

Original Research Article

**ANTIMICROBIAL ACTIVITIES OF *Allium sativum* ON MICROORGANISMS
ISOLATED FROM SPOILT TOMATOES SOLD IN AWKA ANAMBRA STATE,
NIGERIA.**

ABSTRACT

Tomato is a universally consumed vegetable crop. Its spoilage involves changes in which they become less palatable, less attractive to the eyes or even toxic to consumers. These changes may be accompanied by alterations in taste, smell, appearance or texture. The aim of this study is to identify the spoilage pathogens of tomatoes and to ascertain the antimicrobial potential of garlic ethanol extract on the isolates. Spoilt tomato samples were purchased from three markets (Eke Awka, Nnamdi Azikiwe temporary site (Temp. site) and Amenyi) in Awka, Anambra State. They were transported to Alpha Laboratory, Awka in sterile polythene bags for microbial isolation and analysis. The media used for the isolation were Nutrient Agar and Sabouraud Dextrose Agar, both were placed into a conical flask autoclaved at 121°C at 15psi for 20 minutes and the plates were incubated at room temperature. The bacteria isolated from the tomato fruits were: *Pseudomonas sp*, *Bacillus sp*, *Staphylococcus sp* and *Escherichia coli* while the fungi isolates were *Aspergillus sp*, *Penicillium sp* and *Mucor sp*. The antimicrobial activity of ethanol garlic extract against these microorganisms isolated from spoilt tomatoes were determined using disc method. Three different concentrations (25%, 50%, 100%) of ethanol garlic extract were used to test for the antimicrobial activity. The result showed that at different concentrations the ethanol garlic extract possess antimicrobial properties on the selected organisms apart from *Pseudomonas sp* and *Penicillium sp* where there was no zone of inhibition. The presence of these microorganisms is hazardous to health. Therefore, garlic extract could be used as a beneficial substitute of synthetic chemicals.

Keywords: Tomatoes; Microorganism; Garlic; Antimicrobial activity.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is an edible, often red berry fruit that belongs to the family Solanaceae. Tomato fruit is widely used in households for stews, soups, salads, sauce, puree, juices etc. It is a world known vegetable crop. Tomato is one of the most cultivated and extensively consumed horticultural crop (Arbrar *et al.*, 2016). In Nigeria, it is one of the most important vegetable grown for consumption in every home; it can be consumed raw or cooked, fresh and in paste form. It is a crop with high Vitamin A, C, E and minerals which protect the body against diseases (Hosea *et al.*, 2017). Some of the minerals contained include iron, potassium, calcium, zinc; it contains fibre, protein, carotenoid, flavonoid and lycopene which is a pigment that is responsible for the characteristic red colour of tomato fruits when ripe.

Tomato plant grow up to 1-3 meters (3 - 10 ft) in height and have a weak stem that often sprawls over the ground. Tomato crop does well in warm climate. It requires rainfall ranging between 760mm - 1300mm and deep fertile loam soil that is well drained with high content of organic matter. The crop is grown either on an open field or under greenhouse technology (Mohammad *et al.*, 2021).

Nigeria ranks the 16th largest tomato producing nation in the world with over 48 million tomato farmers across the country. Nigeria accounts for 65% of tomato produced in West Africa (Eno-Abasi *et al.*, 2018). Pathogens easily penetrate and infect the crop, usually through lesions and injury caused by improper handling of the fresh produce (Gustavsson *et al.*, 2011). The storage and preservation of tomato is vital to the economy of homes, farmers and country considering the important role played by tomato in health and food security (Irokanulo *et al.*, 2015). Tomato fruits spoil easily after harvest and during storage which result to post harvest losses which can be as a result of microorganism attack, physiological breakdown as well as an ambient

environment for microorganism growth. Postharvest losses are more severe in developing than in developed countries (Enyiukwu *et al.*, 2014). This is estimated to be 20 - 25% in developing countries (Neeta *et al.*, 2010). Due to high perishable nature of tomato fruits, many spoil before they reach various areas where they are not cultivated and where their demand is high. Reducing postharvest losses improves the welfare of farmers and consumers thereby increasing tomato availability. In Nigeria, commercial food vendors, restaurants, some urban and rural dwellers use physically damaged or spoiled tomato fruits for their cooking intentionally, due to the fact that these tomatoes are cheaper than fresh intact ones (Agwaranze *et al.*, 2020).

Over the years, there is a need to identify and isolate the microorganisms associated with the spoilage as a way of finding a means of controlling it (Akinyele and Akinkunmi, 2012). The plant world is a rich store house of natural chemical that could be exploited for use as biopesticides (Nicosia *et al.*, 2016).

The aim of this study is to identify the spoilage pathogens of tomatoes and to ascertain the antimicrobial potential of garlic ethanol extract the isolates

MATERIALS AND METHODS

3.1. Samples Collection

Plant samples of *Solanum lycopersicum* fruits were bought from three markets in Awka: Eke Awka , Amaenyi and Temp site. Laboratory and other facilities used in the practical work were obtained from Alpha research laboratory Awka, Anambra state.

3.2. Fungal Isolation:

3.2.1. Sabouraud Dextrose Agar Media Preparation

In 300ml of distilled water, 5g of the medium was suspended, heated over a Bunsen flame with frequent agitation, and allowed to boil for one minute to completely dissolve the medium. The solution was autoclaved at temperature of 121°C for 15 minutes, at a pressure of one (1) atmosphere (15 Psi). After removing from the autoclave, allowed to cool for 10 minutes. Five hundred (500 mg) streptomycin sulphate was added into the molten solution to serve as antibiotics.

3.2.2. Isolation of Fungi

One gram of each sample was aseptically collected and serially diluted in normal saline to the fourth dilution using a ten-fold serial dilution. About 0.1ml aliquot of each dilution was inoculated onto a freshly prepared SDA agar and incubated at room temperature (37° C) for three (3) days.

3.2.3. Sub-culturing Techniques:

Resulting colonies were then sub-cultured onto Sabouraud Dextrose Agar (SDA), process was repeated whenever more than a single colony of fungi was observed in the petri-dishes, until pure cultures were obtained.

3.2.4. Identification of Isolated Fungi

All the various species of fungi isolated were identified, both macroscopic and microscopic features, and their various characteristics studied, (i.e) colour, texture, form of hyphae, form of conidia, presence of conidiophores, shape of conidial heads (James and Natalie, 2013). The microscopic identification was aided by appropriate taxonomic keys.

3.2.5. Determination of Fungal Frequency (%)

Fungal frequency will be determined location wise as well as culture media wise and later its correlation will be observed with the Percent Disease index calculated based on symptoms. The following formula will be used for fungal frequency percentage determination:

Fungal Frequency (%) = $\frac{\text{Number of particular fungus colony observed in plates} \times 100}{\text{Total number of colonies of all fungi}}$

Total number of colonies of all fungi

3.3. Bacteria Isolation

3.3.1. Isolation of Bacteria

The spread plate method was used for isolation of bacterial pathogens from the sample using nutrient agar. One gram of each sample was aseptically collected and serially diluted in normal

saline to the fourth dilution using a ten-fold serial dilution. About 0.1ml aliquot of each dilution was inoculated onto duplicate set of Nutrient Agar, to determine total bacterial population. All plates were incubated at 35°C for 24 hours.

3.3.2. Total Plate Count of Bacteria (CFU/ml)

Microbial load in each agar plate sample was determined as CFU/ml and was calculated using formula.

$$\text{Cfu/ml} = \{(\text{No. of colonies} \times \text{dilution factor}) / \text{volume of inoculums}\}$$

3.3.3. Purification of Isolates:

Single colonies of bacteria were randomly selected from different media plates based on their morphology. These bacterial cultures were subsequently isolated in pure forms by subculturing on nutrient agar plates incubated for 24hrs and used for microscopic characterization and biochemical analysis.

3.3.4. Identification of Microorganisms

The isolated bacteria were identified on the basis of motility and Gram's-staining.

3.3.5. Gram's staining

The pure bacterial isolates were stained according to Gram's techniques. A thin smear was prepared on clean glass slide, air dried, and heat fixed by placing the slide gently over the flame of the spirit lamp. The smear was stained with crystal violet for 1 minute, and then rinsed with tap water. The smear was then covered with Lugol's iodine for 60 seconds and washed off under gentle running tap water. The slide was then decolourized using 70% ethanol after which it was

washed under tap water and then counterstained with safranin for 30 seconds. It was again rinsed with tap water and the slide blotted dry with a piece of filter paper. The stained cells were examined with the oil immersion objective lens of the light microscope. The gram positive organism is characterized by a purple colour while a gram negative organism takes on a pink colour as well as the shape of the cells were also examined.

3.3.6. Motility test

The stabbing technique was used to carry out this test. Test-tubes containing sterilized Agar were prepared. Sterilized inoculating needle was used to pick up isolates from their pure cultures. Each test-tube was stabbed with the needle rubbed with each isolate in the middle. The test-tubes were then incubated at 37⁰C for 24hours. After 24 hours, the tubes were observed for the motility of the isolates. A motile isolate usually grows away from the point where the medium was stabbed.

3.3.7. Urease Test

Test tubes was used to demonstrate the ability of the isolates to produce the enzyme urease which splits urea forming ammonia. The test is usually used to differentiate organisms like proteus from other non urease positive organisms. A loop full of the isolates was used to inoculate a tube of urea-agar. The tubes were incubated at 37⁰C. a change in colour from yellow to red confirmed the presence of urease.

