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Specialization of Periplaneta Americana (American Cockroach) and Blattella Germanica (German cockroach) Towards Intestinal Parasites: A Public Health Concern

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Abstract: *Disturbed with the increasing number of Cockroaches within Jos metropolis and blessed from the benefit of hindsight that they could serve as mechanical host to various parasites, thus lead leading to undocumented sources of infection; a study was carried out to ascertain the various types of Cockroaches available in two most polluted areas of Jos. Other objectives considered were to identify the various pathogens fauna on both external and internal parts; to determine whether parasites composition were mainly influenced by phylogenetic, evolutionary or by ecological relationships; to determine which species of Cockroaches is more susceptible to parasitic infection; to determine the specific part of the alimentary canal that harbours the highest concentration of parasites load and to recommend where possible the best method for the control of Cockroaches. To achieve these objectives; insects traps were placed at five different locations (kitchens, toilets, living rooms, refuse dumps and shops). Two species of Cockroaches were encountered at point of collections. Of the total of four hundred and twenty three Cockroaches caught, 308(72.81%) were Periplaneta Americana while 115(27.9%) were Blattella germanica. External and internal parts were prone to parasites load and three hundred and sixteen of the Cockroaches (94-B. Germanica: 222-P. Americana) were found to be infected with either a single, dual or multiple types of parasites which were mainly internal parasites of either Nematodes, Cestodes or Protozoans. A grand total showed that the hindgut of the two species of Cockroaches harboured more parasites than the other chosen parts of study. Statistical analysis indicated that there was a significant difference ($P<0.05$) between the two species of Cockroaches in the harbour of parasites; internal organs and types of intestinal parasites. Interplay of ecology, evolution and phylogeny relationships was found to be of utmost important in the accumulation of pathogens fauna by the two species of Cockroaches. Overall, the harbouring of the intestinal parasites by the two species of Cockroaches and their availability within vincinity of utmost human importance calls for serious concern to public health. Drastic measures would therefore be needed to curb the rapid increase of Cockroaches especially, around homes and places of human activities to forestall undocumented sources of human infection.*

Keywords: *Cockroaches (Ecological, Evolutionary and Phylogenetic relationships), Parasites load, Public health.*

I. Introduction

Cockroaches have been reported to have a cosmopolitan distribution. Their ability to spread worldwide and invade range of habitations is attributed to among others: breed all year round, operate in all crepuscular conditions, adapt to all climatic conditions and majorly due to global commerce (Young 1937; Ajayi et. al., 2011; Bell and Adiyodi 1981). Although omnivorous in nature (Bennett 1993; Jacobs 2012), they have been referred to as non-obnoxious biting insects (Piper and Antonelli 2012).

The synanthropic nature of some of the species of Cockroaches which culminate in the transmission of various types of diseases recorded in humans has ignited the debate as to whether to completely classify Cockroaches as vectors (Bracke et. al., 1990; Fotedar et. al., 1989; Graczyket et. al., 2005; Lemos et. al., 2006; Salehzadeh et. al., 2007), as evident in their harbouring of bacteria, fungi, viruses and parasites or as mechanically or occasionally transmitters of diseases (Etim et. al., 2013; Ajayi et. al., 2011). In several studies, Cockroaches have been noted to be abundant in residential buildings, hospitals, hostels, restaurants and in their indiscriminate nocturnal movement from place to place noted to contaminate foods, beer and other materials such as leather, starch, book bindings, flakes, of dried skin, dead animals or plants, garbage with their faeces and exudates (Bracke et. al., 1990; Fotedar et. al., 1989; Graczyket et. al., 2005; Lemos et. al., 2006; Salehzadeh et. al., 2007; Ajayi et. al., 2011).

In most regions where Cockroaches have been reported, constant food poisoning problems (Kopanic 1994; Czaka et. al., 2013) and many ill- health problems associated with the types of pathogens that causes

diarrhoea, dysentery, cholera, leprosy, typhoid fever, poliomyelitis, as well as carry parasitic worms and cause allergic reactions such as dermatitis, itching, swelling of the eyelids and more serious respiratory tract conditions have been reported in human populations (Baumholtz et. al., 1991; Stankus et. al., 1990).

