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Original article

Parasites diversity of edible African giant snails (*Achatina fulica* and *Archachatina marginata*) in the Lekie, Wouri and Santchou localities of Cameroon during the dry season

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ABSTRACT

A study was conducted in Cameroon in the dry season to identify the parasites likely to infect edible African giant snails. A total of 120 snails (*Achatina fulica* and *Archachatina marginata*) were sampled in the Littoral, Center and West regions of Cameroon. After macroscopic observation of the snails, slime, haemolymph and the internal organs (digestive gland, digestive tract and reproductive system) were isolated and examined using the flotation technique and direct smear (simple and stained). The results revealed that, the most common parasites were cyst of *Balantidium coli* (42.5%), larva of *Enterobius vermicularis* (30.8%), cyst of *Isospora* sp (25.8%), *Trichodina achatinae* (24.2%), mesocercariae of *Alaria* sp (21.7%), larva of *Angiostrongylus cantonensis* (18.3%), cysts of *Cryptosporidium* sp (15.8%) and *Enteromonas* sp (10.0%). The least represented were unidentified mite (6.7%), *Riccardoella limacum* (6.7%), larva of *Strongyloides stercoralis* (6.7%), eggs of *Dicrocoelium dendriticum* (3.3%), *Fasciola* sp eggs (2.5%), *Hyostrongylus stercoralis egg* (2.5%), larva of *Protostrongylus* sp (2.5%) and *Schistosoma mansoni* eggs (0.8%). *A. fulica* was more infected (80.0%) than *A. marginata* (70.0%) and snails collected in the Lekie locality were more infected (92.5%) followed by snails from the Wouri locality (82.5%) and finally snails from the Santchou locality (50.0%). Protozoans had the highest infection rate followed by nematodes while the unidentified mite was less prevalent. The host-

parasite relationship between the parasites and the snails is multi-factorial because the snail stands either as final, intermediate or paratenic host for the identified parasites. The pathogenic effect of these parasites on snails should be investigated.

1. Introduction

The demographic growth worldwide has made animal production crucial for the development in many African countries (FAO, 2013). To cover their needs in proteins of animal origin, the populations are leaning more and more on the exploitation of forest food resources. However, the massive exploitation of these resources raises the questions about the continued availability of wildlife resources (Bouye et al., 2017). Among these forest resources, snails occupy a very important place in the mass of game consumed whose consumption continues to increase exponentially. Around 1900 tons of these mollusks are sold in the Abidjan markets in Ivory Coast each year (Kouakou et al., 2014). In Cameroon, statistics are non-existent, even if snails are found in almost all the markets in forest areas (Kwidja, 2001).

Snail meat can help to reduce protein deficiency in developing countries because of its high protein content of about 82% (Okon et al., 2016). Mineral deficiency can also be corrected through consumption of snail meat (Narku, 2013). The interest in snail meat consumption is currently very high because of the high demand in white meat, to the detriment of red meat for perceived health reason (Omole et al., 2005). Many of the snails consumed are fetched from the wild while only few are reared. However the domestication of edible land snails is limited by a number of constraints including health challenges (Pirame, 2003). Parasites are among the main causes of health challenges in snails as previously reported (Pirame, 2003) but few data are available regarding edible snails, especially the giant African snails which are widely eaten all over Africa and beyond. Indeed, Caron et al. (2014) demonstrated that aquatic and terrestrial snails are the intermediate hosts of a diverse range of pests. In addition, giant African snails have been reported to be carrier of zoonotic parasites, one of which is the rat lungworm *Angiostrongylus cantonensis* (Iwanowicz et al., 2015) with the increasing risk of transmission to man and animals (Reece et al., 2013). So, the establishment of a snail farm requires a prior control of parasites of giant snails as well as the risks associated with the consumption of this resource and its derivatives on public health. As seasonally has been shown to affect the occurrence of parasites, the main objective of this study was to identify the parasites of giant African snails with special focus on those present in the dry season. The study was carried out in order to facilitate their domestication on one hand and to prevent the impact of the consumption of this resource on consumers' health on the other hand.

