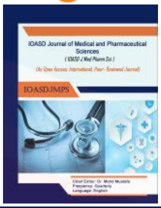
OPEN ACCESS

IOASD Journal of Medical and Pharmaceutical Sciences
IOASD J Med Pharm Sci, Vol-3, Iss-3, Jul-Sept., 2026
Frequency: Quarterly
ISSN: 3049-0294 (Online)
ISSN: 3049-3773 (Print)
Homepage: https://ioasdpublisher.com/ioasdjmps



Antimicrobial Effects of Garlic (*Allium sativum*) on Albino Rats Experimentally Infected with *Escherichia coli*

Chukwuemeka Peace Ngozi[1*], Okolie Nnaemeka[1], and Edward Ukamaka[1]
[1]Department of Medical Laboratory Science, Imo State University, Owerri

Corresponding Author: Chukwuemeka Peace Ngozi
Department of Medical Laboratory Science, Imo State University, Owerri

DOI: 10.67224/ioasdjmps.2026.v03i03.009

Original Research Article

Article History
Received: 01-06-2026
Accepted: 30-07-2026
Published: 04-08-2026

ABSTRACT

Escherichia coli is among the most prevalent bacterial species that cause food-borne diseases, gastroenteritis, urinary tract infections, and septicemia. The rising incidence of antibiotic-resistant strains of E. coli has become a matter of great concern, especially in the developing world where antibiotics are misused. This has led to renewed interest in medicinal plants that possess antimicrobial properties. Garlic (Allium sativum) is well-documented for its broad antimicrobial activity that is mainly attributed to sulfur-containing compounds such as allicin, ajoene, and diallyl sulfides. The current study was undertaken to determine the antimicrobial efficacy of orally administered garlic decoction in albino rats infected with Escherichia coli. An experimental study was conducted using albino rats infected with E. coli. The animals were treated with oral administration of garlic decoction at 3.2 ml/kg and 9.6 ml/kg. The control group received amoxicillin (27.14 mg/kg), while the negative control group was left untreated. The bacterial load was estimated before treatment, immediately after treatment, and at the end of treatment. Analysis of variance (ANOVA) was used to analyze the results with a Games-Howell post hoc comparison test. The significance threshold was set at $P < 0.05$. Garlic decoction was found to have significant antimicrobial activity against E. coli infection. The treatment regimens were associated with progressive decreases in the bacterial load ($P < 0.001$). The 3.2 ml/kg dose regimen was associated with a reduction of the bacterial load from 37.68 ± 7.10 CFU/ml to 0.00 ± 0.00 CFU/ml at the end of treatment. The 9.6 ml/kg dose regimen was associated with a rapid decrease in the bacterial load from 35.59 ± 7.90 CFU/ml to 6.34 ± 8.00 CFU/ml immediately after treatment followed by complete clearance of the organism. Amoxicillin cleared the organism immediately after treatment, while the untreated control animals showed a marked increase in the bacterial load. Garlic decoction was found to be highly effective against E. coli infection in an animal model. The antimicrobial activity was dose-dependent and comparable to that of standard antibiotic therapy, especially with prolonged treatment. The current findings demonstrate the therapeutic potential of garlic in the treatment of infections caused by E. coli. Further studies to evaluate the phytochemical composition, pharmacokinetic properties, and toxicity profile are needed before clinical applications can be considered.

Keywords: Allium sativum; Garlic; Escherichia coli; Antimicrobial activity; Medicinal plants; Albino rats; Experimental infection; Phytotherapy.

INTRODUCTION

Antimicrobial resistance is nowadays a major threat to public health since it renders effective treatments obsolete. The World Health Organization ranks antimicrobial resistance as one of the serious challenges facing humanity today because most pathogenic organisms are becoming resistant to existing antibiotics. Escherichia coli is among the most common Gram-negative bacteria that cause infections such as gastroenteritis, urinary tract infections, meningitis, wound infections, and septicaemia. However, most strains of E. coli are harmless commensals that inhabit the gastro-intestinal tract. Pathogenic strains damage the host tissues as they invade and colonize the urinary tract, produce toxins, and trigger severe infections [1].

