Journal of Pharmaceutics and Therapeutics

Research Article

Antimicrobial Evaluation of Natural Spices (Turmeric, Garlic, Onion, Celery and Cinnamon) Versus Synthetic Antibiotics (Tetracycline, Clindamycin and Ceftriazone) at Three Different Concentrations (10%, 50% and 100%)

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Received: Feb 25, 2017; Accepted: April 15, 2017; Published: April 24, 2017

Abstract

Most Synthetic drugs have several side effects when administered and the cost of synthesizing them is an expensive endeavour. One alternative is to use herbal medicines. Guyana has an abundance of diverse flora which has been receiving attention in this area. However, much more research needs to be done. The antibacterial activity of natural spices (Turmeric, garlic, onion, celery and cinnamon) was investigated against *E. coli*, *S. aureus*, *K. pneumoniae* and *P. aeruginosa* and was compared with synthetic antibiotics (Tetracycline, Clindamycin and Ceftriazone) at three different concentrations of 10%, 50% and 100%. The Disc Diffusion Assay was used to investigate the antimicrobial potency of the synthetic drugs and herbal medicines under aseptic conditions. The synthetic drugs were prepared at different concentrations of 10%, 50% and 100%, whereas the extract was investigated at 100% concentration. Experiments were done in triplicates and the diameter of zone of microbial inhibition (DZOI) was measured and expressed as the mean with standard deviation (SD). The precision of comparisons (e.g. 95% confidence intervals) and Area of Zone of Inhibition, AZOI was also computed. Selected microorganisms were also tested against a reference standard antibiotic, Ampicillin and Nystatin. For the synthetic drugs, the highest Area of Zone of Inhibition, AZOI of 1566.4 mm² was induced by Clindamycin against *S. aureus* at 50% concentration whereas the lowest AZOI of 245.09 mm² was induced by *P. aeruginosa* at 10% concentration. For the herbal extracts, the highest AZOI of 1256.6 mm² was induced by the onion extract versus *K. pneumoniae* whereas the lowest AZOI of 50.3 mm² was induced by the Turmeric extract against *E. coli*. Antimicrobial selectivity was also observed for both synthetic and herbal medicines. For example, for tetracycline against *S. aureus*, AZOI of 1093.92 mm² was obtained whereas against *P. aeruginosa*, AZOI of 530.67 mm² was observed. Garlic exhibited AZOI of 139.49 mm² against *E. coli* whereas a value of 78.5 mm² was obtained against *P. aeruginosa*.

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Keywords: Antimicrobial; Tetracycline; Clindamycin; Ceftriazone; Celery; Onion; Garlic

Introduction

There is an urgent need to find new antimicrobials, considering that bacteria and fungi develop resistance over a period of time and antimicrobial resistance is now a global concern [1-6]. Antimicrobial resistance is due to indiscriminate use of commercial antimicrobial drugs used for the treatment of infectious diseases. The outburst of drug resistant microbial strains necessitates the studies for synergistic effects of antibiotics in combination with plant's derivatives to develop the antimicrobial cocktail with a wider spectrum of activity and reduction of adverse side effects of antimicrobial agents. Many synthetic drugs have several adverse side effects which are usually irreversible when administered and the cost of synthesizing drugs in most cases is an expensive endeavour [1-5]. One alternative is the continued use of herbal medicines. Plants have a long therapeutic history over thousands of years and still considered to be promising source of medicine in the traditional health care system [6,7]. Plants have a wide variety of secondary metabolites such as steroids, triterpenes, glycosides, tannins etc. some of which are antimicrobial, singly or in combination. The leaves, stems, and bark have been used as antimicrobial agents [7-13]. In another approach, the fruit extracts of plants have also been investigated for their antimicrobial properties. Here the fruits are nutritious and antibiotics (neutraceuticals) [14-17]. Another antimicrobial approach uses spices as antimicrobial agents [18-24]. Spices are not only used for their culinary properties but also for their potential health benefits [21-23]. Although the health attributes associated with spice use may arise from their antioxidant properties, their biological effects may arise from their ability to induce changes in a number of cellular processes, including those involved with drug metabolism, cell division, apoptosis, differentiation and immunocompetence.

The U.S. Food and Drug Administration (FDA) defines a spice as an "aromatic vegetable substance, in the whole, broken, or ground form" whose significant function in food is "seasoning, rather than nutrition" and from which "no portion of any volatile oil or other

flavoring principle has been removed" (Food and Drug Administration 2007) [24]. Spices investigated in this research were celery, garlic, turmeric, cinnamon etc.

