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Chemical composition of the flesh and mucus of land snail species (*Archachatina marginata* (Swainson), *Archachatina marginata* (Suturalis), *Achatina fulica, Achatina iostoma, Limicolaria spp*) in Gabon: Case of the Haut-Ogooué Province

Gilbert Comlan Zougou Tovignon[1], Abdourhamane Ibrahim Touré[1], Cédric Sima Obiang[2], Bénédicte-Shadriska Djinda[1], Frédéric Christol Ngansop Nono[3], Arseine Valery Mboko[1], Férence Ndzani Matumuini[1], Louis Clément Obame Engonga[2], Joseph-Privat Ondo[2], Fernand Tendonkeng[4], Benoit Boukila[1] and Etienne Pamo Tedonkeng[4].

1- National Higher Institute of Agronomy and Biotechnology (INSAB), University of Science and Techniques Masuku (USTM), P.O. Box 941, Franceville - Gabon.
2- Laboratory of Biochemistry, Faculty of Science, University of Science and Techniques Masuku (USTM), P.O. Box 941, Franceville - Gabon.
3- Technical School of Agriculture (TSA) Bambili, P.O. Box 15, Bambili (Bamenda), Cameroon.
4- Laboratory of Animal Nutrition, Department of Animal Science, FASA, University of Dschang, P.O. Box 222, Dschang - Cameroon.
Corresponding author: zougou.g@gmail.com, Tel.: (00241) 74 33 67 84.

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ABSTRACT

Objective: The objective of this study was to contribute in the improvement of knowledge on protein sources entering in animal feeding. It was conducted with the aim to determine the chemical composition of the flesh of the snails (*Archachatina marginata* (Swainson), *Archachatina marginata* (Suturalis), *Achatina fulica*, *Achatina iostoma*, *Limicolaria spp*).

Methodology and results: A sample of 60 snails, considering the different species, were slaughtered and the proportions of the mucus, flesh, visceral organs and shell were determined as well as the chemical composition of the flesh and mucus. It emerges that the species identified were *Achatina fulica, Achatina iostoma, Limicolaria spp, Archachatina marginata* (Swainson) and *Archachatina marginata* (Suturalis). The proportions of flesh and shell were respectively 24.90 and 14.88 in *Achatina fulica*; 29.98 and 15.69 in *Archachatina marginata*; 25.40 and 15.80 in *Achatina iostoma* and 44.84 and 17.47 in *Limicolaria spp*. The rates of proteins and fats contained in the mucus were respectively 41.61 and 1.87 in *Achatina fulica*; 44.58 and 1.26 in *Archachatina marginata* (Swainson); 45.21 and 1.03 in *Archachatina marginata* (Suturalis); 42.83 and 4.11 in *Achatina iostoma* and 41.96 and 4.00 in *Limicolaria spp*. Moreover, rates of proteins, fats and ash were respectively 58.34, 0.9 and 3.06 in *Achatina fulica* ; 53.6, 1.15 and 1.56 in *Archachatina*

marginata (Swainson); 72.70, 2.63 and 3.31 in *Archachatina marginata* (Suturalis); 54.36, 2.38 and 1.37 in *Achatina iostoma* and 79.68, 2.37 and 4.68 in *Limicolaria spp*.
Conclusion and application of results : In view of the results, in addition to the two major genera of snails of interest in Heliciculture (*Archachatina* and *Achatina*), having protein levels varying from 53.6 to 72.70%, the genus *Limicolaria* can be used in animal feeding as source of proteins (79.68%).
Key words: Snails, identification, proportion, flesh, mucus, chemical composition.

INTRODUCTION

The problem of food security is now one of the major concerns of FAO and African governments (FAO, 2015). In fact, most Sub-Saharan countries suffer from a significant deficit in proteins of animal origin (Otchoumou et *al*., 2005). The countries of the Central African sub-region, with an estimated population of 110 million (Rio + 20, 2012), are faced with the problem of food security because local productions cannot meet the needs of local populations (FAO, 2012). Whereas, the lack of proteins in a diet causes growth retardation, weight loss and reproductive disorders (Miégoué, 2016; Zougou, 2017). To satisfy theses needs, specialists have turned to breeding of certain species of animals such as pigs, cattle, goats, poultry, fish (Bouye et *al*., 2017). Despite the development of these productions, the animal protein deficit remains a reality in Sub-Saharan countries (Otchoumou et *al*., 2005). Faced with this situation, populations resort to other sources of proteins such as the meat of wild animal species (Ekoue et *al*., 2002). The consumption of bush meat provides a large number of calories, micronutrients as well as essential proteins and fats (Golden et *al.*, 2011). Of all these species, the land snail has the particularity of presenting several interests (Ekoue et *al*., 2002). Indeed, it is highly prized not only for its nutritional value but also for its organoleptic qualities (Bouye et *al*., 2017). The protein content of snail flesh varies between 37-51% (Bouye et *al*., 2017) and lipids from 1.17-1.38% (Fagbuaro et *al*., 2006). This gastropod mollusc has already been the subject of several studies in African countries (Adou Coffi, 2011; Ky, 2013; Bouye et *al.*, 2017). However, to date, knowledge about land snails in Gabon is virtually non-existent. The objective of this study is to contribute to the acquisition of knowledge on the land snail species of Gabon, particularly their performance and the chemical composition of their flesh and mucus according to the different species of snails existing in the Province of Haut-Ogooué.