E. coli infections are high in developing countries because people consume unwashed vegetables and fruits, drink contaminated water, and attend to animals that may carry the bacteria. Experimental infection of albino rats with E. coli resulted in successful colonization of the gastrointestinal tract, diarrhoea, inflammation, and higher bacterial excretion in stools. Therefore, albino rats are appropriate experimental animals for testing antimicrobial agents against bacterial infections affecting humans. The most common treatment for bacterial infections is antibiotics. However, E. coli has become resistant to most antibiotics including β-lactams, fluoroquinolones, aminoglycosides, and cephalosporins. The improper use of antibiotics and self-medication with antimicrobial agents has promoted resistance to existing antibiotics. Therefore, researchers are turning their attention to medicinal plants as alternative sources of infection treatment [2].

Medicinal plants have been used in traditional herbal medicine in Africa, Asia, and other parts of the world. Most people in developing countries rely on herbal medicine for healing because it is cheap and easily available. Herbs have phytochemical compounds with antimicrobial, antioxidant, anti-inflammatory, immunomodulatory, and anti-cancer properties. Therefore, researchers are isolating phytochemicals from medicinal plants that can be developed into novel drugs to combat antibiotic-resistant bacteria. Garlic has been a popular spice and herbal medicine for more than 5000 years. It belongs to the Amaryllidaceae family and is cultivated worldwide for its distinct aroma and medicinal value. Garlic contains organosulfur compounds such as allicin, ajoene, diallyl sulfide, diallyl disulfide, diallyl trisulfide, and S-allyl cysteine. The compound allicin is the most potent antimicrobial agent present in garlic extracts. Scientists have demonstrated that allicin inhibits the growth of Gram-positive and Gram-negative bacteria, as well as some pathogenic protozoa species. It works by damaging the sulphydryl groups of cell enzymes, inhibiting DNA replication, and preventing bacterial metabolism. Fresh garlic also contains phytochemical compounds with antioxidant and anti-inflammatory properties that help the body fight infections [3].

Garlic extracts have been shown to effectively kill most bacteria, including E. coli, Staphylococcus aureus, Salmonella, Shigella, Pseudomonas aeruginosa, Klebsiella pneumoniae, and Candida albicans. However, the antibacterial activity of garlic varies depending on the solvent extraction used to isolate the active compounds [4]. In most cases, aqueous ethanolic extracts of garlic have higher antibacterial activity than cold water extracts. Although in vitro experiments demonstrate that garlic extracts have potent antibacterial properties, such studies do not show how effective the treatment is when administered to adult human volunteers. Therefore, in vivo experiments with animals are needed to establish the efficacy of garlic extract formulations for treating bacterial infections [5, 6].

In Nigeria, diseases caused by E. coli are a serious health concern. People consume unwashed vegetables and fruits and drink from streams and wells that may contain disease-causing organisms. In addition, most Nigerians do not have faith in orthodox medicine and prefer herbal treatments in managing their illnesses. Garlic has antimicrobial properties and is used to treat diarrhoea, dysentery, coughs, colds, high blood pressure, and infections. However, most scientists have not evaluated the antibacterial effect of garlic decoction on Escherichia coli infection. Therefore, this study aims to demonstrate the antimicrobial effect of orally administered garlic decoction by determining the bacterial count of Escherichia coli in albino rats experimentally infected with the bacteria. In addition, this research aims to compare the antimicrobial activity of two garlic decoction doses and amoxicillin in treating E. coli infection.

MATERIALS AND METHODS

Study Area

This study was conducted at the Applied Biochemistry Laboratory, Nnamdi Azikiwe University, Awka, and Ife's Specialist Diagnostic Laboratory, Awka, Anambra State, Nigeria. Awka, the capital city of Anambra State in southeastern Nigeria, lies approximately 199 km north of Port Harcourt and occupies a strategic location between Onitsha and Enugu. The area experiences a tropical climate with average temperatures ranging from 30°C to 32°C and provides suitable laboratory facilities for microbiological and experimental animal research.

Study Design and Duration

This was an experimental laboratory-based study carried out over a period of two months to evaluate the antimicrobial effects of orally administered garlic decoction on albino rats experimentally infected with *Escherichia coli*.

Collection and Identification of Plant Material

Fresh garlic bulbs were purchased from Eke Awka Market, Awka, Anambra State, Nigeria. The plant material was authenticated by a taxonomist in the Department of Botany, Nnamdi Azikiwe University, Awka. The bulbs were washed thoroughly, sliced into small pieces, air-dried at room temperature, pulverized into fine powder, and stored in airtight containers until use.

Phytochemical Screening

Qualitative phytochemical screening was performed according to the standard methods The garlic powder was analyzed for alkaloids, tannins, flavonoids, saponins, terpenoids, cardiac glycosides, and phlobatannins using standard colorimetric procedures. Quantitative phytochemical analysis was performed using Gas Chromatography–Mass Spectrometry (GC–MS). Ethanol extracts of garlic were prepared and injected into the GC–MS system, while compounds were identified by comparison with the instrument's spectral library.