2. Materials and methods

2.1. Study area and period

The study was carried out from December 2018 to February 2019 in three localities of the Littoral (Wouri), Centre (Lekie) and West (Santchou) regions of Cameroon. The Littoral region is a coastal city belonging to the humid dense forests zone of Cameroon with a monomodal rainfall. The town is located between latitude 2°6" - 6°12" North, and longitude 8°48" - 10°30" East. The climate is very humid and hot while the rains are abundant (mean rainfall 2,500 to 4,000 mm). The annual temperature varies between 22 and 29 °C and the annual air humidity between 85 and 90% (IRAD, 2008). The Center region belongs to the wet forests zone with a bimodal rainfall. It is located between latitude 2°6"- 4°54" North and longitude 10°30"- 16°12" East. The climate is warm and humid with an average temperature of 25 ˚C and a rainfall of 1500 - 2000 mm per year (IRAD, 2008). The West region is located between latitude 4 ° 54 "to 6 ° 36" North and 9 ° 18 "to longitude 11 ° 24" East. The climate is marked by two seasons of unequal length: a dry season, going from mid-November to mid-March, and a rainy season which lasts from mid-March to mid-November. The mean temperature is low (19 °C), and the rain falls are heavy (1500 - 2000 mm) (IRAD, 2008).

2.2. Snail collection and identification

A number of 120 snails belonging to two species, *Achatina fulica* (60) and *Archachatina marginata* (60) (Figure 1) were collected in the nature by a local snail collector in each locality and stored in a ventilated container. The container was covered with a piece of mosquito net and transported to the laboratory. Snails were identified at the species level according to their shape, sizes, colors, the marks on the shells and the shape of apex of their shells (Raut and Barker, 2002).

Fig. 1. Picture of *Achatina fulica* (left) and *Archachatina marginata* (right).
The whitish film over their peristome is due to the fact that they are summer snails collected in the dry season.

2.3. Procedure for parasite collection and identification

The snails were observed macroscopically using a stereomicroscope in order to detect any presence of ectoparasites. The observed parasites were removed from the snail using forceps and kept into a Petri dish until identification.

After the macroscopic analysis of the outer part of the snails, the snail was washed with tap water and the slime was removed by scratching the foot and put onto a slide for examination. Then, the apex of the snail shell was broken to extract the hemolymph. The apex was broken using a clean hammer. Following extraction, various organs (digestive gland, digestive tract and reproductive system) were gently isolated into Petri dishes.

Smear of the slime and hemolymph were performed and examined using the lugol staining techniques. A drop of the sample was placed on the slide and a drop of dye was added on it. Then, the mixture was homogenized before observation with a microscope.

The digestive gland, digestive tract and genitals tract were carefully examined macroscopically for the presence of any parasite. Then, each organ was crushed into a mortar and subjected to the flotation analysis, using granulated sugar as flotation solution (Dryden et al., 2005; Aubry and Gauzère, 2015). All these preparations were observed under the microscope with the 10X and 40X objectives.

The ectoparasites were identified based on their morphology, shape, size, structure, colour, shape of the head, shape of the legs, number of legs, structure and colour as described by Villeneuve and Damour (2010).

The larvae of nematode were identified based on the shape of the tail, the nature of the cell nuclei, the nature of the tail and the shape of the head as previously described (Villeneuve and Damour, 2010). The egg, oocyst and cyst were identified based on their morphology, size, structure, wall, shape and their color as described by Troncy et al. (1981), Thienpont et al. (2003), Basson (2010) and Villeneuve et Damour (2010).

2.4. Statistical analysis

The analysis of the infection rate of the different groups of parasites per host species, weight, organs and sampling area was done by running the Chi 2 test with a significant level of 0.05 using the SPSS 20.0 software.

