BACTERIAL FLORA OF COCKROACH NYMPH FED GARLIC (*ALLIUM SATIVUM*) POWDER

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ABSTRACT

The increased cost of fishmeal in compounding fish feed has prompted the use of cheaper and readily accessible animal protein (insect protein). The effects of garlic powder supplement in diets fed to the 3rd nymphal stages of Blattodea germanica and Supella longipalpa on bacterial activities were studied. Adult cockroaches with eggs were collected from Lapai town and reared under laboratory conditions for 10 weeks. The nymphs were stocked in groups of 50 nymphs each per replication in plastic containers. The cockroaches were fed formulated diets; A (Diet D plus 0.1 g garlic meal); B (Diet D plus 0.2 g garlic meal), C(Diet D plus 0.3 g garlic meal); D (experimental control; carrot, lettuce, milk, sorghum, flour and yeast); E (standard control; cabin biscuit)) during the study period. At the end of the experiment, cockroaches were sacrificed and assay for the bacterial population on the external body surface and in the gut. The bacteria load on the body surface of B. germanica ranged from 4.77 ± 0.15 to 9.50 ± 0.25 CFU/ml, while bacterial load in the gut ranged from 5.57 ± 0.29 to 9.80 ± 0.06 CFU/ml. Similarly, bacterial load in S. longipalpa ranged from 4.53 ± 0.32 to 9.57 ± 0.28 CFU/ml, while those of the gut ranged from 5.70 ± 0.25 to 9.33 ± 0.15 CFU/ml. Isolates identified include; Escherichia coli, Klebsiella spp., Pseudomonas aeruginosa, Proteus spp., Bacillus spp., Streptococcus spp., Salmonella spp., Shigella spp. and Staphylococcus aureus. This study supports the use of garlic as an effective antibacterial agent.

Keywords: Insect protein meal, *Blattodea germanica*, *Supella longipalpa,* Garlic meal, Bacterial isolates

INTRODUCTION

Cockroaches are omnivorous insects which feed indiscriminately on garbage and sewage and also have copious opportunity to transmit human pathogens when they come across food substances (Pai *et al.*, 2005). There are approximately 4,600 species of cockroaches worldwide and 50 species of them have been reported living in or around homes (Kinfua and Erkob, 2008; Memona *et al.,* 2017). Their nocturnal and filthy habits have made them to be ideal carriers of several pathogenic micro-organisms and in the process contaminate food by leaving droppings and bacteria that may be detrimental to human health. Numerous pathogenic bacteria have been isolated from cockroaches which include; *Salmonella* spp., *Pseudomonas aeruginosa*, *Shigella* spp., *Campylobacter* spp. and *Klebsiella pneumoniae* and these insects greatly contribute to food borne disease outbreaks (Cotton *et al.*, 2000).

The German cockroach *Blattodea germanica* Linnaeus, 1767 (Blattodea: Ectobiidae) is by far the most serious and predominant cosmopolitan pest in the world due to changes in human travel, commerce and the urban environment. They can contaminate food with bacterial pathogens that may result in dysentery, food poisoning and diarrhea (Solomon *et al.*, 2016; Donkor, 2020). The brown-banded cockroach *Supella longipalpa* Fabricius, 1798 (Blattodea: Ectobiidae) on the other hand are usually found in drier parts of the house and are capable of harbouring and transmitting bacteria of different species in and around the home premises (Mosayebian *et al.*, 2017).

During the last few decades, the global interest in the study of various medicinal plants has increased rapidly due to their antibacterial and antioxidant activities. Plants such as oregano, mint, thyme, clove, cinnamon and garlic have been employed for centuries as either food preservative or as medicinal plants mainly due to their antioxidant and antimicrobial properties. Also, their use in nutrition is considered a health improvement factor due to their medicinal properties (Naimushina *et al.*, 2014)