Preparation of Garlic Decoction

Fresh garlic powder (200 g) was soaked in one litre of distilled water for 24 hours at room temperature. The mixture was homogenized with a sterile blender and filtered successively through sterile muslin cloth and Whatman No. 1 filter paper. The resulting aqueous garlic decoction was stored at 2–8°C until administration.

Experimental Animals

Healthy albino rats weighing between 150 and 220 g were obtained from Onyewuchi Farms, Ifite Awka, Nigeria. The animals were housed in clean polypropylene cages under standard laboratory conditions with a 12-hour light/dark cycle and allowed free access to commercial rat feed and clean drinking water. The animals were acclimatized for seven days before commencement of the experiment.

Experimental Design

A total of fifty-four albino rats were randomly assigned into nine groups of six animals each:

- Group A: Normal control
- Group B: Untreated infected control
- Group C: Garlic decoction (3.2 ml/kg)
- Group D: Garlic decoction (9.6 ml/kg)
- Group E: Standard drug (Amoxicillin, 27.14 mg/kg)

Only the garlic-treated groups (Groups E and F), untreated control (Group B), normal control (Group A), and standard drug group (Group I) are presented in this report.

Preparation of *Escherichia coli* Inoculum

A standard strain of *Escherichia coli* was obtained from the National Agency for Food and Drug Administration and Control (NAFDAC), Agulu, Anambra State, Nigeria. The organism was cultured in peptone water and incubated on a shaker for 48 hours. Bacterial concentration was determined using the McFarland turbidity standard. The stock suspension (7.2×10^9 CFU/ml) was diluted using the formula $C_1V_1 = C_2V_2$ to obtain a final concentration of 1×10^9 CFU/ml for experimental infection.

Infection of Experimental Animals and Treatment

Food poisoning was induced by oral administration of 0.5 ml of *E. coli* suspension containing 1×10^9 CFU/ml once daily for two consecutive days. Garlic decoction treatment commenced on the fourth day after infection and continued once daily for 14 consecutive days. Garlic was administered orally at doses of 3.2 ml/kg and 9.6 ml/kg body weight. The positive control group received amoxicillin at a dose of 27.14 mg/kg body weight, while untreated infected animals received distilled water.

Determination of Microbial Load

Fresh faecal samples were collected aseptically before treatment, immediately after treatment, and at the end of the treatment period. Stool samples were homogenized in sterile distilled water and serially diluted five-fold. Aliquots of the final dilution were cultured on CLED agar prepared according to the manufacturer's instructions. Plates were incubated under appropriate microbiological conditions, and bacterial colonies were enumerated as colony-forming units per millilitre (CFU/ml). All cultures were performed in triplicate, and the mean counts were recorded.

Culture Media Preparation

CLED agar was prepared according to the manufacturer's specifications. The prepared medium was sterilized by autoclaving, cooled to the recommended temperature, poured into sterile Petri dishes, and allowed to solidify before inoculation.

Acute Toxicity Study

Acute oral toxicity of the garlic decoction was evaluated using Lorke's method. Thirty-six albino rats were used in two phases. In the first phase, animals received doses of 10, 100, and 1000 mg/kg body weight. Since no mortality occurred, higher doses of 1600, 2900, and 5000 mg/kg were administered during the second phase. Animals were observed continuously during the first 24 hours and subsequently for 14 days for signs of toxicity, behavioural changes, and mortality.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 29. Results were expressed as mean ± standard deviation. One-way analysis of variance (ANOVA) was used to compare differences among groups, followed by the Games–Howell post hoc test for pairwise comparisons where appropriate. Student's *t*-test was used for selected comparisons. A *P*-value less than 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Results

Effect of Oral Administration of Garlic Decoction on *Escherichia coli* Counts in Experimentally Infected Albino Rats

Table 1: The Average Microbial Counts (× 5 Dilution) of E. coli Exposed to Garlic

