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Evaluation of the process of transformation of the flesh of the Achatines in Benin

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ABSTRACT: African giant snails are transformed in Benin in different forms that are not well known. The purpose of the study is to characterize processing method, conservation and distribution of giant snails' flesh in southern Benin. Thus, a survey was carried out in 59 snail processing units. The data collected was analyzed and the Multiple Correspondence Analysis was used to identify three groups of transformers. *Archachatina marginata, Achatina achatina, Archachatina ventricosa* and *Achatina fulica* are more processed and consumed in southern Benin. In group 1 the snail flesh is obtained by breaking the shell outdoor and in the family kitchen. The group 2 are distinguished from the first by the place of processing (not frequently used outdoor), the use of bleach to wash the snail before processing and lemon to remove mucus from the snail's flesh. The group 3 are distinguished from the other two by the method of obtaining the flesh. They pull the flesh after heating the shell. The processors of snail flesh in South-Benin were mostly women (96.77%) against a minority of men (3.23%) from group 3. The flesh had higher organoleptic qualities than the flesh obtained by boiling. The flesh of African giant snails to be marketed in South-Benin is mainly sold in fried forms (95.2%), then boiled (2.4%) and braised (2.4%). The three types of processors described made it possible to better understand the processing of African giant snail meat in Benin. The application of good hygiene practices during snail processing would guarantee better quality snail meat.

KEYWORDS: Technology, Tourism, African giant snails, Processing, Marketing, Conservation, Benin.

1 INTRODUCTION

In Benin, national meat production is far from sufficient to cover the population's needs. This production has been estimated at 84,567.23 tonnes in 2021 [1] and should be enough to feed a population of 11, 884,127 [2] to make up the shortfall, on the one hand imports of products are authorized and on the other hand the population resorts to wildlife to satisfy its needs ([3], [4]). The consumption of bushmeat is not only explained by the deficit that exists, but also by the taste of this meat, which is highly appreciated and accessible by the population [5]. Forest resources include giant African snails (or achatines), whose meat is highly prized by the Beninese population. This meat is more processed and consumed in southern Benin ([6], [7]). Given the population's passion for snail meat, it was essential to know which African giant snail species were being processed and to master the snail meat processing chain. Previous studies have focused on characterizing the harvesting sector in order to assess population pressure [6]. This characterization shows strong population pressure, leading to the disappearance of species if farming is not promoted [8]. For this reason, several studies have been carried out on breeding techniques to improve the breeding conditions and zootechnical performance of giant African snails ([9], [10], [11], [12]). The

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work carried out has ensured that giant African snails are available all year round. The promotion of high-performance species and their organoleptic, nutritional and microbiological quality have yet to be determined. To do this, we first need to know which species are processed and consumed in southern Benin. The aim of this study is therefore to assess the processing and marketing of giant snail meat in southern Benin. Specifically, we will: a.) establish a typology of groups of processors of giant African snails in southern Benin; b.) identify the species processed and consumed in southern Benin; c.) characterize the various forms of snail meat processing and its presentation.

