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THE ANTIBACTERIAL ACTIVITY OF LOCALLY GROWN TURMERIC (GUYANA) USING ETHANOL EXTRACTS AT DIFFERENT CONCENTRATIONS AGAINST *ESCHERICHIA COLI, PROTEUS VULGARIS, PSEUDOMONAS AERUGINOSA AND STAPHYLOCOCCUS AUREUS*

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ABSTRACT

The present study was conducted to investigate the antibacterial activity of ethanol extracts of turmeric (*Curcuma longa* L.) locally grown in Guyana against the different strains of bacteria, namely *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Different concentrations of the turmeric extract were prepared ranging from 100%, 75%, 50% and 25% using the solvent 95% ethanol. The antibacterial activity was tested against the aforementioned bacterial strains at the different concentrations of the extract using the disc diffusion method. According to the results, the ethanolic turmeric extract exhibited considerable antibacterial activity against all the tested bacteria. Maximum antibacterial activity was seen at 25% concentration against three of the tested bacteria, namely *E. coli*, *P. aeruginosa* and *S. aureus*. Overall, the effect of the ethanolic turmeric extract varied with the concentrations against the four tested bacteria whereby *Pseudomonas aeruginosa* was the most susceptible to the extracts while *Proteus vulgaris* was the most resistant. The use of ethanolic turmeric extract as an antibacterial agent in treatment of infections caused by bacteria has been suggested by many researchers.

Contribution/Originality: Guyana has a rich biodiversity. One can only be searching to find a cure by alternate methods to fight against diseases that are rampant across the globe. In this original research, we are trying to find the effect of locally grown turmeric, the findings that help to contribute to the scientific community by seeing its effect on selected bacteria thus adding to the existing literature of its significance.

1. INTRODUCTION

The oldest known method for healing is the use of plants. Plants and plant products have been used as medicines since the beginning of man's existence to treat diseases. According to World Health Organization, medicinal plants are the best to obtain a variety of new herbal drugs [1, 2]. Antibiotics are usually administered for microbial infections, however due to the irrational use of antibiotics; numerous bacterial strains have developed resistance. According to World Health Organization's 2014 report on global surveillance of antimicrobial resistance, antibiotic resistance is happening currently across the world, and is putting at risk the ability to treat common infections in the community and hospitals [3]. Turmeric (*Curcuma longa* L.) has been used for approximately 4,000 years to treat a variety of ailments [4]. It is well known for its unique medicinal properties. For instance, several actions of turmeric have been documented in classical literature such as antibacterial, antiparasitic, antiviral, antiseptic, anti-inflammatory, anti-oxidative, anticancer, astringent, blood purifier, clear skin colour, wound healing, and as a stimulant and sedative in the food industry [5].

Curcuma longa L., commonly known as turmeric, is an herbaceous perennial plant of the *Zingiberaceae* family also known as the Ginger family. Turmeric is native to South Asia and is believed to be indigenous to India, in particular. It is cultivated in tropical and subtropical regions, predominantly in India, Pakistan and China [6]. Turmeric has a short stem with large oblong leaves and flowers which are yellow-white in colour that bears on a spike. It also bears ovate, pyriform or oblong rhizomes, which are highly branched and externally brownish-yellow in colour, whilst deep orange or reddish brown internally. It has a unique odour and a bitter, slightly acrid taste [7]. Turmeric is a medicinal plant which is extensively used in Ayurveda (Indian traditional medicine), Unani and Siddha medicine for many centuries as a remedy to numerous ailments [7]. Such ailments include wounds, blistering diseases, acne, parasitic infections, common cold, liver diseases, urinary tract diseases, hepatic disorders, anorexia, rheumatism, sinusitis, biliary disorders and for the treatment of inflammation, sprains and swelling caused by injury [8]. Also research has suggested it may be helpful in conditions such as heart diseases, cancers, neurodegenerative diseases, indigestion and osteoarthritis [9]. In addition, it is widely used as a food additive (spice), colouring agent and preservative. It is also used in Hindu religious ceremonies as it was considered auspicious since it is believed to symbolize purity and prosperity.

Turmeric has gained significant interest in the field of Microbiology due to its antimicrobial properties. The chemical composition of turmeric includes protein, fat, carbohydrates, minerals, vitamins, fiber, volatile (essential) oil, curcumin and moisture [10]. Also, its essential oil acquired by steam distillation of rhizome contains α-phellandrene, sabinene, cineol, borneol, zingiberene and sesquiterpines [7]. Turmeric contains phenolic compounds collectively known as curcuminoids which possess all the bio-proactive properties [11]. Curcumin (diferuloylmethane) is a yellow pigment present in turmeric which is mainly associated with its biological actions [12]. Among the other curcuminoids are demethoxycurcumin and bisdemethoxycurcumin.

"Wounds are a type of injury that breaks the skin or other body tissues and are broadly classified as having an acute or chronic etiology. Acute wounds are caused by external damage to intact skin and they include surgical wounds, burns, minor cuts, abrasions, bites, and more severe traumatic wounds such as laceration and those caused by gunshot injuries or crush. On the other hand, chronic wounds are caused by endogenous mechanisms associated with predisposing conditions which will ultimately affect the dermal and epidermal tissues such as ulcers and pressure sores" [13].