In a quest to unravel sources of undocumented constant illnesses reported in Jos, having been blessed with the role Cockroaches play as host of pathogens, this study was drafted with the specific objectives to ascertain the various types of Cockroaches available in two most polluted areas of Jos; isolate and identify the various types of parasites associated with the various types of Cockroaches; identify the various pathogens fauna on both external and internal parts; to determine whether parasites composition were mainly influenced by phylogenetic, evolutionary or by ecological relationships; determine which species of Cockroaches is more susceptible to parasitic infection; determine the specific part of the alimentary canal that harbours the highest concentration of parasites load and to recommend where possible the best method for the control of Cockroaches. Although the study fell short of the collections of samples of stool and health records of possible sources of infections in patients from various clinics and hospitals within these vicinity at the particular time of study, it is envisaged that it will in a lot of ways contribute to the dangers of having increased number of Cockroaches around human activity areas.

II. Materials And Methods

2.1 Description of area of study

The study was carried out in two most Cockroaches infested areas-Tudun Wada and Rikkos all in Jos metropolis of Plateau State. Jos metropolis is situated approximately on latitude 9.5 °N and longitude 8.5 °E; it lies well over 1,200m above sea level (Department of Geography, Faculty of Environmental Sciences, University of Jos).

2.2 Sample collections, Identifications and Screening

2.2.1 Collections of cockroaches

Cockroaches were collected manually at night by knocking them down with a broom or, alternatively, where it becomes difficult to get sample, spraying of insecticide was done to move them from their hiding places and those temporarily dosed with the pyrethroids were then handpicked. They were placed in labelled sample bottle and were transported to the Applied Entomology and Parasitology laboratory, University of Jos.

2.2.2 Identification of cockroaches

The sex, species of the cockroaches was identified using standard taxonomic keys as described by Ross (1965). Briefly:

Blattella germanica

They measure between 1.1 cm to 1.6 cm; have colour that varies from tan to almost black; and has two dark, roughly parallel streaks on the pronotum running antero-posteriorly from behind the head to the base of the wings, but could barely fly at all, although it may glide when disturbed (Jackman and Bastiaan 1998; Bell et. al., 2007).

Periplaneta americana

The adults measure to an average length of around 4cm and about 7mm tall; reddish brown with a yellowish margin on the body region behind the head; and have immature stages that resemble adults except they are wingless (Barbara 2008).

2.2.3 Screening of parasites and pathogens from external surfaces of the insects

After identification, each cockroach was placed in a test tube containing 2 mls of sterile normal saline. The test tube was shaken vigorously for two minutes. Thereafter, the fluid was transferred to a centrifuge test tube and centrifuged for five minutes at 3000 rev/sec. After decanting the excess top fluid, the residual deposit was placed on a clean glass slide, covered with a cover slip and stained with Lugol's iodine and viewed under the ×10 and ×40 microscope objectives lens. The parasites and/or their stages encountered were identified and counted.

2.2.4 Screening and Identifications of parasites and pathogens from internal organs of the insects

The method of Ajayi et. al. (2011) as modified from Cameron (2009) was adopted. **Briefly:** the Cockroaches were allowed to dry at room temperature after external examination; then placed on a dissecting board with the ventral side upward, and with a scissors the six legs were removed; insertion of scissors in between the last abdominal segment was made and cut towards its head along the side of the exoskeleton to make two lengthwise parallel cuts up the sides. The fat bodies were then removed and digestive canal was

observed. The oesophagus, crop, gizzard, and the proventriculus (part of the insect's stomach: the foregut that is used for grinding food); the gastric caecae which are curly finger like extensions, the malpighian tubules which are kidney like structures in the hindgut, colon and rectum were all observed. Carefully, the gut was cut into the different sections and split open with a pair of scissors and the content of each gut section was dissolved in normal saline, then centrifuged at 3000 rev/sec for five minutes and the sediments were mounted on a slide and covered with a cover slip. These cut sections were then also viewed under the microscope at ×10 and ×40 objective and the oval cysts of the parasites identified with keys provided by Arora and Arora (2010) and Center for Disease Control and Prevention (2013).