MATERIAL AND METHODS

The study took place in the Haut-Ogooué Province, in the South-East of Gabon. The average temperature of this zone is 24 °C with an equatorial climate characterized by a rainy season going from mid-September to the end of May with a weak inter-cycle around January; the average insolation being 160 hours per month; a dry season, from early June to mid-September, with low average insolation of 100 hours per month (Onouviet, 2007).

The study area was divided into three sub-areas:

- **The city of Franceville:** It is located at 1°37'60" South latitude and 13°35'1" East longitude. This city has a tropical climate. The average temperature is 27 °C and the average annual precipitation is 1669 mm. The vegetation consists of grassy savannas interspersed with gallery forests around sunken rivers (Onouviet, 2007).

- **The city of Okondja:** It is located at 0°40'60" South latitude and 13°46'60" East longitude. Okondja enjoys a tropical climate with an average temperature of 24.8 °C and an average annual precipitation of 1669 mm. The vegetation present in this region is the forest (Onouviet, 2007)
- **The city of Moanda:** It is located at 1°33'27" South latitude and 13°13'4" East longitude. Moanda has a tropical climate with an average annual temperature of 24.7 °C and an average annual rainfall of 1858 mm. Its vegetation consists of grassy savannas interspersed with gallery forests around sunken rivers (Onouviet, 2007). The snail collection was carried out in the 3 cities. After collection, they were identified according to each of these cities. The identification of the species was made on the basis of the morphological characteristics of the shell, the colour of the latter, the colour of the flesh, the size and the number of eggs laid (Memel et *al.*, 2009; Hornick, 2010). A sample of 60 snails was used for the determination of the proportion of the different constituent elements on one hand, and the chemical composition of the flesh and mucus of the different species on the other hand. Once the body weight recorded, the mucus was extracted from the shell with a pointed end iron bar, collected in sterile tubes and weighed; the inanimate animal was soaked for a few seconds in hot water (60 °C) before being extracted from the shell. Afterwards, the flesh (the foot) was separated from the viscera and the weighing of these 2 elements as well as of the shell was carried out. These were then transferred into labelled sachets and kept cool at 18 °C. The snails and their constituent elements (mucus, flesh, viscera and shell) were weighed using a "CAMRY" brand electronic balance (model: EK2151HK) with a capacity of 5 kg and a precision of 1 g (figure 1). For the laboratory analyses, a “Sartorius” brand electronic balance with a capacity of 500 g and a precision of 0.1 g was used.

Figure 12: Determination of the weight of a snail.

The chemical analyses of the flesh and mucus of the snails were carried out at the Laboratory for Biochemical Research (LAREBIO) of the Faculty of Science of the University of Science and Technology of Masuku (USTM). For the flesh, the levels of dry matter, moisture, crude protein (CP), fat (F) and ash were determined. Regarding mucus, the determination of lipid and crude protein levels was carried out. Fresh flesh samples were pooled, taking into account the species and dried in a Memmert brand oven at 100 °C for 48 h (Figure 2) before being ground. The powders thus obtained were used to determine the protein and lipid content of the flesh.

Figure 2: Oven meat samples

The dry matter or total dry residue is all the substances which do not volatilize under the drying conditions defined by the method used; its determination was carried out by the method of AOAC (1990) which consists in drying the samples in an oven at 105 °C for 24 h. More precisely, 30 g of the sample of fresh flesh were introduced into crucibles, previously dried and weighed (M0). Then, the whole (M1) was placed in the oven at 105 °C for 24 h. The whole was cooled in open air before being weighed again (M2). The total dry residue or dry matter (DM) was expressed as a percentage of dry matter according to the formula:

$$\% \text{ MS} = \frac{M2 - M0}{M1 - M0} \times 100$$

With $\mathbf{M}_0$ = mass in grams of the empty crucible; $\mathbf{M}_1$ = mass in grams of the crucible containing the test portion before baking and $\mathbf{M}_2$ = mass in grams of the crucible containing the test portion after baking.

