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Full Length Research Paper

Antimicrobial Activity of *Allium sativum Linn*. Extracts Against Hospital-Acquired Bacteria

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The presence of pathogenic microorganisms causing infections to hospitalized populations in the 750 bed Specialist Hospital, Yola, Nigeria was investigated for a period of two and a half years. *Staphylococcus aureus, Escherichia coli, Streptococcus pneumoniea* and *Pseudomonas aeruginosa* were selected through the use of questionnaires as the commonest bacteria causing nosocomial infections, and were isolated from clinical specimens obtained from patients who were admitted to the hospital for reasons other than the infections caused by these bacteria. The effects of water, ethanol and chloroform extracts of garlic against the nosocomial *S. aureus, E. coli, S. pneumoniea* and *P. aeruginosa* were investigated under various use conditions, such as variations in temperatures and pH. At a concentration of 100 mg/ml, all the crude extracts inhibited the growth of the pathogenic bacteria, though with varying degrees of susceptibility. However, laboratory based bacteria which were used as controls were more susceptible than their corresponding nosocomial bacteria. Activities were stronger under elevated temperatures and slightly acidic pH values. The MBC values of the aqueous extract for *S. aureus* was 75 mg/ml; *S. pneumoneae,* 100 mg/ml; *E. coli,* 125 mg/ml and *P. aeruginosa,* 150 mg/ml. The water extract was more potent than the organic extracts, and all were inferior in activity, when compared to the standard antibiotic, metronidazole. The gram positive *S. aureus* was more susceptible to the toxic effects of garlic than its gram negative counterparts. The results obtained in this study indicate that water extracts of garlic can be used alongside conventional antibiotics to fight agents of nosocomial infections that are so prevalent in our hospitals.

Key words: Pathogenic, antibacterial, garlic, susceptibility, nosocomial, prevalent.

INTRODUCTION

Man has been using natural products of animals, plants and microbial sources for thousands of years either in the pure forms or crude extracts (Parekh and Chanda, 2007). Bioactive compounds from these diverse sources have been isolated and characterized worldwide. Systematic screening of plant materials represent an all important effort to find some new bioactive compounds with the needed therapeutic potential to fight against pathogenic microorganisms, particularly with respect to those that are hospital based. The elucidation of the chemical structures of some of these compounds had led to the synthesis and production of more potent and safer drugs. However, within the last few decades, microbial resistance has emerged for most of the available agents, thus necessitating the search for newer drugs (Bhattacharjee et al*.,* 2005). The increasing reliance on drugs from natu-ral sources has led to the extraction and development of several drugs and chemotherapeutic agents from traditional herbs which are present in abundance in the tro-pics (Falodun et al*.,* 2006). In fact, the use of medicinal

plants to treat diseases of varying etiology is part of the African tradition, but in spite of thousands of years of use, none of these bioactive plant compounds have been exploited for clinical uses as antibiotics, though some alkaloidal compounds like quinine and emetine have been developed as chemotherapeutic agents. Reviewing the effectiveness of plant based antimicrobial com-pounds, Sibanda and Okoh (2007) noted that a good proportion of such compounds are agents with weak or narrow spectrum of activities that act in synergy with intrinsically produced efflux inhibitors. However, bioactive compounds of plant origin when used together with anti-biotics can increase the sensitivity of microbial cells to such antibiotics. This can be of immense value in com-bating infections caused by virulent strains of pathogenic and drug-resistant bacteria that are now causing enor-mous public health concerns in both rich and poor coun-tries.