3.3.8. Catalase Test

This test was used to demonstrate which of the isolates could produce the enzyme catalase that release oxygen from hydrogen peroxide. A loopful of the pure colony was transferred into a

plane, clean glass slide. The sample was then mixed with a drop of 3% hydrogen peroxide. The reaction was observed immediately. Gas production indicated by the production of gas bubbles confirmed the presence of catalase.

3.3.9. Indole Test

This test was used to determine which of the isolates has the ability to split indole from tryptophan present in buffered peptone water. The test is usually used as an aid in the differentiation of Gram negative, *Bacilli* especially those of the *Enterobacteriaceae*. Tubes of peptone water were inoculated with young culture of the isolates. The tubes were incubated at 37°C for 48hrs. About 4 drops of Kovac reagent were added into 1ml of each of the culture tubes. Positive test was indicated by a red colour that occurs immediately at upper part of the test tube.

3.3.10. Citrate Utilization Test

This test was used to identify which of the isolates can utilize citrate as the sole source of carbon for metabolism. The test is usually used as an aid in the differentiation of organisms in the *Enterobacteriaceae* and most other genera. The medium used for this test was the Simon's citrate agar. Slant tubes of Simon's citrate agar were inoculated with young culture of the isolates. The inoculation was done by stabbing the medium on the tubes using sterile straight inoculating wire containing the culture. The tubes were then incubated at 37°C for about 24hours. Change in colour from green to blue after about 24hours of incubation indicated positive result.

3.3.11. Coagulase Test

A very homogenous suspension of the inoculum was mixed on a drop of normal saline in a grease free slide.

1. Loopful undiluted rabbit plasma was added to the suspension and mixed thoroughly for 5 seconds.
2. A control was set up in the same manner without blood plasma.
3. Coagulase positive staphylococci showed clumping or agglutination within 5-15 seconds while negative suspension showed no clumping.

3.3.12. Oxidase Test

This was carried out to identify bacterial species that will produce the cytochrome oxidase enzyme. A piece of filter paper was placed in a clean Petri dish and 2-3 drops of fresh or nascent oxidase reagent was added. A colony of test organism was collected using a glass rod and smeared on the filter paper and observed. Blue-purple color within few seconds showed a positive test.

3.5.4. In vitro Antimicrobial Tests with Plant Extracts:

Disc diffusion method adopted from Birhanu et al. (2014) was applied to the ethanolic extract. A 100 μ L of prepared inoculum (10^4 CFU/mL) was spread uniformly onto SDA and Nutrient Agar using a sterile cotton swab. The sterile paper disc impregnated with 100, 50 and 25% of extract then placed on top of the agar media. The plate was then incubated upright for 48 hrs at 30°C. The clear inhibition zones surrounding the disc were then measured in millimetre. Three replicates of five plates each were maintained for each treatment and inoculated plates were incubated for seven days at room temperature (28°C). The diameter of the radial growth of the bacteria and fungus was measured at the end of the incubation period and then used to determine the activity of the extracts using the formula:

Percentage growth inhibition (%) = $\frac{dc - dt}{dc} \times 100$

dc = 1

Where

dc = average diameter of fungal and bacterial colony in control treatment

dt = average diameter of fungal and bacteria colony with extract.

Statistical analysis

Percentages and means of fungal colonies were calculated. Data obtained was subjected to Analysis of Variance (ANOVA), and Duncan Multiple Range Test (DMRT) was used to separate the treatment means when significant at 5 % level of probability.

RESULT

The research study showed the presence of microorganisms in all the tested samples. The pathogens that were isolated and identified were *Bacillus sp*, *Staphylococcus sp*, *Escherichia coli*, *Pseudomonas sp*, *Aspergillus sp*, *Mucor sp* and *Penicillium sp* (Table 1). They were found in association with spoiled tomato fruits sold at three different locations in Awka, Anambra State. The research also revealed the potentiality of garlic extract on the Isolated microorganisms. Among all the Isolates garlic gave the highest inhibition of *Aspergillus sp* and lowest of *Penicillium sp* and *Pseudomonas sp*. It should that the higher the concentration the more efficient it is in the control of the microorganisms. In comparison between the plant extract (*Allium sativum*) and the controls (streptomycin and fluconazole), the controls had more effect on all the pathogens by suppressing their growth.

Table 1 Prevalent bacteria isolates

Collection Sites	Bacteria Isolates
Eke Awka	<i>Escherichia coli</i> <i>Staphylococcus sp</i> <i>Bacillus sp</i>
Temporary site	<i>Staphylococcus sp</i> <i>Bacillus sp</i> <i>Escherichia coli</i>
Nkwo Amenyi	<i>Bacillus sp</i> <i>Staphylococcus sp</i> <i>Pseudomonas sp</i>

Table 1 shows the Bacteria isolates from each collection sites.

It reveals that *Pseudomonas sp* was found on tomatoes from Nkwo Amaenyi only. *Escherichia coli* was isolated from tomato samples from Eke Awka and Temporary site, while, *Staphylococcus sp* and *Bacillus sp* were found on tomatoes from the three collection sites.

Table 2. Total Bacteria Count of Tomato

Collection Sites	Total Bacteria Count (cfu/ml)
Eke Awka	$6.10 \times 10^4 \pm 0.03^a$
Temporary site	$4.71 \times 10^4 \pm 1.120^a$
Nkwo Amaenyi	$5.64 \times 10^4 \pm 0.101^c$

Table 2 shows Bacteria colonies from each location. Tomato samples from Eke Awka had the highest colonies ($6.10 \times 10^4 \pm 0.03^a$) while tomatoes from Temporary site had the lowest colonies ($4.71 \times 10^4 \pm 1.120^a$). Results are mean scores + Standard deviation of three replicates. Data in the same column bearing different superscript differ significantly ($p < 0.05$).

Table 3. Frequency of Occurrence of Fungi Isolates

Sample site	Fungi Isolates
Eke Awka	<i>Aspergillus sp</i>

	<i>Mucor sp</i>
Temporary site	<i>Aspergillus sp</i> <i>Mucor sp</i> <i>Penicillium sp</i>
Nkwo Amaenyi	<i>Aspergillus sp</i> <i>Mucor sp</i>

Table 3 shows the Fungi isolates from each site.

Aspergillus sp and *Mucor sp* occurred in tomato samples from the three locations while *Penicillium sp* occurred in samples from Temporary site.

Table 4 Mean Fungi Count for Tomato Samples in SDA

Sample site	Mean Total Fungi Count (cfu/g)
Eke Awka	$2.70 \times 10^4 \pm 0.200^c$
Temporary site	$3.15 \times 10^4 \pm 0.100^b$
Nkwo Amenyi	$4.50 \times 10^4 \pm 0.00^a$

Table 4 shows Fungi count for the three locations.

Nkwo Amaenyi had the highest fungi colony ($4.50 \times 10^4 \pm 0.00^a$) while Eke Awka had the lowest colony count ($2.70 \times 10^4 \pm 0.200^c$).

Results are mean scores + Standard deviation of three replicates

Data in the same column bearing different superscript differ significantly ($p < 0.05$).

Table 5. Invitro Antibacterial Activities of Ethanol Extract of Garlic

Extract Concentrations	<i>Staphylococcus</i> sp	<i>Escherichia coli</i>	<i>Bacillus</i> sp	<i>Pseudomonas</i> sp
Garlic 100% (mm)	19.00 ± 0.112	17.00 ± 3.01	9.000 ± 0.55	0.000 ± 0.00
Garlic 50% (mm)	10.00 ± 0.030	7.50 ± 1.110	0.000 ± 0.00	0.000 ± 0.00
Garlic 25% (mm)	0.000 ± 0.000	5.00 ± 2.00	0.000 ± 0.00	0.000 ± 0.00
Control (Fluconazole) 30 ug/ml	34.833 ± 1.110	34.83 ± 0.300	19.16 ± 1.00	34.833 ± 0.200

Table 5 shows the Invitro antibacterial activities of ethanol garlic extract on the isolated bacteria strains.

The garlic extract had the highest inhibition on *Staphylococcus* sp at 100% and 50% (19.00 ± 0.112 and 10.00 ± 0.030) among other isolates, at 25% the garlic extract inhibited the growth of

Escherichia coli (5.00 ± 2.00) only while *Pseudomonassp* showed the least susceptibility to the plant extract (0.00 ± 0.00). When compared with the plant extracts, the control had higher rate of inhibition on all bacteria isolates.

Results are mean scores + Standard deviation of three replicates

Data in the same column bearing different superscript differ significantly ($p < 0.05$).

Table 6. Invitro Anifungal Activities of Ethanol Extract of Garlic

Extract Concentrations	<i>Aspergillus sp</i>	<i>Penicillium sp</i>	<i>Mucor sp</i>	
Garlic 100% (mm)	18.4 ± 1.00	0.000 ± 0.00	18.13 ± 2.00	
Garlic 50% (mm)	13.67 ± 0.01	0.000 ± 0.00	12.20 ± 1.00	
Garlic 25% (mm)	12.00 ± 0.30	0.000 ± 0.00	9.86 ± 0.20	
Control (Streptomycin) 30ug/ml	22.33 ± 0.11	34.833 ± 0.15	41.60 ± 1.06	

Table 6 shows the Invitro antifungal activities of ethanol garlic extract on the fungi pathogens. The garlic extract gave the highest inhibition on *Aspergillus sp.* 100% of the concentrations had the highest inhibition effect (18.4 ± 1.00). *Penicillium sp* showed the lowest inhibition effect of the garlic extract (0.00 ± 0.00). The control had effect on the three Fungi isolates and showed to be stronger and effective than the plant extract. The control had the highest effect on the growth of *Mucor sp* (41.60 ± 1.06) while *Aspergillus sp* showed the least susceptibility to the control (22.33 ± 0.11).