The risk of wounds involves "infection since the exposure of subcutaneous tissues following loss of skin integrity provides a moist, warm and nutritious environment for microbial colonization and proliferation" [13]. Factors such as wound type, depth, location, and quality, the level of tissue perfusion and the antimicrobial efficacy of the host immune response all influence the abundance and diversity of microorganisms in any type of wound [13]. Microorganisms associated with wound infection include both gram-positive and gram-negative bacteria such as *Staphylococcus aureus*, *Streptococcus* spp., *Escherichia coli*, *Pseudomonas* spp., *Klebsiella* spp., and *Proteus* spp. as well as fungi such *Candida*. Moreover, wound infections influence the healing of a wound thus causing a victim to suffer greater trauma, as well as increase the cost of treatment and requires greater medical care.

Wound infections, in particular those caused by bacteria are amongst the common and important infectious diseases. However, though there are numerous clinical drugs such as antibiotics that have been administered to treat such bacterial infections, bacteria are developing resistance to these drugs. Hence, research has grown over the past decades to find new antibacterial agents. Natural products from medicinal plants such as onion, turmeric, oregano, mustard, ginger and cinnamon among others have been under intense studies to be used as alternatives for treatment of infections [11]. Turmeric has been known to suppress the growth of several bacteria such as *Streptococcus*, *Staphylococcus*, *Lactobacillus*, *Escherichia*, *Vibrio*, *Entrococcus*, and *Salmonella*. Therefore, *Curcuma longa* L. can be a potential alternative for the treatment of wound infections due to its antimicrobial and anti-inflammatory properties.

The study of this research will be to investigate the antibacterial activity of the ethanolic extracts of local turmeric against the different strains of bacteria, namely *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* and to determine if ethanolic extracts of local turmeric can inhibit the growth of the selected strains of bacteria also to determine the lowest concentration of ethanolic extract of local turmeric that would be used against the bacterial growth of those strains.

2. MATERIALS AND METHOD

4lbs raw Turmeric,Barium Chloride ($BaCl_2$),95% Ethanol,98% Sulphuric Acid (H_2SO_4), Sodium Chloride (NaCl)

2.1. Bacterial Strains

The following bacterial strains were used in this study: *Escherichia coli*,*Proteus vulgaris Pseudomonas aeruginosa*,*Staphylococcus aureus* .Pure cultures of these bacteria were obtained from the laboratory of Georgetown Public Hospital Corporation, Georgetown (Region 4).

2.2. Maintenance of Bacterial Culture

The pure cultures of each bacterium were sub-cultured on nutrient agar petri-dishes two days prior to the commencement of the antibacterial sensitivity testing. The cultures were streaked on sterile nutrient agar petri-dishes which were subjected to incubation for twenty-four hours at 37˚C in an incubator. The subcultures were stored at 4˚C (in the refrigerator).

2.3. Preparation of Ethanolic Turmeric Extract

The spice, turmeric (*Curcuma longa*) was purchased from the local market, specifically the Bourda Market. A total weight of 4 lbs. (or 1.8kg) of raw turmeric was used for the preparation of the extract. The rhizomes were peeled, using a knife, to remove the skin and then washed thoroughly with distilled water to further remove any dirt, soil particles or other solid contaminants and debris. They were again rinsed with 95% ethanol. The whole, peeled turmeric rhizomes were chopped, using a knife, into smaller pieces in order to increase the surface area for grinding. The turmeric was homogenized using a sterile mortar and pestle until it was thin shreds. The thin shreds of the turmeric were placed and spread out in aluminium foil pans which were then placed into the oven for approximately 24-48 hours until they were dried.

The dried shreds of turmeric were ground using the sterile mortar and pestle until they became fine grains. The turmeric powder was sieved through a double layer of sterile fine mesh cloth.

It was then weighed using a manual balance whereby a total of 128.5g of turmeric powder was produced from 1.8kg of raw turmeric rhizomes. 100g of the turmeric powder was placed into a glass jar whereby 200mL of 95% ethanol was poured into it. The combination of the turmeric powder and 95% ethanol was stirred and left to soak for 24 hours at room temperature for extraction. The solution was then filtered using Whatman No. 1 filter paper; to maximise the turmeric-ethanol mixture, the remaining residue was subjected to squeezing in layers of sterile gauze to release any further liquid. The filtrate was then heated using a water bath at 40˚C- 50˚C until a thick paste was formed. An unstirred water bath was used in this study whereby it heated the turmeric-ethanol solution in a body of water at a temperature range between 40˚C- 50˚C; it was maintained approximately at 45˚C. The researcher used a laboratory water bath as indicated in the Mukhtar and Ghori methodology instead of using a rotary evaporator. The water bath similarly functioned to remove the solvent from the sample by evaporation. The paste was brick orange-red in colour, and thick in consistency. It was approximately 25mL. The thick paste was considered as 100% concentration of the ethanolic turmeric extract.

From the crude extract (100% ethanol turmeric extract), the extract was further diluted to make different concentrations which included 75%, 50% and 25%. Each concentration of the extract was made to have a volume of

10mL. The dilutions were prepared by diluting the crude extract with corresponding volumes of 95% ethanol using the $C_1V_1=C_2V_2$ formula. The ethanolic turmeric extracts of each concentration were separately stored in glass vials with secured caps.

Each of the glass vials containing the extracts was labelled appropriately with the concentration.

The glass vials containing the ethanolic turmeric extracts were stored in a refrigerator at 4˚C.

2.4. Preparation of Medium

The nutrient agar was prepared by suspending 23g of nutrient agar powder into 1L of distilled water contained in a large conical flask. It was then autoclaved and used when preparing the plates.