The water and volatile matter (TE) content was then deduced from the dry matter content by the following formula:

%TE = 100 - MS

The mineral matter (MM) for its part was obtained by incineration of a mass (M1) of the sample of flesh in an oven at 450 ° C. for 6 hours. The latter was placed in crucibles of which the empty weight had been taken previously (Pc). Before baking, the weight Pf_1 (empty crucible + sample) was also noted. On leaving the furnace, the crucibles containing the mineral matter were weighed again (Pf_1).

The percentage of mineral matter was obtained from the following formula:

$$\%MM = ((Pf1 - Pc) / P_0)) \times 100$$

With $\mathbf{Pf}_1$ = crucible weight + sample after 6 hours in the oven; **Pc** = weight of the empty crucible and $\mathbf{P}_0$ = weight of the sample.

The organic matter was obtained by subtracting the percentage of mineral matter

from 100 g of dry matter (DM) from the following formula:

$$OM = 100 - MM (\%DM)$$

With **MM =** mineral matter; **OM =** organic matter and **DM =** dry matter.

Lipids are a group of substances, which in general are soluble in chloroform, petroleum ether, hexane or other nonpolar solvents, but are poorly soluble in water (Bachir Bey, 2016). In practice, hexane and hot petroleum ether are the most commonly used. A reflux extractor is used for this. The hot solvent vapours pass through the milling in a cartridge, condense higher in a condenser, and fall back into the cartridge containing the milling. There is then maceration and extraction of the oils from the milling. When the solvent fills the cartridge, there is siphoning and the solvent falls back into the boiling flask. The cycle continues until the complete extraction of fat. The solvent contained in the flask is then saturated with the extracted oils. It then remains to evaporate the solvent using a ROTAVAPOR apparatus to collect the oils and recover the solvent, which could be reused several times.

The fat content was determined according to the following formula:

$$\text{Fat content (\%)} = [(P_1 - P_0) / \text{Test sample}] \times 100$$

With $\mathbf{P_0}$ = weight of the empty flask and $\mathbf{P_1}$ = weight of the flask containing the lipid.

For the extraction and assay of crude protein, the Bradford / Sedmak method (Kruger, 2009) was used. The determination of proteins in solution by the Bradford method is based on the interaction between the proteins and Coomassie Brillant Blue G250 (CBBG-250) in an acidic medium. In the presence of proteins, a red shift in the spectrum is obtained (bathochrome effect) with a maximum wavelength of 620 nm. In general, CBBG-250 reacts more specifically with basic amino acids (K, R, H) but it interacts with other amino acids. Thus, the OD (optical density) at 620 nm is a function of the protein concentration. The plot of this curve gives a line of the form y = ax (if the white is subtracted) or a line of the form y = ax + b (without subtraction of the white).

For its realization, the prepare of the calibration curve for the protein assay, the extraction and assay of the proteins of the sample and the calculation of the protein level are necessary.

- **Preparation of the calibration curve for the protein assay**: The standard protein used for the protein assay was "bovine serum albumin" (BSA) at a concentration of 1 mg / ml in distilled water. Six (06) test tubes are used (Table 1).

Table 1: Preparation of the standard range.

Tube	**White**	1	2	3	4	5	6
BSA (1mg / ml) in ml	0	0.1	0.2	0.4	0.6	0.8	1
Distilled water	1	0.9	0.8	0.6	0.4	0.2	0
Coomassie Blue Reagent	1	1	1	1	1	1	1

The ODs were read on an UV-visible spectrophotometer (450 to 620 nm) within 2 to 5 minutes after the addition of reagent. Then, it was a question of plotting the curve: (OD620nm) = f ([proteins]).

- **Extraction and determination of proteins from the sample:** Extraction of proteins from the sample required the use of a solution. To have this solution, 7.5g of Sodium Dodecyl Sulphate (SDS) were mixed with 225µl

of β-mercaptoethanol, the whole then completed to 500ml with of distilled water. As for the sample solution, it was obtained by dissolving 0.5 g of the biological material in 10 ml of the extraction solution. This solution was then centrifuged at 5,000 rpm for 5 minutes. After centrifugation, the supernatant was collected and filtered with filter paper or, failing that, lotus paper to retain the solid particles. The assay is carried out as shown in Table 2.

Table 2: Sample assay

Tube	**White**	1
Sample (ml)	0	0.1
Solute extraction containing ion S DS	0.01	0
Distilled water	1	0.9
Coomassie Blue Reagent	1	1

Figure 3 shows the blue coloration obtained after adding Coomassie Blue to the sample tubes.