2 MATERIAL AND METHODS

2.1 STUDY FRAMEWORK

The flesh of giant African snails is more processed and consumed in South-Benin ([6], [7]). Indeed, our study was carried out in the six (06) departments of Sud-Benin. The Littoral department has the smallest area of Benin's departments. It extends over 10 km to the west, where it borders the commune of Abomey-Calvi in the Atlantic department, and over 6 km to the east, bordering the commune of Sèmè-kpodji in the Ouémé department. The Atlantic Ocean forms the department's southern boundary. To the north, it is bounded by Lake Nokoué. This department is the only one with a single commune, Cotonou. Covering an area of 79 $km^{2,}$ it comprises 13 arrondissements and 140 city districts. Then there's the Atlantic department, with a area of 3,233 $km^{2,}$ a population of 801,683 inhabitants in 2002 and a density of 248 inhabitants/km^2. The Atlantic Ocean forms the southern boundary of the department, which is bordered to the west by the Mono department. To the north, the Atlantic department is bordered by the Zou department. To the east, it is bounded by the Ouémé department. In this department, the communes included in our study are: Toffo, Kpomassè, Zè and Allada. Ouémé department is located in southeastern Benin, with a total area of 1,281 $km^{2,}$ a population of 730,772 in 2002 and a density of 570 inhabitants/km^2. Ouémé department is bordered to the south by the Atlantic Ocean and the Littoral department, to the north by the Plateau department, to the west by the Atlantic department and to the east by the Federal Republic of Nigeria. In the context of our study, this department includes the communes of Adjarra and Dangbo. The Plateau department includes the communes of Pobè, Adja-Ouèrè and Sakété. It covers an area of 3,264 $km^{2,}$ or around 3% of the national territory, with a total population of 407,116 and a density of 125 inhabitants/km^2. Plateau department is bordered to the north by Collines department, to the east by the Federal Republic of Nigeria, to the west by Zou department and to the south by Ouémé department. Also in southern Benin is the department of Zou, which includes the commune of Bohicon. With a surface area of 5243 $km^{2,}$ a population of 599,954 in 2002 and a population density of 114 inhabitants per $km^{2,}$ Zou is bordered to the north by Collines, to the south by Atlantique and Ouémé, to the east by Plateau and to the west by Couffo and Togo. Finally, the department of Mono, where only the commune of Comè was surveyed. Covering an area of 3,800 km2, they are located in the south-west of the national territory, between the sixth (6th) and seventh (7th) degrees of north latitude and the first (1st) and second (2nd) degrees of east longitude. It is bordered to the northeast by the Zou department, to the south by a 40 km coastline on the Atlantic Ocean, to the east by the Atlantic department and to the west by Togo.

2.2 MATERIALS AND METHODS

Using a sm**a**rtphone, data were collected using Kobocollect software. Sampling was carried out on a snowball basis. In all, fifty-nine (59) processors were surveyed in the six departments, representing a sample of 50% of Benin's departments. The breakdown of respondents by department is reported in Table 1.

Table 1. Breakdown of processors by department

Departement	TRANSFORMERS	Frequency (%)
Atlantique	31	52,55
Ouémé	05	8,47
Mono	05	8,47
Littoral	02	3,39
Plateau	12	20,34
Zou	04	6,78

2.3 SURVEY TECHNIQUE

It took place over a 12-week period. It took the form of visits to processing sites, direct observations among the players involved, and interviews with them while they were working. The aim was to gather targeted information, structured according to a predetermined questionnaire. For some players, the interview took place immediately after the first visit, while for others it took place a few days later, depending on the respondent's availability. Parameters such as location, respondent identity, species processed, processing and preservation were recorded during the survey.

2.4 STATISTICAL ANALYSIS

Statistical processing of the data was carried out using Kobotools software for inputting the data collected from the processors, and Epi info for analysis. Epi info software version 7.4.2.0 was used to perform descriptive statistical analyses (frequency, mean, standard deviation, etc.) for quantitative variables. Results were discriminated using ANOVA at the 5% threshold. For categorical variables, a multiple correspondence analysis (MCA) was implemented using R software version 4.1.3 using the MCA function of the FactoMineR library ([13], [14]) on the selected qualitative variables, namely: processing location, snail washing method after purchase, deposit for a few days before slaughter, meat obtaining technique, washing method after slaughter, mucus removal technique, meat removal technique, specific work clothing, waste management, product packaging method and management of unsold products. The MCA was followed by a hierarchical ascending classification, using FactoMineR's HCPC function, based on the snail meat processing characteristics of the most significant MCA components. Transformer groups were then identified by selecting the most relevant partition in terms of inter-class variance explained. These groups were then characterized by testing differences in frequencies on a contingency table crossing the variables and the identified groups (using the Chi^2 test) with the Proc Freq procedure in SAS Version 9.4 software [15]. Two-tailed Z-tests were used to compare relative frequencies between groups. For each relative frequency, a 95% confidence interval (CI) was calculated according to the formula:

$$IC = 1{,}96\sqrt{\frac{P(1-P)}{N}}$$

Where P is the relative frequency and N is the sample size.