Thus, with the comparative advantage of cockroach as protein source with high quality values of nutritional and amino acid profiles (Adamu *et al.*, 2021), the need to use natural products with antibacterial, antifungal and antimicrobial active ingredients to reduce or eliminate the associated pathogen becomes necessary. Garlic - *Allium sativum* Linnaeus (Asparagales: Amaryllidaceae) in particular has attracted serious attention due to its potent antimicrobial activity. Some bioactive compounds within these plants are responsible for their medicinal value. The most prominent of these bioactive compounds in garlic are alkaloids, tannins, flavonoids, phenolic compounds, allicin, alliin, diallyl sulfide, diallyl disulfide, diallyl trisulfide, ajoene and S-allyl-cysteine among many others (Shang *et al.*, 2019; El-Saber Batiha *et al.*, 2020). Their concentration may vary in different garlic species which result in unique medicinal properties for a specific plant species. Garlic has a few advantages for both humans and animals as it bioactive compounds exhibits antioxidant, anti-inflammatory, immunomodulatory, antibacterial, antifungal, cardiovascular protective, anticancer, hepatoprotective, digestive system protective, neuroprotective, anti-diabetic, anti-obesity, and renal protective properties (Shang *et al.*, 2019; El-Saber Batiha *et al.*, 2020). The repellent activities of different medicinal plants have been reported on cockroaches (Rejitha *et al.*, 2014; Soonwera *et al.*, 2022). However, limited literatures are reported on the effects of garlic on the bacteria composition of cockroaches.

This study thus investigated the effects of garlic powder as supplement in the diets fed to the nymphal stages of *B. germanica* and *S. longipalpa* on bacterial composition.

MATERIALS AND METHODS

The study was carried out at the Insectary of the Department of Biological Sciences, Ibrahim Badamasi Babangida University, Lapai, Niger State. Located within latitude 9°02′ N and longitude 6°34′ E. Adult cockroaches with eggs (*Blattodea germanica* and *Supella longipalpa*) were collected physically from housing apartments (kitchen and cupboards) within Lapai town. Cockroaches were identified to species level using standard taxonomic entomological keys based on the morphological characteristics (Hathorne and Zungoli, 1999; Choate *et al.*, 2000). Voucher specimens of the cockroaches (*B. germanica* IBBUA230404 and *S. longipalpa* IBBUA230405) were kept in the departmental museum for referral purposes. The cockroaches were captured by handpicking and use of brooms and placed in plastic containers (15 × 20 cm^2). The containers were covered with net held in place with a rubber band to prevent escape of cockroaches. Egg cartons were placed in each container to provide shelter and harbourage. Cockroaches were fed biscuits and water for a period of 10 weeks. Newly emerged nymphs were carefully sorted into 50 nymphs per setup and separated at the 3rd nymphal stage prior to the start of the experiment.

The experiment was laid down using completely randomised design of four treatments replicated five times with each replicate having ten nymphs.

All ingredients which include; carrot, lettuce, milk powder sorghum flour, yeast and garlic bulbs were locally purchased from Lapai market. Garlic powder was prepared by peeling, drying and crushing into powder as described by Rahman *et al*. (2009). All other ingredients were also dried and ground into powdered. Four diets were formulated following the methods of Mohamed *et al*. (2014) using a ratio of 1:1:2:10:1 for carrot, lettuce, milk, sorghum flour and yeast. This Diet called Diet D serve as the control diet. The diets were formulated with a 0.1, 0.2, 0.3 and 0 g inclusion level of garlic powder. Diet A contained Diet D with 0.1 g garlic powder, Diet B contained Diet D with 0.2 g garlic powder, Diet C contained Diet D with 0.3 g garlic powder, Diet D (experimental control diet contains 0 g garlic powder). A fifth diet, Diet E (cabin biscuit, a standard diet) was equally tested. Cockroaches were fed the various diets according to their treatments and at the end of the four months study period (May 4th 2020 – August 3rd 2020), bacteriological analyses were carried out.