Groups	Group 1	Group 2	Group 3	F value	P-value	1 vs 2 p-value	1 vs 3 p-value	2 vs 3 p-value
Normal control	NG	NG	0.00±0.00	-	-	-	-	-
3.2ml/kg of Garlic decoction	37.68 ± 7.10	10.48±5.21	0.00±0.00	57.7	0.000	0.7757	0.000	0.000
9.6ml/kg of Garlic decoction	35.59 ± 7.90	6.34±8.00	0.00±0.00	51.3	0.000	0.000	0.000	0.2405
Standard drug 27.14mg/kg	37.89± 9.80	0.00±0.00	0.00±0.00	89.7	0.000	0.000	0.000	NA
Untreated	35.74±11.14	36.67±10.14	66.67±10.93	16.1	0.0002	0.9877	0.0005	0.0006

Key:
Group 1 = E Coli count before treatment (CFU/ml)
Group 2 = Initial E. Coli count after treatment (CFU/ml)
Group 3 = Final E. coli count after treatment (CFU/ml)
NG = No growth
NA = Not Applicable

The antimicrobial effect of garlic decoction on E. coli is presented in Table1 below: Initially there were no significant differences in the bacterial counts among the infected groups since the bacterial isolates ranged from 35.59 ± 7.90 CFU/ml to 37.89 ± 9.80 CFU/ml signifying that all the animals were equally infected. As expected, the normal control group registered zero percent bacterial infection, an indication that the culture media was not contaminated.

There was a drastic reduction in the bacterial counts of the groups that were administered oral doses of 3.2 ml/kg and 9.6 ml/kg of the garlic decoction. The animals that were given 3.2 ml/kg of the decoction showed a drastic reduction from 37.68 ± 7.10 CFU/ml to 10.48 ± 5.21 CFU/ml immediately after treatment and finally cleared of the infection registering 0.00 ± 0.00 CFU/ml of E. coli at the final stage of the experiment ($F = 57.7$, $P < 0.001$). The other treated group that received 9.6 ml/kg of the decoction had a faster rate of decline of the bacterial count as compared to the group that received 3.2 ml/kg of the decoction. The bacterial count declined from 35.59 ± 7.90 CFU/ml to 6.34 ± 8.00 CFU/ml right after treatment and finally cleared from the system registering 0.00 ± 0.00 CFU/ml bacterial infection at the final stage of the experiment ($F = 51.3$, $P < 0.001$). The standard drug amoxicillin (27.14 mg/kg) cleared the infection immediately after treatment with no traces of E. coli infection recorded thereafter ($F = 89.7$, $P < 0.001$). The untreated infected control group registered an increase in the bacterial isolate from 35.74 ± 11.14 CFU/ml to 36.67 ± 10.14 CFU/ml immediately after observation commencing and eventually developed to 66.67 ± 10.93 CFU/ml of E. coli at the end of the experiment. This increase in bacterial count was significant statistically ($F = 16.1$, $P = 0.0002$); individual comparison revealed a significant difference in the bacterial count between the initial (before treatment) observation and the final observation ($P = 0.0005$), also significant difference was recorded between the initial observation and the observation right after treatment ($P = 0.0006$).

DISCUSSION

The current study revealed that the aqueous decoction of garlic has antimicrobial properties. The treatment groups showed decreased viable bacterial counts contrary to what was observed in the untreated infected control group. The evidence from this study suggests that oral administration of aqueous garlic decoction helps reduce E. coli infection in albino rats.

The significant decrease in the number of viable bacteria recorded in this study is an indication of the antibacterial effect of garlic decoction. Allicin is considered to be the most potent antibacterial among all the organosulfur compounds present in garlic. Allicin reacts readily with sulfhydryl enzymes which are required for metabolism in bacteria thereby inhibiting bacterial metabolism thus stopping proliferation right away. Ajoene found in garlic has also been reported to possess antibacterial property, other sulfur containing compounds such as diallyl disulfide and diallyl trisulfide have been reported to have antibacterial activity [7,8]. Moreover, the compound S-allyl cysteine found in garlic inhibits the production of nitric oxide thus counteracting the effects of bacterial infection. Additionally, garlic extract has been reported to inhibit adhesion of bacteria to cell surfaces and also inhibits biofilm formation which in turn reduces the chances of bacterial infection [9]. Therefore, it is safe to assume that the antibacterial properties of garlic contribute towards its antimicrobial effect.

The current study also shows that there is a dose dependent antibacterial effect of garlic decoction. Even though both treatment groups had similar percentage clearance in bacterial infection at the end of the experiment, the group that was administered a higher dose of the decoction registered faster rate of reduction in bacterial count as compared to the group that received a lower dose [10]. Although both doses of the decoction helped clear bacterial infection, it took a longer time for the lower dose (3.2 ml/kg) to clear the infection as compared to the higher dose (9.6 ml/kg). Therefore, we can conclude that higher doses of garlic decoction may help clear bacterial infection faster. There have been reports from experimental studies supporting that garlic possesses dose dependant antimicrobial activity. This property has been associated with many of the therapeutic effects of garlic.