2.3 Statistical Analysis

The data obtained were statistically analysed using R-console software version 2.9.2. Chi-square was then used to determine the proportions of associations and significant level was achieved if $P < 0.05$. Results were as presented in Tables and Figures.

III. Results

3.1. Ascertain The Various Types Of Cockroaches Available, Most Caught Cockroach And Sites With Most Infected Cockroaches.

To establish a robust table to equate the various types of Cockroaches encountered at the course of study, table 1 was put in place. Two species of Cockroaches (Blattella germanica and Periplaneta americana) were trapped at the course of the study. More P. americana were caught than B. germanica. Comparison of the abundance of the species of Cockroaches indicated it varied significantly ($\chi^2 = 88.0591$, df = 1, $P < 0.001$). To ascertain the area most infested with Cockroaches, Table 1 further indicated that more numbers (157) of Cockroaches were caught around the toilet areas (24-B. germanica: 133-P. americana), the least caught site was the Living room (15-B. germanica:36-P. americana). The abundance of cockroaches in relation to sites showed a high significant difference ($\chi^2 = 81.5272$, df = 4, $P < 0.001$). Comparably in terms of infection, the table also showed that those caught around the toilet areas-129(30.50%) were more infected with pathogens than those caught around the Living room-39(9.22%). The infection rate in relation to sites varied significantly ($\chi^2 = 87.7025$, df = 4, $P < 0.001$). A striking note of interest was that of all the species of Cockroaches caught at the various sites, they were all positive (316 of 423) with pathogens. There was a very high significant difference in the infection rate between species of cockroaches ($\chi^2=51.8481$, df=1, $P<0.001$).

Table 1: Population of Cockroaches trapped from various sites

	Species of Cockroaches					
	Blattella germanica		**Periplaneta americana**		**Total**	
Sites	No. Trapped	No. Positive (%)	No. trapped	No. Positive (%)	No. trapped	No. Positive (%)
Kitchens	33	30(90.91)	39	20(51.28)	72	50(69.44)
Toilets	24	24(100)	133	105(78.95)	157	129(82.17)
Living Rooms	15	13(86.67)	36	26(72.22)	51	39(76.47)
Refuse Dumps	24	17(70.83)	44	37(84.09)	68	54(79.41)
Shops	19	10(52.63)	56	34(60.71)	75	44(58.67)
Total	**115**	**94(81.74)**	**308**	**222(72.08)**	**423**	**316(74.70)**

Infection rate between species of cockroaches ($\chi^2 = 51.8481$, df = 1, $P < 0.001$).

Abundance between species of cockroaches trapped ($\chi^2 = 88.0591$, df = 1, $P < 0.001$).

Infection rate in relation to sites significantly ($\chi^2 = 87.7025$, df = 4, $P < 0.001$).

Abundance of cockroaches in relation to sites ($\chi^2 = 81.5272$, df = 4, $P < 0.001$)

3.2 Comparison Of Internal And External Parts Of Both Cockroaches

The external and internal parts of the various Cockroaches showed that the two species both harbour pathogens but with their internal parts (75-B. germanica: 186-P. americana) harbouring more of the pathogens than the external parts (19-B. germanica: 36-P. americana). Statistical analysis indicates that there was a very high significant difference in the infection rate between external and internal parts of cockroaches ($\chi^2 = 134.2911$, df = 1, $P < 0.001$).