Many studies have implicated *Staphylococcus aureus, Escherichia coli, Streptococcus pneumoniae* and *Pseudomonas aeruginosa* as leading causative agents of both community and hospital acquired infections (Amita et al*.,* 2003; Branger et al*.,* 2005; Oteo et al*.,* 2005). Soon after admission, microorganisms prevalent in the patients' immediate hospital environment colonize the patients' skin, mucous membrane, eye, ear and nostrils as well as the anterior urethra. With insertion of catheter and or other medical devices, the microbes may be pushed into the bladder or with indwelling catheter, may migrate along to the bladder and from there enter the blood (Sherer et al*.,* 2005). Nosocomial infection is a global health problem affecting both developed and developing countries (Lark, 2001). The most frequent infections are those of surgical and catheter site wounds, blood, skin, lower and upper respiratory tract infections. These infec-tions are caused by a relatively few opportunistic orga-nisms (Beardin et al*.,* 2002; Stosovic et al*.,* 2004) . These organisms that cause nosocomial infections have several virulent factors including the formation of biofilms on colonized surfaces. Biofilms are notoriously difficult to eliminate and act as a source of many recalcitrant infec-tions (Donlan, 2001). Biofilm formation on biomedical devices may explain the relapsing nature of infections in some patients and contribute to the lack of bacteriologic eradication in infected valves and intravascular thrombi. Factors facilitating the emergence and spread of the nosocomial infections are poor hygiene, overcrowding, extremities of age, impaired immunity, severity of illness, exposure to broad spectrum antibiotics and use of immunos uppressants as well as surgical procedures and invasive techniques (Sherer et al*.,* 2005) . The impact of nosocomial infection on the individual or community include frequent hospital visits, high rates of illnesses, loss of productivity and death, straining of family and hospital budgets and extra time of hospital staff. It also diverts financial resources that could otherwise be used for promoting health and threatens the success of global efforts to combat the major infectious diseases of poverty and ignorance (WHO, 2002; Amita et al*.,* 2003). These organisms that cause nosocomial infections are prevalent in the hospital environment, frequently multi-drug resistant, do not have any fastidious growth requirement and can survive in wide variations of temperatures and pH using various substrates as sources of carbon and energy (Sherer et al*,* 2005).

Garlic (*Allium sativum* Linn.) is one of those plants that was seriously investigated over the years. It has been used for centuries to fight infections (Onyeagba et al., 2006). The early Egyptians used it to treat diarrhoea, the ancient Greeks used it to treat intestinal and extrain-testinal diseases, while the ancient Japanese and Chinese used it to treat headache, flu, sore throat and fever. In Africa, particularly in Nigeria, it is used to treat abdominal discomfort, diarrhoea, otitis media and respi-ratory tract infections (Ankri and Mirelman, 1999; Jaber and Al-Mossawi, 2007). The phytochemical constituents of garlic have been established in previous studies (Farb-man, et al ., 1993; Cavallito and Bailey, 1994; Ankri and Mirelman, 1999; Prados-Rosales et al., 2003). The anti-microbial properties of garlic were first described by Pas-teur in 1958, and since then, research had demonstrated its effectiveness against bacteria, protozoa, fungi and some viruses (Jaber and Al-Mossawi, 2007). Previous studies have also indicated that garlic has anti-neoplastic, cardiovascular, immuno-stimulatory and hypoglycaemic properties (Sato and Miyata, 1999). The development of resistance to most of the antimicrobial agents, the emergence of newer diseases and the resurgence of older diseases thought to be brought under control necessitate the search for newer agents. However, in spite of the volumes of literature describing the usefulness of garlic in treating infections, there is little or no work done to assess the usefulness of garlic to fight hospital based infections. The aim of this work was to study the effect-tiveness of garlic against some microorganisms that fre-quently cause nosocomial infections in the 750-bed referral hospital

MATERIAL AND METHODS

Two kilograms (2.0 kg) of garlic bulbs were purchased in Yola market, Yola South Local Government Area of Adamawa State, Nige-ria. The bulbs were identified and authenticated at the depart-ment of Biological Sciences, School Pure and Applied Sciences, Federal University of Technology, Yola.

The garlic bulbs were washed thoroughly under tap running water, aseptically cut into small pieces with a knife and then kept in the shade for 7 days at 32-35ºC. The semi-dried pieces were then crushed using pestle and mortar, and left to dry in the shade at room temperature for further 7 days. The dried garlic materials were further ground to powdery form with a Kenwood electric blender.

Preparation of extracts

Two hundred gram (200.0 g) of garlic powder were extracted with 500 ml of solvents (distilled water, 95% ethanol and chloroform, respectively) for 24 h by using Soxhlet apparatus. The extract were concentrated using a rotary evaporator at 40ºC.