3 RESULTS

3.1 TYPOLOGY OF SNAIL PROCESSORS IN SOUTHERN BENIN

The first three axes were used to interpret the results of the multiple correspondence analysis (MCA). The contribution to total inertia of the three factorial axes was 42.48% (18.33% for the first axis, 14.37% for the second and 9.77% for the third) (Figure1). Each axis describes a group of processors. The results of the factorial analysis are shown in Figure 2. Three (03) groups were determined on the basis of processing environment, type of water and additives used for washing, method of separating cephalopods, shells and viscera, and type of clothing used during processing. The first group is made up of 33 women processors from southern Benin. They process snails in the open air and in the family kitchen. Before processing, they wash the snail with plain water. To obtain the snail meat, they break the shell and twist it. Alum is then used to remove the mucus from the flesh. In terms of hygiene, what distinguishes these processors from those of other groups is the absence of work clothes for those in charge. However, they do have clothes for the workers. The second group contained 14 processors. They process snails in the family kitchen, a dedicated kitchen and the communal kitchen. The snail to be processed is often washed with plain water, and sometimes with bleach. In this group, snail meat is obtained by breaking and twisting. Processors in this group use alum and lemon to remove mucus from snail meat. Unlike Group 1, the manager of a unit in this group has the same working clothes as the workers. In terms of processing techniques, this group differs from the first in that the processing site is located in the open air, and bleach is used to wash the snail before processing, and lemon is used to remove the snail meat. The third group is composed with 15 processors (two men in this group). These people process snails in the open air and in the family kitchen, a dedicated kitchen and the communal kitchen. The snails to be processed are often washed with plain water, and sometimes with bleach. To obtain the meat, the snails are drawn off after heating. The resulting flesh is cleaned of mucus using alum. The manager of a unit in this group wears the same work clothes as the workers. This group differs from the other two in the technique used to obtain the flesh.