Celery (*Apium graveolens*, Apiaceae, has been cultivated as a vegetable since antiquity. Either its stalks, leaves, or hypocotyl are eaten and used in cooking. Celery seeds contain a compound, 3-n-butylphthalide, that lowers blood pressure in rats [25]. Celery juice significantly reduced hypertension in 87.5% of patients [26]. Another study showed the same effect on hypertension associated with pregnancy.

Garlic, *Allium sativum*, is widely used around the world for its pungent flavor as a seasoning or condiment. Garlic preparations may effectively lower total cholesterol by 11-23 mg/dL and LDL cholesterol by 3-15 mg/dL in adults with high cholesterol if taken for longer than two months. The same analysis found that garlic had a marginally positive effect on HDL cholesterol and no significant effect on blood triglyceride levels, and that garlic preparations were generally well tolerated with very few side effects. As garlic may reduce platelet aggregation, patients taking anticoagulant medication are cautioned about consuming garlic [27].

Cinnamon is a spice obtained from the inner bark of several trees from the genus *Cinnamomum* that is used in both sweet and savoury foods [28,29]. Cinnamon bark is used as a spice. It is principally employed in cookery as a condiment and flavouring material. It is used in the preparation of chocolate, especially in Mexico, which is the main importer of cinnamon. Cinnamon powder has long been an important spice in enhancing the flavor of Persian cuisine, used in a variety of thick soups, drinks, and sweets.

Turmeric is a rhizomatous herbaceous perennial Zingiberaceae. In Ayurvedic practices, turmeric has been used to treat a variety of internal disorders, such as indigestion, throat infections, common colds, or liver ailments, as well as topically to cleanse wounds or treat skin sores [28]. Basic research shows extracts from turmeric may have antifungal and antibacterial properties [29]. Turmeric is under study for its potential to affect human diseases, including Alzheimer's disease [30,31].

Onion also known as the bulb onion or common

Figure 1: Clindamycin.

onion, is a vegetable and is the most widely cultivated species of the genus *Allium* [32,33].

Clindamycin (Figure 1) is an antibiotic of the lincosamide class, which inhibits bacterial protein synthesis at the level of the bacterial ribosome. The antibiotic binds preferentially to the 50S ribosomal subunit and affects the process of peptide chain initiation. Although clindamycin phosphate is inactive *in vitro*, rapid *in vivo* hydrolysis converts this compound to the antibacterially active clindamycin. Clindamycin is well absorbed by the oral route. Clindamycin is employed primarily in the treatment of infections caused by anaerobic bacteria such as *Bacteroides fragilis*, which often causes abdominal infections associated with trauma. However, it is also significantly active against nonenterococcal, gram-positive cocci. Clindamycin undergoes extensive oxidative metabolism to inactive products. The drug is excreted into the bile or urine by glomerular filtration but therapeutically effective levels of the parent drug are not achieved in the urine. In addition to skin rashes, the most serious adverse effect is potentially fatal *pseudomembranous colitis* caused by overgrowth of *C. difficile*, which elaborates necrotizing toxins [34,35].

Ceftriaxone (Figure 2) is a new third generation semisynthetic cephalosporin. It is administered

intravenously or intramuscularly and has a broad spectrum of activity against Gram-positive and Gram-negative aerobic, and some anaerobic, bacteria. The activity of ceftriaxone is generally greater than that of the 'first' and 'second generation' cephalosporins against Gram-negative bacteria, but less than that of the earlier generations of cephalosporins against many Gram-positive bacteria. Although ceftriaxone has some activity against *Pseudomonas aeruginosa*, it cannot be recommended as sole antibiotic therapy in pseudomonal infections. Ceftriaxone has been effective in treating infections due to other difficult organisms such as multidrug-resistant *Enterobacteriaceae* [34].

Tetracycline, Figure 3, is a broad-spectrum polyketide antibiotic produced by the *Streptomyces* genus of actinobacteria, indicated for use against many bacterial infections, exhibiting activity against a wide range of microorganisms including gram-positive and gram-negative bacteria, chlamydiae, mycoplasmas, rickettsiae, and protozoan parasites, it is a protein synthesis inhibitor. However the presence of tetracycline resistant pathogens limits the use of these agents in the treatment of diseases [34].

This paper evaluate and compared the antimicrobial effects of different concentrations (10%, 50% and 100%) of Clindamycin, Tetracycline and Ceftriaxone

Figure 2: Ceftriazone.