3. Results and discussion

3.1. Results

3.1.1. Parasite species identified

A total of 16 parasites species (Figure 2) were detected in both African giant snails, with various infection rates (Table 1) and belonging to different phyla and class. A total of 10 parasites species were identified in snails

collected in Wouri against 8 in Santchou and 13 in Lekie (Table 1). There was a significant difference (p<0.05) in the infection rate for *Isospora* sp, *B. coli*, *E. vermicularis*, *A. cantonensis*, *Cryptosporidium* sp., *Alaria* sp., *S. stercoralis*, and *D. dendriticum*, *T. achatinae* and *R. limacum* between the study locations. The infection rate of most parasites was significantly greater in Lekie than in the two other localities except *Ricardoela* which was found only in Wouri. However, the parasite most represented in Wouri was *E. vermicularis* whereas in Lekie and Santchou it was *B. coli*.

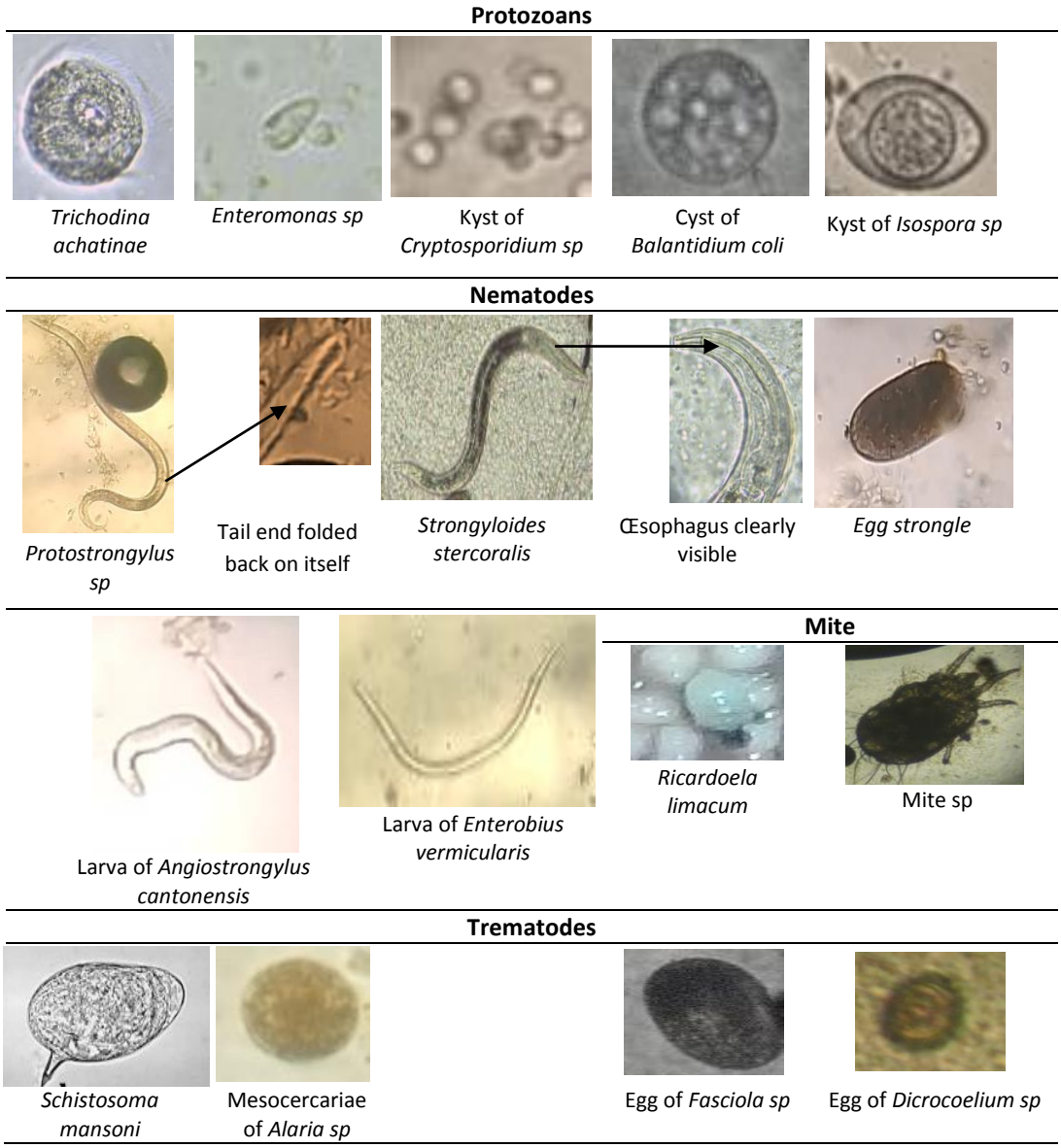

Fig. 2. Gallery of the parasite stages (not to scale) found in giant African snails in Cameroon.