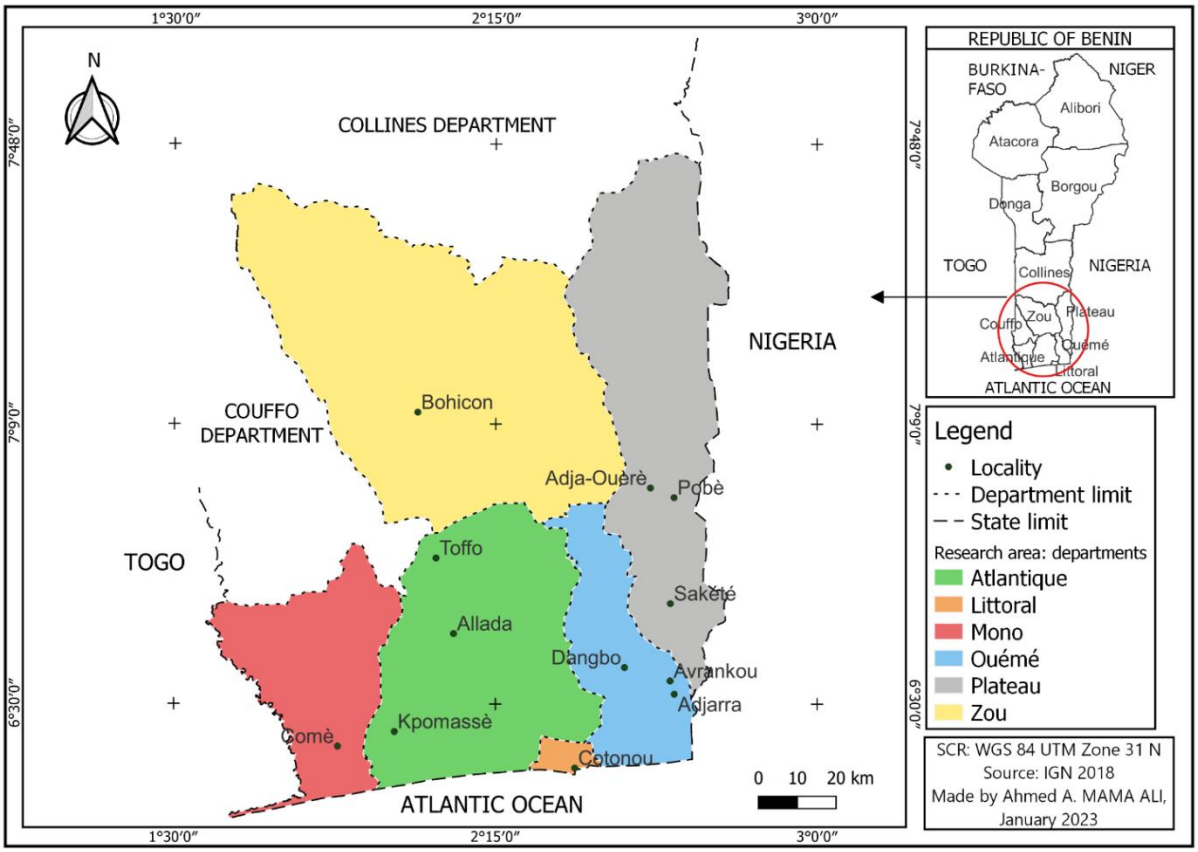

Fig. 1. Survey locality

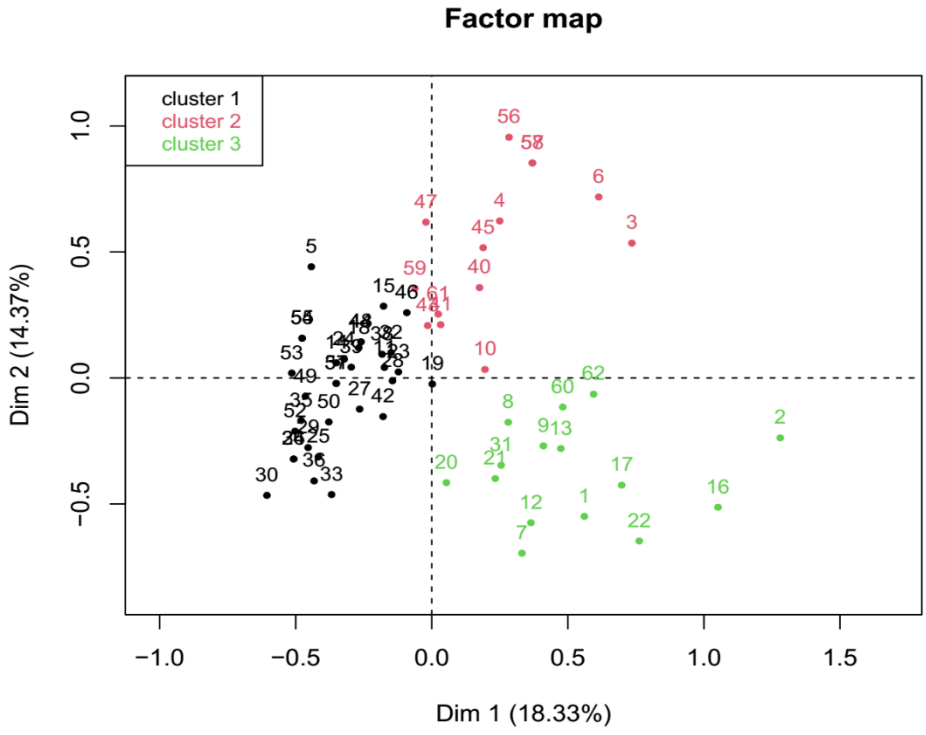

Fig. 2. Typology of snail processors in southern Benin

3.2 PROFILE OF SNAIL MEAT PROCESSORS

Table 2 reported the gender and activity between the groups. The surveys revealed that the majority of snail meat processors in southern Benin were women (96.77%), with a minority of men (3.23%). The proportions of female processors in groups 1 and 2 were significantly higher ($p<0.05$) than those in group 3. The proportion of processors in group 3 was significantly higher ($p<0.05$) than in groups 1 and 2. Overall, processing (88.71%) was the main activity carried out by the processors surveyed, compared with 11.29% who traded. However, in addition to processing, 66.13% of respondents engage in other activities such as selling akassa, aulacod meat, etc. The percentage of processors in group 1 (78.79%) and group 3 (73.33%) who carry out other activities in addition to processing was significantly higher ($p<0.01$) than that of processors in group 2.