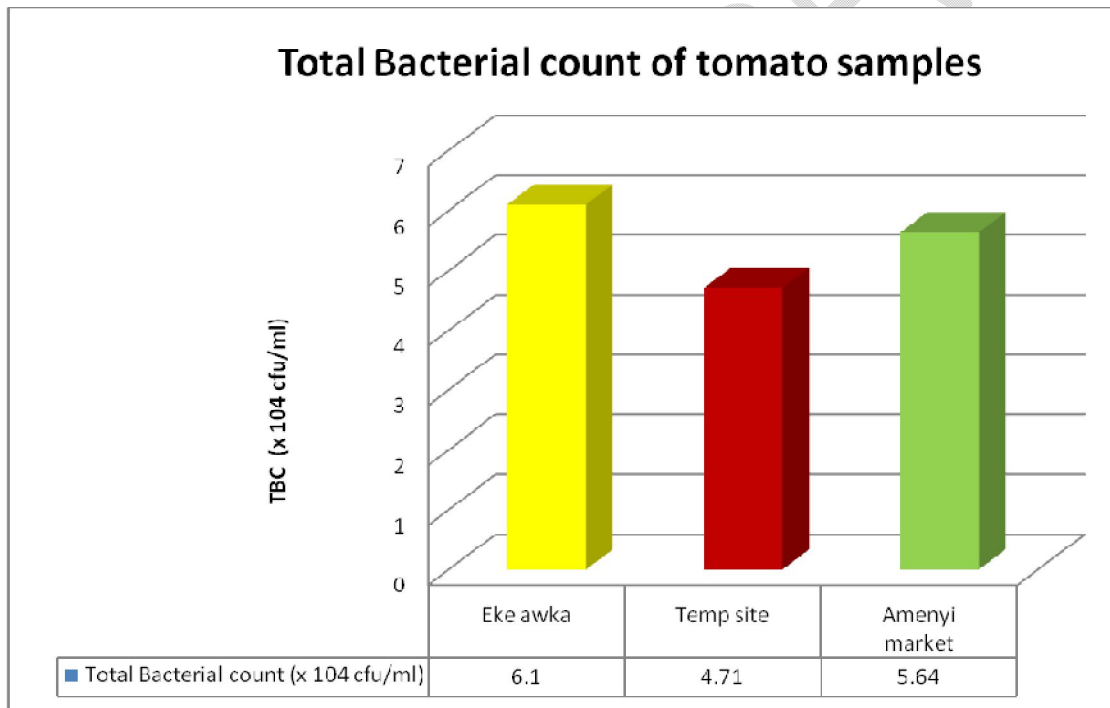


Figure 1. Shows the total bacteria isolate count from tomatoes tested. Eke Awka had the highest count (6.1ml), while Temp site was with the lowest bacteria count (4.71ml).

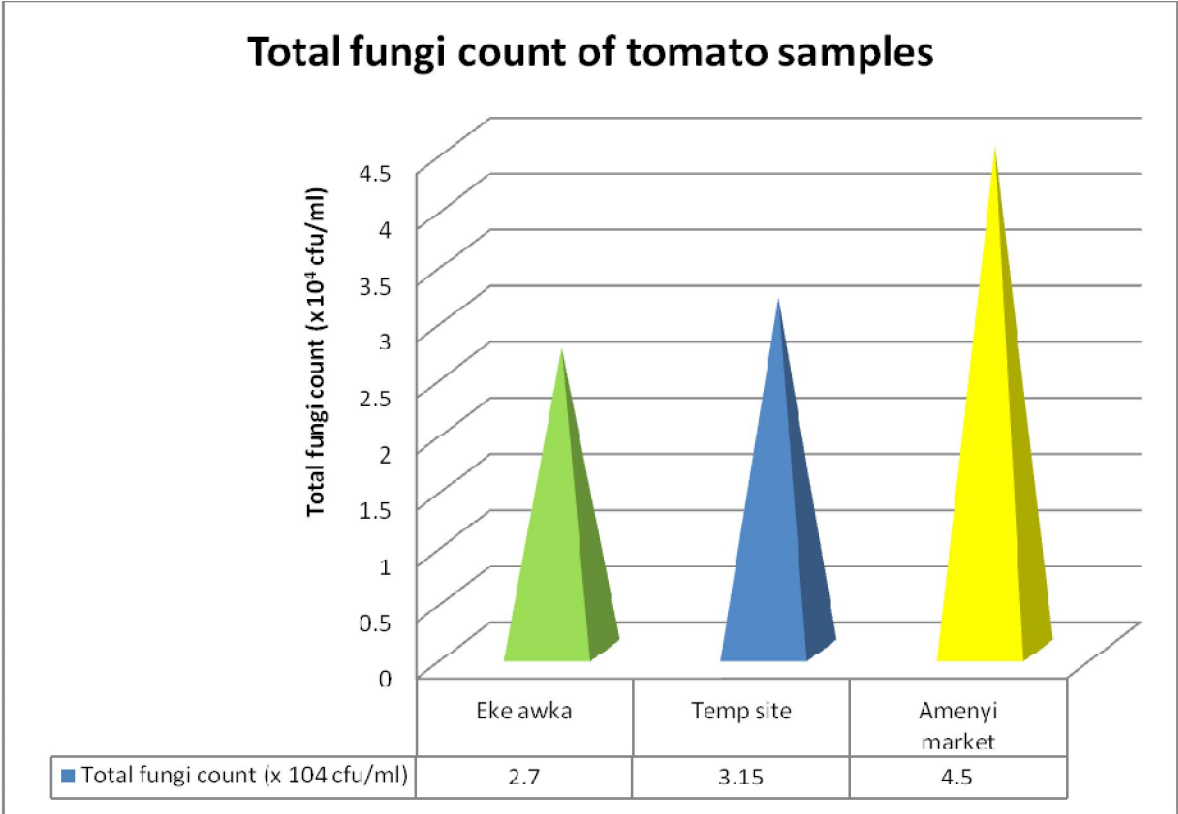


Figure 2 shows the Fungi isolates count. The collection site that had the highest fungi count is Nkwo Amaenyi (4.5ml) whilst the site with the lowest count is Eke Awka (2.7ml).

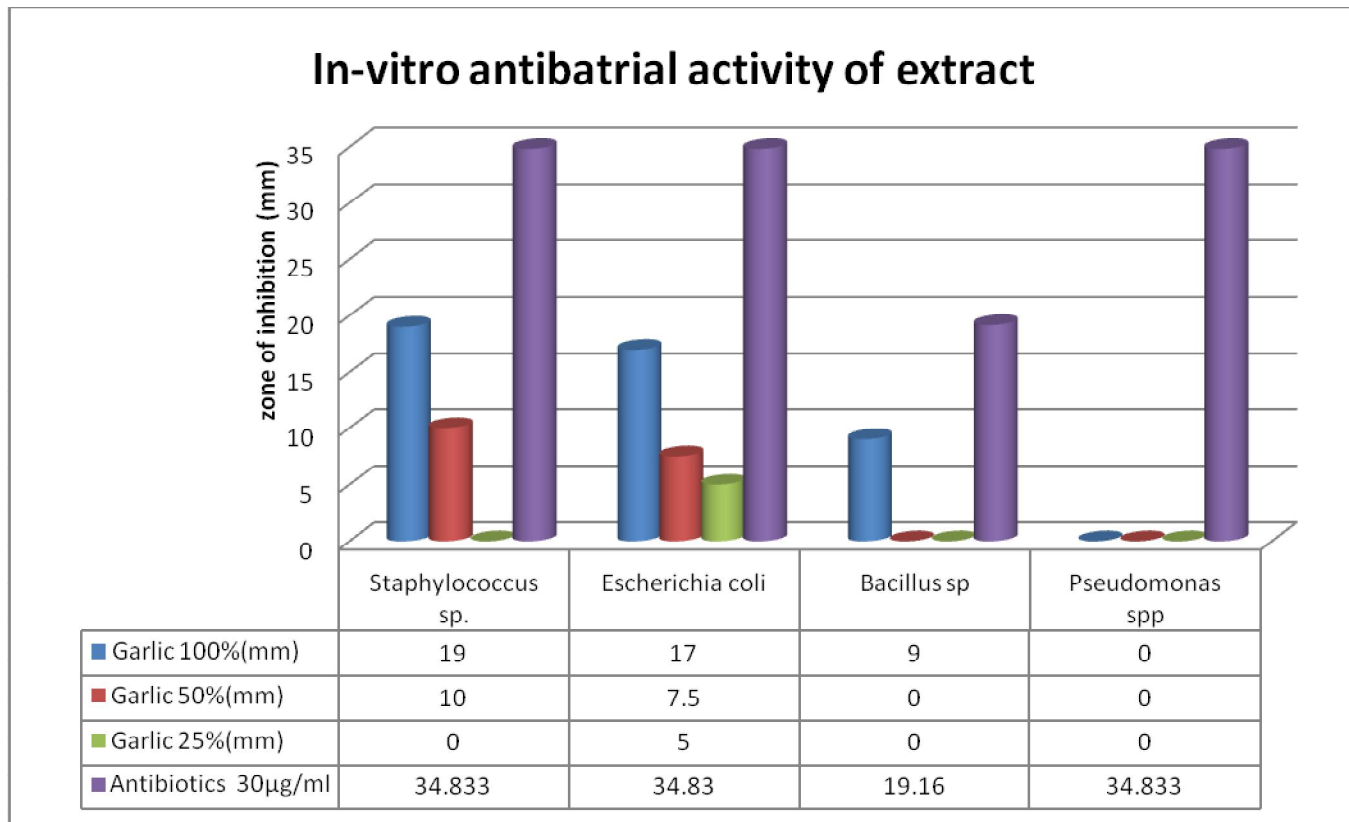


Figure 3 reveals the invitro antibacteria activities of garlic at various concentration.