3.1.2. Distribution of parasites according to organs

The various parasites identified were shown in almost all organs except for *Schistosoma mansoni, Protostrongylus* sp., *Trichodinae achatinae* and *Ricardoela limacum* parasites that were found on specific organs. Indeed, *Schistosoma mansoni*, *Protostrongylus* sp. and *Trichodinae achatinae* were specific to the slime while *R. limacum* was found only on the foot (Table 2).

Table 1
Parasites species of edible African giant snails (*Achatina fulica* and *Archachatina marginata*) in the dry season in Cameroon.

	Sampling area								
	Wouri (N=40)		Santchou (N=40)		Lekie (N=40)		Total(N=120)		
Parasites	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	***p-value***
Balantidium coli	12	30.0^{c}	11	27.5^{b}	28	70.0^{a}	51	42.5	0.000*
Cryptosporidium sp.	7	17.5^{b}	0	0.0^{c}	12	30.0^{a}	19	15.8	0.001*
Enteromonas sp.	6	15.0^{a}	0	0.0^{a}	6	15.0^{a}	12	10.0	0.058
Isospora sp.	6	15.0^{b}	0	0.0^{c}	25	62.5^{a}	31	25.8	0.000*
Trichodina achatinae	6	15.0^{cb}	7	17.5^{cb}	16	40.0^{a}	29	24.2	0.023*
Protozoa	20	50.0	11	27.5	35	87.5	66	55.0	0.000
Angiostrongylus cantonensis	8	20.0^{b}	1	2.5^{c}	13	32.5^{a}	22	18.3	0.003*
Enterobius vermicularis	13	32.5^{b}	5	12.5^{c}	19	47.5^{a}	37	30.8	0.005*
Protostrongylus sp.	0	0.0^{a}	3	7.5^{a}	0	0.0^{a}	3	2.5	0.110
Stongyle	0	0.0^{a}	2	5.0^{a}	1	2.5^{a}	3	2.5	0.780
Strongyloides stercoralis	1	2,5^{b}	0	0.0^{c}	7	17.5^{a}	8	6.7	0.008*
Nematodes	18	45.0	11	27.5	26	65.0	55	45.8	0.006*
Alaria sp.	8	20.0^{b}	0	0.0^{c}	18	45.0^{a}	26	21.7	0.000*
Dicrocoelium dendriticum	0	0.0^{cb}	0	0.0^{cb}	4	10.0^{a}	4	3.3	0.038*
Fasciola hepatica	0	0.0^{a}	1	2.5^{a}	2	5.0^{a}	3	2.5	0.780
Schistosoma masoni	1	2.5^{a}	0	0.0^{a}	0	0.0^{a}	1	0,8	1.000
Trematodes	8	20.0	2	5.0	21	52.5	31	25.8	0.000*
Unidentified mite	0	0.0^{a}	5	12.5^{a}	1	2.5^{a}	6	5.0	0.055
Ricardoela limacum	8	20.0^{a}	0	0.0^{cb}	0	0.0^{cb}	8	6.7	0.000*
Mite	8	20.0	5	12.5	1	2.5	14	11.67	0.056

a, b, c: numbers bearing the same letters on the same line are not significantly different (P>0.05); N: total number of samples; n: number of positive samples; (%) infection rate in percentage; *: significant p value.

Table 2
Distribution of parasites by snail organ.