Figure 3: Coomassie blue staining in the presence of samples

- **Calculation of the protein level:** After reading the ODs on a spectrophotometer at 620 nm, the protein concentration was determined from the line equation of the standard curve. The yield was determined using the formula:

$$\%\text{Proteins} = \frac{\text{Weight of protein in the sample}}{\text{Weight of the sample in the tube}} \times 100$$

Data on the various constituent parts of snails and the chemical composition of mucus and flesh were subjected to one-way (species) analysis of variance according to the General Linear Model (GLM). When significant differences existed, the separation of averages was done by the Waller Duncan test at the 5% significance level (Stelle and Torrie, 1980). Correlation tests (Person) were used to assess the relationships between the different constituent parts of snails. The analysis software used was SPSS.20.0.

RESULTS

Abundance of snail species collected during by the study areas: The abundance of snail species collected during the study as a function of the study areas is presented in Table 3. It appears that, during this study, a high number of snails was recorded in the city of Okondja (1240 snails) followed by that of the city of Franceville (1034 snails). *A. marginata* (Swainson) was more abundant in Okondja (540 snails) and Franceville (335 snails), as was *Limicolaria spp* which was more abundant in Okondja (320 snails) and Franceville (243 snails).

Table 3: snail species collected per study areas.

Species	Study areas			Totals
	Franceville	Okondja	Moanda	
A. marginata (Swainson)	335	540	300	1175
A. marginata (Suturalis)	150	0	0	150
A. fulica	206	120	164	490
A. iostoma	100	260	12	372
Limicolaria spp	243	320	110	673
Totals	1034	1240	586	**2860**

Proportion of the different constituent elements of snail species: The proportions of the various constituent elements of the snail species collected during this study are recorded in table 4. It emerges from table 4 that the live weight, length, width, proportions of the shell, of the flesh, mucus and viscera of different species of snails vary from species to species. Indeed, statistical analysis reveals that the average body weight, length and width of the species *Achatina fulica* and *Achatina iostoma* remained comparable ($p>0.05$) but significantly ($p<0.05$) lower than obtained in the species *Limicolaria spp* and significantly ($p < 0.05$) higher than those obtained in the species *Archachatina marginata* . The proportions of the shell recorded in the species *Archachatina marginata* and *Limicolaria spp* remained comparable ($p>0.05$) but significantly ($p < 0.05$) higher than those recorded in the species *Achatina fulica* and *Achatina iostoma.* In addition, the proportions of the flesh obtained in the *Achatina fulica*, *Archachatina marginata* and *Achatina iostoma species* remained comparable ($p>0.05$) but significantly ($p<0.05$) lower than those recorded in the species *Limicolaria spp.* The proportions of mucus obtained in the *Achatina fulica* and *Limicolaria spp* species remained comparable ($p>0.05$) but significantly ($p<0.05$) higher than those obtained in the species *Archachatina marginata* and *Achatina iostoma*.

Table 4: Proportion of flesh, mucus, viscera and shell according to snail species

Settings	Cash			
	Achatina fulica	***Archachatina marginata***	***Achatina iostoma***	***Limicolaria spp***
Average live weight (g)	62.91 ± 18.89[b]	127.96 ± 40.87[a]	62.36 ± 15.60 [b]	2.91 ± 1.22 [c]
Length (cm)	10.30 ± 1.58 [b]	11.94 ± 1.08 [a]	10.31 ± 0.79 [b]	4.91 ± 0.42 [c]
Width (cm)	7.62 ± 0.64 [b]	9.47 ± 1.02 [a]	7.64 ± 0.59 [b]	3.30 ± 0.19 [c]
% shell	24.90 ± 3.28 [b]	29.98 ± 2.56 [a]	25.40 ± 3.40 [b]	28.465 ± 2.6 [a]
% flesh	14.89 ± 1.55 [b]	15.69 ± 1.05 [b]	15.78 ± 1.85 [b]	21.66 ± 1.8 [a]
%mucus	24.72 ± 2.34 [a]	19.52 ± 1.84 [b]	17.20 ± 1.84 [c]	23.43 ± 1.04 [a]
% viscera	35.50 ± 3.21 [b]	34.80 ± 1.70 [b]	41.63 ± 2.44 [a]	26.57 ± 1.4 [c]

a, b and c: the averages bearing the same letters on the same line are not significantly different at the 5% level.

Correlation between the different constituent parts of snail species: Tables 5, 6, 7 and 8 show the correlations between the different building blocks of *A. marginata*, *A. fulica*, *A. iostoma* and *Limicolaria spp*, respectively.

Table 5: Correlation between the constituent elements of the species *Archachatina marginata*

Characteristics	Live weight	Length	Width	%Shell	%Flesh	%Intestines	%Mucus
Live weight	1	0.91 **	0.85 **	0.07	0.11 **	- 0.02 **	- 0.14 **
Length	-	1	0.79 **	0.04 **	0.02	- 0.05 **	- 0.02 **
Width	-	-	1	- 0.03 **	0.05 **	0.15	- 0.12 **
%Shell		-	-	1	- 0.46	- 0.70	- 0.48 *
% Flesh	-	-	-	-	1	0.40	- 0.29
% Intestines	-	-	-	-	-	1	- 0.18
%Mucus	-	-	-	-	-	-	1

*. Significant correlation at 5%; **. Significant correlation at 1%.