The fact that the garlic decoction cleared the infection after prolonged administration indicates that the phytochemicals present in garlic might have played a role in helping the experimental animals combat E. coli infection [11]. This study supports the use of garlic as a therapeutic agent in the management of bacterial infections. Even though the standard antibiotic cleared the infection faster, it is likely that continual administration of the garlic decoction helps the body maintain a high level of the active phytochemicals needed for prolonged suppression of bacterial infection [12].

Unlike in the untreated control group, continual administration of the standard antibiotic ensured that bacterial count was drastically reduced from the very first observation. It is safe to assume that the continual administration of the standard antibiotic helped clear the infection immediately. However, after the initial observation following continual dosage of the standard antibiotic, bacterial infection dropped significantly from 35.59 ± 7.90 CFU/ml to 6.34 ± 8.00 CFU/ml. This suggests that although the standard antibiotic cleared the infection faster, its continual administration helped the body keep the bacterial count low and manageable. Although the standard antibiotic ensured quicker clearance, continual administration of garlic decoction was useful in suppressing the infection [13].

It is noteworthy that the untreated control group recorded a significant rise in the bacterial isolate as compared to the initial observation. This indicates that E. coli infection was present throughout the experimental period and it was able to multiply uninhibited registering 66.67 ± 10.93 CFU/ml at the end of the experiment. The observation indicates that E. coli infection was viable throughout the experiment and it was not spontaneously cleared following treatment as expected in the case of a bacterial infection [14]. This observation coincides with the results recorded from untreated experimental models.

The antimicrobial effect demonstrated by the garlic decoction may also be attributed to the antioxidant properties of garlic. This study highlights only the antibacterial property of garlic decoction; however, there is evidence linking antioxidant activity of garlic to the antimicrobial effect it demonstrated. Allicin, ajoene, diallyl disulfide and other sulfur containing compounds present in garlic possess antioxidant properties [15]. Moreover, other bioactive compounds present in garlic enhance the action of the antioxidant compounds. The antioxidant compounds present in garlic help in enhancing the immune response to infections by scavenging free radicals produced in the body as a result of E. coli infection. Therefore, not only does garlic possess antimicrobial properties, but it also possesses antioxidant properties that contribute towards its antibacterial property [16].

This study provides empirical evidence supporting the use of medicinal plants as effective antimicrobial agents. The current study demonstrates that the aqueous decoction of garlic possesses antimicrobial activity against E. coli infection. The study also supports the use of garlic as a treatment for bacterial infection. Given the fact that garlic has antimicrobial activity and given the fact that multidrug resistant bacterial strains are becoming alarming, a call for more studies exploring the antimicrobial activity of other medicinal plants is paramount [17].

Although the results of this study are quite encouraging, there are some limitations associated with this study. First and foremost, the effect of garlic decoction on E. coli infected albino rats was only demonstrated by comparing the bacterial counts among the various groups. No histopathological examination was done to determine how effective the decoction was in combating the effects of bacterial infection. Additionally, the study does not provide any information regarding the mechanism by which the decoction exerts its antimicrobial effect. Furthermore, this study only provides evidence of the antimicrobial effect of the decoction as a whole. There is need to isolate and examine the effect of individual constituents in the decoction [18]. Finally, the study does not provide evidence regarding the pharmacological aspects of the decoction.

Even though the results of this study clearly show that garlic decoction possesses antimicrobial activity against E. coli infection in albino rats, there is need for more research to establish the exact mechanism by which the decoction exert its antimicrobial effect. The study also needs to be extended to examine the effect of the garlic decoction in other animal models.

CONCLUSION

The present study showed that the oral administration of aqueous decoction of garlic (Allium sativum) has antimicrobial effect against E. coli infection in albino rats. The treatment groups showed significant bacterial clearance compared to the untreated control group. The standard antibiotic cleared the infection faster than the garlic decoction. The fact that the garlic decoction cleared the infection at the end of the treatment period indicates that it has antimicrobial activity against E. The study also suggests that there is a dose dependent antimicrobial effect of garlic decoction on E. It is worthy of note that the antibacterial activity of garlic decoction may be due to the presence of allicin and ajoene which inhibit bacterial protein synthesis.

The antimicrobial effect demonstrated by this study provides evidence supporting the use of garlic in the treatment of bacterial infections. Further research exploring the antimicrobial activity of other medicinal plants is warranted.