Staphylococcus sp was highly susceptible at 50% and 100% (10mm and 19mm) at 100, 50 and 25 % *Escherichia coli* w inhibited (17, 7.5, 5mm) while *Pseudomonas sp* showed the least susceptibility to the garlic extract (0.00). The control (Streptomycin) had a great inhibitory effect on the bacteria strain over the plant extract.

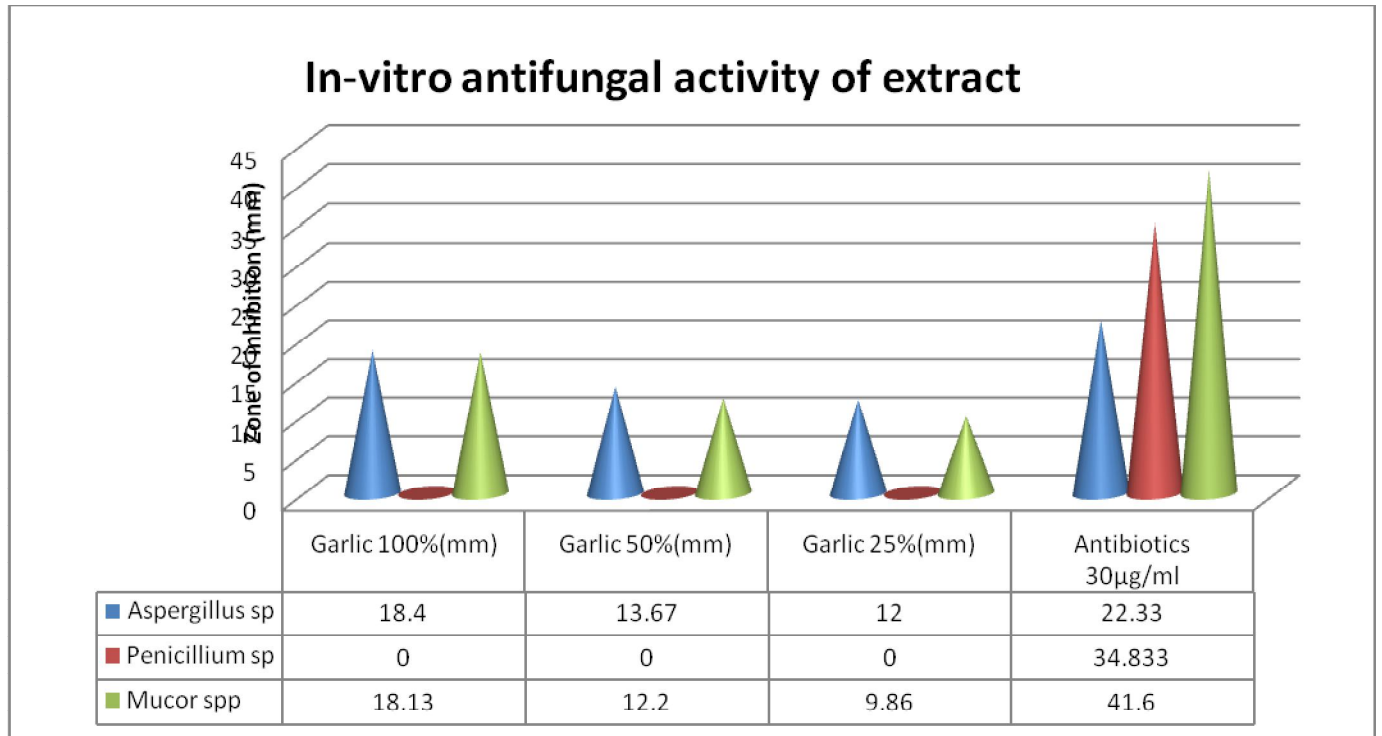


Figure 4 shows the inhibitory effects of garlic extract on the Fungi isolates. The garlic extract had positive effect on *Mucor sp* (18.13, 12.2, 9.86mm) and *Aspergillus sp* (18.4,13.67,12mm) and negative effects on *Penicilliumsp* (0.00) at various concentrations used in the study.