Selection of patients for collection of specimens and isolation of microorganisms

Selection of patients for specimen collection as well as selection of microorganisms were based on analysis of responses to questionnaires earlier on issued to hospital staff (Doctors, Nurses and Laboratory staff) of the 750 bed Specialist Hospital, Yola, Nigeria, to among other things, name the microorganisms that frequently cause nosocomial infections and the various infectious sites from where the organisms would be recovered. From the analysis of the questionnaires, *S. aureus, E. coli, S. pneumoniae* and *P. aeru-ginosa* were selected as the commonest bacteria that were causing nosocomial infections in the 750 bed hospital. Diseases that pruned hospitalized population to acquisition of hospital based infections were also assessed and these diseases included surgical wounds, catheter sites, skin and soft tissue sites, burns, urinary and respiretory tracts, HIV/AIDS, cancer, intensive care unit residency, tuberculosis and those with blood related diseases. Patients admitted into the wards for those diseases were selected as case patients (Potashmacher et al*.,* 1979). It was from these patients that specimens were collected and screened for the presence of the selected organisms, and any patient found harboring any of the selected organisms at initial stages of their hospital stay were excluded from the study. Those patients whose specimen did not yield any of the test organisms were further observed during their long hospital stay (at least 48-72 h) and appropriate specimen (urine, sputum, blood, wound exudates, pus, stool) were then collected for microbiological investigations. This prolong period was to ensure that the organisms to be isolated from the collected specimens might likely be nosocomial pathogens acquired during the hospital stay. The period of collection of specimens was between January, 2003-July, 2005. Specimens were collected after explaining the aim of the research to the patients concerned. The time of collection of specimens was determined by the hospital staff. A duly signed request form accompanied each specimen. The organisms isolated from the various specimen (urine, burns, sputum, stool, surgical wounds and catheter sites, blood and pus) were *E. coli* (NEC1), *S. aurus* (NSA1), *P. aeruginosa* (NPA1) and *S. pneumonia* (NSP1). Each of the bacteria were isolated and properly identified following standard microbiological procedures as described by Cheesbrough (2002) for handling and identification of clinical specimens. Of course, a lot of other bacteria were also isolated from some of the specimens. A parallel experiment involving standard laboratory bacterial strains involving *S. aureus* (FMSA2), *E. coli* (FMEC2), *S. pneumoneae* (FMSP2) and *P. aeru-ginosa* (FMPA2) used as controls were ran concurrently, with the isolated nosocomial pathogens.

The isolated bacteria were then transported to the Microbiology Department of the Federal University of Technology, Yola on nutrient agar slants and stored in a refrigerator maintained at 2-8^{o}C until required. Purity of the organisms was checked at regular inter-vals by plating and staining (El-Mahmood and Amey, 2007).

Preparation of inoculum

The standardization of culture was done according to the method of Baker and Thornsberg (1983). Briefly,1 ml of the culture an orga-nism was pippeted into sterile universal bottle containing 1 ml of nutrient broth. Then Normal saline was added gradually to it so as to compare the turbidity to that of 0.5 Mac Farland Standard that corresponded to approximately 1.0x10^{8} cells.

Antibacterial assays

The method described by Emeruwa (1982) was used. One milliliter (1 ml) of an organism adjusted to 0.5 Mac Farland standard above was inoculated into 90 mm Petri plate, then 19 ml molten nutrient agar at 45^{o}C added, and the plate shaken gently for even mixing of the contents. The agar was allowed to solidify on a flat bench. Six 4 mm deep wells were punched in the agar with the aid of a sterile 6 mm cork borer. The dried garlic powders were reconstituted by dissolving 20 g each in 10 ml solvent. Five hundred microliter (500 ul) of the 50 mg/ml of each of the crude extracts was pippetted into holes bored from the agar. Five hundred microliter of each of the pure solvents was used as negative controls, and 500 ul of 50 mg/ml solution of metronidazole antibiotic was used as positive control. The plates were left on a flat bench for 1 h to dry, before incubation at 37^{o} C for 18 h. Antibacterial activity was evaluated by measuring the diameters of zones of growth inhibition. Each experi-ment was conducted thrice, and the mean of three results taken for both the test and control organisms.

Effects of P^{H} on activity

This was performed using the method of Emeruwa (1982). Twenty gram (20.0 g) of dried powdered sample was dissolved in 10.0 ml of sterile distilled water, then 1N HCL was added in drops at intervals and the test tube shaken. This was checked with a digital P^{H} meter. Then 500 ul of the extract adjusted to P^{H} 3-6 was introduced into wells bored on nutrient agar plates containing a culture of the organisms adjusted to Mac Farland Standard 0.5. This was incubated at 37ºC for 24 h and the zones of growth inhibition produced were measured. The same procedure was repeated as in above except that 1M NaOH was used in place of 1NHCL to adjust the P^{H} 7-10.The mean of three results were taken for both the test and control organisms.

