concentrations of ethanolic and aqueous extracts of ginger (*Zingiber officinale*) compared to Ofloxacin against test isolates

Isolate code	*E.coli* EA1	*E.coli* EB4	*E.coli* EA2
OFX (10µg) control	39 ±0.70	34 ±0.70	41±0.70
Aqueous (Ginger) 50 µg (20%)	24 ±0.70	21 ± 1.41	22 ± 1.41
Ethanol (Ginger) 50 µg (20%)	27 ± 1.41	23 ± 1.41	25± 2.82
Aqueous (Ginger) 100 µg (40%)	31 ± 2.12	22 ± 2.12	27 ± 1.41
Ethanol (Ginger) 100 µg (40%)	33 ± 0.70	26 ± 0.70	30 ± 0.70
Aqueous (Ginger) 200 µg (80%)	33 ± 2.82	25 ± 2.12	28 ± 1.41
Ethanol (Ginger) 200 µg (80%)	37 ± 1.41	31 ± 2.82	34 ± 2.12
Aqueous (Ginger) 250 µg (100%)	34 ± 0.70	2.5 ± 1.41	30 ± 1.41
Ethanol (Ginger) 250 µg (100%)	39 ± 2.12	33 ± 0.70	35± 2.12

Table 5. Antimicrobial activity of the different concentrations of ethanolic and aqueous extracts of garlic (*Allium sativum*) compared to Ofloxacin against test isolates

	E.coli EA1	*E.coli* EB4	*E.coli* EA2
OFX(10µg) (control)	39.0 ±0.70	34 ±0.70	41±0.70
Aqueous (Garlic) 50 µg (20%)	28± 2.12	27± 2.82	28 ± 1.41
Ethanol (Garlic) 50 µg (20%)	31± 2.12	27 ± 1.41	29. ± 0.70
Aqueous (Garlic) 100 µg (40%)	31 ±0.70	29 ± 1.41	30 ± 2.12
Ethanol (Garlic) 100 µg (40%)	35 ±1.41	32 ± 1.41	31 ± 1.41
Aqueous (Garlic) 200 µg (80%)	33 ± 2.82	30 ±0.70	31 ± 2.12
Ethanol (Garlic) 200 µg (80%)	35 ±0.70	35 ± 2.82	34 ± 2.82
Aqueous (Garlic) 250 µg (100%)	37 ±0.10	32 ± 1.41	35 ± 1.41
Ethanol (Garlic) 250 µg (100%)	41 ± 0.70	35 ±0.70	37 ± 2.82

Table 6. Antimicrobial activity of the different concentrations of ethanolic and aqueous extracts of scent leaf (*Ocimum gratissimum*), compared to Ofloxacin against test isolates

	E.coli EA1	*E.coli* EB4	*E.coli* EA2
OFX(10µg) (control)	39 ±0.70	34 ±0.70	41±0.70
Aqueous (Scent leaf) 50 µg (20%)	12 ± 1.41	0.0 ±0.00	8 ±1.41
Ethanol (Scent leaf) 50 µg (20%)	22 ±1.41	19±0.70	15 ± 2.12
Aqueous (Scent leaf) 100 µg (40%)	24 ±0.70	0.0 ±0.00	15 ±0.70
Ethanol (Scent leaf) 100 µg (40%)	29 ±0.70	24 ±1.41	19 ±1.41
Aqueous (Scent leaf) 200 µg (80%)	36 ± 2.12	16 ±0.70	24 ±0.70
Ethanol (Scent leaf) 200 µg (80%)	33 ±0.04	28 ± 2.12	30 ± 2.12
Aqueous (Scent leaf) 250 µg (100%)	28 ± 2.12	25.0 ± 0.70	26 ± 2.12
Ethanol (Scent leaf) 250 µg (100%)	36 ± 2.12	31 ±1.41	33 ±1.41

garlic extract, the MIC was at 25 mg/ml for all isolates while for aqueous scent leaf it was 50 mg/ml for all isolates. The MIC for the combined aqueous ginger solution on *E. coli* EA1 and *E. coli* EA2 was 100 and 50 mg/ml respectively while on *E. coli* EB4 was 50 mg/ml. The MBC of the ethanol ginger and garlic extract against *E. coli* EA2 was determined at 100 mg/ml, MBC of aqueous garlic and scent leaf extract against *E. coli* was determined to be 100 mg/ml. The MBC of aqueous scent leaf extract on *E. coli* EA4 and *E. coli* EA1 was at 100mg/ml. The values of the MIC and MBC are not surprising due to the varying antimicrobial activity of the extracts in different concentrations. Since the extracts are in their crude form, some major components in the extracts maybe responsible for the antimicrobial activities of the extracts.