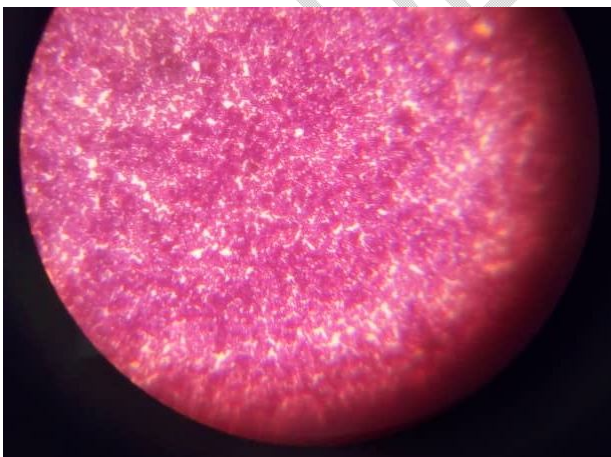


Plate 1: Microscopic Picture of *Pseudomonas sp*

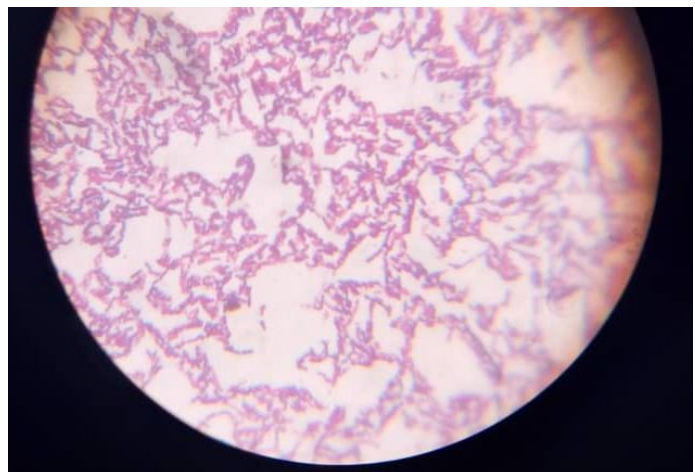


Plate 2:Microscopic picture of *E. coli*

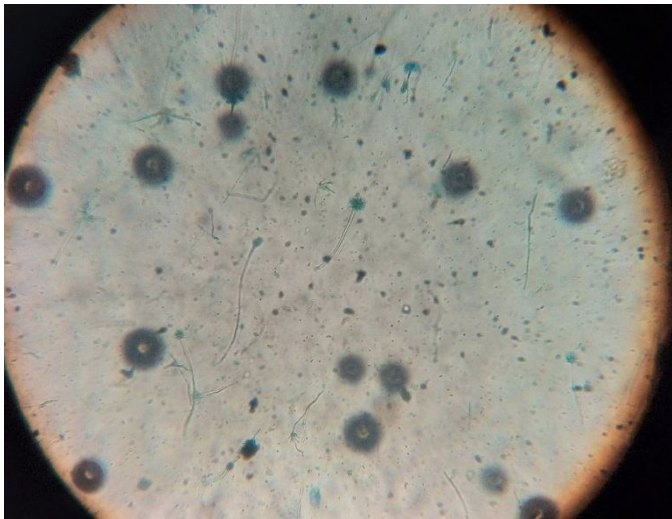


Plate 3:Microscopic picture of *Penicillium* sp

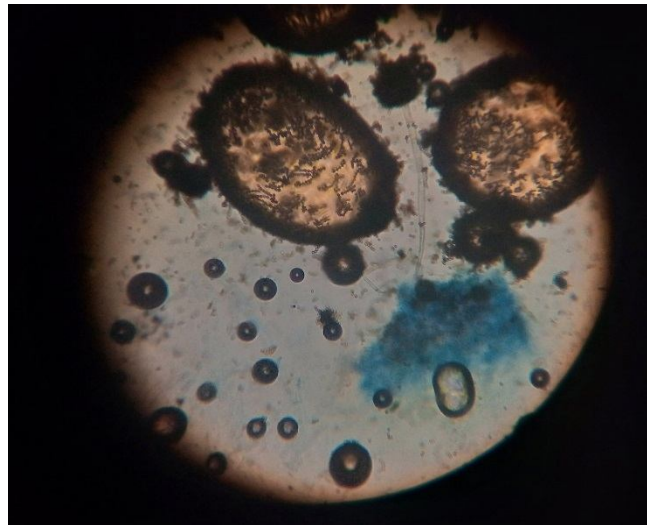


Plate 4:Microscopic picture of *Aspergillus* sp

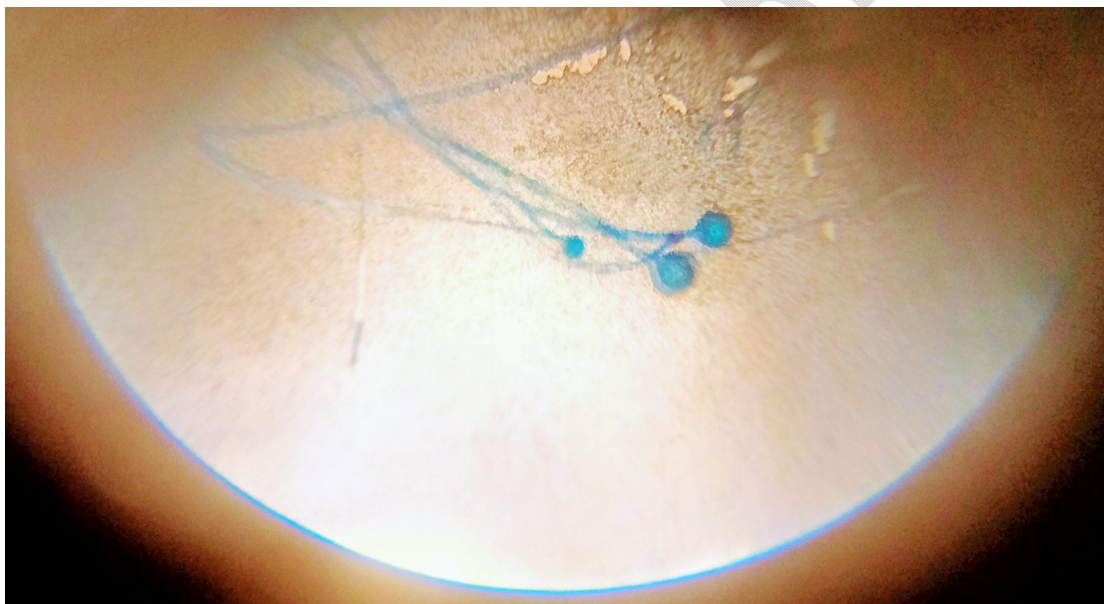


Plate 5:Microscopic picture of *Mucor* sp

CHAPTER FIVE

DISCUSSION

The research study was based on Isolation of pathogens causing spoilage on tomatoes and antimicrobial properties of garlic extract. The pathogens associated with spoilt tomato fruits were studied and the results reviewed the presence of a teeming population of microorganisms. Spoilt tomatoes from Eke Awka had the highest bacterial count (6.1×10^4 cfu/ml) while those from Temporary site had the lowest bacterial counts (4.7×10^4 cfu/ml). Spoilt tomatoes from Eke Awka had the least fungal count (2.7×10^4 cfu/g) while samples from Amaenyi had the highest fungal count (4.5×10^4 cfu/g). The research showed seven microbial pathogens in association with spoilt tomatoes bought from three locations in Awka. The Bacteria isolated were *Escherichia coli*, *Staphylococcus sp*, *Pseudomonas sp* and *Bacillus sp*. While the Fungi Isolates were *Aspergillus sp*, *Penicillium sp* and *Mucor sp*. Some of these microorganisms had been reported previously by other researchers as pathogens and are responsible for spoilage of tomatoes (Ikon *et al.*, 2017; Wogu and Ofuase, 2014). A similar study revealed the high level of *Bacillus sp*, *Staphylococcus sp* and *Escherichia coli* in Lagos State Nigeria (Ogundipe *et al.*, 2012). Also, some of the fungal organisms that were isolated and identified in this research were also reported by other researchers in the past. In Annual Research and Review in Biology 2018, 5 fungi species were identified after Isolation from tomato samples which include *Aspergillus sp*, *Penicillium sp*, *Botryodiplodia theobromae*, *Fusarium sp*, and *Colletotrichum sp* (Liamgee *et al.*, 2018). Mohammed and Kuhiyep, (2020), reported that *Staphylococcus sp*, *Escherichia coli* and *Salmonella sp* were isolated from tomatoes sold in Kaduna. Garlic bulb ethanol extract was used for the antimicrobial assay. The garlic extract was able to inhibit the growth of the isolated pathogens. The antimicrobial properties of garlic have been reported to be due to the presence of

a variety of alkaloids, flavonoids, terpenoids, tannins and saponins (Shang *et al.*, 2019). The *Allium sativum* antimicrobial activities at different concentrations against the bacteria and fungi pathogens were evaluated. The concentrations of the garlic extract used: 25, 50 and 100%. Zone of inhibition obtained varies based on concentrations. In almost all of the concentrations, the garlic extract gave antimicrobial activity against all the pathogens isolated. For the bacteria isolates, the garlic bulb extract gave the highest inhibition on *Staphylococcus sp* and the lowest of *Pseudomonas sp*. While for the Fungi isolates, the garlic extract gave the highest inhibition of *Aspergillus sp* and the lowest of *Penicillium sp*. Several research carried out has shown the efficacy of garlic in suppressing the growth of pathogenic microorganism. A similar result was observed by other researchers using garlic extract against tomato diseases. The result agrees with earlier work of Mugao, (2021); Tijjani *et al.*, (2014) and Ikon *et al.*, (2017) on the inhibition of growth and sporulation of microorganism pathogens on *Solanum lycopersicum* by *Allium sativum*. A similar study reported garlic to be a significant antimicrobial agent (Rehman *et al.*, 2021). Ashraf *et al.*, (2020), reported that ethanol extract of garlic suppressed the growth of *Escherichia coli*, *Bacillus so* and *Aeromonas hydrophila*. Two different studies revealed no inhibitory effect of garlic on *Mucor sp* (Saravanasingh, 2016) and *Aspergillus sp* (Mohammad *et al.*, 2021) is in contrast with the findings which might be as a result of method of extract preparations and extraction and solvent used. According to Senhaji *et al.*, (2013), the efficiency of any

plant extracts against pathogenic organisms depends on the nature and quantity of the active ingredients it contains as well as the mode of extraction. *Aspergillus sp* largely exist as saprophytes (obtain their nutritional needs from dead and decaying leaves, fruits, vegetables). They are ubiquitous causing a wide range diseases. *Mucor sp* belongs to the order Mucorales and

comprise mainly saprobes, endophytes, parasite of plants and human pathogens causing mucormycosis (Wagner *et al.*, 2020). *Penicillium sp* are wide spread attacking various fruits and vegetables especially during storage and often producing a variety of mycotoxins. Harmful mycotoxins and carcinogenic compounds such as citrinine, patulin, penicilic acid and other secondary metabolites are produced by *Penicillium sp* (Abramson *et al.*, 2009). *Staphylococcus sp* is a gram positive bacteria that colonizes 30% of healthy individuals from different body parts (Oliveira *et al.*, 2018). Its susceptibility to the plant extract is a huge relief since it plays a significant role in causing infections ranging between simple to life threatening infections (Bitrus *et al.*, 2018). *Escherichia coli* was found susceptible to the plant extract. It has been reported to cause a serious food poisoning which can be transmitted to humans primarily through consumption of contaminated foods such as contaminated raw vegetables and sprouts (WHO, 2018). According to Chaudhuri and Henderson, (2012), *Escherichia coli* has been associated with a large number of infections in healthy and immunocompromised persons (diarrhea, pneumonia, urinary tract infections, wound infections, sepsis and meningitis). *Pseudomonas sp* is a ubiquitous gram negative bacterium belonging to the family Pseudomonadaceae and is able to survive in a wide range of environments (Silby *et al.*, 2011), is the highest resistant microorganism among the four bacteria Isolated. Its high

resistance to the garlic extract could be its restricted outer membrane permeability, efflux systems that pump antibiotics out of the cell, production of antibiotics inactivating enzymes such as B lactamases, horizontal transfer of resistance genes or mutational changes (Breidenstein *et al.*, 2011). Its resistance is a problem to the world as it has been reported to be associated with nosocomial infections and ventilator associated pneumonia (Barbier *et al.*, 2013).

Conclusion

Despite tomato being fruit it is generally prepared and eaten like a vegetable. At the end of this study, it was observed that there are microbial organisms that causes postharvest diseases on tomatoes sold in Awka. The consequences of microbial contamination and growth of these pathogens on tomatoes causes spoilage, mitigate sensory appeal and lead to great economic losses and wastage of products. The study revealed that garlic possesses antimicrobial properties since it was able to suppress the growth of tested microbial isolates. Therefore there is need for further improvements and research on the plant extracts for effective control of microbial isolates. Also garlic can be used by pharmaceutical industries and manufacturing industries in production of drugs against tested isolates and in developing plant based biofungicides and bio-bactericide for the management of tomato diseases since the plants are always available, cheap and environmental friendly with lower risk of hazardous residues.

Recommendation

1. Farmer should employ control measures at every point in postharvest chain to mitigate contamination.
2. Government should sponsor research scientist in this discipline for isolation, extraction and purification of the active compounds in the medicinal plants that could be used in producing drug against several diseases.
3. More research should be carried out to find plant alternatives for *Pseudomonas sp* and *Penicillium sp* other than chemicals and higher concentrations of plant extract should be used which might serve as a perfect substitute of chemicals used.

References

- Abraham Juárez, M., Cárdenas, R., SantoyoVilla, N., Devin O'Connor, Aaron, S., Sarah H., José Ordaz-Ortiz, Leon T., Simpson, J. (2015). Functionally different PIN proteins control auxin flux during bulbil development in *Agave tequilana*, *Journal of Experimental Botany*, **66**,(13):3893–3905.
- Abramson, D., Lombaert, G., Clear, R., Sholberg, P., Treika, R. and Rosin, E. (2009). Production of patulin and citrinin by *Penicillium expansum* from British Columbia(Canada) apples. *Mycotoxin Research*, **25**(2):85-88.
- Adepeju, A. O., (2014). Postharvest losses and welfare of tomato farmers in Ogbomosho, Osun state, Nigeria. *Journal of Store Products and Post Harvest*, **5**(2):8-13.
- Agwaranze, D. I., Kalu, A.C., Sabo, I. A., Aso, R. E., Okachi, M. A. (2020). Mycologicalassessment of deteriorated tomato fruits sold in Wukari, Nigeria. *Journal of Biotechnological Research*, **6**:(7):84-89.
- Akinfasoye, J., Dotun, J. A., Emmanuel, O. O., Emmanuel, A. (2011). Phenotypicrelationship among Agronomic characters of commercial tomato hybrids. *American Eurasian Journal of Agronomy*, **4**(1):17-22
- Akinyele, B. J. and Akinkunmi, C. O. (2012). Fungi associated with the spoilage of berry and their reaction to magnetic field, *Microbiology, Biotechnology and Food Science*, **2**(2):701-712.