Effects of temperature on activity

This was also performed using the techniques described by Emeruwa (1982). Using a shaker water bath, the temperatures of the extract was raised to temperatures of 30, 50, 60, 80 and 100ºC respectively. 500 ul of the aqueous extract at each of these tempe-ratures were introduced into wells bored on nutrient agar plates containing an organism previously adjusted to Mac Farland Stan-dard 0.5. This was incubated at 37ºC for 18 h and the zones of inhibition produced were measured. The extract with unadjusted Ph7 was used as control. The mean of triplicate results were taken for each of the six organisms.

Determination of minimum inhibitory concentration (MIC)

The minimum inhibitory concentration was determined by the broth dilution method of Sahm and Washington (1990). The crude extracts were diluted to various concentrations ranging from 50-500 mg/ml in nutrient broth. 500 ul of each concentration was added to 2 ml sterile nutrient broth in test tubes arranged on a test tube rack. Then 1 ml (10^{8} Cfu/ml) of an organism was added to the content of

Table 1. The antibacterial activity of crude extracts of garlic.

Bacteria	Code	Zone of inhibition diameter (mm)			
		Aqueous	Ethanol	Chloroform	Metronidazole
S. aureus	NSA_1	28	24	23	32
,, ,,	$FMSA_2$	33	30	30	34
E. coli	NEC_1	20	18	16	28
,, ,,	$FMEC_2$	27	25	25	31
S. pneumoniae	NSP_1	23	21	19	30
,, ,,	$FMSP_2$	29	28	28	33
P. aeruginosa	NPA_1	10	8	7	21
,, ,,	$FMPA_2$	15	13	12	26

the test tubes and the test tubes incubated at 37ºC for 18 h. 500 ul of solutions of metronidazole (5 – 200 mg/ml) were included in each experiment as positive control. 500 ul of the solutions of the puresolvents were added in to the test tubes and used as negative controls. The MIC was taken as the lowest concentration of extracts that did not permit any visible growth for each of the six bacteria.

Determination of minimum bacterial concentration (MBC)

For the determination of the MBC, 100 ul of culture was taken from each of the broth tubes that showed no growth and introduced into fresh agar plates. After incubation for 48 h, the plates were observed for growth. The concentration of the extracts that showed no visible growth was recorded as the MBC.

RESULTS AND DISCUSSION

The phytoconstituents of garlic have longed been known and its antimicrobial properties have been widely repor-ted (Roy et al*.,* 2006). The antimicrobial activities of plant extracts including garlic have been linked to the presence of some bioactive compounds. These secondary meta-bolites also serve to protect the plants themselves against bacterial, fungal and viral infections (De and Ijeoma, 2003; El-Mahmood and Amey, 2007). These bioactive compounds are known to work synergistically to produce various effects on the human and animal sub-jects (Amagace, 2006). However, most reports on the activity of garlic have focused mainly on the commensal microflora and community acquired infections, while infor-mations on its activity against hospital based pathogens is scanty.

The large sizes of zones of growth inhibition produced by the garlic extracts against the nosocomial bacteria indicated the potency of the active principles in garlic. Drugs present in plants are known as active principles .These active principles are divided chemically into a number of chemical classes including glycosides, alka-loids, volatile oils, steroids, flavonoids, resins and sterols. Most of these active principles have measurable anti-bacterial activities against microorganisms. In this study, *S. aureus* (NSA1) was most susceptible to the active principles present in garlic, closely followed by *S. pneu-moniae* (NSP1) as shown in Table 1. *S. aureus* (NSA1) had a zone of growth inhibition diameter of 28 mm in water, 24 mm in ethanol and 23 mm in chloroform ex-tracts, while *S. pneumoniae* (NSP1) had a zone of growth of inhibition diameter of 23 mmin in water, 21 mm in ethanol and 19 mm in chloroform extracts. These bac-teria may lack some alternative biochemical pathways which cannot be affected by crude extract of the garlic. *E . coli* (NEC1) is less susceptible, with diameters of 20 mm in water, 18 mm in ethanol and 16 mm in chloroform extracts. *P. aeroginosa* (NPA1) was least susceptible of all the test bacteria used, with growth inhibition diameters of 10 mm in water, 8 mm ethanol and 7 mm in chloroform extracts. These behaviors of *E. coli* (NEC1) and *P. aero-ginosa* (NPA1) may be due to elaboration of enzymes that possibly destroy or in activate some of the bioactive phytoconstituents in garlic. In addition, the complex nature of the cell envelope of gram-negative bacteria has been observed to retard or prevent the passage of many antimicrobial agents through the cell wall (Ahmadu et al., 2006). In general, the growth of all test bacteria was inhi-bited though varying degrees, similar to the results pre-sented by Ankri and Mirelman (1999). The data pre-sented by Jaber and Al-Mossawi (2007) showed that *S. aureus* was more susceptible than *E. coli*, and a similar observation was made in this study. The aqueous extract was more potent than the organic extracts, similar to observations of Roy et al*.* (2006) and Jaber and Al-Mossawi (2007), but contrasted with that of Debnath (2005). This is clear indication that the solvent system plays an important role in the solubility of the plant mate-rial and this also influences the antibacterial activity of the crude drug. Since the herbalist usually uses water to prepare infusions and decoctions, and since most con-stituents of garlic are soluble in water, there is every likelihood that the traditional healer is able to extract all