Table 2. Gender and activities of transformers

Variable	General (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Gender									
Female	96,77a	4,40	100a	0	100ab	0	86,67b	17,20	*
Male	3,23b	4,40	0b	0	0ab	0	13,33a	17,20	*
Activities									
Processing	88,71a	7,88	81,82a	13,16	92,86a	13,49	100a	0	NS
Trading	11,29c	7,88	18,18a	13,16	7,14a	13,49	0a	0	NS
Other	66,13b	11,78	78,79a	13,95	28,57b	23,66	73,33a	22,38	**

*NS: p>0,05; *: p<0,05; $^{a, b,c}$: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.3 LOCAL AND MATERIALS FOR SNAIL PROCESSING

More snail meat is processed indoors (79%) than outdoors (62.9%). However, processors in groups 1 (84.85%) and 3 (60%) processed more snail meat in the open air ($p<0.001$) than those in group 2 (14.3%). The premises used for processing are represented by family kitchens, communal kitchens and dedicated kitchens. More snail meat was processed in family kitchens (87.3%) than in dedicated kitchens (9.1%) and communal kitchens (7.3%). Group 1 (90.6%) and group 3 (100%) use home kitchens more ($p<0.05$) than group 2 (63.6%). Similarly, the use of the kitchen reserved for processing was more reported ($p<0.01$) in group 2 than in groups 1 and 3.

Buckets, basins, knives and other equipments were used by respondents to process snail meat. These materials did not vary significantly from one group to another (Table 3).

Table 3. Processing local and materials

Variable	General (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Processing location									
Open air	62,9a	12	84,85a	12,2	14,3b	18,3	60a	24,8	***
Local	79a	10,1	75,76a	14,6	100a	0	66,7a	23,9	NS
Premises used									
Family kitchen	87,3a	8,8	90,6a	10,1	63,6b	28,4	100a	0	*
Private kitchen	9,1b	7,6	0b	0	36,3a	28,4	8,33b	15,6	**
Shared kitchen	7,3b	6,9	9,4a	10,1	18,2a	22,8	8,33a	15,6	NS
Equipment used									
Basin	100a	0	100a	0	100a	0	100a	0	NS
Bucket	100a	0	100a	0	100a	0	100a	0	NS
Knife	100a	0	100a	0	100a	0	100a	0	NS
Others	88,1b	8,3	96,9a	5,9	78,6b	21,5	76,9	22,9	NS

*NS: p>0,05; *: p<0,05; ***: p<0,001; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.4 SNAIL PROCESSING

Figure 3 describes the process by which snail meat is obtained for consumption. Firstly, after purchase, snails are put on a diet for a few days before slaughter by a minority of processors (17.74%), compared with a majority (82.26%) who do not observe a diet. Secondly, before slaughter, snails are washed with plain water by the majority of processors (88.7%), against a minority who wash them with bleach. Simple water was used more often ($p<0.01$) in group 1 (100%) than in groups 2 (85.7%) and 3 (66.7%). Unlike those in group 1, the majority of processors in groups 2 and 3 ($p<0.01$) washed their snails with bleach (table 4). Thirdly, 85.48% of respondents crack or break the shell at the apex (for hard-shelled snail species such as *Archachatina marginata*) or break the shell (especially for brittle-shelled species such as *Achatina fulica*), against a minority who shell by scalding (20.97%) for hard-shelled species. After shucking, the meat and viscera are removed from the shell by pulling with a pointed stick. It is observed in the majority of Group 3 processors ($p<0.01$). Fourthly, once slaughtered and shelled by breaking, cracking or scalding, the visceral mass and flesh are separated by twisting by the processors (100%). Fifthly, the flesh obtained is then washed with water from SONEB (83.87%) or from wells (48.39%) or boreholes (14.52%) or cisterns (3.23%) to eliminate not only toxic waste, but also grains of sand. Sexto, hot water is poured over the flesh obtained after breaking or shattering, to better remove shell residues, grains of sand and the like. Septimo, the majority of processors (90.32%) recover the slime, while a minority (9.68%) do not. The snail meat is then cleaned with water in which lemon juice or alum is added to eliminate mucus. Lemon juice was used more in group 2 ($p<0.05$) than in groups 1 and 3. Octavo, snail meat is seasoned to improve taste and then boiled by processors for 5 to 10 min. The products sold are either cooked or boiled snail meat (100%), or fried snail meat (88.7%) in peanut or palm oil and presented either as a skewer or not.