Four cockroaches per replicate were randomly collected for the external bacteria assay and anesthetized with chloroform fumes in a desiccator. Each cockroach was then placed in a beaker and rinsed in 0.9% normal sterile saline for three minutes. The digestive organ of each cockroach was dissected and was prepared in a homogenous suspension of 5 ml nutrient agar in order to assay for the internal bacterial flora. Appropriate serial dilutions were performed in seven folds with sterile distilled water to determine the microbial load of the samples. Nutrient Agar (L.S. Biotech), MacConkey Agar (L.S. Biotech), Salmonella-shigella Agar (T.M. Media) and Eosin methylene blue Agar (Sisco Research Laboratory) media were prepared according to the manufacturer's instructions. Aliquots of 0.1 ml of serial dilutions were cultured using pour plate technique on the media in order to determine the total viable counts. The plates were then inverted to prevent condensation, droppings from the lid of the plate onto surface of the agar and incubated at 37^{0}C for 24 hours. The total viable colony were counted and expressed as colony forming unit per ml (CFU/ml). Culture was conducted with the media and the discrete colonies were inoculated onto another appropriate media to have a pure isolate, which were further transferred into Nutrient Agar slant bottles and were stored at 4^{o}C for further microbiological identification (Cheesbourgh, 2002).

Data obtained were analyzed using one-way analysis of variance (ANOVA). The abundance of bacteria isolates were expressed in percentage using MS Excel 2010. Individual means were compared using Bonferroni multiple comparison test. Differences were considered statistically significant at $p<0.05$. All statistical analysis was performed using GraphPad prism version 5.0 software.

RESULTS

The total bacterial counts on the external body surface of *B. germanica* ranged from 4.77 ± 0.15 to 9.50 ± 0.25, while the gut ranged from 5.57 ± 0.29 to 9.80 ± 0.06 CFU/ml (Table 1).

Table 1: Bacterial count on the external body surface and gut of *Blattodea germanica* fed garlic meal

Diets	Sampling Sites (CFU/ml×10^5)	
	External body surface	Gut
A	6.50 ± 1.15^b	8.06 ± 0.58^c
B	4.77 ± 0.15^a	5.57 ± 0.29^a
C	7.20 ± 0.47^c	7.23 ± 0.72^b
D	8.90 ± 0.49^d	9.73 ± 0.12^d
E	9.50 ± 0.25^e	9.80 ± 0.06^d

A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit). Means with different superscript on the column are significantly different at p<0.05

The external body surface revealed the highest bacteria count for Diet E, while the least was recorded for Diet B. It was also noted that there were significant differences ($p<0.05$) in the bacterial count on the external body surface of cockroach fed Diet B when compared with those fed Diet D. The gut samples revealed the highest bacterial count in the cockroaches fed Diet E, while the least was observed in cockroaches fed Diets B. However, the samples revealed significant differences ($p<0.05$) in cockroach fed Diet B when compared with the control diets.

Similarly, bacterial counts on the external body surface of *S. longipalpa* ranged from 4.53 ± 0.32 to 9.57 ± 0.28 CFU/ml, while the gut ranged from 5.70 ± 0.25 to 9.33 ± 0.15 CFU/ml (Table 2).

Table 2: Bacterial count on the external body surface and gut of *Supella longipalpa* fed garlic meal

Diets	Sampling Sites (CFU/ $\times 10^5$)	
	External body surface	Gut
A	6.37 ± 1.03^b	7.73 ± 0.98^b
B	4.53 ± 0.32^a	5.70 ± 0.25^a
C	6.77 ± 0.39^b	7.17 ± 0.44^b
D	9.20 ± 0.12^c	9.33 ± 0.15^c
E	9.57 ± 0.28^c	9.17 ± 0.09^c

A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit). Means with different superscript on the column are significantly different at p<0.05

The external body surface recorded its highest bacterial count in the cockroaches fed Diet D. while the least was observed in the cockroaches fed Diet B. Similarly, there were significant differences ($p<0.05$) in the bacterial count on the external body surface of cockroaches fed diets A, B and C when compared with Diet D. The gut samples revealed highest bacterial count in cockroaches fed Diet D, while the least bacterial count was observed in cockroaches fed Diet B. However, significant differences ($p<0.05$) were observed in cockroaches fed Diets B and C when compared with the control and standard diets.