Figure 3: Tetracycline.

versus some natural herbs and spices: garlic, turmeric, cinnamon, onion and celery at 100% concentration against human pathogens: *Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumonia* and *Pseudomonas aeruginosa*.

Materials and Methods

Plant collection and identification

The plant material *Allium sativum* (Garlic), *Apium graveolens* (Celery), *Allium cepa* (Onion), *Curcuma longa* (Turmeric) and *Cinnamaldehyde* (Cinnamon) were purchased from Stabroek Market in Georgetown during June, 2015.

Figure 4: AZOI induced by Tetracycline against *S. aureus*.

Figure 5: AZOI induced by Garlic against *S. aureus*.

Figure 6: AZOI induced by Cinnamon against *S. aureus*.

Collection of pathogenic microorganism

One strain of gram positive (*Staphylococcus aureus*) and three strains of gram negative (*Escherichia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa*) bacteria were used as test organisms. These microorganisms were obtained from the Georgetown Public Hospital Cooperation, GPHC.

Preparation of agar plates

Two 1000 ml autoclave beakers were used to pour the Mueller Hilton agar powder. 57.06 g of Mueller Hilton

agar were weighed using an electronic balance and added to 1500ml of distilled water. The solution was placed on a Thermo-Scientific Cimarec hotplate/stirrer and allowed to boil until the agar was fully dissolved. The magnetic stirrer was removed and the solution was allowed to cool to room temperature. The agar solution was then placed into the autoclave at 121°C for 60 minutes. The cooled Mueller Hilton agar (15ml) was poured into sterile petri dishes on a level horizontal surface to give uniform depth, under the Enviralab Sterility Module. The plates were allowed to dry for approximately 1 hour and then stored in the refrigerator.

Graph 1: Antimicrobial activity of Cindamycin at three different concentrations.

Graph 2: Antimicrobial activity of Tetracycline at three different concentrations.

Preparation of microbial inoculum

The colonies were transferred from the plates to the Nutrient broth with a sterilized straight nichrome wire. The turbidity was adjusted with Nutrient Broth to equal that of a 0.5 MacFarland unit turbidity standard that has been freshly prepared.

Preparation of plant extracts

The fresh plant was washed, peeled, sliced and sun

dried for seven days. After drying, each of the plant extract was ground to a fine powder using an electric blender. 10 g powder of each plant extracts was extracted in 100 ml of distilled water. The flasks were incubated at room temperature for 72 hours with shaking at 120 rpm. The crude extracts were centrifuged at 3000 rpm for 10 minutes at 25°C. All dried extract samples were dissolved in distilled water, separately to the final concentration of 100 mg/ml and centrifuged again at 10,000 rpm to remove the undissolved residues. The extract solutions were labeled and stored in the

Graph 3: Antimicrobial activity of Ceftriazone at three different concentrations.

Table 1: Antimicrobial activity of Clindamycin at three different concentrations of 10%, 50% and 100%.

Pathogenic Microorganism	DZOI (mm) at 10%	AZOI (mm ²)	DZOI (mm) at 50%	AZOI (mm ²)	DZOI (mm) at 100%	AZOI (mm ²)
<i>E. coli</i>	24.3 ± 0.33	464.68	28 ± 1.0	615.4	32.7 ± 1.15	837.85
<i>S. aureus</i>	42.7 ± 4.61	1428.60	44.7 ± 0.82	1566.39	42.7 ± 2.43	1429.27
<i>K. pneumoniae</i>	30.7 ± 4.62	738.4	26.3 ± 1.3	544.22	36 ± 7.55	1017.36
<i>P. auriginosa</i>	17.7 ± 1.57	245.09	22.7 ± 1.53	403.43	20.3 ± 0.71	324.45

Table 2: Antibacterial activity of Tetracycline at three different concentrations of 10, 20 and 100%.

Pathogenic Microorganism	DZOI (mm) at 10%	AZOI (mm ²)	DZOI (mm) at 50%	AZOI (mm ²)	DZOI (mm) at 100%	AZOI (mm ²)
<i>E. coli</i>	30.3 ± 1.27	706.86	34.3 ± 0.58	907.92	34 ± 2.4	907.46
<i>S. aureus</i>	34.3 ± 1.15	907.92	34.7 ± 0.57	962.11	37.3 ± 1.53	1093.92
<i>K. pneumoniae</i>	28.3 ± 1.33	615.75	34 ± 1.22	706.86	34 ± 0.00	907.92
<i>P. auriginosa</i>	19 ± 0.00	283.53	24 ± 1.22	452.39	26 ± 0.71	530.67

Table 3: Antibacterial activity of Ceftriazone at three different concentrations of 10, 20 and 100%.