Table 4. Snail transformation process

Variable	General (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Washing snails after purchase									
Plain water	88,71a	7,9	100a	0	85,7b	18,3	66,7b	23,9	**
Bleach water	11,29b	7,9	0b	0	14,3a	18,3	33,3a	23,9	**
Storage for a few days before slaughtering									
Yes	17,74b	9,5	9,09a	9,8	28,6a	23,7	26,7a	22,4	NS
No	82,26a	9,5	90,91a	9,8	71,4a	23,7	73,3a	22,4	NS
Flesh production technique									
Shell breaking at the apex	85,48a	8,8	100a	0	100a	0	40b	24,8	***
Shell removal by boiling	20,97b	10,1	0b	0	0b	0	86,67a	17,2	***
Out of the flesh									
Pulling	22,58b	10,4	0b	0	0b	0	93,3a	12,6	***
Twisting	100a	0	100a	0	100a	0	100a	0	NS
Washing after felling									
Water from SONEB	83,87a	9,2	78,8a	13,9	92,9a	13,4	86,7a	17,2	NS
Well water	48,39b	12,4	54,6a	16,9	57,1a	25,9	26,7a	22,4	NS
Borehole water	14,52c	8,8	24,4a	14,6	0a	0	6,7a	12,6	NS
Cistern water	3,23d	4,4	3,03a	5,8	7,14a	13,5	0a	0	NS
Mucus elimination									
Alum	87,1a	8,3	87,9a	11,1	71,4a	30,3	100a	0	NS
Lemon	45,2b	12,4	24,2b	14,6	100a	0	33,3b	23,8	***
Separation of flesh from slime									
Yes	90,32a	7,4	96,97a	5,22	78,6b	28,4	86,7ab	17,2	NS
No	9,68b	7,4	3,03	5,22	21,43	28,4	13,3	17,2	NS
Flesh preparation									
Boiled	100a	0	100a	0	100a	0	100a	0	NS
Fried	88,7b	7,9	90,9a	9,8	92,9a	13,4	80a	20,2	NS

*NS: p>0,05; *: p<0,05; **: p<0,01; ***: p<0,001; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (for the general).*