Table 2: External and Internal Parts of Cockroaches

Species of Cockroaches	**No. Collected**	**Parts infected**		**Total Number Infected (%)**
		External (%)	**Internal (%)**	
Blattella germanica	115	19(16.52)	75(65.22)	94(81.74)
Periplaneta americana	308	36(11.69)	186(60.39)	222(72.08)
TOTAL	**423**	**55(13.00)**	**261(61.70)**	**316(74.70)**

Infection rate between external and internal parts of cockroaches ($\chi^2 = 134.2911$, df = 1, $P < 0.001$).

3.3 Parasites Types And Specifications Of Parasites At The Internal And External Parts Cockroaches

When parasites type and specifications were considered, it was interesting to note that on both the external and internal parts, intestinal Nematodes were more common, followed by intestinal Protozoan, while the least was intestinal Cestodes (Table 3). There was a very high significant difference on the abundance between intestinal parasites in Cockroaches (χ^2 =313.981, df = 2, P < 0.001). To ascertain the parasites types on the external and internal parts. Whereas Ascaris lumbricoides cysts was found to be more common on the external part, at the internal part, Enterobius vermicularis and Giardia lamblia were more common (Table 3). There was a very high significant difference in the infection rate between internal parts of cockroaches (χ^2 =106.1379, df = 2, P <0.001). A breakdown of comparison of Cockroaches carrying dual pathogens showed that those carrying dual pathogens were of the Nematodes/Protozoans group as compared to those of the Nematode/ Cestodes group (Tables 4). There was a very high significant difference in the abundance between dual intestinal parasites in cockroaches (χ^2 =108.4516, df = 3, P < 0.001) and also, the abundance of dual intestinal parasites between external and internal parts of cockroaches showed a high significant difference (χ^2 =43.6129, df = 1, P < 0.001).

A further breakdown of comparison of Cockroaches carrying multiple pathogens also attest to the fact that those carrying multiple pathogens were of the Nematodes/Protozoans group as compared to those of the Nematode/ Cestodes group (Tables 5). There was significant difference in the abundance between multiple intestinal parasites in cockroaches (χ^2 =5.4, df =1, P = 0.0204). Overall, the hindgut of the two species of Cockroaches indicate a possibility of carrying more parasites load that the other parts. The abundance of multiple intestinal parasites between external and internal parts of cockroaches showed a high significant difference (χ^2 = 15, df = 1, P = 0.0001075).

TABLE 3: PARASITES TYPES AND SPECIFICATIONS OF PARASITES AT VARIOUS PARTS

			External		**Internal**						
Parasites Type	**S/ No**	**Parasites**			**Foregut**		**Midgut**		**Hindgut**		**Total (%)**
			B. germanica	P. americana	B. germanica	P. americana	B. germanica	P. americana	B. germanica	P. americana	
INTESTINAL NEMATODES	1	Ascaris lumbricoides	16	26	1	11	0	10	6	2	72
	2	Enterobius vermicularis	0	1	1	0	5	21	23	67	118
	3	Trichurus trichiura	0	0	1	0	5	6	16	11	39
	4	Strongyloides stercoralis	1	1	3	5	2	9	0	3	24
TOTAL			**17**	**28**	**6**	**16**	**12**	**46**	**45**	**83**	**253(80.06)**
INTESTINAL CESTODES	1	Hymenolepis nana	1	4	1	0	1	0	1	2	10
	2	Taenia species	0	0	0	0	0	8	0	0	8
TOTAL			**1**	**4**	**1**	**0**	**1**	**8**	**1**	**2**	**18(5.70)**
INTESTINAL PROTOZOAN	1	Giardia lamblia	1	4	1	0	1	10	7	21	45
TOTAL			**1**	**4**	**1**	**0**	**1**	**10**	**7**	**21**	**45(14.24)**
SEMI-TOTAL OF INFECTED INSECTS			**19(34.55)**	**36(65.45)**	**8(3.07)**	**16(6.13)**	**14(5.36)**	**64(24.52)**	**53(20.31)**	**106(40.61)**	**316**
GRAND TOTAL OF INFECTED INSECTS			**55(17.41%)**		**261(82.59%)**						

Abundance between intestinal parasites in cockroaches (χ^2 =313.981, df = 2, P < 0.001).