From Table 5, it emerges that the correlation between body weight and length (r = 0.91) was positive and highly significant (p<0.01). The same observation was made between the live weight and the width (r = 0.85) on one hand and between the length and the width (r = 0.79) on the other hand. A poor but highly significant correlation (p < 0.01) was observed between live weight and percentage flesh (r = 0.11), between length and percentage shell (r = 0.04) and between the width and the percentage of flesh (r = 0.05). In contrast, body weight was negatively (p < 0.01) correlated with percentages of intestine (r = - 0.02), mucus (r = - 0.14) and length was negatively (p < 0.01) correlated to the percentage of the intestine (r = - 0.05) and to the mucus (r = - 0.02). The width was negative (p<0.01) correlated e percentage of the shell (r = - 0.03) and to the mucus (r = - 0.12). The correlations between the live weight and the percentage of the shell (r = 0.07), between the length and the percentage of the flesh (r = 0.02), between the width and the percentage of the intestine (r = 0.15) and between the percentage of the flesh and that of the intestine (r = 0.40), were poorly positive and not significant. Likewise, negative and insignificant correlations were between the percentage of the shell and that of the flesh (r = - 0.46) and that of the intestine (r = - 0.70), between the percentage of the flesh and that of mucus (r = - 0.29) and between the percentage

of intestine and that of mucus (r = - 0.18). Percent shell was negatively (p<0.05) correlated with percentage mucus.

Table 6: Correlation between the constituent elements of the species *Achatina fulica*

Characteristics	Live weight	Length	Width	%Shell	% Flesh	% Intestines	% Mucus
Live weight	1	0.47 **	0.76 **	- 0.01	0.01 **	- 0.05 **	0.07 **
Length	-	1	0.49 **	0.09 **	0.21	- 0.47 **	0.38 **
Width	-	-	1	0.04 **	- 0.01 **	- 0.05	0.02 **
%Shell	-	-	-	1	- 0.50	- 0.56	- 0.31 *
% Flesh	-	-	-	-	1	- 0.12	0.20
% Intestines	-	-	-	-	-	1	- 0.51
%Mucus	-	-	-	-	-	-	1

*. Significant correlation at 5%; **. Significant correlation at 1%

It appears from Table 6 that the correlation between body weight and width (r = 0.76) was positive and highly significant (p<0.01). A poor but highly significant correlation (p<0.01) was observed between body weight and length (r = 0.47), between body weight and percentage of flesh (r = 0.01), between live weight and percentage of mucus (r = 0.07), between length and width (r = 0.49), between length and percentage of shell (r = 0.09), between length and the percentage of mucus (r = 0.38), between the width and the percentage of the shell (r = 0.04) and between the width and the percentage of the mucus (r = 0.02). On the other hand, the live weight was negatively (p < 0.01) correlated with the percentage of the intestine (r = - 0.05). Length was negatively (p < 0.01) correlated to percentage of intestine (r = - 0.47) and width to percentage of flesh (0.01). The correlations between length and percentage of flesh (r = 0.21) and percentage of flesh and percentage of mucus (r = 0.20), were weakly positive and not significant. Likewise, negative and insignificant correlations were between body weight and percentage of shell (r = - 0.01), between width and percentage of intestine (r = - 0.05), between the percentage of the shell and that of the flesh (r = - 0.50) and that of the intestine (r = - 0.56), between the percentage of the flesh and that of the intestine (r = - 0 , 12) and between the percentage of the intestine and that of the mucus (r = - 0.51). Percentage of the shell was negatively (p < 0.05) correlated with percentage of the mucus.

Table 7: Correlation between the constituent elements of the species *Achatina iostoma*

Characteristics	Live weight	Length	Width	%Shell	% Flesh	% Intestines	%Mucus
Live weight	1	0.80 **	0.77 **	0.16	- 0.08 **	- 0.27 **	0.14 **
Length	-	1	0.83 **	0.12 **	- 0.08	- 0.22 **	0.16 **
Width	-	-	1	0.05 **	- 0.03 **	- 0.15	0.14 **
%Shell	-	-	-	1	- 0.43	- 0.72	- 0.47 *
% Flesh	-	-	-	-	1	- 0.03	- 0.17
% Intestines	-	-	-	-	-	1	0.02
%Mucus	-	-	-	-	-	-	1