2.5. Preparation of Culture Suspension

Sterile saline solution was used for the preparation of culture suspension. Saline is 0.9% sodium chloride solution. A total volume of 200mL was required for the number of test tubes arranged. 200mL of distilled water was added to 1.8g of 100% NaCl to prepare 200mL of 0.9% NaCl.10mL of the 0.9% saline solution was poured into each test tube. The test tubes containing the saline solution were autoclaved for approximately 45-60 minutes.

2.6. Preparation of 0.5 McFarland Standards

McFarland Standards are turbidity standards which are used to standardize the quantity of bacteria present in a liquid suspension. They are used to visually compare the turbidity of a suspension of bacteria with the turbidity of the appropriate standard. Generally, the standards are prepared by adding barium chloride ($BaCl_2$) to sulphuric acid (H_2SO_4) to acquire a barium precipitate. In this study, 0.5 McFarland Standard was prepared whereby the volumes of the reagents, barium chloride and sulphuric acid, were adjusted to follow the guidelines for the 'Preparation of McFarland Standards'. 0.5mL of 1% $BaCl_2$ and 99.5mL of 1% H_2SO_4 were required to prepare 0.5 McFarland Standard which would represent approximately 1.5 x 10^8 bacterial cells per 1mL, i.e. (150,000,000 bacterial cells/ 1mL). Approximately 0.5mL of 1% $BaCl_2$ was added to 99.5mL of 1% H_2SO_4 in a conical flask while constantly swirling the flask. The solution was stirred until it appeared homogenous and free of any suspensions. The conical flask was then plugged with cotton wool logs (i.e. cotton wool rolled in the paper) and wrapped in aluminium foil paper.

It was stored in a dark area until ready for use. Before the antibacterial sensitivity testing, the turbidity of the bacterial suspension and the 0.5 McFarland Standard were visually compared against a background comprised of black and white stripes, which resembled a Wickerham card.

2.7. Antibacterial Sensitivity Testing using Disc Diffusion Method

The agar petri-dishes were dried in an incubator at 37˚C to remove the moisture that was present from the refrigerating procedure. After drying, the bottoms of the petri-dishes were labelled around the circumference using a black permanent marker. They were each labelled with the following information; Initials of the researcher, Date of the experiment, Name of bacteria + Sample (whether it was the concentrations of the ethanolic turmeric extract/ 95% ethanol/ 500mg Ampicillin solution) and plate letter (Plt. A/B/C). The Whatman No. 3 filter paper discs of approximately 6mm in diameter were prepared using a paper hole puncher. The discs were stored in a glass petri-dish, wrapped with aluminum foil paper, and sterilized in an autoclave. The test microorganisms (*E. coli*, *P. vulgaris*, *P. aeruginosa* and *S. aureus*) were transferred from the cultures to the saline solutions using an inoculating loop. Then, the culture suspensions were visually compared to the 0.5 McFarland Standards. Any suitable adjustments were made to the suspension culture to allow it to match the turbidity of the 0.5 McFarland Standards. For instance, in the case, if the suspension was too dilute, then it was inoculated with additional bacteria until there is a match. In contrast, if it was too dense it was diluted with suspension until comparable to the 0.5 McFarland

Standards. The inoculating loop was flamed before and after each transfer of bacteria. The test microorganisms were transferred from the culture suspension to the sterile agar petri-dishes using sterile cotton swabs. The swab uptake is approximately 0.9-1.0mL of culture suspension of the bacteria.

The agar petri-dishes were streaked from corner to corner following a technique which entailed streaking the inoculum (culture suspension of bacteria) halfway across the petri-dish, turning the dish at right angles to the first streak, streaking the dish halfway across the dish, rotating the petri-dish 90˚ and streaking halfway across half of it again. This streaking technique allowed the researcher to produce well-separated colonies of bacteria from the culture suspension and covered the surface from corner to corner with it as well. Several filter paper discs were aseptically transferred into small, disposable petri-dishes.

Each small petri-dish was labelled with the sample that was going to be placed into it. A new, cleaned pipette was each time used to apply the sample onto each filter paper disc. The samples were applied drop-wise onto each disc until they were saturated with the sample (ranging between 100-300 µL; 1 drop ≡ 100µL). The sample-impregnated filter paper discs were aseptically transferred to the streaked petri-dishes. Each sample for each test bacteria was done in triplicates, hence the plates A, B, and C. Four sample-impregnated discs were placed equilateral to each other in the streaked petri-dishes. Forceps were flamed and cooled upon each administration of those discs. After the transfer of the sample-impregnated filter paper discs, the streaked petri-dishes were sealed around the circumference using transparent scotch tape. The test petri-dishes were then placed into an incubator, at a temperature of 37˚C for a period of 24 hours, in an inverted position. After 24 hours, the test petri-dishes were observed and the diameters of zone of inhibition for each disc were measured in millimetres using a transparent, plastic ruler.

2.8. Antibacterial Sensitivity Testing

The test bacteria, *Escherichia coli*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus* were also tested for their sensitivity against the antibiotic Ampicillin (500mg). The ampicillin solution was prepared by using a 500mg capsule of ampicillin purchased from a local pharmacy and sterilized distilled water. The content of a 500mg ampicillin capsule was dissolved in 20mL of sterilized, distilled water. Hence, the reference had a concentration of 25mg/ml.