The distribution of bacteria isolates on the external body surface and gut of *B. germanica* shown in Tables 3 and 4 indicated that *Escherichia coli*, *Proteus* spp. and *Salmonella* spp. were slightly present in all sampled cockroaches fed garlic meal. *P. aeruginosa* was present in Diet B and absent in Diets A and C. *Shigella* spp. was absent in Diets A and B but present in Diet C. however, *Streptococcus* spp., *Bacillus* spp. and *Staphylococcus aureus* was completely absent in all diets containing garlic meal. The gut contents revealed that *E. coli, Klebsiella* spp. and *Salmonella* spp. was present in almost all samples containing garlic meal. *Streptococcus* spp. was present only in Diets A and C, but was absent in Diet B, *Proteus* spp. on the other hand was absent in Diet A, but present in Diets B and C. *P. aeruginosa* and *Shigella* spp. was present only in Diet A but absent in Diets B and C, while *Bacillus* spp. and *S. aureus* were completely absent in all diets containing garlic meal.

The distribution of bacterial isolates on the external body surface and gut of *S. longipalpa* shown in Tables 5 and 6 indicated that *E. coli* and *Salmonella* spp. were present in all samples containing garlic meal. *Klebsiella* spp. was present in Diets B and C, but absent in Diet A. *P. aeruginosa* and *S. aureus* were present in Diets A and C, but absent in Diet B. *Bacillus* spp. was present in Diets A and B, but absent in Diet C, while *Streptococcus* spp., *Proteus* spp. and *Shigella* spp. were completely absent in all diets containing garlic meal. The gut content revealed that *E. coli, Proteus* spp. and *Salmonella* spp. were present in almost all samples containing garlic meal. *P. aeruginosa* was present in Diets A and B, but absent in Diet C. *S. aureus* was present in Diets A and C, but absent in Diet B, while *Streptococcus* spp., *Klebsiella* spp., *Shigella* spp. and *Bacillus* spp. were completely absent in all samples containing garlic meal.

Nine bacterial isolates were isolated from the external body surface of both species as shown in Figure 1. It was observed that the occurrence of *E. coli, P. aeruginosa, Proteus* spp., *Salmonella* spp. and *Shigella* spp. were higher on the body surface of *B. germanica* than on the body surface of *S. longipalpa*. The highest isolate in abundance on the body surface of both species was *E. coli* (22.92 and 23.81%), followed by isolates of *Salmonella* spp. (25.00 and 21.43%). The least encountered organism on the body surface of *B. germanica* was *S. aureus* with 2.08% and the least on the body surface of *S. longipalpa* was *Proteus* spp. (2.38%). Similarly, nine bacterial isolates were also isolated in the gut of both species as shown in Figure 2. The occurrence of *Klebsiella* spp., *Proteus* spp., *Shigella* spp., *Streptococcus* spp. and *Bacillus* spp. were higher in the gut of *B. germanica* than in the gut of *S. longipalpa*. The highest isolate in abundance in the gut of both species was *Salmonella* spp. (22.92 and 28.95%), followed by isolates of *E. coli* (20.83 and 26.32%).

Table 3: Bacteria isolates on the external body surface of *Blattodea germanica* fed garlic meal

Diets	Media	Bacteria isolates on the external body surface of *Blattodea germanica*								
		Escherichia coli	*Streptococcus* spp.	*Klebsiella* spp.	*Proteus* spp.	*Pseudomonas aeruginosa*	*Salmonella* spp.	*Shigella* spp.	*Bacillus* spp.	*Staphylococcus aureus*
A	NA	+	-	+	-	-	-	-	-	-
	MAC	+	-	+	+	-	-	-	-	-
	EMB	+	-	-	+	-	+	-	-	-
	SS	-	-	-	-	-	+	-	-	-
B	NA	+	-	-	-	+	-	-	-	-
	MAC	-	-	-	-	+	+	-	-	-
	EMB	-	-	+	+	-	-	-	-	-
	SS	-	-	-	-	-	+	+	-	-
C	NA	-	-	-	+	-	+	-	-	-
	MAC	+	-	-	-	-	+	+	-	-
	EMB	+	-	+	-	-	-	-	-	-
	SS	-	-	-	-	-	+	-	-	-
D	NA	+	-	+	-	+	-	-	-	-
	MAC	+	-	-	+	-	+	-	-	-
	EMB	-	+	-	-	-	+	-	+	-
	SS	-	-	-	-	-	+	+	-	-
E	NA	-	-	-	+	+	-	-	-	+
	MAC	+	-	-	+	-	+	-	-	-
	EMB	+	+	-	-	-	-	-	+	-
	SS	-	-	-	-	-	+	+	-	-