Infection rate between internal parts of cockroaches (χ^2 =106.1379, df = 2, P <0.001).

TABLE 4: DUAL PARASITES TYPES AND SPECIFICATIONS OF PARASITES AT VARIOUS PARTS											
			External		**Internal**						
Parasites Type	**S/No**	**Parasites**			**Foregut**		**Midgut**		**Hindgut**		**Total (%)**
			Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	
INTESTINAL NEMATODES	1	Ascaris lumbricoides and Strongyloides stercoralis	0	4	0	0	0	0	0	0	4
TOTAL			**0**	**4**	**0**	**0**	**0**	**0**	**0**	**0**	**4(6.45)**
INTESTINAL NEMATODES AND CESTODES	1	Hymenolepis nana and Trichurus trichuira	0	0	0	0	0	0	0	3	3
	2	Hymenolepis nana and Enterobius vermicularis	0	0	0	0	0	0	0	1	1
TOTAL			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**4(6.45)**
INTESTINAL NEMATODES AND PROTOZOAN	1	Ascaris lumbricoides and Giardia lamblia	0	1	0	0	0	0	0	1	2
	2	Enterobius vermicularis and Giardia lamblia	0	0	0	0	0	0	11	37	48
	3	Trichurus trichuira and Giardia lamblia	0	0	0	0	0	0	0	2	2
TOTAL			**0**	**1**	**0**	**0**	**0**	**0**	**11**	**39**	**51(82.26)**
INTESTINAL CESTODES AND PROTOZOAN	1	Hymenolepis nana and Giardia lamblia	0	0	0	0	0	0	0	3	3
TOTAL			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**3(4.84)**
SEMI- TOTAL OF INFECTED INSECTS			**0**	**5**	**0**	**0**	**0**	**0**	**11(19.29)**	**46(80.70)**	**62**
GRAND TOTAL OF INFECTED INSECTS			**5(8.06%)**		**57(91.94%)**						

Abundance between dual intestinal parasites in cockroaches (χ^2 =108.4516, df = 3, P < 0.001).

Abundance of dual intestinal parasites between external and internal parts of cockroaches (χ^2 =43.6129, df = 1, P < 0.001).

TABLE 5: MULTIPLE INFECTIONS WITH PARASITES TYPES AND SPECIFICATIONS OF PARASITES AT VARIOUS PARTS											
			External		**Internal**						
Parasites Type	**S/No**	**Parasites**			**Foregut**		**Midgut**		**Hindgut**		**Total (%)**
			Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	Blattella germanica	Periplaneta americana	
INTESTINAL NEMATODES AND PROTOZOAN	1	Ascaris lumbricoides, Enterobius vermicularis and Giardia lamblia	0	0	0	0	0	0	0	3	3
TOTAL			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**3(20.00)**

INTESTINAL NEMATODES, CESTODES AND PROTOZOAN	1	Trichurus trichuira, Hymenolepis nana and Trichurus trichuira	0	0	0	0	0	0	0	12	12
TOTAL			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**12**	**12(80.00)**
SEMI GRAND TOTAL OF INFECTED INSECTS			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**15**	**15**
GRAND TOTAL OF INFECTED INSECTS			**0(0%)**		**15(100%)**						

Abundance between multiple intestinal parasites in cockroaches (χ^2 =5.4, df =1, P = 0.0204)
Abundance of multiple intestinal parasites between external and internal parts of cockroaches (χ^2 = 15, df = 1, P = 0.0001075)

IV. Discussion

4.1. Types Of Cockroaches, Abundant Cockroaches, Sites With Most Caught Cockroaches And Sites With Most Infected Cockroaches.