	Hepatopancreas (N= 120)		Digestive tract (N=120)		Genital tract (N=120)		Hemolymph (N=120)		Slime (N=120)		Foot (N=120)	
Parasites	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Protozoa												
Balantidium coli	16	13.3	17	14.2	3	9.2	9	7.5	20	16.7	0	0
Cryptosporidium sp.	0	0	19	15.8	0	0	1	0.8	0	0	0	0
Enteromonas sp.	0	0	8	6.7	4	3.3	3	2.5	0	0	0	0
Isospora sp.	28	23.3	7	5.8	3	2.5	6	5	4	3.3	0	0
Trichodinae achatinae	0	0	0	0	0	0	0	0	29	24.2	0	0
Nematodes												
Angiostrongylus sp.	4	3.3	1	0.8	28	2.5	3	2.5	12	10	0	0
Enterobius vermicularis	30	25	0	0	0	0	7	5.8	2	1.7	0	0
Protostrongylus sp.	0	0	0	0	0	0	0	0	3	2.5	0	0
Strongyloides stercoralis	2	1.7	0	0	0	0	3	2.5	4	3.3	0	0
Hyostrongylus egg	2	1.7	0	0	0	0	1	0.8	0	0	0	0
Trematodes												
Fasciola sp.	1	0.8	2	1.7	0	0	1	0.8	11	9.2	0	0
Dicrocoelium dendriticum	3	2.5	0	0	0	0	0	0	1	0.8	0	0
Schistosoma mansoni	0	0	0	0	0	0	0	0	1	0.8	0	0
Alaria sp.	13	10.8	5	4.2	4	3.3	11	9.2	0	0	0	0
Mites												
Ricardoela limacum	0	0	0	0	0	0	0	0	0	0	8	6.7
Non identified mite	1	0.8	2	1.7	3	2.5	0	0	0	0	0	0

N: number of examined organs; n: number of infected organs; %: infection rate in percentages.

3.1.3. Infection rate of parasites by location, weight and species

Of the 120 snails sampled, 90 (75%) were infected, that is 48 (80%) for *A. fulica and* 42 (70%) for *A. marginata* respectively. With respect of infection rate by weight, no significant difference was observed. In contrast, there was a significant difference ($p<0.005$) in the infection rate of parasites by location. Snails collected in Lekie had the highest infection rates (92.5%) followed by those collected in Wouri (82.5%) and finally those of Santchou (50.0%) (Table 3).

Table 3
Over all infection rate (%) of parasites by location, weight and species.

Variation factors		N	n	Infection rate (%)	*p-value*
Species	*A. fulica*	60	48	80.0[a]	0.146
	A. marginata	60	42	70.0[a]	
Locality	Wouri	40	33	82.5[b]	0.000*
	Lekie	40	37	92.5[a]	
	Santchou	40	20	50.0[c]	
Weight	<20	14	13	92.9[a]	0.133
	20-50	83	63	75.9[a]	
	50-100	23	14	60.9[a]	

N: total number of samples; n: number of positive samples; (%) infection rate in percentage; a, b, c: numbers bearing the same letters on the same line are not significantly different ($p>0.05$); *: significant p value.

3.1.4. Infection rate of detected parasites by host species

Up to 16 species of parasites were identified in both *A. fulica* (16) and *A. marginata* (14) (Table 4). The difference in infection rate between *A. fulica* and *A. marginata* was significantly different only for *Isospora* sp and *A. cantonenesis* ($p< 0.05$). The highest infection rate was recorded with *B. coli* in *A. fulica* (46.7%) and *A. marginata* (38.3%).

Table 4
Infection rate of parasites by host species.