3. STATISTICAL ANALYSIS

The collected data was analyzed using the following statistical test: Mean value and standard deviation and Two-factor without replication analysis of variance.

4. RESULTS

The antibacterial activities of the 95% ethanolic extracts of local *Curcuma longa* L. rhizomes are listed in Table 1. All values were expressed as mean±standard deviation of the four replicates. Furthermore, the results were analyzed statistically by two-factor without replication analysis of variance (ANOVA) at P≤0.05 (5%) confidence limit. The ethanol extracts of local *Curcuma longa* L. rhizomes exhibited antibacterial activity against all four isolates of bacteria Figure 5-8.

Table-1. The Effect of *C. longa* ethanol extracts on the tested pathogenic bacteria.

Bacteria Species	Zone of Inhibition (mm)			
	Crude(100%)	75%	50%	25%
E. coli	9.63±1.13	9.33±0.58	8.50±0.52	9.75±1.22
P. vulgaris	8.46±0.75	9.54±0.72	9.50±0.98	7.75±0.66
P. aeruginosa	9.96±1.86	9.83±1.34	9.29±1.01	11.75±3.11
S. aureus	9.79±1.12	9.42±0.73	9.00±1.21	10.33±0.78

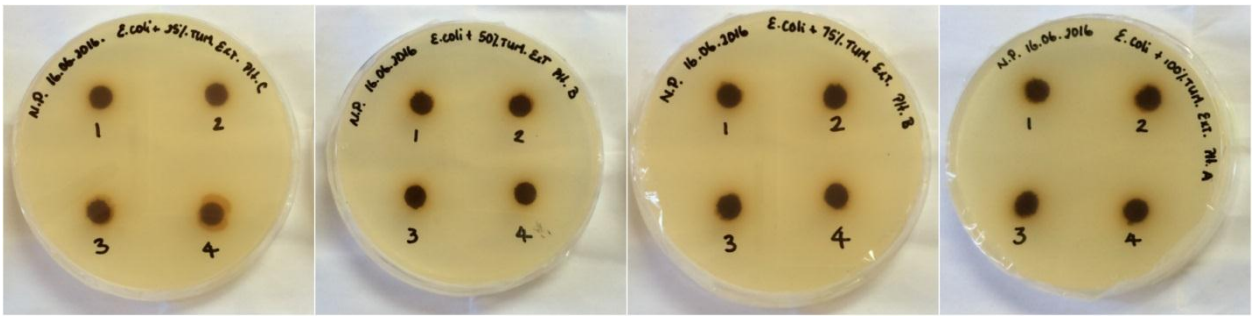

Figure-5. Antibacterial activity of ethanolic turmeric extract on *E. coli*

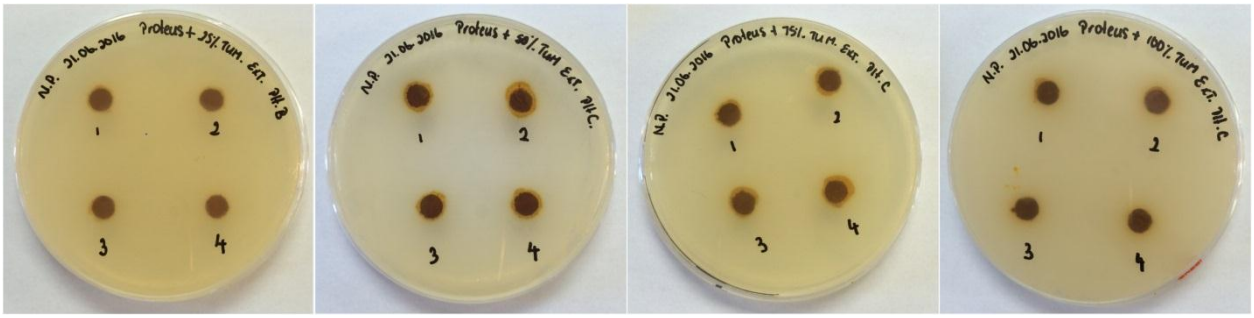

Figure-6. Antibacterial activity of ethanolic turmeric extract on *P. vulgaris*.

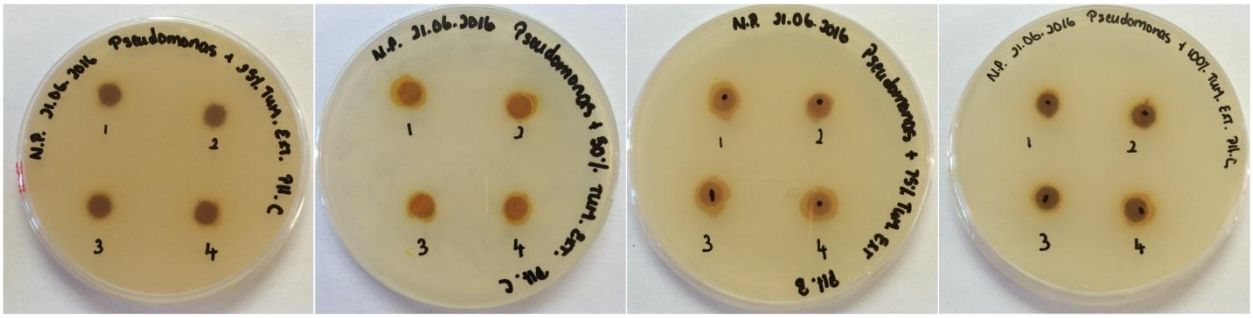

Figure-7. Antibacterial activity of ethanolic turmeric extract on *P. aeruginosa*