*. Significant correlation at 5 %; **. Significant correlation at 1%

From Table 7, it emerges that the correlation between body weight and length (r = 0.80) was positive and highly significant (p<0.01). The same observation was made between the live weight and the width (r = 0.77) on one hand, and between the length and the width (r = 0.83) on the other hand. A poor but highly significant correlation (p<0.01) was observed between body weight and percentage of mucus (r = 0.14), between length and percentage of shell (r = 0.12) and the percentage of mucus (r = 0.16) and between the width and percentage of the shell (r = 0.05) and that of the mucus (r = 0.14). On the other hand, the live weight was negatively (p<0.01) correlated with the percentages of the flesh (r = - 0.08), of the intestine (r = - 0.27), the length was negatively (p<0.01) correlated with percentage of intestine (r = - 0.22) and width with percentage of flesh (r = - 0.03). The correlations between the body weight and the percentage of the shell (r = 0.16) and between the percentage of the intestine and that of the mucus (r = 0.02), were poorly positive and not significant. Likewise, negative and insignificant correlations were between length and percentage of flesh (r = - 0.08), between width and percentage of intestines (r = - 0.15), between percentage of the shell and that of the flesh (r = - 0.43) and that of the intestine (r = - 0.72) and between the percentage of the flesh and that of the intestine (r = - 0.03) and that of mucus (r = - 0.17). Percentage of the shell was negatively (p<0.05) correlated with percentage of the mucus.

Table 8: Correlation between the constituent elements of the species *Limicolaria spp*

Characteristics	Live weight	Length	Width	%Shell	% Flesh	% Intestines	%Mucus
Live weight	1	0.39 **	0.47 **	0.21	- 0.12 **	0.11 **	- 0.20 **
Length	-	1	0.50 **	0.06 **	- 0.22	0.34 **	- 0.15 **
Width	-	-	1	0.09 **	- 0.19 **	0.10	- 0.02 **
%Shell	-	-	-	1	- 0.34	- 0.18	- 0.54 *
% Flesh	-	-	-	-	1	- 0.32	- 0.23
% Intestines	-	-	-	-	-	1	- 0.37
%Mucus	-	-	-	-	-	-	1

*. Significant correlation at 5%; **. Significant correlation at 1%

It appears from Table 8 that the correlation between length and width (r = 0.50) was positive and highly significant (p<0.01). A poor but highly significant correlation (p<0.01) was observed between body weight and length (r = 0.39), width (r = 0.47) and percentage of bowel (r = 0.11), between the length and the percentage of the shell (r = 0.06) and that of the intestine (r = 0.34) and between the width and the percentage of the shell (r = 0.09). On the other hand, the live weight was negatively (p<0.01) correlated with the percentages of the flesh (r = - 0.02), of the mucus (r = - 0.20) and the length was negatively (p<0.01) correlated with the percentage of mucus (r = - 0.15). Width was negatively (p<0.01) correlated with percentage of the flesh (r = - 0.19) and percentage of mucus (r = - 0.02). The correlations between body weight and percent shell (r = 0.21) and between width and percentage of the intestines (r = 0.10) were poorly positive and not significant. Likewise, negative and insignificant correlations were between the length and the percentage of flesh (r = - 0.22), between the percentage of the shell and that of the flesh (r = - 0.34) and that of the intestine (r = - 0.18), between the percentage of the flesh

and that of the intestine (r = - 0.32) and that of the mucus (r = - 0.23) and between the percentage of the intestine and that of the mucus (r = - 0.37). Percentage of the shell was negatively (p<0.05) correlated with percentage of the mucus.

Chemical composition of the mucus and flesh of the collected snail species

Chemical composition of the mucus of collected snail species: The protein and lipid levels of the mucus of the different species of snails collected are shown in Table 9.

Table 9: Levels of proteins and lipids in the mucus of different species of snails collected.

Chemical composition	Snail species				
	A. fulica	***A. marginata* (Swainson)**	***A. marginata* (Suturalis)**	***A. iostoma***	***Limicolaria spp***
% Protein	41.61 ± 0.62 ^{b}	44.59 ± 0.65 ^{a}	45.21 ± 0.78 ^{a}	42.83 ± 0.70 ^{b}	41.93 ± 0.48 ^{b}
% Fat	1.87 ± 0.50 ^{b}	1.26 ± 0.12 ^{c}	1.03 ± 0.03 ^{c}	4.11 ± 0.10 ^{a}	4.00 ± 0.20 ^{a}

a, b and c : The means with the same letters on the same line are not significantly different at the 5% level.