	Snail species						
	***A. fulica* (N=60)**		***A. marginata* (N=60)**		**Total**		
Parasites	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	***p-value***
Balantidium coli	28	46.7[a]	23	38.3[a]	51	42.5	0.230
Cryptosporidium sp.	11	18.3[a]	8	13.3[a]	19	15.8	0.340
Enteromonas sp.	5	8.3[a]	7	11.7[a]	12	10.0	0.381
Isospora sp.	22	36.7[a]	9	15.0[b]	31	25.8	0.006*
Trichodina achatinae	16	26.7[a]	13	21.7[a]	29	24.2	0.335
Protozoa	37	61.7	29	48.3	66	55.0	0.099
Angiostrongylus Cantonensis	7	11.7[b]	15	25.0[a]	22	18.3	0.049*
Enterobius vermicularis	16	26.7[a]	21	35.0[a]	37	30.8	0.215
Protostrongylus sp.	2	3.3[a]	1	1.7[a]	3	2.5	0.500
Hyostrongylus egg	2	3.3[a]	1	1.7[a]	3	2.5	0.500
Strongyloides stercoralis	5	8.3[a]	3	5.0[a]	8	6.7	0.359
Nematodes	25	41.7	30	50.0	55	45.8	0.232
Alaria sp.	16	26.7[a]	10	16.7[a]	26	21.7	0.134
Dicrocoelium dendriticum	4	6.7[a]	0	0.0[a]	4	3.3	0.059
Fasciola sp.	2	3.3[a]	1	1.7[a]	3	2.5	0.500
Schistosoma masoni	1	1.7[a]	0	0.0[a]	1	0.8	0.500
Trematodes	20	33.3	11	18.3	31	25.8	0.047
Unidentified mite	4	6.7	2	3.3	6	5.0	0.309
Ricardoela limacum	3	5.0[a]	5	8.3[a]	8	6.7	0.359
Mites	7	11.67	7	11.67	14	11.67	1.000

N: total number of samples; n: number of positive samples; (%) infection rate in percentage; a, b: numbers bearing the same letters on the same line are not significantly different ($p>0.05$); *: significant p value.

3.1.5. Infection rate of parasites by snail host weight

The infection rate for *A. cantonensis, E. vermicularis* and *Alaria sp* was significantly higher ($p<0.05$) in young snails weighing less than 20g compared with those weighing more than 20g (Table 5).

Table 5
Infection rate (%) by snail host weight.

	Weight (g)								
	<20 (N=14)		20-50 (N=83)		50-100 (N=23)		Total (N=120)		
Parasites	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	**(n)**	**(%)**	***P-value***
Balantidium coli	7	50.0[a]	37	44.6[a]	7	31.8[a]	51	42.5	0.576
Cryptosporidium sp.	2	14.3[a]	16	19.3[a]	1	4.5[a]	19	15.8	0.391
Enteromonas sp.	2	14.3[a]	10	12.0[a]	0	0.0[a]	12	10.0	0.317
Isospora sp.	5	35.77[a]	20	24.1[a]	6	27.3[a]	31	25.8	0.773
Trichodina achatinae	6	42.9[a]	18	21.7[a]	5	22.7[a]	29	24.2	0.432
Protozoa	10	71.4	47	56.6	9	40.9	66	55.0	0.189
Angiostrongylus cantonensis	7	50.0[a]	13	15.7[b]	2	9.1[c]	22	18.3	0.012*
Enterobius vermicularis	6	42.19[a]	29	34.9[b]	2	8.7[c]	37	30.8	0.010*
Protostrongylus sp.	0	0.0[a]	2	2.4[a]	1	4.5[a]	3	2.5	1.000
Hyostrongylus egg	0	0.0[a]	1	1.2[a]	2	9.1[a]	3	2.5	0.153
Strongyloides stercoralis	2	14.3[a]	4	4.8[a]	2	9.1[a]	8	6.7	0.476
Nematodes	10	71.4	38	45.8	7	30.4	55	45.8	0.035*
Alaria sp.	7	50.0[a]	17	20.5[b]	2	9.1[c]	26	21.7	0.028*
Dicrocoelium dendriticum	1	7.1[a]	3	3.6[a]	0	0.0[a]	4	3.3	0.638
Fasciola sp.	0	0.0[a]	3	3.6[a]	0	0.0[a]	3	2.4	0.741
Schistosoma masoni	0	0.0[a]	1	1.2[a]	0	0.0[a]	1	0.8	1.000
Trématodes	7	50.0	21	25.3	3	13.6	31	25.8	0.093
Non identified mite	0	0.0[a]	3	3.6[a]	3	13.6[a]	6	5.0	0.155
Ricardoela limacum	3	21.4[a]	5	6.0[a]	0	0.0[a]	8	6.7	0.103
Mites	3	21.4	8	9.64	3	13.6	14	11.67	0.320

N: total number of samples; n: number of positive samples; (%) infection rate in percentage; a, b, c: numbers bearing the same letters on the same line are not significantly different ($p>0.05$); *: significant p value.