Pathogenic Microorganism	DZOI (mm) at 10%	AZOI (mm ²)	DZOI (mm) at 50%	AZOI (mm ²)	DZOI (mm) at 100%	AZOI (mm ²)
<i>E. coli</i>	34 ± 0.00	907.46	39.7 ± 1.16	1235.36	41.3 ± 2.31	1340.91
<i>S. aureus</i>	33 ± 7.94	854.87	40 ± 1.22	1256.64	42 ± 3.2	1384.74
<i>K. pneumoniae</i>	36 ± 1.0	1017.36	41.3 ± 2.12	1340.91	41.7 ± 1.53	1363.07
<i>P. aeruginosa</i>	28.7 ± 1.15	645.25	34.3 ± 0.35	925.16	32 ± 1.0	803.84

Table 4: Antibacterial activity of the reference sample, Ampicillin at three different concentrations of 10, 20 and 100%.

Pathogenic Microorganism	DZOI (mm) at 10%	AZOI (mm ²)	DZOI (mm) at 50%	AZOI (mm ²)	DZOI (mm) at 100%	AZOI (mm ²)
<i>E. coli</i>	29	660.19	30	706.5	29	660.19
<i>S. aureus</i>	49	1884.79	50	1962.5	52	2122.64
<i>K. pneumoniae</i>	27	572.27	23	415.27	24	452.16
<i>P. aeruginosa</i>	0	0.00	10	78.5	9	63.59

refrigerator at 4°C.

Preparation of antibiotic concentrations

The antibiotics (Clindamycin, Tetracycline, Ceftriazone and Amoxicillin) were weighed to 1 g in triplicate and were placed in sterile test tubes. Dilution methods were used to prepare the three different concentrations 10%, 50% and 100% respectively. 1 ml of water was placed in 1g of the antibiotic powder to make up a solution equal to 100% concentration, 2 ml of distilled water in 1 g of powder to make up 50% concentration and 10 ml in 1 g powder to make up 10% concentration respectively.

Preparation of sensitivity disk

Discs of 6 mm in diameter were punched out using Whatman No. 1 filter paper with the aid of a paper punch and placed in petri dish. The discs were then sterilized by autoclaving at 121°C for one hour after which they were allowed to cool.

Antimicrobial Susceptibility test [36,37]

Disc diffusion: Stokes Disc diffusion technique 6 mm discs were placed in a sterile petri dish and 20 microliter of the different antibiotic concentrations were placed onto each disk and allowed to dry at room temperature for 3 hours. The agar plates were removed from the refrigerator and placed in the incubator for 1 hour to dry. The plates were then labeled to differentiate the microorganism and antibiotic concentrations being tested. Using Stokes Disc diffusion sensitivity technique, an inoculum containing 200 microliter of bacterial cells were applied onto the agar plates. On each plate three discs were applied and separate plates were used as the reference. The positive control used was Amoxicillin for the bacterial strains. The reference antibiotic disc contained 100 mg antibiotic/ml. The antibiotic test discs with the different concentrations were placed onto the inoculated agar plates. The disc containing the herbal extracts were also placed onto their respective inoculated agar plates. After all the disc were placed onto their respective plates, it was left to dry for 3-5 minutes. The plates were inverted and placed into the incubator for 24 hours at 37°C. The