REFERENCES

1. Batiha GE, Beshbishy AM, Wasef LG, Elewa YHA, Al-Sagan AA, Abd El-Hack ME, Chemical constituents and pharmacological activities of garlic (*Allium sativum* L.): A review. Nutrients. 2020;12(3):872.
2. Ofokansi, K.C., Mbanefo, A.N., Ofokinsi, M. N., Esimone, C.O. "Antibacterial interaction of crude methanol extract of Garcinia kola seed with gatifloxacin." Troical. Journal Pharmaceutical Resources 2018:7(4): 1159-1165.
3. Ogunmoyole, T., Olalekan, O.O., Fatai, O., Makun, J. O and Kade, I.J. (2012), Antioxidant and phytochemical profile of aqueous and ethanolic extract of Garcinia kola. Journal of Pharmacognosy and Phytotherapy 2012:4(5):66-74.
4. Farombi, E.O. and Owoeye, O. (). Antioxidative and Chemopreventive Properties of Vernonia amygdalina and Garcinia biflavonoid. International Journal for Environmental Research and Public Health, 2017:8(6), 2533–2555
5. Chong PP, Chin VK, Wong WF, Madhavan P, Yong VC, Looi CY. Review: Antimicrobial properties of allicin used alone or in combination with other medications. Folia Microbiol (Praha). 2020;65:451–65.
6. Silpa, D., & Kumar, G. K. (2025). Bio production of Indole 3-Acetic Acid by Bacillus pumilus DS5 isolated from agricultural field soils of Andhra Pradesh. *IOASD Journal of Medical and Pharmaceutical Sciences*, *2*(1), 27-32.
7. World Health Organization. Global antimicrobial resistance and use surveillance system (GLASS) report. Geneva: WHO; 2023.
8. Said, M. D., Albakoush, A. M., & Azab, A. E. (2025). Assessment of Detection of Helicobacter pylori by Using the Stool Antigen and Blood Antibody Tests among Patients with Upper Gastrointestinal Disorders in Western Libya. *IOASD Journal of Medical and Pharmaceutical Sciences*, *2*(2), 64-71.
9. Tauchen, J, Huml L, Rimpelova S, Jurášek MFlavonoids and related members of the aromatic polyketide group in human health and disease: do they really work? Molecules 2020:25:25173846.
10. Zecconi, A and Scali, F., (2021), Staphylococcus aureus virulence factors in evasion from innate immune defenses in human and animal diseases, Immunology Letters 150:12-22.
11. Harborne JB. Phytochemical Methods. 3rd ed. London: Chapman & Hall; 1998.
12. Sofowora A. Medicinal Plants and Traditional Medicine in Africa. 3rd ed. Ibadan: Spectrum Books; 2008.
13. Gupta, M. (2025). Reflection of Bloom's Taxonomy in the Learning Outcomes of B. Ed. Syllabus of Agriculture science in Jagannath University. *IOASD Journal of Medical and Pharmaceutical Sciences*, *2*(1), 35-37.
14. Cheesbrough M. District Laboratory Practice in Tropical Countries. 2nd ed. Cambridge: Cambridge University Press; 2006.
15. Murray PR, Rosenthal KS, Pfaller MA. Medical Microbiology. 9th ed. Philadelphia: Elsevier; 2020. Uko, O.J., Usman A.M., and Ataja A.M. (2020) "Some biological activities of *Garcinia kola* in growing rats." *Veterinarski Arhiy*, 71, 287-297
16. Egoro, E. T., Musa, A. S., & Ilegbedion, I. G. (2024). Status of some Toxic Heavy Metals, Oxidative Stress and Inflammatory Biomarkers Among Petty Traders in Swali Market Yenagoa Bayelsa State Nigeria. *IOASD Journal of Medical and Pharmaceutical Sciences*, *1*(1), 28-33.
17. Warra, A.A., R.A. Umar, F.A. Atiku, A. Nasiru and M.K. Gafar. (2021). Physical and phytochemical characteristics of seed oils from selected cultivars grown in northern Nigeria.Research and Reviews: Journal of Agriculture and Allied Sciences, vol 1, no 1, pp. 4-8.
18. Nwaneri-Chidozie VO, Anyanwu OA, Adaramoye OA, Emerole O (2020). Cardio-protective effect of Kolavion (Garcinia kola seed extract) in cholesterol fed rats. International Journal of Pharmaceutical Science 5(3): 96-99.