3.2. Discussion

Several factors influenced the infection rate of the observed parasites including species, sampling area and weight. The total infection rate was 75% (80% in *A. fulica* and 70% in *A. marginata*). These results corroborate with those obtained by Karamoko et al. (2016) who had an infection rate of 52% in *A. achatina* and 74% in *Archachatina ventricosa.* This could be explained by the fact that the Littoral, Center and West regions of Cameroon have approximately the same geo-climatic characteristics as the locality of Azaguié investigated by Karamoko et al. (2016) in Ivory Coast. At the same time, there was a significant difference in the infection rate of parasites by location. Indeed, snails collected in Lekie had the highest prevalence (92.5%) followed by those collected in Wouri (82.5%) and finally those of Santchou (50.0%). This could be justified by the differences in temperatures observed in these different regions. In fact, the Central and the coastal region have simultaneously an average temperature of 25°C and 26°C, which are suitable for the development of parasites. The western region has a mean low temperature of 19°C, which is inappropriate for parasite multiplication (IRAD, 2008). Weight had a significant influence on the infection rate of *A. cantonensis* and *S. mansoni* parasites. Similarly, the infection rate of parasites was greater with the low weight animals (<20g). This could be explained by the dietary habits of small snails regarded as real "snacks". This habit they have to devour everything in their path exposes them to a varied range of infections besides their immune system not yet fully developed.

With regard to the different groups of parasites identified, the most represented group was that of protozoa (79.2%) followed by that of nematodes (45.8%) while the least represented was that of Non identified mite (5%). These results corroborate the findings of Karamoko et al. (2016) in which protozoa were also highly represented (97.7%) followed by 95.8% nematodes and finally trematodes (0.4%). This preponderance of protozoa would be

due to the fact that, relatively to the snail size, protozoa are small in size and are one-host species. These snails are probable final hosts for theses protozoan parasites which are known to be ubiqueous. Because these parasites belong to zoonotic groups of parasites, further studies on the host statute of these edible snails are urgently needed.

A total of 16 parasite species were identified in the snails (16 in *A. fulica* and 14 in *A. marginata*). The presence of these parasites corroborates with the work of Igbinosa et al. (2016) who isolated *S. ransoni, Alaria* sp, *D. dendriticum, A. cantonensis* and *S. mansoni* in terrestrial snails (*Achatina achatina, Achatina fulica, Archachatina marginata, Limicolaria aurora, L. flammeaand Limicolariopsis* spp) in Benin. It also corroborates with the work of Karamoko et al. (2016) who found *B. coli*, *Protostrongylus* spp and *D. dendriticum* in two snail species (*Achatina achatina* and *Archachatina ventricosa*) in southeastern Ivory Coast. These correlations could be justified by the fact that these two localities roughly share the same geo-climatic characteristics with the surveyed regions of Cameroon. Finding of the same parasites both in Cameroon and in West Africa in different snail species is an indication that the host range of these parasites is very large.

The most prevalent parasite in this study was *B. coli* (42.5%). These results are contradictory to those of Karamoko et al. (2016) who found *B. coli* in two snail species *Achatina achatina and Archachatina ventricosa* but, with low infection rate (8%). The infection rate of this parasite raises many questions because of its monoxenic life cycle. As its life cycle proceeds on the same host or partially in the external environment (Nanfah, 2008), African giant snails can be considered as a definitive host for this parasite. The relatively high infection rate of this parasite in this study could be explained by the fact that this parasite has the capacity to secrete hyaluronidase, a substance which would help the microorganism to invade the mucous membranes.

E. vermicularis was the second most prevalent parasite. This could be explained by the fact that this parasite is a cosmopolitan parasite (frequent in developing countries, Russia, Europe and North América) (Zrara et al., 1998). In this study, its larval stage was found in the snail body. African giant snail can be considered as an intermediate host for this parasite or as a simple carrier of this parasite.