Table 7. Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC) of different concentrations of the plants extracts on the test isolates in mg/ml

Isolates	Eth. Gin.		Eth. Gar.		Eth. Scent L.		Aq. Gin.		Aq. Gar.		Aq. Scent L.	
	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
E.coli. EB4	50	-	50	100	50	-	-	-	25	-	50	-
E. coli EA1	50	-	50	-	50	-	100	-	25	-	50	100
E. coli EA2	50	100	50	100	50	-	50	-	25	100	50	100

DISCUSSION

E. coli which is a colonic microbiota of animals and humans, has the potential of developing resistance against conventional antibiotics overtime [19]. In this study, *E. coli* isolated from poultry drinking trough showed resistance against conventional antibiotics. The resistance patterns found were in line with previous research [20]. The multi-antibiotic resistance index (MARI) of the isolates ranged from 0.2 – 0.6, indicating varying degrees of antibiotic resistance. Values within this range suggest potential for the isolates to evolve into multidrug-resistant strains, corroborating observations previously reported by Noman et al. [21]. These findings indicate that the evolution of resistant bacterial strains may be due to multiple antibiotics overuse and abuse in agricultural activities. It is crucial to consider that several factors, such as the extreme use of antibiotics, environmental stress, and genetics can lead to the development of multi-antibiotics resistance [11].

Keeping track of the existence of plasmids linked to significant resistant phenotypic traits can be accomplished through the analysis of plasmid profiles. Above all, the trait of drug resistance in microbes is frequently encoded on plasmids, which are easily transmissible across isolates [22]. *E. coli* isolated from the poultry drinking trough were found to possess single plasmids weighing 10kbp. The presence of these plasmids supports the hypothesis that resistance genes are carried on plasmids, facilitating horizontal gene transfer, and potentially spreading resistance.

According to previous findings, *Allium sativum* has long been used in medicine as an anti-infective agent [23]. In the present study, aqueous *Allium sativum* showed higher zones of inhibition against both isolates than the ethanol *Allium sativum* extract, which corresponds with the findings of Rafique et al. (2022) [23]. The study by Juariah et al. (2023) [24] found that ethanol extraction of *Zingiber officinale* showed higher zones of inhibition than the aqueous extract, with the ethanol extract's zones of inhibition ranging from 15 mm – 20.5 mm on *Klebsiella* spp. The study also observed that there was no zone of inhibition on *E. coli*, while the aqueous extract also had no zone of inhibition on both isolates. This was in contrast to the findings of the present study as the aqueous extract had higher zones of inhibition than the ethanol extract. Traditionally, scent leaf has been used to heal wounds, respiratory problems, diarrhea, and infections caused by *E. coli* [12]. It was observed in the current study that ethanol extraction of scent leaf had significant inhibition of bacterial growth than the aqueous extraction, which is in line

with the findings from the research by Azuamah et al. (2024) [12]. The extracts showed antimicrobial potential against the isolates with most of the effectiveness being observed in the aqueous extract, except for the scent leaf extract that recorded higher zones of inhibition in ethanol than aqueous extraction. Similar to the findings, the efficacy of ethanol over aqueous extract of this plant could be influenced by variations in compound solubility, diffusion capacity, and potency of extract at different concentrations.

The majority of the world's population lives in low-income nations, which are impacted by the problem of antibiotic resistance caused by the excessive use of traditional antimicrobials [24]. This has given rise to the consideration of alternative antimicrobial agents. The values obtained from the MIC and MBC rationally indicate the pharmacological significance of drug effectiveness against resistant isolates. The MIC and MBC of the plant extracts ranged from 25 – 100 mg/ml. Generally, the aqueous extract was found to be more effective than the ethanol extract, attaining an MIC of 25 mg/ml, compared to 50 mg/ml for the ethanol extract. However, this finding is in contrast to the findings by Egonu et al. (2023) [25]. The aqueous extract of *Allium sativum* was more effective than all other plant extracts used, which is in accordance to Rafique et al. (2023) [23]. The ethanol and aqueous *Ocimum gratissimum* extracts had the same therapeutic effect based on inhibition of the isolates. For the MBC, higher concentrations of the extracts will be needed to further determine the bactericidal effects of the extracts against the isolates.

The antimicrobial activities of the ethanolic and aqueous extracts of all three plants against strains of *E. coli* isolated from poultry drinking troughs, revealed an increase in zones of inhibition as the concentration of the extracts increased, with ethanolic extracts being more effective than the aqueous extracts. This is in line with the findings of by Egonu et al. (2023) [25]. The ethanolic extract of garlic at the highest concentration (250 µg), showed a 41 mm inhibition for *E. coli* EA1 and 35 mm for EB4, exceeding that of the aqueous extract, and also when compared with Ofloxacin. This shows its potency of the ethanol extract at a higher concentration.

The results generally showed that all plant extracts used for this study possess antibacterial activity against *E. coli,* with garlic being the most effective, and the activity is determined by the concentration. The study also revealed that the inhibition zones exceeded that of the conventional antibiotics Ofloxacin, but at an increased concentration.

Garlic was the the most effective, which could have been due to the presence of allicin, an antimicrobial agent present in garlic [21]. The antibacterial activity of ginger, which was also visible in ethanolic extracts when compared to its aqueous, could have been due to the presence of some phytochemicals, such as shogaols and gingerol [11].

CONCLUSION

This study shows that plant extracts of *Zingiber officinale, Allium sativium* and *Ocimum gratissimum* have potential antimicrobial activity against all *E. coli* isolates. Although the antimicrobial activity of Ofloxacin and Ciprofloxacin antibiotics were slightly higher than that of the ethanol plant extracts, the ethanol extracts also showed considerable antimicrobial activity against *E. coli* isolates. The plant extracts are crude components from which the active component has not been isolated. As such, these plant extracts show a prospective potential as antimicrobials. Further studies involving the fractionation and isolation of the principal component will be of interest to assess the antimicrobial activity of these plants.

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