It appears from Table 9 that the proportions of proteins and lipids in the mucus of the different species of snails vary from one species to another. Indeed, the statistical analysis has revealed that the protein proportions in mucus obtained from species *Archachatina marginata* (Swainson) and *Archachatina marginata* (suturalis) remained comparable (p>0.05) but significantly (p<0.05) higher than those obtained in *Achatina fulica, Achatina iostoma* and *Limicolaria spp*. In addition, it appears that the proportions of mucus lipids recorded in the *Achatina iostoma* and *Limicolaria spp* species remained comparable (p >0.05) but significantly (p<0.05) higher than those obtained in the *Archachatina marginata* species. (Swainson), *Archachatina marginata* (Suturalis) and *Achatina fulica;* however, those obtained in the species *Archachatina marginata* (Swainson) and *Archachatina marginata* (Suturalis) were significantly (p<0.05) lower than those recorded in the species *Achatina fulica.*

Chemical composition of the flesh of the different species of snails collected: Table 10 shows the chemical composition of the flesh of the different species of snails collected.

Table 10: Chemical composition of the flesh of different species of snails collected.

Chemical composition	Snail species				
	A. fulica	***A. marginata* (Swainson)**	***A. marginata* (Suturalis)**	***A. iostoma***	***Limicolaria spp***
% humidity	78.32 ± 0.32 ^{b}	72.63 ± 0.05 ^{c}	76.12 ± 1.84 ^{b}	72.58 ± 0.18^{c}	83.14 ± 2.45^{a}
% DM	21.68 ± 0.32 ^{b}	27.37 ± 0.05 ^{a}	23.88 ± 1.84 ^{b}	27.41 ± 0.18 ^{a}	16.86 ± 2.45^{c}
% OM	96.93 ± 0.62 ^{b}	98.43 ± 0.31 ^{a}	96.68 ± 0.34 ^{b}	98.63 ± 0.20 ^{a}	95.32 ± 0.41^{c}
% Protein	58.35 ± 1.18 ^{c}	53.60 ± 1.87 ^{c}	72.71 ± 2.06 ^{b}	54.36 ± 1.09 ^{c}	79.68 ± 5.13^{a}
% lipids	0.90 ± 0.10 ^{b}	1.15 ± 0.22 ^{b}	2.64 ± 0.38 ^{a}	2.38 ± 0.13 ^{a}	2.37 ± 0.24^{a}
% Ash	3.07 ± 0.76 ^{b}	1.57 ± 0.38 ^{c}	3.32 ± 0.41 ^{b}	1.37 ± 0.25 ^{c}	4.68 ± 0.51^{a}

DM: dry matter; **MO**: Organic Matter.

a, b and c : the averages with the same letters in superscript on the same line are statistically identical.

It appears from the table that the parameters of the chemical composition of the flesh of different species of snails collected vary from one species to another. Indeed, statistical analysis showed that the proportions of DM and OM recorded in the species *Archachatina marginata* (Suturalis) and *Achatina iostoma* had remained comparable ($p>0.05$) but significantly ($p<0.05$) higher than those obtained from the *Achatina fulica*, *Archachatina marginata* (Suturalis) and *Limicolaria spp* species; however, those recorded in the *Achatina fulica* and *Archachatina marginata* (Suturalis) species remained comparable ($p>0.05$) but significantly ($p<0.05$) higher than those recorded in the species *Limicolaria spp* . Moreover, with regard to the moisture and ash contents, those obtained in the *Achatina fulica* and *Archachatina marginata* (Suturalis) species remained comparable ($p>0.05$) but significantly ($p<0.05$) higher than those obtained in the *Archachatina marginata* (Swainson) and *Achatina iostoma species that are* comparable ($p>0.05$) to each other; but these were significantly ($p<0.05$) higher than those recorded in the species *Limicolaria spp.* The protein contents obtained in the *Achatina fulica*, *Archachatina marginata* (Swainson) and *Achatina iostoma species* remained comparable ($p>0.05$) but significantly ($p<0.05$) lower than those recorded in the species *Archachatina marginata* (Suturalis) and *Limicolaria spp* ; however, those recorded in the species *Limicolaria spp* were significantly ($p<0.05$) higher than those recorded in the species *Archachatina marginata* (Suturalis). It also appears that the lipid contents obtained in the species *Archachatina marginata* (Suturalis), *Achatina iostoma* and *Limicolaria spp* had remained comparable ($p>0.05$) but significantly ($p<0.05$) higher than those obtained in the species. *Achatina fulica* and *Archachatina marginata* (Swainson) comparable ($p>0.05$) to each other.