Key: *A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit), NA = Nutrient agar, Mac-Agar = MacConkey agar, EMB agar, SS = Salmonella-Shigella agar, + = present, - = absent*

Table 4: Bacteria isolates in the gut of *Blattodea germanica* fed garlic meal

Diets	Media	Bacteria isolates in the gut of *Blattodea germanica*								
		Escherichia coli	*Streptococcus* spp.	*Klebsiella* spp.	*Proteus* spp.	*Pseudomonas aeruginosa*	*Salmonella* spp.	*Shigella* spp.	*Bacillus* spp.	*Staphylococcus aureus*
A	NA	+	+	+	-	-	-	-	-	-
	MAC	+	-	-	-	+	-	-	-	-
	EMB	+	+	-	-	-	-	-	-	-
	SS	-	-	-	-	-	+	+	-	-
B	NA	+	-	-	+	-	-	-	-	-
	MAC	+	-	+	-	-	+	-	-	-
	EMB	+	-	-	+	-	+	-	-	-
	SS	-	-	-	-	-	+	-	-	-
C	NA	-	+	+	-	-	-	-	-	-
	MAC	-	-	-	+	-	+	-	-	-
	EMB	+	+	-	-	-	-	-	-	-
	SS	-	-	-	-	-	+	-	-	-
D	NA	+	+	-	-	+	-	-	-	-
	MAC	-	-	+	-	-	-	+	+	-
	EMB	+	-	-	+	-	+	-	-	-
	SS	-	-	-	-	-	+	+	-	-
E	NA	-	-	+	-	-	-	-	+	+

	MAC	+	-	-	+	+	-	-	-	-
	EMB	-	+	-	+	-	+	-	-	-
	SS	-	-	-	-	-	+	+	-	-

***Key:** A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit), NA = Nutrient agar, Mac-Agar = MacConkey agar, EMB agar, SS = Salmonella-Shigella agar, + = present, - = absent*

Table 5: Bacteria isolates on the external body surface of *Supella longipalpa fed* garlic meal

Diets	Media	Bacteria isolates on the body surface of *Supella longipalpa*								
		Escherichia coli	*Streptococcus* spp.	*Klebsiella* spp.	*Proteus* spp.	*Pseudomonas aeruginosa*	*Salmonella* spp.	*Shigella* spp.	*Bacillus* spp.	*Staphylococcus aureus*
A	NA	+	-	-	-	-	-	-	-	+
	MAC	+	-	-	-	+	-	-	-	-
	EMB	-	-	-	-	-	+	-	+	-
	SS	-	-	-	-	-	+	-	-	-
B	NA	-	-	+	-	-	+	-	-	-
	MAC	+	-	-	-	-	+	-	+	-
	EMB	+	-	-	-	-	-	-	+	-
	SS	-	-	-	-	-	+	-	-	-
C	NA	-	-	+	-	-	-	-	-	+
	MAC	+	-	-	-	+	-	-	-	-
	EMB	+	-	-	-	-	+	-	-	-
	SS	-	-	-	-	-	-	-	-	-
D	NA	+	-	+	-	-	-	-	-	+
	MAC	+	-	-	-	+	-	-	+	-
	EMB	-	-	-	-	-	+	-	+	-
	SS	-	-	-	-	-	+	+	-	-
E	NA	-	+	+	-	-	-	-	-	+
	MAC	+	-	-	-	+	-	-	+	-
	EMB	+	+	-	+	-	-	-	-	-
	SS	-	-	-	-	-	+	+	-	-

***Key:** A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit), NA = Nutrient agar, Mac-Agar = MacConkey agar, EMB agar, SS = Salmonella-Shigella agar, + = present, - = absent*