4.1.1. Types Of Cockroaches

Two species of Cockroaches (Periplaneta americana and Blattella germanica) were found to be the dominant types in Jos. It was not surprising that they are the two types, majorly due to their cosmopolitan distribution, closeness to human habitations, ability to reproduce more easily, and ability to survive easily in tropical climate. Roth and Willis (1957) in Ghana; Agbodaze and Owusu (1989) in Ghana; Ajero et. al. (2011) in Owerri; Al-Mayali and Al-yaqoobi (2010) in Iraq; Umunnabuike and Irokanula (1986) in Vom; Steinbrink (1987) in Rostock; Mimioglu and Sahin (1976) in Turkey and Chan et. al. (2004) in Hawaii, have all confirmed the distribution of the two types of Cockroaches in their locality of study. Specifically, Kumie et. al. (2002); Gullan and Cranston (2005); Salehzadeh et. al. (2007) noted that despite over 3,500 species of Cockroaches and 30 species more adapted to human habitation or synanthropic, B. germanica and P. Americana are considered the most common pest to humans. In a related development, Kumie et. al. (2002) and Salezadeh et. al. (2007) both reported in their studies that Periplaneta americana and Blattella germanica are considered the most common pests and are adapted to human habitations. Additionally, Bell and Adiyodi (1981) noted that the availability of both species in tropical climates and cosmopolitan in distribution could be due to human activity such as global commerce which could have extended the insects range of habitation. As noted by Vatandoost and Mousavi (2001), German Cockroach (Blattella germanica) is important worldwide due to their small size, nutritional habits and specific behaviour and as confirmed by Ebeling (2013) the ability of Blattella germanica to establish could be alluded to their ability to reproduce at a rapid rate. Another means of B. germanica cosmopolitanism and the occasional presence of P. americana as reported by Steinbrink (1987) in Rostock is their introduction from warmer regions of the globe via containers. This raises the question as to the eco-evo pattern of migration of the two forms of Cockroaches.

4.1.2. Abundant Cockroaches

P. Americana was the most frequently trapped cockroach. This is in variance with claims by Ebeling (2013) that B. germanica reproduces faster than any other residential Cockroach, growing from egg to reproductive adult. The ability of the P. Americana to be trapped more easily could be attributed to as noted by Bala and Sale (2012), their tendencies of roaming more than B. germanica, as they move quickly in search of food and sites to lay their eggs as compared to B. germanica which can barely fly but could glide when disturbed.

4.1.3. Sites With Most Caught Cockroaches

The sites most caught were the toilets, shops and refuse dumps for P. americana, whereas kitchen, refuse dumps and toilets had the highest caught for B. germanica. Bell and Adidoyi (1981) described Cockroaches as opportunistic omnivous that can feed on almost anything. This agrees with the findings of Ajayi et. al. (2011) who reported that 91.55% of Cockroaches caught was from the toilets as they could be found scurrying in and out of toilets as they feed on faeces. Importantly, CheGharu et. al. (1993) pointed that P. americana are among the most notorious pests of premises; they frequently feed on human faeces and therefore can disseminate cysts of enteric protozoans in the environment if such faeces are contaminated. Additionally, Jones (2008) reported that P. americana prefer dark sites with high humidity, such as sewers, tunnels, and basement and around pipes and drains. The second highest trapping of P. americana in shops is not surprising as

it agrees with Bell and Adiyodi (1981) who explained that the common occurrence of P. americana around garbage piles might not be unconnected with their feeding on leftover food by humans and also due to their preferences for moist dark areas which leads them in contact with unhygienic environments such as sewers and garbage piles. Consequently, Brenner et. al. (1987) reported that Cockroaches such as P. americana and B. germanica have filthy habits with ability to spoil food, transfer pathogens and cause allergic reactions and psychological distress. For B. germanica, Russ et. al. (1994) pointed out that German Cockroaches are omnivorous scavengers as they are attracted particularly to meat, starches, sugars and foods.