- Alam, P., Raka, M. A., Khan, S., Sarkar, J., Ahmed, N., Sagor, A.T., (2018). A clinical review of the effectiveness of tomato (*Solanum Lycopersicum*) against cardiovascular dysfunction and related metabolic syndrome. *Journal of Herbal Medicine*, **16**:100-235.
- Ameh, G., Eze, S. and Omeje, F. (2013). Phytochemical screening and antimicrobial studies on the methanolic bulb extract of *Allium sativum* L. *African Journal of Biotechnology*, **12**(14):1665-1668.
- Arah, I. K., Amaglo, H., Kumar, E. K. (2015). Preharvest and post harvest factors affecting the quality and shelf life of tomatoes. *International Journal of Agronomy*, 1-6.
- Arbrar, S., Abera, D., Simegne, K., Ali, M. (2016). Effect of storage conditions and packing materials on shelf life of tomato. *Food Science and Quality Management*, **56**:2224-6088.
- Ashraf, Z., Ali, Q., Rashid, M. and Malik, A. (2020). Antibacterial, antifungi and anti-cancer activities of multistress affected *Allium sativum* plant extracts. *Plant Cell Biotechnology and Molecular Biology*, **21** 55 13 22
- Ayandiji, A. O. and Omidiji, D. (2011). Determinants of postharvest losses among tomato farmers in Imeko Afon Local Government Area of Ogun state, Nigeria, *Global Journal of Science Frontier Research*, **11**(5):23-28.
- Babaola, D. A., Makinde, Y. O., Oyekanmi, M. O., Omonona, B. T. (2010). Determinants of postharvest losses in tomato production: A case study of Imeko Afon local government area of Ogun state. *Journal Life Physiology Science*, **3**(2):14-18.

- Baitha, G., Alkazmi, L., Wasef, L., Beshbishy, A., Nadwa, E., Rashwan, E. (2020). *Syzygium aromaticum* L (Myrtaceae) traditional uses, bioactive chemical constituents, pharmacological and toxicological activities. *Biomolecules*, 10:202.
- Barbier, F., Andremont, A., Wolff, M., Bouadma, L. (2013). Hospital acquired pneumonia and ventilator associated pneumonia, recent advances in epidemiology and management. *Current Opinion Pulmonary Medicine*, **19**:216-228.
- Bergougnot, (2014). The history of tomato: from domestication to biopharmaceutical. *Biotechnology Advances*,**32**(1)-170-189.
- Beshbishy, A., Baitha, G., Adeyemi, O., Yokohama, N., Igarashi, I. (2019). Inhibitory effects of methanolic *Olea europaea* and acetonic *Acacia laeta* on the growth of *Babesia* and *Theileria*. *Asian Pacific Journal of Tropical Medicine*,**12**:425-434.
- Breidenstein, B., de la Fuente-Nunez, C., Hancock, R. (2011). *Pseudomonas*: all roads lead to resistance. *Trends in Microbiology*,**19**:419-426.
- Bitrus, A., Peter, O., Abbas, M. and Goni, M. (2018). *Staphylococcus*: A review of antimicrobial resistance mechanisms. *Veterinary Sciences Research and Reviews*, **4** :2-10.
- Borlinghaus, J., Albrecht, F., Gruhlke, M., Nwachukwu, I., Slusarenko, A. (2014). Allicin: Chemistry and biological properties. *Molecular Basel*, **19**(8):12591-12618.
- Buzby, J. C. and Human, J. (2012). Total and per capita value of food loss in the United States. *Food Policy*, **37**:561-570.
- Carbonell, P., Alonso, A., Grau, A., Salinas, F. J., Gracia-Martinez, S. and Ruiz, J. J. (2018). twenty years of tomato breeding at EPSO-UMH. Transfer resistance from wild types to

- local landraces from the first molecular markers to genotyping by sequencing (GBS). *Diversity*, 10:12.
- Chaudhary, S. (2014). Effect of biofertilizers and organic manures on growth yield and quality of tomato (*Lycopersicum esculentum*) cv Arka vikas Department of Horticulture Institute of Agricultural Science Banaras Hindu University Varanasi India, 1-7.
- Chaudhuri, R.R.. and Henderson, I. R. (2012). The evolution of *E. coli* phylogeny. *Infection Genetic Evolution*, **12**:214-226.
- Deribe, H., Beyene, B. and Beyene, B. (2016). Review on pre and post harvest management on quality tomato production. *Food Science and Quality Management*, **54**:72-79.
- Eno-Abasi, S., Gbenga, A., Joke, M. and Abdulganiu, A. (2018). A long way to self sufficient in tomato production. *Sunday Magazine*, **50**:7-8.
- Enyiukwu, D. N., Awurum, A.N., Nwaneri, J. A. (2014). Efficacy of plant derived pesticides in the control of myco induced postharvest rots of tubers and agricultural products. *Net Journal of Agricultural Science*, **2**(1):30-46.
- Etebu, E., Nwauzoma, A. B., Bawo, D. D. (2013). Post harvest spoilage of tomato and control strategies in Nigeria. *Journal of Biology, Agriculture and Healthcare*, **3**:10
- Ezenwaji, E., Awopeju, A., Otti, V., Eduputa, B. (2014). Spatial patterns of residential water supply accessibility levels in Anambra State, Nigeria. *International Journal of Engineering Research and Applications*, **4**(1):326-336.
- Frankel, F., Matthew, P., Elizabeth, R., Chloe, S., Oni, T., Abrielle, N., Barth, E., Slejzer, K. (2016). Health functionality of organosulfides . *International Journal of Food*

- Properties*, **19**:537-548. Food and Agricultural statistics (2019). Ranking of countries that produce the most tomatoes. <https://beef2live.com/story-ranking-countries-produce-tomatoes-fao-204-2-13004>. Accessed 10th January, 2022.
- Gao, Z., Zhang, B., Liu, H. (2017). Identification of endophytic bacillus velezensis ZSY-1 strain and antifungal activity of its volatile compounds against *Alternaria solani* and *Botrytis cinerea*. *Biological Control*, **105**:27-39.
- Gustavsson, J., Cederberg, C., Sonesson, U., Vanotterdijk, R. and Meybeck, A. (2011). Global food losses and food waste- Extent, Causes and Prevention. Available [https://scholar.google.com/scholar?q=Gustavsson+J.+Cederberg+C.+Sonesson+U.+van+Otterdijk+R.+Meybeck+A.+Global+Food+Losses+and+Food+Waste%E2%80%93Extent,+Causes+and+Prevention+2011+Food+and+Agriculture+Organization+of+the+United+Nations+\(FAO\)+Rome,+Italy+](https://scholar.google.com/scholar?q=Gustavsson+J.+Cederberg+C.+Sonesson+U.+van+Otterdijk+R.+Meybeck+A.+Global+Food+Losses+and+Food+Waste%E2%80%93Extent,+Causes+and+Prevention+2011+Food+and+Agriculture+Organization+of+the+United+Nations+(FAO)+Rome,+Italy+). Accessed 2nd January 2022.
- Hanen, N., Ammar, E., Fattouch, S., Neffati, M., (2012). *Allium* species, ancient health food for the future? *Scientific, Health and Social Aspects of the Food Industry*, 343-355.
- Héctor, S., Olvio, H., Darío, S., Lus, L., MacíasValdez, L., Tarsicio, C., Maro, L., and JuanForencio, G. (2012). Agronomic and biotechnological strategies for breeding cultivated Garlic in Mexco, *Genetic Diversity in Plants* Prof Mahmut Caliskan (Ed.), SBN 978-953-51-0185-7, InTech, Available from: <http://www.intechopen.com/books/genetic-diversity-in-plants/agronomic-and-biotechnological-strategies-for-breeding-cultivated-garlic-in-mexico>

- Hodges, R. J., Buzyby, J. C. and Bennett, B. (2011). Post harvest losses and wastes in developed and less developed countries: opportunities to improve resource use. *The Journal of Agricultural Science*, **149**(1):37-45.
- Hollomon, D. W. (2015). Fungicide resistance forty years on and still a major problem. In H. Ishii and D. Hollomon (eds). *Fungicide Resistance in Plant Pathogen*. Springer International Publishing, Tokyo, 3-11.
- Hosea, Z. Y., Kator, L., Ameh, L. O., Terms, D. A. (2017). Effect of been leaf powder on post harvest shelf life and quality of tomato fruits in storage. *International Journal Of Development and Sustainability*, **6**(10):1338-13349.
- Ijato, J. (2011). Inhibitory effect of two indigenous plant extract of *Zingiber officinale* and *Ocimum gratissimum* on post harvest yam rot invitro. *Journal of American Science*, **7**(1):43-47.
- Ikon, G., Abasiubong, V. and Amadi, C. (2017). Antimicrobial activity of garlic extract On organisms isolated from tomato rot. *Journal Advances in Microbiology*, **7**(2):1-10.
- Irokaanulo, E. O., Egbezien, I. L., Owa, S. O. (2015). Uses of *Moringa oleifera* in the preservation of fresh tomatoes, *Journal of Agriculture and Veterinary Science*, **8**(2):127-132.
- Islamian, P. (2015). Lycopene as a carotenoid provides radio protection and Antioxidant effects by quenching radiation induced free radical singlet oxygen. *Cell Journal*, **16**(4):386-391.