Table 5: Antibacterial activity of selected herbs & spices measured at 100%

Organisms	Garlic T1	Garlic T2	Garlic T3	Mean± SD	
<i>E.coli</i>	19	10	11	13.3 ± 4.93	139.49
<i>S.aureus</i>	24	24	26	24.7 ± 1.15	477.76
<i>K.pneumonia</i>	13	11	11	12.7 ± 1.69	126.02
<i>P.aeruginosa</i>	10	10	10	10 ± 0.00	78.5
Organisms	Tumeric T1	Tumeric T2	Tumeric T3	Mean± SD	
<i>E.coli</i>	8	8	9	8 ± 0.71	50.27
<i>S.aureus</i>	11	9	9	9.7 ± 1.15	73.40
<i>K.pneumonia</i>	12	10	10	10.7 ± 1.33	89.37
<i>P.aeruginosa</i>	8	9	11	9.3 ± 1.53	68.33
Organisms	Celery T1	Celery T2	Celery T3	Mean± SD	
<i>E.coli</i>	14	10	11	11.7 ± 2.08	106.9
<i>S.aureus</i>	16	15	14	15 ± 1.0	176.6
<i>K.pneumonia</i>	14	13	13	13.3 ± 0.57	139.5
<i>P.aeruginosa</i>	11	17	14	14 ± 3.0	153.9
Organisms	Cinnamon T1	Cinnamon T2	Cinnamon T3	Mean± SD	
<i>E.coli</i>	13	15	13	13.7 ± 1.15	146.7
<i>S.aureus</i>	10	15	15	13.3 ± 2.9	139.5
<i>K.pneumonia</i>	12	12	11	11.7 ± 0.6	106.9
<i>P.aeruginosa</i>	12	9	10	10.3 ± 1.51	83.8
Organisms	Onion T1	Onion T2	Onion T3	Mean± SD	
<i>E.coli</i>	9	9	9	9 ± 0.00	63.6
<i>S.aureus</i>	13	14	14	13.7 ± 0.6	146.7
<i>K.pneumonia</i>	40	40	40	40 ± 0.00	1256.64
<i>P.aeruginosa</i>	8	9	9	9 ± 0.71	59.0

Table 6: P-value for the synthetic drugs at 100% concentration.

Name of the drug	P-value	F-value	Comments
Clindamycin	0.8543	0.1603	Not significant
Tetracycline	0.4231	0.9478	Not significant
Ceftriazone	0.0752	0.0792	Not significant

Table 7: P-value for the herbs at 100% concentration.

Name of the drug	P-value	F-value	Comments
Garlic	0.20		Not significant
Tumeric	0.0776		Not significant
Celery	0.0779		Not significant
Cinnamon	0.1194		Not significant
Onion	0.4003		Not significant

Table 8: P-value for the reference antibiotics at three different concentrations.

Name of the drug	P-value	F-value	Comments
Amoxicillin	0.3664	1.1248	Not significant

antimicrobial compound is expected to diffuse from the disc into the medium. Following overnight incubation, the culture was examined for areas of no growth around the disc (zone of inhibition). The diameter of the zone of inhibition was measured. The end point of inhibition is where growth stops. The larger the zone of inhibition, greater is the antimicrobial activities.

Results

The Disc Diffusion assay was used to evaluate and compared the antimicrobial activity of four drugs: Ceftriaxone, Tetracycline and Clindamycin at different concentrations of 10%, 50% and 100% and was then compared to few natural herbs and spices (garlic, turmeric, cinnamon, celery, onion). The diameter, DZOI and area of the zone of inhibition, AZOI were computed and used as an indication of the plant extracts or drug antimicrobial potency.

The experiments were done in triplicate to assess the reliability and validity of the results findings. The mean, Standard Deviation, S.D and statistical significance were assessed for the different independent variables [38]. These results are tabulated in Tables 1-5. Graphical analyses, Graphs 1-3 are also presented.

The one way Analysis of Variance (ANOVA) was used to compare multiple groups. The independent sample T-test was used to compare just two groups. Results are

tabulated in Tables 6-8.

Discussion

The results obtained were then compared to some natural herbs and spices (garlic, turmeric, cinnamon, onion and celery) using the Disk Diffusion method. The experiment was done in triplicate to assess the reliability and validity of the results findings. The mean, standard deviation and statistical significance were assessed for the different independent variables. The results reveal that each antibiotics as well as the natural herbs and spices exhibit varying degree of inhibition to the different microorganisms.

For the synthetic antibiotics, the largest AZOI of 1429.27 mm² was induced by Clindamycin against *S. aureus* at 100% concentration. The lowest AZOI of 324.45 mm² was induced by Clindamycin at the 10% concentration against *P. auriginosa*. The AZOI for all three antibiotics range from 324.45 mm² to 1429.27 mm² (Table 1).

In all cases, antibacterial activity seem to increase as the concentration of the drug increased from 10% to 100%. For example, Ceftriazone showed AZOI of 1017.36 mm², 1340.91 mm² and 1363.07 mm² against *K. pneumoniae* at 10, 50 and 100% respectively (Table 3).