4.1.4 Sites With Most Infected Cockroaches

Overall, it was found out that Cockroaches from toilets were the most infected, followed by refuse dumps and then kitchen. Individually, P. Americana caught from toilets were the most infected, whereas for the B. germanica, it was the kitchen. Bala and Sule (2012) reported that irrespective of species of Cockroaches, they play significant role in transmitting parasitic diseases as they discovered that 70% of the Cockroaches examined were capable of transmitting them to humans or animals. Cotton et. al. (2000) and Pai et. al. (2004), noted that Cockroaches feed on garbage and sewage and so have copious opportunities to disseminate humans' pathogens. Chan et. al. (2004) reported that parasites are common in different localities, especially in those areas where personal hygiene is lacking. As noted by Allen (1987), Cockroaches due to their nocturnal and filthy habits made them ideal carriers of pathogenic microorganisms. It was also not surprising that those caught within living rooms also have high infection rate, as noted by Bala and Sule (2012), that P. Americana enter houses in different ways from outside through cracks and crevices, vents, sewer and drain pipes and may also enter products like grocery, bags, boxes, purses and so on. The implications of having most infected Cockroaches in toilets, living rooms, shops and kitchens is that parasites of human importance could easily be passed on to humans where proper hygiene is not observed and could help increase hospital attendance by residence of such communities.

4.2. Comparison Of Internal And External Parts Of Cockroaches

A comparison of the external and internal parts of both Cockroaches indicated that they were infected with parasites, but more parasites were collected from the internal parts. A peruse at both the external and internal parts showed that B. germanica were infected with parasites than the external and internal parts of P. Americana. This agrees with the findings of Addisu and Berhanu (2008) who revealed in their study that microscopic examination of the external body washes of pooled and individual gut contents of cockroaches carry parasites such as Enterobius vermicularis, Trichuris trichiura, Taenia species and Ascaris lumbricoides ova. This also corroborated with the reports of Jacobs (2012; 2013; 2014) that disease-producing organisms such as bacteria, protozoans and viruses have been found on cockroach (German cockroach) bodies and that these different forms of gastroenteritis (food poisoning, dysentery, diarrhea and other illness) carried on the legs and bodies of Cockroaches could be deposited on food and utensils where Cockroaches forage and could possibly lead to principal diseases recorded in humans. In addition, Clement et. al. (2014) demonstrated that more parasites were collected in the alimentary canal than the body surfaces of Periplaneta americana. Kopanic (1994) and Czajka et. al. (2003) reported that they can not only contaminate food by leaving droppings and bacteria that can cause food poisoning but they can also transmit bacteria, fungi, and other pathogenic microorganisms in infested areas. It has been noted that Blattella germanica is an effective mechanical transmitter of Salmonella enteritidis via faeces (Ash and Greenberg 1980). Kopanic (1994) and Czajka et. al. (2003); Ajayi et. al. (2011) reported that they can not only contaminate food by leaving droppings and bacteria that can cause food poisoning but they can also transmit bacteria, fungi, and other pathogenic microorganisms in infested areas. Consequently, Fotedar et. al. (1991) in a study underground sewer facilities or utility networks from hospitals and residential areas carry medically important microorganisms cited that they carry viral and bacterial pathogens on their bodies and in their faeces which can cause poisoning, diarrhoea and dysentery. The implication of this finding is that cockroaches can easily contaminate food and other materials with their droppings which contain parasites found in the hindguts.

4.3 Parasites Types And Specifications Of Parasites At The Internal And External Parts Cockroaches

Overall, more parasites were recovered from the internal parts of both Cockroaches than the external parts. A breakdown indicated that more intestinal nematodes of Enterobius vermicularis, followed by protozoans of Giardia lamblia, then Cestodes of Hymenolepis nana were recovered from the internal parts of the two species of Cockroaches whereas Ascaris lumbricoides was most encountered on the external surfaces of Blattella germanica and Periplaneta americana. Intestinal Cestodes like Taenia spp. were not recovered from the external parts nor the foregut and hindgut but from the midgut. The implication of Enterobius vermicularis which causes peri-anal itching in humans encountered more in the internal organs of both Blattella germanica and Periplaneta americana is an indication that the cockroaches feed on contaminated food. Whereas the

observation of the large number of Ascaris lumbricoides encountered on the external surfaces of Blattella germanica and Periplaneta americana conforms with the reports by Crompton (1999) that Ascaris lumbricoides is the most common helminth parasite especially in developing countries and their presence in humans could as noted by Chandler and Read (1982) cause vomiting, diarrhoea, acute colic pains, and fatal intestinal obstructions.