James, C.J and Natalie, S(2013), Microbiology. A Laboratory manual, pp.43.

Khonglah and Kayang (2018). Antagonism of indigenous fungal isolates against *Botrytis cinerea* the causal of gray mold disease of tomato, *International Journal of Current Research in Life Science*, **7**(1):806-812.

Kovarovič, J., Bystrická, J., Vollmannová, A., Tóth, T. and Brindza, J. (2019). Biologically valuable substance in garlic (*Allium sativum* L). *Journal of Central European Agriculture*, **20**(1):292-304.

Lawal, A., Dangoggo, S. and Umar, K. (2010). Phytochemical and antibacteria screening of garlic. *Katsina Journal of Pure and Applied Science*, **2**(2):101-104.

Liamgee, K., Iheanacho, A. and Aloho, K. (2018). Isolation, identification and pathogenicity of fungi causing post-harvest spoilage of tomato fruits during storage. *Annual Research and Reviews in Biology*, **26** (6): 1- 7.

Marchese, A., Barbieri, R., Sanches-Silva, A., Daglia, M., Nabavi, S.F., Jafari, N.J., Izadi, M., Ajami, M., and Nabavie, S.M. (2016). Antifungal and antibacterial activities of allicin: A review. *Trends in Food Science and Technology*, **52**, 49 –56.

Martins, N., Petropoulos, S., and Ferreira, I., (2016). Chemical composition and bioactive compounds of garlic as affected by pre and post harvest conditions. A review. *Food Chemistry*, **211**:41-50.

Mbajiuka, S.C and Emmanuel, E. (2014). Isoation of microorganisms associated with deterioraton of Tomato and paw paw, *International Journal of Current Microbiology and Applied Sciences*, **3** (5) 501-512.

- Mohammad, D and Kuhiyep, C. (2020). Bacteria and fungi co-biodeterioration of selected fresh tomatoes sold within Kaduna. *Science World Journal*, **15** (1):48-55.
- Mohammad, A., Abdullahi, A. and Nasiru, A. M. (2021), Effects of neem leaves and garlic bulbs on fungi causing post harvest spoilage of tomatoes in Sokoto North Western Nigeria, *Journal of Agriculture and Veterinary Science*, **14**(16):8-14.
- Morris, W., and Taylor, M. (2017). The Solanaceous Vegetable Crops: Potato, Tomato, Pepper, and Eggplant. In: Thomas, B., Murray, B. G. and Murphy, D.J. (Eds). *Encyclopedia of Applied Plant Sciences*. Academic Press, Amsterdam, Netherlands, 55-58.
- Mikaili, P., Maadirad, S., Moloudizargari, M., Aghajanshakeri, S., Sarahroodi, S. (2013). Therapeutic uses and pharmacological properties of garlic, shallot, and their biologically active compounds. *Iran Journal of Basic Medical Sciences*, **16**:1031–1048.
- Milner, J. and Donato, F.(2010). *Bioactive compounds and cancer*. Springer Science Business Media, New York. 896
- Mugao, L. (2021). Invitro activity of selected plant extract on post harvest pathogens causing tomato fruit rot. *Journal of Phytopharmacology*, **10**(4):236-241.
- Mujtaba, A and Masud, T. (2014). Enhancing post harvest storage life of tomato (*Lycopersicon esculentum mill*) CV. Rio Grandi using calcium chloride. *American Eurasian Journal of Agricultural and Environmental Science*, **14**(2):143-149.
- Neeta, N. P., Gol, B. and Ramana, R. (2010). Effect of post harvest treatment on physicochemical characteristic of and shelf life of tomato fruits during storage, *American Eurasian Journal of Agriculture and Environmental Science*, **9**:470-479.

- Nicosia, D., Pangallo, S., Raphael, G., Pomeo, F., Strano, M., Rapisard, P., Droby, S. and Schena, L. (2016). Control of postharvest fungal rots on citrus fruit and sweet cherries using a pomegranate peel extract. *Postharvest Biology and Technology*, **114**:54-61.
- Nunes, C. A. (2012). Biological control of post harvest diseases of fruits, *European Journal of Plant Pathology*, **133**:181-196.
- Ochar, K. (2015). Studies on genetic variability in agronomic and fruit quality traits among some tomato (*Solanum lycopersicum* L.) genotypes. Published thesis University of Ghana.
- Ogundipe F., Bamdee, F., Adebayo-Oyetero A., Ogundipe, O. and Tajudeen, O. (2012). Incidence of bacteria with potencial pubic health implications on raw Tomato sold in Lagos State, Nigeria. *Nigerian Food Journal*, **30** (2), 106-113.
- Oliveira, D., Borges, A. and Simoes, M. (2018). *Staphylococcus* toxins and their molecular activity in infectious diseases. *Toxins*, **10**(6): 30-38.
- Osei, M. K. Akromah, R., Shilh, S. L. and Green, S. K. (2010). Evaluation of some tomato Germplasm for resistance to tomato yellow leaf virus (TYLCV) in Ghana. *Aspects Applied Biology*, **96**:315-323.
- Osman, A. O. A. (2015). Antifungal evaluation of some plant extracts and fungicides against *Fusarium oxysporum f.sp.lycopersici*, causal agent of wilt of tomato. Sudan University of Science and Technology College of Graduate Studies, 1-73.
- Palani, K., Ruba, A., Shanmugam, S. and Jeyaeya, S. (2014). Proximate and major mineral composition of 23 medium sized marine fin fishes landed in the Thoothukudi Coast of India. *Journal of Nutrition and Food Science*. **4**(1):1-7.

- Paulo, L. (2013). Heat treatments for the control of citrus post-harvest green mold caused by *Penicillium digitatum*. In: microbial pathogens and strategies for combating them: *Science technology and education*. Formatex Badajoz, Spain, 508-514.
- Pavni, K, Esha B, Neha J, Tushar A. (2011). Phytochemical screening of developing garlic and effect of its aqueous extracts on viability of cardiac cell line. *Journal of Pharmaceutical Research*, **4**(3):902-904.
- Peralta, I. E. and Spooner, D. M. (2007). History, origin and early cultivation of tomato(Solanaceae) in: Razdan, M. K., Mattoo, A. K.(eds), *Genetic Improvement of Solanaceous crops*, Science Publishers, Enfield Nueva Hampshire, 1-27.
- Pinheiro, J., Aiegria, C., Abreu, M., Sol, M., Goncalvee, B. M. and Silva, C. L. M.(2014). Post harvest quality of refrigerated tomato fruit (*SolaniumLycopersicum* 'zinac') at 2 maturity stages following heat treatment. *Journalof Food Processing and Preservation*,**39**(6):697-709.
- Puyaubert and Baudouin (2014). New clues for a cold case: nitric oxide response to low temperature. *Plant, Cell and Environment*, **37**:2623-2630.
- Rahman, H., Asaduzzaman, M and Kabir, S. (2021). Determination of antimicrobial activity of traditional spices extracts against clinical isolates in Dhaka City. *StanfordJournal of Microbiology*, **11**(1):17- 19.
- Reddy, B. R., Reddy, D. S. Reddaiah, K., Sunil, N. (2013). Studies on genetic variability, heritability and genetic advance for yield and quality traits in tomato. *CurrentMicrobiology and Applied Science*, **2**(9):238-244.

- Rehman, Z. and Munir, M. (2015). Effect of garlic on the health performance of broilers. *Veterinaria*, **3**(1):32-39.
- Saravanasingh, K., Frdrik, G and Ramamurthy, M. (2016). A study on antibacteria and antifungal activities of extract of medicinal plant *Aeglemarmelos*. *International Journal of Advanced Research in Biological Sciences*, **3**(2): 321-328.
- Salehi, Bahare, Raziieh Shari-Rad, Farukh Sharopov, Jacek Namiesnik, AmirRoointan, Madhu Kamle, Pradeep Kumar, Natalia Martins, Javad Shari-Rad (2019). Beneficial effects and potential risks of tomato consumption for human health. *Nutrition*, **62**:201-208.
- Samavatean, N., Rafiee, S., Mobli, H., and Mohammad, A. (2011). An analysis of energy use and relation between energy inputs and yield, costs and income of garlic production in Iran. *Renewable Energy*, **36**: 1808-1813.
- Senhaji, B., Ben, H. and Salghi, R. (2013). *Asteriscus imbricatus* extract: Antifungal activity and anticorrosion inhibition. *International Journal of Electrochemical Science*, **8**:6033-6046.
- Seravanthi, J . and Gangadhar, S. (2015). Phytochemical and antioxidants composition in *Lycopersicum esculentum*. *Journal of Medicinal Plants Studies*, **3**:107-110.
- Sethi, N., Kaura, S., Dilbaghi, N., Parle, M., and Pal, M., (2014). Garlic a pungent wonder from nature, *International Research Journal of Pharmaceutical*, **5**(7):523-529.
- Shamshiri, R. R., Jones, J. W., Thorp, K. R. (2018). A review of optimum temperature, humidity and vapor pressure deficit for microclimate evaluation and control in green house cultivation of tomato: *International Journal of Agrophysics*, **32**:287-302.