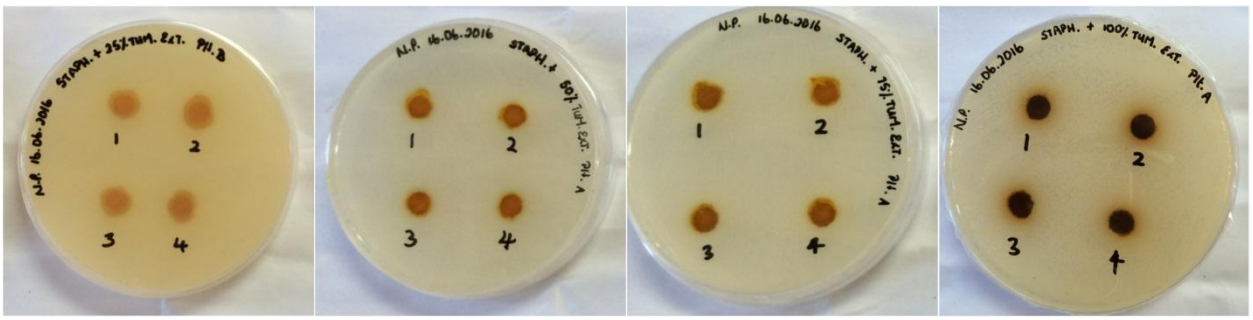

Figure-8. Antibacterial activity of ethanolic turmeric extract on *S. aureus*.

The 95% ethanolic turmeric extract showed maximum antibacterial activity against all four bacteria except for one, namely *P. vulgaris* at 25% concentration. However, the extract showed a minimum antibacterial activity against *P. vulgaris* at 25% concentration. Interestingly, *E. coli*, *P. aeruginosa*, and *S. aureus* showed a greater zone of inhibition at the lowest concentration of 25%. From Table 1, it can be seen that as the ethanolic turmeric extract concentration increased from 50% concentration so did the diameter of zone of inhibition for three of the four tested bacteria. The effect of the ethanolic turmeric extract varied in respect to the concentrations against the four tested bacteria. Overall, *P. aeruginosa* has shown the highest sensitivity at each concentration, except 50% concentration, in comparison to the other bacteria in this study Table 1. It was observed that there is a low standard deviation for

all the diameter of zones of inhibition. Thus, this implies that the data obtained from the triplicates of the antibacterial sensitivity test did not deviate much from the mean.

Table-2. The Effect of 500mg Ampicillin solution on the tested pathogenic bacteria.

Bacteria Species	Zone of Inhibition (mm)
	500mg Ampicillin solution
E. coli	36.42±1.02
P. vulgaris	27.50±8.92
P. aeruginosa	15.00±1.38
S. aureus	47.66±2.07

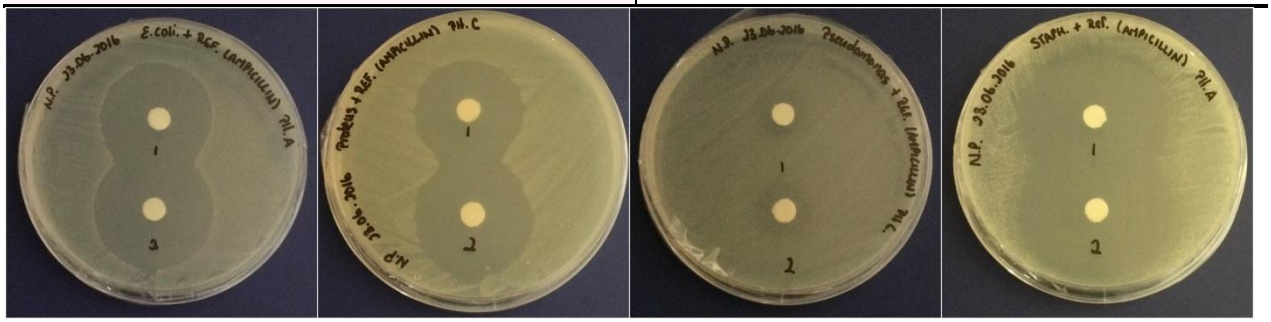

Figure-9. Antibacterial activity of 500mg Ampicillin solution on the tested bacteria- *E.coli*, *P. vulgaris*, *P. aeruginosa* & *S. aureus* (from L-R).

The antibacterial activities of 500mg Ampicillin solution are listed in Table 2. The antibiotic drug showed maximum activity against the bacteria *S. aureus* whereas minimum activity against *P. aeruginosa* Figure 9. From the results obtained, the antibiotic Ampicillin showed greater zones of inhibition against all four bacteria in comparison to the ethanol extract of local *Curcuma longa* L. prepared in this present study. In addition, the presence of zones of inhibition in the control replicates of this present study was negative.

Table-3. The Statistical Analysis (Anova) of the zones of inhibition seen on *E. coli*, *P. vulgaris*, *P. aeruginosa*, and *S. aureus* when treated with ethanol extracts of local *Curcuma longa* L.