It was not surprising that the hindgut, followed by the foregut, then the midgut harbour more of both single, dual and multiple parasites; and most importantly, the same types of parasites recovered from the two species of Cockroaches. We hypothesised that the large presence of parasites in the hindgut and foregut could be due to the presence of micropines which are absent in the midgut. These micropines have been found to be useful in the understanding of systematic and evolution of insects and as noted by Elzinga and Hopkins (1994), micropines are useful in retaining food particles during regurgitation behaviour. The large presence of single, dual and multiple parasites in the hindgut could also be attributed to the absorption of water capacity and the retention of undigested food that is formed into pellets and secreted through the anus which warrants the presence of the faunas. Of evolutionary importance is the availability of the lining of the hindgut by cuticle and the entire foregut with chitin. Whereas both cuticle and chitin are absent in the midgut, but is lined by a peritrophic membrane which protects the stomach wall from abrasion and is fully permeable to enzymes and digested food. This agrees with the reports by Poulin (1995) that the composition of parasites communities is affected by, among many factors, the result of the interactions between their evolutionary history and ecological characteristics of the host. As further noted by Poulin and Rhode (1987), during their evolutionary history, host lose and/or acquire parasites due to the speciation of native parasite or the acquisition of new parasites from other hosts. It further agrees with Arora and Arora (2010) and Iwuala and Ogbalu, (1979) who both reported that the parasites are likely to be of human origin since the cockroaches collected were from human habitation. On the other hand, the recovery of the same type of parasites from the two species of Cockroaches confirms their ecological characteristics, in that, it is associated with the host, such as diet, habitat and niche composition which have a great influence on the composition and structure of the parasite communities (Esch et. al. 1990; Poulin, 1995). Although phylogenetically, both species are of the same clade, the findings agrees with Poulin and Morand (1999); Gonzalez and Oliva (2006) that host geographical range is a main factor affecting the interchanges of parasite species that are phylogenetically related.

V. Conclusion/Recommendations

Although Cockroaches are not usually the most important cause of diseases, they could as noted to play supplementary role in the spread of diseases since they carry eggs of parasitic worms that could cause allergic reactions, dermatitis, itching, swelling of the eyelids and more serious respiratory conditions (Stankus et. al. 1990; Theyseen et. al. 2004). It is therefore recommended that, as a precautionary measure, a good sanitary insect-free environment of highest priority in homes and shops should be encouraged; adequate sanitation and enlightenment campaigns on a clean environment be encouraged; daily emptying of garbage and proper disposal to eliminate cockroach habitats should be enhanced; good sanitation in buildings to make it less favourable for insects should be practiced; windows and doors should be kept tight in homes; Cracks in outside walls, sills and foundations should be sealed to prevent movement of cockroaches; all openings where electrical lines or water, steam and cooling pipes pass through walls and floors should be sealed to slow down movement of cockroaches into a building; plumbing leaks should be sealed and seal all moisture sources; all food crumbs and garbage should be removed to containers with tightly fitting lids; foods should be stored in sealed containers; Cockroach traps (baited boxes with sticky material inside) are very helpful and should be used; using of traps to reduce the severity of the problem should be put in place, as this will prevent an infestation by catching cockroaches that are carried into the home in bags or boxes before they find hiding places; insecticides could be used in their control as this penetrates their shelters and hiding places, treat these locations and provide much better control than those placed where cockroaches move only occasionally; eliminate all routes of possible re-infestations and all houses should be thoroughly cleaned and an approved insecticide should be applied.

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