Table 2. Effects of PH variation on the activity of crude aqueous extract of garlic.

Bacteria	Code	Zone of inhibition diameter (mm) pH					
		NT	3	4	6	8	10
S. aueus	NSA_1	20	22	24	27	26	25
,, ,,	$FMSA_2$	29	24	28	30	28	26
E. coli	NEC_1	18	17	18	20	19	18
,, ,,	$FMEC_2$	26	23	27	28	26	23
S. pneumoniae	NSP_1	21	22	23	24	25	24
,, ,,	$FMSP_2$	28	25	26	27	25	25
P. aeruginosa	NPA_1	8	7	8	9	7	7
,, ,,	$FMPA_2$	20	21	23	25	20	19

NT-not treated.

Table 3. Effects of temperature variation on the activity of crude aqueous extract of garlic.

Bacteria	Code	Zone of inhibition diameter (mm) °C					
		NT	30°C	50°C	60°C	80°C	100°C
S. aureus	NSA_1	21	21	23	27	26	24
,, ,,	$FMSA_2$	25	25	27	29	30	26
E. coli	NEC_1	17	17	18	19	20	18
,, ,,	$FMEC_2$	24	24	27	28	28	25
S. pneumoniae	NSP_1	20	21	21	23	23	23
,, ,,	$FMSP_2$	24	23	26	28	28	27
P. aeruginosa	NPA_1	6	7	7	8	9	8
,, ,,	$FMPA_2$	18	19	20	22	22	16

the bioactive drug components in garlic.

The nosocomial bacteria are known to survive under varieties of environmental conditions, including pH and temperature fluctuations, and still remain infective. Also, since garlic can be taken orally and the fresh bulbs can be pressed on infectious sites, it is of utmost importance to test the effectiveness of garlic under these conditions in order to simulate the conditions in the stomach and gastrointestinal tract. The large zones of growth inhibition diameters produced between pH 4-8 values were indications that garlic is more stable under slightly acidic and alkaline environments, similar to the reports of Jaber and Al-Mossawi (2007), who also noticed a decrease in the activity of garlic at lower acidic and higher alkaline pH values. Other constituents of garlic are cystein derivatives, the aqueous solutions of which have been reported to be stable under neutral or sligthly acidic conditions (Amagace, 2006) (Table 2).

The effect of raising the temperature on the effectiveness of garlic is shown in Table 3.The activity of garlic increased with increase in temperature up to 80^{o}C, beyond which the activity remained either constant or decreased, similar to the reports presented by Roy et al. (2006). It is known that raising the temperature increases the solubility of chemical compounds. The traditional healers usually boil their preparations before dispensing out to their patients. The results in this study tend to sup-port the methods of boiling of the plant material by the traditional healers.

The MIC and the MBC assay procedures are frequently used to evaluate some diverse agents such as anti-biotics, antiseptics, disinfectants and chemotherapeutic agents (Croshaw, 1983; Acheampong et al*.,* 1988). Anti-microbial agents with low activity against an organism usually gives a high MIC and MBC values, while those that are highly effective give low MIC and MBC values. In this study, the MIC values for *S. aureus* (NSA1) were 50 mg/ml and MBC values were 75 mg/ml; while for *S. pneumoniae* (NSP1), the MIC value was 75 mg/ml and MBC value was 100 mg/ml for water extracts (Table 4).The MIC value for *E. coli* (NEC1) was 100 mg/ml and MBC value was 125 mg/ml; while for *P. aeruginosa* (NPA1), the MIC value was 125 mg/ml and MBC value was 150
mg/ml for the aqueous extracts. The MIC and MBC values for the ethanol and chloroform extracts followed similar patterns to that of the water extract, though with higher

Table 4. The MIC and MBC values of crude extracts of garlic.