Anova: Two-Factor Without Replication

Summary	Count	Sum	Average	Variance
Row 1	4	37.21	9.3025	0.317425
Row 2	4	35.25	8.8125	0.751692
Row 3	4	40.83	10.2075	1.141625
Row 4	4	38.54	9.635	0.318833
Column 1	4	37.84	9.46	0.4626
Column 2	4	38.12	9.53	0.0474
Column 3	4	36.29	9.0725	0.187692
Column 4	4	39.58	9.895	2.750767

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Rows	4.119969	3	1.373323	1.985398	0.186781	3.862548
Columns	1.363319	3	0.45444	0.656978	0.598693	3.862548
Error	6.225406	9	0.691712			
Total	11.70869	15				

Table-4. ANOVA analysis: Two factor without replication Analysis.

ANOVA: Two factor without replication			
Ethanol extract of *C. longa*	**F**	**P-value**	**F crit**
Rows	1.985398	0.186781	3.862548
Columns	0.656978	0.598693	3.862548

The Anova test greater F crit value than F value, hence indicating that there is no significant differences between the ethanolic turmeric extract treatment on the colonies of *E. coli*, *S. aureus*, *P. aeruginosa* and *P. vulgaris*. In

addition, the different concentrations of the 95% ethanol extract of local *Curcuma longa* L. have a similar effect on the different bacteria with no statistically significant difference (F value (0.66) < F crit (3.86)) Table 4 Overall, in each case the statistical data obtained showed that the F calculated value was always less than the F crit value at 0.05 probability level. However, the ethanolic turmeric extract is clinically effective with minor differences in causing inhibition of growth against these bacteria as seen in Table 1.

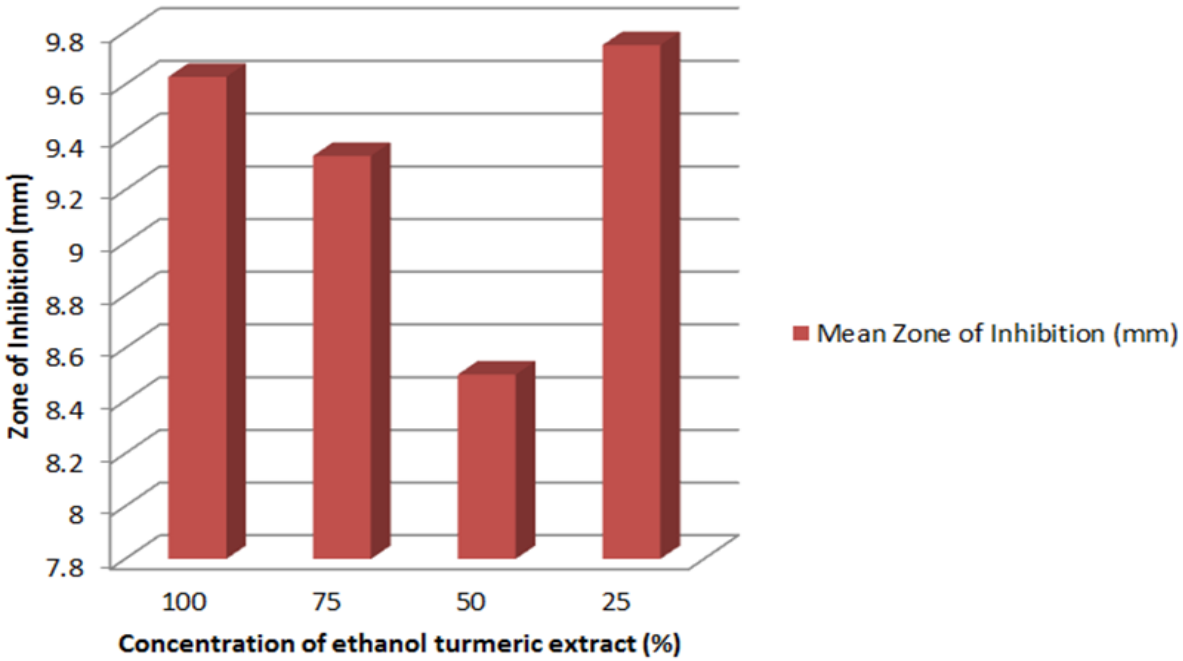

Figure-1. Column Graph showing 'zones of inhibition against the various concentrations of the ethanolic turmeric extract on *E. coli*'.