Cantonensis has also been isolated from these snails. Its presence here corroborates the work of Igbinosa et al. (2016) who isolated this nematode in the African giant snail (*A. fulica)* in Nigeria. *A. fulica* has been incriminated as the intermediate host of *A. canonensis* (Hu et al., 2011). Thus, its presence in edible snails in Cameroon is a cause of concern because human are at risk of infection with *A. cantonensis* if infective larvae are ingested (Cross, 1987; Heyneman and Lim, 1967).

Strongyloides stercoralis being a soil parasite was isolated in this study with a low infection rate of 6.7%. These results are contradictory to those of Igbinosa et al. (2016) who had a prevalence of 54.04% in terrestrial snails (*A. fulica)* in Nigeria in both dry and wet seasons. This contradiction could be explained by the fact that this study was carried out during the dry season, whereas, this parasite is known to thrive in wetlands of the tropical and subtropical regions, and also in regions with a temperate climate (Boggild et al., 2016). The presence of this parasite could be attributed to its abundance in the soil coupled with its ability to easily locate the snail host because of its secretions (Safer et al., 2007).

Protostrongylus sp was also isolated in this study with low infection rate (2.5%). This result contradict those of Karamoko et al. (2016) who obtained an infection rate of 24% and 48% respectively in *Archachatina ventricosa* and *Achatina achatina*. According to Dreyfuss and Rondelaud (2011), these parasites require the terrestrial mollusk intervention to ensure their transmission to the herbivorous because one part of their life cycle takes place into the snail body.

The presence of resistance stages (eggs) of relatively large parasites notably trematodes (*Fasciola* sp and *Shistosoma mansoni*) in snails suggest the environment where the snails were collected is polluted by these eggs shed by the vertebrate hosts. In fact, the African giant snails investigated are (5-17 cm) unlikely to harbour the adult stages of these trematodes. Contamination of the snails by these trematodes probably results from feeding habits of these terrestrial snails. Therefore, these snails should be regarded as vectors for the trematodes.

Isospora sp, *Enteromonas* sp*, Cryptosporidium* sp and strongyle parasites have not been previously reported in snails. Whether the investigated snails stand as intermediate, final or paratenic hosts for these parasites is not known. Further studies on the relationship between the two groups are required.

Results relating to organ distribution of parasites showed that *Protostrongylus* sp was restricted to the slime. These results contradict those of Karamoko et al. (2016) who isolated this parasite on the snail foot, mantle, intestine and even the stomach with a high prevalence (48% in *A. achatina* and 24% in *A. ventricosa*) against a total infection rate of 2.5% recorded in this study. The preferential localization of this parasite in the slime could be

explained by the fact that this parasite infects the mollusk in its larval form (L1) by transcutaneous penetration (Dreyfuss and Rondelaud, 2011). *A. cantonensis* was identified in all organs except on the foot of snails. This may be explained by the fact that the morphological characteristics of this parasite facilitate its penetration through the foot of the snail or through other exposed regions, which justifies its presence in the mantle (Kim et al., 2014; Iwanowicz et al., 2015). In this study, only one mite (*R. limacum)* was identified. This parasite was exclusively found on the foot. This could be explained by the fact that, the foot is the only exposed area of the body which is suitable for ectoparasite infestation. Data on the presence of this parasite elsewhere is scare. However, this mite has been cited as part of snail parasites (Pirame et al., 2003).

In conclusion, the giant snails *Archachatina marginata* and *Achatina fulica* were colonized by different groups of parasites, including nematodes, trematode, protozoa and mite. The parasite range of these edible snails in Cameroon is very large. The highest infection rate was recorded with *B. coli* followed by *E. vermicularis. Achatina fulica* was more infected than *Archachatina marginata*. The host-parasite relationship between the snails and parasites is multi-factorial because the snail stands either as final, intermediate or paratenic host for the identified parasites. The pathogenic effect of these parasites on snails should be investigated.

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Compliance with ethical standards

Ethical approval: N/A. The study is reporting results from an experiment on snails.

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