Bacteria	Code	Concentration (mg/ml)							
		Aqueous		Ethanol		Chloroform		Metronidazole	
		MIC	MBC	MIC	MBC	MIC	MBC	MIC	MBC
S. aureus	NSA_1	50	75	75	100	75	125	25	25
,, ,,	$FMSA_2$	25	25	25	50	25	50	12.5	12.5
E. coli	NEC_1	100	125	125	150	150	175	25	25
,, ,,	$FMEC_2$	50	50	50	75	75	75	25	25
S. pneumoniae	NSP_1	75	100	100	125	100	150	12.5	25
,, ,,	$FMSP_2$	25	50	25	50	25	50	12.5	12.5
P. aeruginosa	NPA_1	125	150	150	175	150	200	25	50
,, ,,	$FMPA_2$	50	50	75	75	50	75	25	25

values. The MIC values obtained in this study were either the same or lower than the MBC values, similar to the observation made by Croshaw (1983). In treating open wounds, the traditional healer usually presses the juice from the squeezed bulbs and applies same to the infected area several times. And in doing so, it is possible to achieve the antibacterial dosage level as indicated by the MIC and MBC values. In this study, the MIC and MBC values were low for *S. aureus* (NSA1) and *S. pneumonieae* (NSP1), and high for *E. coli* (NSC1) and *P. aeruginosa* (NPA1), an indication that garlic has some therapeutic potential and attests to its continued use in traditional medical practice. Jaber and Al-Mossawi (2007) had reported that it is very difficult for most bacteria to develop resistance to garlic, ostensibly because the mode of action of garlic is completely different from that of other antibiotics. Earlier on, Ankri and Mirelman (1999) had proposed that the development of resistance to beta-lactam antibiotics was 1000 folds easier than the develop-ment of resistance to allicin, the main active principle in garlic, thus making garlic suitable to be used in fighting hospital based pathogens. The effects of the crude extracts as measured by the MIC and MBC values on the pathogens, corroborated with various reports that microorganisms varied significantly in their susceptibility to toxic agents (Emeruwa, 1982; El-Mahmood and Amey, 2007). The data from this study showed that water extracts were more effective than the organic extracts. When plant materials are ground in water, a number of phenolases and hydrolases

are released and these enzymes might serve to modulate the activity of the active compounds in the extract (De and Ifeoma, 2002).

In the present study, the standard antibiotic, metronidazole, consistently displayed superior potency when compared with the crude extracts. This may be attributed to the fact that metronidazole, as a conventional antibiotic, is prepared by means of a reproduceable manufacturing processes and procedures, extracts of herbal medicines are subject to degradation and decomposition on storage (El-Mahmood and Amey, 2007) . Roy et al. (2006) had reported the decrease in potency of garlic extracts upon storage and attributed this to the volatile nature of the active principles in garlic. The preparation and storage of plant materials like other pharmaceuticals also require special conditions of storage. Both crude extracts and pure compounds of some plants have been reported to potentiate the activity of antibiotics, hence the need to use both side by side to fight recalcitrant infec-tions, especially in the hospital environment. In some parts of the African continent, herbal medicines are sometimes administered concomitantly with antibiotics (Esimone et al., 2006) and this can lead to either bene-ficial or deleterious effects. As expected, the standard laboratory bacteria used as controls were consistently more susceptible to both the metronidazole and the crude drug extracts than their corresponding nosocomial bac-teria. This may suggest that the nosocomial pathogens were less susceptible to the effects of the crude drugs than the control bacteria. Also, the ability of garlic to inhibit the growth of both gram-positive and gram-nega-tive bacteria shows that it has a broad spectrum of acti-vity and can be used for formulation of newer broad spectrum antibacterial substances.

Conclusion

This study has consistently demonstrated the effectiveness of garlic against the nosocomial *S. aureus*, *E. coli, S. pneumonieae* and *P. aeruginosa* that frequently dis-play above average resistance to many antimicrobial agents. If well processed, garlic preparations can be used to treat nosocomial infections caused by susceptible bac-teria. Garlic can also be used for the development of broad spectrum antibbiotics

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