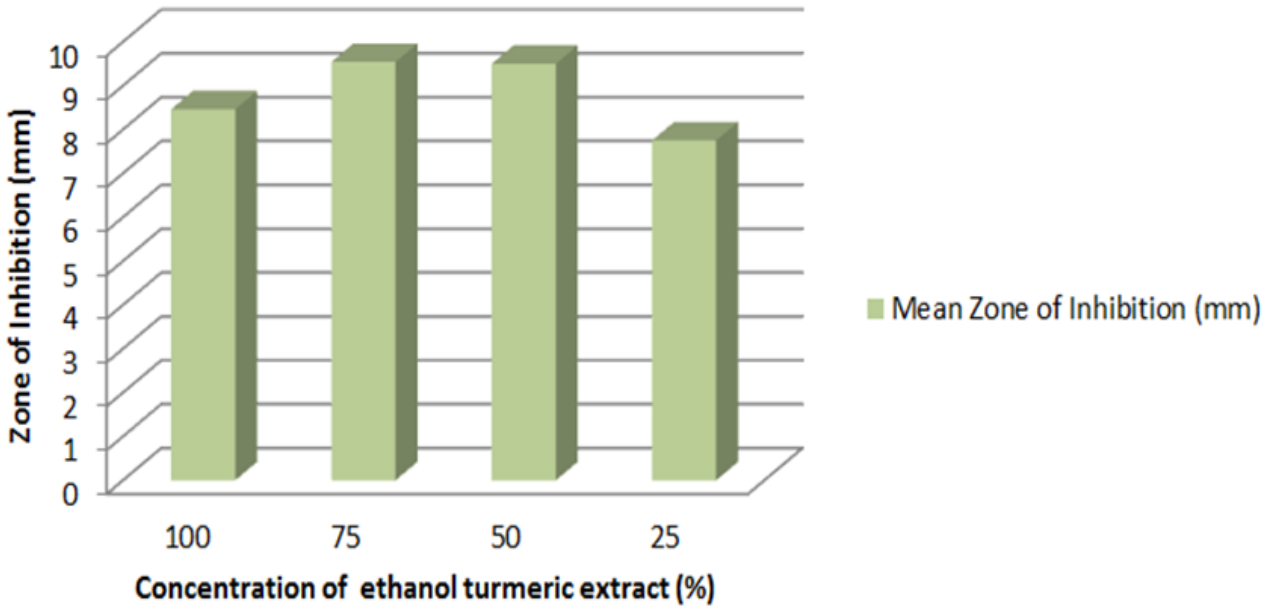

Figure-2. Column Graph showing 'zones of inhibition against the various concentrations of the ethanolic turmeric extract on P. vulgaris'.

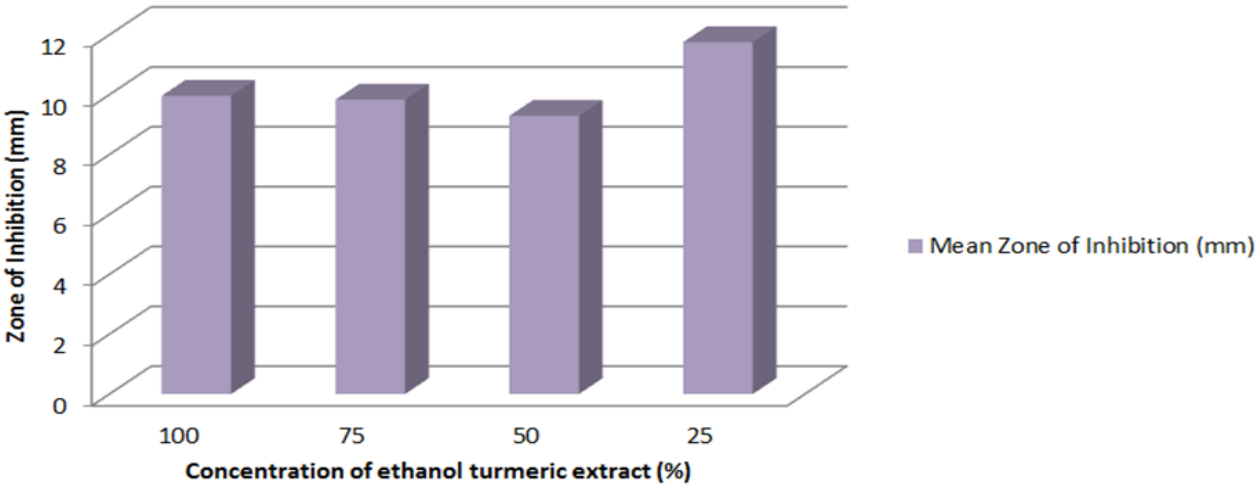

Figure-3. Column Graph showing 'zones of inhibition against the various concentrations of the ethanolic turmeric extract on *P. aeruginosa*'.

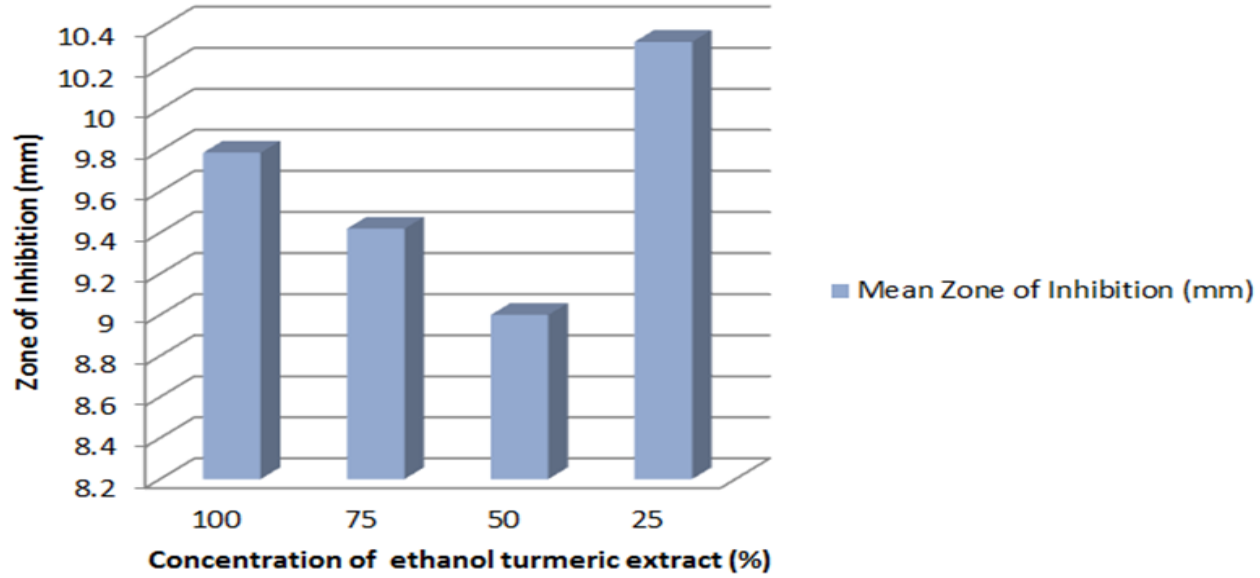

Figure-4. Column Graph showing 'zones of inhibition against the various concentrations of the ethanolic turmeric extract on *S. aureus*'.