- Shang, A., Cao S., Xu, X., Gan, R., Tang, G., Corke, H., Mavumengwana, V., Li, H. (2019). Bioactive compounds and biological functions of garlic (*Allium sativum* L.). *Foods*, **8**:246.
- Sibomana, M. S., Workneh, T. S. and Audain, K. (2016). A review of post-harvest handling and losses in fresh tomato supply chain: A focus on Sub Saharan Africa. *Food Security*, **8**(2):389-404.
- Siddiqui, M. W., Ayala zavalá, J. F., Dhua, R. S. (2015). Genotypic variations in tomatoes affecting processing and antioxidant properties. *Critical Review in Food Science and Nutritional Technology*, **2** (3), 3740.
- Sigei, K. G., Ngeno, K.H., Kibe, M. A., Mwangi, M. M. and Mutai, C. M. (2014). Challenges and strategies to improve tomato competitiveness along the tomato value chain in Kenya. *International Journal of Business and Management*, **9**(9):230-245.
- Silby, W., Eraig, W., Scott, A. C., Stuart, B., Robert, W. (2011). *Pseudomonas* genomes: diverse and adaptable. *FEMS Microbiology Reviews*, **35**(4):652-680.
- Silvia, C., Paola, H., Teresa, S., Raul, S., Irving, I. and Carlos, E. (2019). Antimicrobial activity of *Zingiber officinale* and its application in food products. *Food Reviews International*, **35**(5):407-426.
- Spadoni, A., Guidarelli, M., Sanzani, S. M., Ippolito, A. and Mari, M. (2014). Influence of hot water treatments on brown rot of peach and rapid fruit response to heat stress. *Postharvest Biology and Technology*, **94**: 66 -73.
- Starke Ayres, (2014). Tomato production guidelines.

<https://www.starkeyres.com/uploads/files/Tomato/Tomato-production-guideline-2019.pdf>.

Accessed January 5, 2021.

Stocco, A. F., Diaz, M. E., Rodriguez Romera, M. C., Mercado, L. A., Rivero, M. L., and Ponsone, M. L. (2019). Biocontrol of Postharvest *Alternaria* Decay in grapes from Argentina. *Biological Control*, **134**, 114-122.

Szychowski, K., Rybczynska-Tkaczyk, K., Gawel-Beben, K., Swieca, M., Kara's, M., Jakubczyk, A., Gmniski, J. (2018). Characterization of active compounds of different garlic cultivars. *Polish Journal of Food and Nutrition Sciences*, **68**:73-81.

Tan, H., Thomas-Ahner, J., Grainger, E., Wan, L., Francis, D., Schwartze, S. and Clitin, S. (2010). Tomato based food products for prostate cancer prevention. *Cancer and Metastasis Reviews*, **29**(3)553-568.

Tang, J., Liu, Y., Li, H. (2015). Combining antagonistic yeast with harp in treatment to control post harvest decay in kiwi fruit, *Biology Control*, **89**:61-67.

Teofilo, M., Emir, S., Margarita, T., Dagoberto, O., Roberto, Q., Oscar, D., Miguel, B. (2020). Garlic (*Allium sativum* L) and its beneficial properties for health: A review. *Agro-industrial Science*, **10**(1): 103-115.

Tocmo, R., Wang, C., Liang, D., Huang, D. (2015). Organic sulfide profile and hydrogen sulfites releasing capacity of garlic (*Allium sativum* L.) scape oil: Effects of pH and cooking . *Journal of Functional Foods*, **17**:410-421.

- Touloupakis, E. and Ghanotakis, D., (2010). Nutraceutical use of garlic sulphur containing compounds in bio farms for nutraceuticals, *Functional Food and Safety Control by Bio Sensors*, **698**:110-121.
- Tijjani, A., Adebitan, S., Gurama, A., Aliyul, M., Haruna, S. Mohammad, G and Mus'ab, I. (2014). In vitro and in vivo efficacy of some plant extracts for the control of tomato fruit rot caused by *Aspergillus flavus*.
- Ugonna, C. N., Jolaoso, M. A., and Onwualu, A. P. (2015). Tomato value chain in Nigeria: issues, challenges and strategies. *Research Reports*,**7(7)**:501-515.
- Wagner, L., Stielow, J., de Hoog, G., Bensch, K., Schwartz, V., Voigt, K., Alastruey-Izquierdo, A., Kurzai, O., Walther, G. (2020). A new species concept for the clinically relevant *Mucor circinelloides* complex. *Persoonia* ,**44**: 6797.
- Wogu, M. and Ofuase, O. (2014). Microorganisms responsible for the spoilage of tomato fruits sold in markets in Benin City Southern Nigeria. *School of Academics and Journal of Bioscience*, **2 (7)**, 459-466.
- World Health Organization, (2018). *Escherichia coli*. <https://www.who.int/news-room/fact-sheets/detail/e-coli>. Accessed 2nd February, 2022.
- Zapata, P., Navarro, D., Guillen, F., Castillo, S., Valero, D., Serrano, M. and Martinez-Romero, D. (2013). Characterization of gels from different *Aloe sp* as antifungal treatment: Potential crops for industrial applications. *Industrial Crop Production*, **42**:223-230.

Zhang, L., Min, D., Li, F., Ji, N., Meng, D., Li, L. (2017). Synergistic effects of L-arginine and methyl salicylate on alleviating post harvest diseases caused by *Botrytis cinera* in tomato fruit, *Journal of Agricultural Food Chemistry*, **65**:4890-4896.

Znidarcic, D., Ban, D., Oplanic, M. (2010). Influence of postharvest temperature on physicochemical qualities of tomato. *Journal of Food, Agriculture and Environment*, **8**(1):21-25.

Znini, M., Cristofari, G., Majidi, H., Mazouz, P., Tomi, J. and Paolini, J. (2011). Antifungal activity of essential oil from *Asteriscus graveolens* against postharvest phytopathogenic fungi in apples. *National Production Community*, **6**(11):1763-1768.

UNDER PEER REVIEW

Appendix

Table 1

Nature of bacterial growth in nutrient agar media for tomatoes samples

SAMPLE	NATURE OF GROWTH
Eke Awka Sample + NA	Moderate growth
Temp site Sample + NA	Moderate growth
Amenyi market Sample + NA	Heavy growth

Table 2

Morphological and biochemical characteristics bacteria isolates

Parameters	Isolate 1	Isolate 2	Isolate 3	Isolate 4
Colony Characterization	Milky circular with flat elevation	Whitish irregular shape with flat elevation	Yellowish irregular shape with flat elevation	Milky irregular shape with flat elevation
Cell characterization	Short rods in singles	Rods in clusters	Cocci in clusters	Cocci in clusters
Gram's Test	Positive	Negative	Positive	Negative
Motility Test	Negative	Positive	Positive	Positive
Catalase	Positive	Negative	Positive	Positive
Coagulase	Negative	Negative	Positive	Positive
Citrate	Negative	Positive	Negative	Positive
Indole	Positive	Negative	Negative	Positive

Oxidase	Negative	Positive	Negative	Positive
Urease	Negative	Positive	Negative	Positive
Probable organism	<i>Bacillus spp</i>	<i>E-coli</i>	<i>Staphylococcus spp</i>	<i>Pseudomonas spp</i>

Table 3

Nature of fungal growth in SDA for onion samples

SAMPLE	NATURE OF GROWTH
Eke awka Sample + SDA	Heavy growth
Temp site Sample + SDA	Heavy growth
Amenyi market Sample + SDA	Heavy growth

Table 4

Identification of Fungi

Isolate code	Description	Probable identity
SD1	They are typically powdery black, Conidiophores arising from long, broad, thick-walled, sometimes branched foot cell, it has tall conidiophores. Conidia are large with radiating heads, mostly globose and irregularly roughed.	<i>Aspergillus sp</i>
SD2	Colonies are whitish to olivaceous-buff, odour aromatic; in the dark differentiated into tall and short sporangiophores. Sporangia blackish with ellipsoidal, pyriform or subglobose. Chlamydo spores absent.	<i>Mucor sp.</i>
SD3	Colonies are fast growing conidiophores in fresh isolate typically loosely synematous, giving the colony a zonate appearance. Colonies are light green, reversed colourless, yellow-brown conidiophores usually smooth walled, pencilli 2-3 staged branched with numerous usually oppressed mutulae, conidia sub-globose to ellipsoidal smooth-walled,.	<i>Penicillium sp.</i>

Table 5

ZONE OF INHIBITION

EXTRACT	<i>Staphylococcus</i> sp.	<i>Escherichia</i> <i>coli</i>	<i>Bacillus</i> sp	<i>Pseudomonas</i> spp	<i>Aspergillus</i> sp	<i>Penicillium</i> sp	<i>Mucor</i> spp
Garlic 100%(mm)	19.00	17.00	9.00	0.000	18.40	0.000	18.13
	21.00	17.70	9.00	0.000	18.80	0.000	18.00
	18.50	16.30	9.40	0.000	18.00	0.000	18.300
Garlic 50%(mm)	10.00	7.50	0.000	0.000	13.67	0.000	12.20
	10.00	7.50	0.000	0.000	13.60	0.000	12.50
	10.00	7.50	0.000	0.000	13.72	0.000	12.00
Garlic 25%(mm)	0.000	5.00	0.000	0.000	12.00	0.000	9.86
	0.000	6.00	0.000	0.000	12.00	0.000	9.88
	0.000	4.00	0.000	0.000	12.00	0.000	9.85
Antibiotics 30µg/ml	34.83	34.83	19.16	34.83	22.33	34.00	41.60
	34.80	5.00	19.20	34.00	22.30	36.00	41.60
	34.88	33.80	19.15	34.50	22.36	30.00	41.60