Antimicrobial selectivity was also observed. For example, Clindamycin seems to be more selective against *S. aureus* over *P. aeruginosa*, registering values of 1429.27 and 324.45 mm² respectively with a selectivity factor of 4.4. Likewise, Tetracycline exhibit antimicrobial selectivity against *S. aureus* over *P. aeruginosa*, registering values of 1093.9 mm² and 530.67 mm² respectively with a selectivity factor of 2.0. Antimicrobial selectivity is important to combat antimicrobial resistance by pathogenic microorganisms.

Antibacterial activity of the herbs were conducted at 100% concentration. AZOI range from 50.27 mm² to 1256.64 mm². The lowest AZOI of 50.27 mm² was induced by Tumeric against *E. coli*. The highest AZOI of 1256.64 mm² was induced by onion extract against *K. pneumonia*.

Like the synthetic antibiotic, the lowest AZOI was induced against *P. aeruginosa*. The order of antimicrobial susceptibility follows the trend for each herb.

Garlic: *S. aureus* < *E. coli* < *P. pneumonia* < *E. coli*

Tumeric: *K. pneumonia* < *S. aureus* < *P. aeruginosa* < *E. coli*

Celery: *S. aureus* < *P. aeruginosa* < *K. pneumonia* < *E. coli*

Cinnamon: *E. coli* < *S. aureus* < *K. pneumonia* < *P. aeruginosa*

Onion: *K. pneumonia* < *S. aureus* < *E. coli* < *P. aeruginosa*

The antimicrobial activity of natural herbs and spices are due to the presence of plant natural products/ phytochemicals. These include steroids, triterpenes, coumarins, tannins, cardiac glycosides etc. These phytochemicals act singly or in combination to illicit a favourable antimicrobial response.

All synthetic drugs at 100% concentration seem to exhibit a higher area of zone of inhibition, AZOI in comparison to the reference sample, Ampicillin against all pathogens. An exception being against *S. aureus*. All herbs and spices seem to produce a lower Area

of Zone of Inhibition, AZOI against all pathogens in comparison to the reference sample. An exception being the garlic, turmeric, celery and cinnamon extract against *P. aeruginosa*, exhibiting AZOI in the range 68.3 mm² to 83.8 mm². Another exception is the onion extract against *K. pneumonia*. AZOI of 1256.6 mm² was induced by the onion extract in comparison to 452.2 mm² exhibited by the reference, Ampicillin at 100% concentration.

The herbs seem to exhibit a lower degree of antimicrobial selectivity in comparison to the synthetic drugs. The selectivity factor is small. An exception being the onion extract against *K. pneumonia* which exhibit significant AZOI of 1256.6 mm² in comparison to AZOI of 63.6 and 146.7 mm² against *E. coli* and *S. aureus* i.e., a selectivity factor of 19.78 and 8.57, respectively.

The P-value is often coupled to a significance or alpha level. The p value used in this study was set at 0.05 or 5% significant level. When the p-value is found to be less than 0.05, then the results would be statistically significant and the null hypothesis would be rejected. If the p value is greater than 0.05, then the results would not be statistically significant. Based on all our results, there is no significant difference between the groups; therefore the Null hypothesis is accepted.

Conclusion

Both synthetic and herbal extracts exhibit antimicrobial activity and selectivity against human pathogens: *E. coli*, *S. aureus*, *K. pneumoniae* and *P. aeruginosa*. For the synthetic drugs, the highest Area of Zone of Inhibition, AZOI of 1566.4 mm² was induced by Clindamycin against *S. aureus* at 50% concentration, whereas the lowest AZOI of 283.5 mm² was induced by *P. aeruginosa* at 10% concentration. For the herbal extracts, the highest AZOI of 1256.6 mm² was induced by the onion extract versus *K. pneumonia*, whereas the lowest AZOI of 50.3 mm² was induced by the Tumeric extract against *E. coli*. Antimicrobial selectivity was also observed for both synthetic and herbal medicines. However, it was less evident with the latter. For example, against *S. aureus*, AZOI of 1093.92 mm² was obtained against *S. aureus*, whereas against *P. aeruginosa*, AZOI of 530.67 mm² was observed. Garlic exhibited AZOI

of 139.49 mm² against *E. coli* whereas a value of 78.5 mm² was obtained against *P. aeruginosa*. The potency and selectivity of synthetic drugs seem to be greater than that of herbal extracts. An exception to this being onion which showed more potency than Clindamycin and Tetracycline against *K. pneumonia*.

Acknowledgement

Gratitude is extended to the Faculty of Health Sciences, University of Guyana for the provision of Bench Space to conduct the above research. The author also thanks his co-workers for their effort and enthusiasm shown.

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