DISCUSSION

Proportion of the different constituent elements of the snail species collected: The average weight of *Archachatina marginata* obtained during this study was 127.96 g. This weight was lower than those recorded by Ekoué and Kuevi-Akue (2002) and by Stiévenart and Hardouin (1990), respectively 150 to 300 g and 500 g. The weight of 62.91 g obtained in *Achatina fulica* during this study was close to that recorded by Ekoué and Kuevi-Akue (2002) (50 to 80 g), but lower than that recorded by Stiévenart and Hardouin (1990) (250 g) in the same species. The proportion of the flesh of *Achatina fulica* (14.88%) obtained in this study was lower than that recorded by Zongo (1996) (26%). In addition, the proportion of the shell of *Archachatina marginata* (29.98%) recorded was higher than that obtained by Koudandé et *al*., (2006) (26%). This difference in weight and proportions could be justified not only by the ages of the snails during these different studies but also by the species of snails used.

Chemical composition of the flesh of the collected snail species: In the present study, the level of proteins of the different species ranged from 53.60 to 79.68%. These rates are higher than those recorded by Sika and *al*., (2015) (40%), by Mbétid-Bessane (2006) (37 to 51%) and by Nyameasem and Borketey-La (2014) (12 to 16%). However, they were close to those obtained by Bouye and *al*., (2017) (74.6 %) and by Adamou et *al*., (2019) (62 to 75%). Moreover, in this study, *Limicolaria spp* presented a protein level of 79.68%, which is higher than those obtained by Fagbuaro et *al*., (2006) (18.66%), by Sea et *al*., (2011) (48.63%) and by Sogbesan and Ugwumba (2012) (66.76%) in the flesh of the same species. For the *Achatina fulica* species, the

protein level was 58.34%. This result is close to that recorded by Zongo (1996) (64.3%). The protein level of the species *Archachatina marginata* (Suturalis), in the present study, was 72.70%. This rate is higher than those obtained by Fagbuaro et *al*., (2006) (20.34%) and by Kouadio et *al*., (2015) (62.53%) in the flesh of the same species. As for *Archachatina marginata* (Swainson), its protein level was 53.6%, lower than that obtained by Kouadio et *al*., (2015) (62.66%). These differences in results could be linked not only to the feeding of snails in nature, which would change from one country to another, to the animal species but also to the age of slaughter. Moreover, in this study, the fat content was variable from one species to another and oscillated from 0.9 to 2.37%. This rate is lower than that of 7.85% obtained by Sogbesan and Ugwumba (2012). Moreover, the rate of 0.9% fat obtained in the flesh of *Achatina fulica*, in the present study, is similar to the rate of 0.8% reported by Memel et *al*., (2009), but lower than that of 3.5% reported by Zongo (1996). The species *Limicolaria spp* has a fat content of 2.37%; this rate is higher than that recorded by Fagbuaro et *al*., (2006) (1.17 %) in the flesh of the same species, but lower than that recorded by Sea et *al*., (2011) (8.76%) in the flesh of *Limicolaria flammea*. As for *Archachatina marginata* (Suturalis), the fat content was 2.63%. This rate is higher than that reported by Fagbuaro et *al*., (2006) (1.23%), but similar to the rate of 2.83% obtained by Kouadio et *al*., (2015). *Archachatina marginata* (Swainson) has a fat content of 1.15%, lower than the 2.98% reported by Kouadio et *al*., (2015). These differences could be related to the slaughter age of the snails. In fact, the lipid content of meat increases with the age and weight of the animals (Tandzong et *al*., 2015; Zougou, 2017). Regarding the ash content, *Achatina fulica* had an ash content of 3.06%, this rate is lower than that of 5.4% reported by Zongo (1996) in the flesh of the same species. Regarding the species *Archachatina marginata* (Swainson) and *Archachatina marginata* (Suturalis), their ash content was 1.56% and 3.31% respectively, lower than that recorded by Kouadio et *al.*, (2015) (9.86%). In addition, the ash content of *Limicolaria spp* was 4.68%; higher rate than that reported by Fagbuaro et *al*., (2006) (1.35%), but lower than that recorded (6.48%) by Sogbesan and Ugwumba (2012) in the flesh of the same species. These differences could be justified by the age of slaughter and the diet of the snails.

CONCLUSION AND APPLICATION OF RESULTS

At the end of this study on the chemical composition of the flesh and mucus of terrestrial species of snails in Gabon, it emerges that mucus from the species *Archachatina marginata* (Swainson) and *Archachatina marginata* (Suturalis) were highly rich in proteins and that from *Achatina iostoma* and *Limicolaria spp* had the highest fat contents. Moreover, highest protein and ash levels were obtained in the flesh of the species *Limicolaria spp* and *Archachatina marginata* (Suturalis). As far as fat content is concerned, its lowest value was found in the flesh of the species *Achatina fulica* and *Archachatina marginata* (Swainson). In view of the results, in addition to the two major genera of snails having an interest in Heliciculture (*Archachatina* and *Achatina*), having significant protein levels, the genus *Limicolaria*, having highest protein level, can equally be used in animal feeding as source of proteins.

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