Table 6: Bacteria isolates in the gut of *Supella longipalpa* fed garlic meal

Diets	Media	Bacteria isolates in the gut of *Supella longipalpa*								
		Escherichia coli	*Streptococcus* spp.	*Klebsiella* spp.	*Proteus* spp.	*Pseudomonas aeruginosa*	*Salmonella* spp.	*Shigella* spp.	*Bacillus* spp.	*Staphylococcus aureus*
A	NA	+	-	-	-	-	-	-	-	+
	MAC	+	-	-	-	+	-	-	-	-
	EMB	+	-	-	+	-	-	-	-	-
	SS	-	-	-	-	-	+	-	-	-
B	NA	+	-	-	-	+	+	-	-	-
	MAC	-	-	-	+	-	+	-	-	-
	EMB	-	-	-	+	-	+	-	-	-
	SS	-	-	-	-	-	+	-	-	-
C	NA	-	-	-	-	-	-	-	-	+
	MAC	+	-	-	+	-	-	-	-	-

	EMB	+	-	-	-	-	+	-	-	-
	SS	-	-	-	-	-	-	-	-	-
D	NA	+	+	-	-	-	-	-	-	+
	MAC	-	-	-	+	+	+	-	-	-
	EMB	+	-	-	-	-	+	-	-	-
	SS	-	-	-	-	-	+	-	-	-
E	NA	+	+	+	-	-	-	-	-	-
	MAC	-	-	-	-	+	-	-	+	-
	EMB	+	+	-	-	-	-	-	-	-
	SS	-	-	-	-	-	+	+	-	-

Key: *A (Diet D with 0.1 g garlic meal); B (Diet D with 0.2 g garlic meal), C ((Diet D with 0.3 g garlic meal); D (carrot, lettuce, milk, sorghum, flour and yeast (1:1:2:10:1)); E (cabin biscuit), NA = Nutrient agar, Mac-Agar = MacConkey agar, EMB agar, SS = Salmonella-Shigella agar, + = present, - = absent*

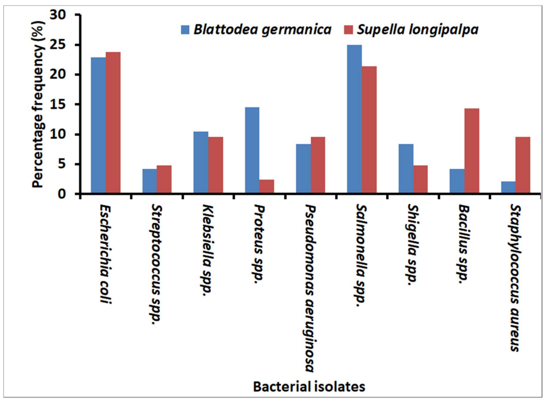

Figure 1: Bacteria isolates on the external body surface of *Blattodea germanica* and *Supella longipalpa*

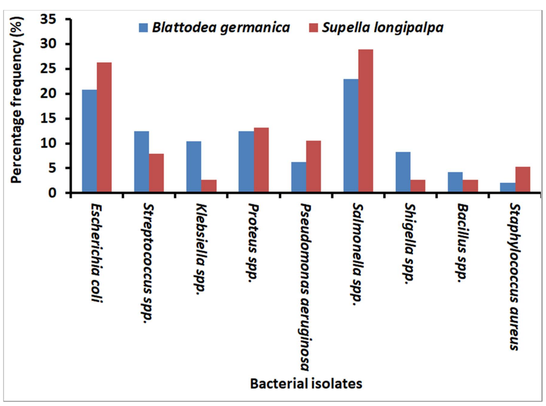

Figure 2: Bacteria isolates on the gut of *Blattodea germanica* and *Supella longipalpa*

The least encountered organism in the gut of *B. germanica* was *S. aureus* (2.08%) and the least encountered bacteria species in the gut of *S. longipalpa* were *Klebsiella* spp., *Shigella* spp. and *Bacillus* spp. (2.63%).

DISCUSSION

The bacterial load on the external body surface and gut of *B. germanica* revealed bacterial total counts which were lower than the findings of Paul *et al.* (1992) who reported bacterial counts of 1.35×10^8, 5.99×10^7 and 1.64×10^8 CFU/ml for *B. germanica*. Also, the total microbial counts enumerated from all sampled *S. longipalpa* fed diets containing garlic were below the counts reported by Prescott *et al.* (2008) who signified that any total count above 1.0×106 CFU/ml is a microbial count capable of causing diseases in humans.