5. DISCUSSION

The extracts of plants have been long used to prevent and treat infections as well as illnesses. In support, many studies have reported the potential use of medicinal plants and herbs as an antimicrobial agent. The beneficial effect of plants is attributed to the natural compounds found in plants known as secondary metabolites. A wide array of secondary metabolites such as tannins, alkaloids, flavonoids, and terpenoids has been found *in vitro* to have antimicrobial properties. Turmeric (*Curcuma longa* L.) possesses curcuminoids, a phenolic compound, which is responsible for the antimicrobial activity [11].

In vitro studies in this work showed that ethanol extracts of *Curcuma longa* L. rhizomes inhibited bacterial growth; however, their effectiveness at different concentrations varied. The results of this study were in agreement with previous studies whereby different concentrations of turmeric caused inhibition of growth against the tested bacteria. Besides, the antibacterial activities of turmeric proved to be effective against gram-positive bacteria (*S. aureus*) and gram-negative bacteria (*E. coli*, *P. vulgaris*, and *P. aeruginosa*). "The thick structural components of gram-positive bacteria can be held responsible for the increased interaction between the active compound of turmeric, curcumin, and the structural lipoproteins. Therefore, this increased interaction may result in the inhibition of gram-positive bacteria" [11]. Also, "the phenolic compounds of turmeric are capable of further cellular destruction and inhibition through the establishment of hydrophobic and hydrogen bonds of the phenolic

compounds to membrane proteins which results in the portioning of the lipid bilayer" [11, 14]. Similar to this present study, aqueous, chloroform, ether, methanol, xylene, benzene and acetone extracts of turmeric rhizomes showed antibacterial activities [15, 16].

The ethanolic extract of local *Curcuma longa* L. rhizomes showed the highest inhibitory activity at 25% concentration against three of the tested bacteria namely *E. coli*, *P. aeruginosa*, and *S. aureus* (9.75mm, 11.75mm, and 10.33mm inhibition, respectively). On the other hand, the 25% concentration of the extract showed the least inhibitory activity against *P. vulgaris* (7.75mm inhibition). Interestingly, *E. coli*, *P. aeruginosa*, and *S. aureus* were least inhibited at 50% concentration of the ethanolic turmeric extract (8.50mm, 9.29mm, and 9.00mm inhibition, respectively). However, *P. vulgaris* was not least inhibited by the 50% concentration of the extract, instead, the 50% and 75% concentration showed similar results of inhibition against the bacteria (9.50mm and 9.54mm, respectively).

In contrast to the results of this present study, previous studies showed that as the concentration of the ethanolic turmeric extract increased so did the zones of inhibition [11]. Furthermore, to have comprehensive knowledge for such deviations in this present study in comparison to previous studies such as Mukhtar and Ghori's; tests and analyses have to be conducted to investigate the mechanism of action that the extract has against the tested bacteria. Some possible reasoning for deviations may include the diffusion rate of the ethanolic turmeric extract which may have been influenced by the concentration make-up (crude extract: ethanol ratio) as well as the type of filter paper used as discs. Although some of the antibacterial activities of turmeric are well-documented, their antibacterial capacity *in vitro* may vary on a wide basis depending on several factors such as the difference in nature of the plant, tested organisms, test medium, and different methods [17].

In previous studies, the phytochemical activity of *Curcuma longa* L. rhizomes demonstrated the presence of alkaloids, terpenoids, and flavonoids. Besides, other contents that were tested positive included carbohydrates, proteins, and amino acids [18].

In this present study, it was confirmed that turmeric inhibits the growth of the selected bacterial strains. Furthermore, the selected bacterial strains are those that have been known to inhabit wounds and cause infections. Wound infections are commonly treated with antibiotics and wound cleansing. However, the use of antibiotics, whether administered topically or orally, to treat wound infections may not always be effective. For instance, bacteria are developing resistance to antibiotics which ultimately jeopardizes the purpose of using antibiotics since it may only inhibit or kill little to no bacteria. Also, antibiotics can cause possible allergic reactions and potential side effects. Therefore, interest has widened to identify and develop new antibacterial agents. Turmeric has been traditionally used for the treatment of various conditions including wounds since compounds in turmeric have antibacterial, antiviral, antifungal, antioxidant, analgesic, and anti-inflammatory properties. Therefore, since turmeric is known to have such properties, to be non-toxic, readily available, and cheap it can be a great alternative for the treatment of wound infections. Besides, further development of wound infection treatments can incorporate the golden spice, turmeric in the forms of ointments and dressings.

It can be concluded that different species of bacteria differ in their susceptibility to turmeric. This antibacterial study of the ethanolic extracts of local turmeric demonstrated that the lowest concentration to inhibit the growth of the bacterial strains was 25% concentration. From this study, it can be safely concluded that turmeric which is cheap, easily available as well as known to be non-toxic can be used as an alternative to treat wound infections caused by bacteria.

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