Nine species of bacteria were isolated from the body surface and gut of both species. Amongst them include; *Salmonella* spp., *Shigella* spp., *Bacillus* spp., *Proteus* spp., *P. aeruginosa*, *Klebsiella* spp., *S. aureus* and *Streptococcus* spp. which have been earlier reported by Akinjogunla *et al.* (2012) in *Periplaneta americana* and *Blattella germanica* from Uyo, Akwa Ibom State. The occurrence of bacterial isolates on the body surface of *B. germanica* was higher than those reported in the gut which was in agreement with the reports of Makumana (2018) who stated that in cockroaches, bacteria can be easily transferred through contact than through food habits.

The predominant bacteria isolated from the body surface and guts of both species were *E. coli* and *Salmonella* spp. which are similar to the findings of previous researchers (Rivault *et al.*, 1993; Mpuchane *et al.*, 2005; Pai *et al.*, 2005). The presence of *Salmonella* spp. and *E. coli* in samples usually indicates faecal contamination which could cause serious foodborne disease outbreaks; however, most strains of *E. coli* are known to be harmless (WHO, 2018). According to Fotedar *et al.* (1991), the most frequently identified bacterial species from cockroaches are Gram-negative bacilli, in the family Enterobacteriaceae. In agreement with Fotedar *et al*. (1991), four different species of bacteria were isolated belonging to the family Enterobacteriaceae (*Klebsiella* spp., *Proteus* spp., *Salmonella* spp. and *E. coli*) in this study.

Higher repellency has been recorded with highest repellency concentrations of 1.0, 1.5 and 2.0 g of garlic powder as reported by Rejitha *et al*. (2014), which differs from the findings of the present study as the cockroaches were able to feed on the diets due to the lower inclusion of garlic powder. Garlic has been shown to inhibit the growth of several pathogenic bacteria such as *B. cereus*, *S. aureus*, *S. typhi* and *E. coli* (Eltaweel, 2014). The inclusion of garlic at 0.1 g inhibited the growth of pathogenic bacteria such as *Klebsiella* spp., *P. aeruginosa*, *Shigella* spp., *Bacillus* spp. and *S. aureus*. *P. aeruginosa* is an opportunistic human pathogen with increasing medical and veterinary importance. It is marked by its great resistance to antimicrobials and antiseptics and the presence of multiple virulence factors (Moradali *et al*., 2017*). Klebsiella* spp. on the other hand is known to be opportunistic pathogen that colonizes mucosal surfaces without causing diseases. However, from mucosa, *Klebsiella* may disseminate to other tissues causing life threatening infections including pneumonia, blood stream infections and urinary tract infections (Paczosa and Mecsas, 2016).The inhibition of the growth of *S. aureus* was similar to the findings of Abiy and Berhe (2016). Similarly, the inclusion of garlic in the cockroach's diet inhibited the growth of *S. aureus* and *B. cereus*. *Bacillus* spp. is known to cause numerous infectious diseases such as bacteremia, abscesses, wound and food borne infections, ophthalmitis, endocarditis, ear infections, meningitis, peritonitis, respiratory and urinary infections and osteomyelitis (Adamu *et al*., 2020). However, minimum inhibition was observed in *E. coli* as well as in *Salmonella* spp. in the gut and body surface. Studies have revealed that the antimicrobial activity of garlic is totally dependent on the allicin compound which is three times more effective on Gram-positive bacteria than Gram-negative ones. It was also revealed that only cockroaches fed 0.1 g concentration of garlic meal was positive for the bacteria *P. aeruginosa* which differs with the findings of Knockgether *et al*. (2011).

Conclusion: The presence of cockroaches in homes compromises food safety and quality and should be taken into consideration. Studies have shown that common bacteria pathogen isolated from cockroaches are often antibiotic resistant. However, the results obtained in the present study are quite encouraging as the inclusion of garlic in diets of these insects exhibited antibacterial activity against certain pathogens. It can therefore be concluded that the inclusions of garlic at lower concentrations were more effective than when used at higher concentration.

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