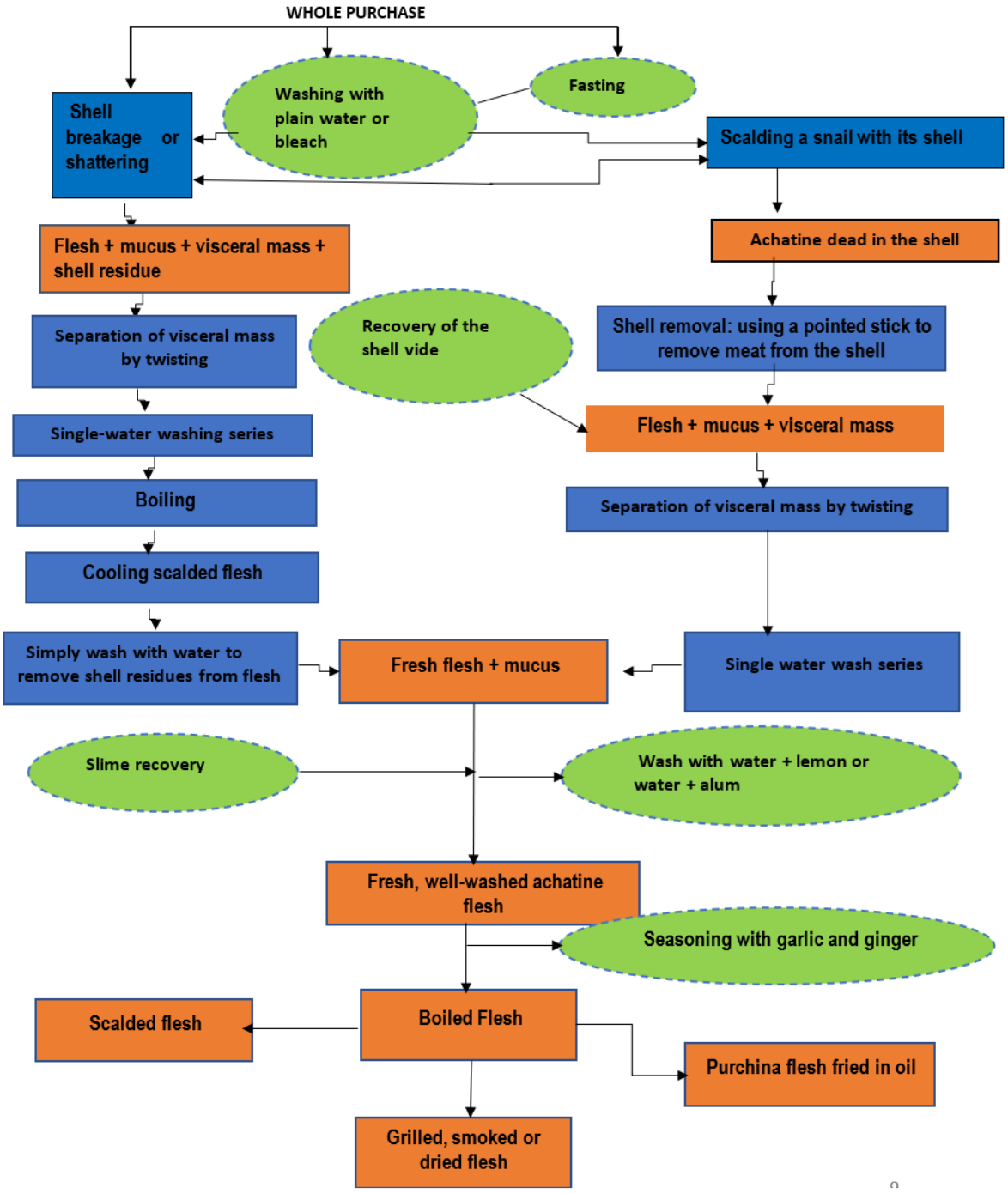

Fig. 3. Achatine processing in South-Benin

3.5 ORIGIN OF SNAILS AND PROCESSED SPECIES

Table 5 shows the African giant snail species processed, their origin, availability and preference. The most processed giant snails are, in respective order: *Archachatina marginata* (98.39%), *Achatinia achatina* (96.77%), *Archachatina ventricosa* (96.77%), *Achatina fulica* (93.55%). The percentage of respondents processing *Achatina fulica* in groups 3 (100%) and 1 (96.97%) is significantly higher ($p<0.05$) than in group 2 (78.57%). The majority of respondents (91.94%) admitted that processed snails are not available at all times. Moreover, the majority of processors (96.77%) stressed that they had no preference for any particular species. In the rainy season (100%) of players buy from collectors and resellers. In the dry season, 6.45% of players buy from breeders. Thus, processed achatines are purchased mainly from collectors and resellers. Few achatines are purchased from breeders.

Table 5. Origin of snails and processed species

Variable	General (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Processed species									
Archachatina marginata	98,39a	3,13	100a	0	92,86a	13,49	100a	0	NS
Archachatina ventricosa	96,77a	4,40	96,97a	5,8	92,86a	13,49	100a	0	NS
Achatina fulica	93,55a	0	96,97a	5,8	78,57b	21,49	100a	0	*
Achatna achatina	96,77a	4,40	96,97a	5,8	100a	0	93,33a	12,63	NS
Origin of processed snails									
Buying from breeders	6,45b	6,11	6,06a	8,14	0a	0	13,33a	17,2	NS
Purchase from collectors	100a	0	100a	0	100a	0	100a	0	NS
Purchase from resellers	100a	0	100a	0	100a	0	100a	0	NS
Snail availability at all times									
Yes	8,06b	6,78	3,03a	5,8	7,14a	13,49	20a	20,24	NS
No	91,94a	6,78	96,97a	5,8	92,86a	13,49	80a	20,24	NS
Species preference									
Yes	3,23b	4,40	3,03a	5,8	0a	0	6,67a	12,63	NS
No	96,77a	4,40	96,97a	5,8	100a	0	93,33a	12,63	NS

*NS: p>0,05; *: p<0,05; **: p<0,01; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.6 HYGIENE PRACTICES DURING SNAIL PROCESSING

Hygiene and processing practices vary between groups (Table 6). Respondents consider that they comply with hygiene rules at the level of the 5 M, namely: Raw Materials, Environment, Equipment, Labor and Methods. Surveys and observations revealed that many processors (61.3%) do not have specific clothing for processing. The majority of Group 1 processors ($p<0.001$) do not own any in contrast to Group 1, the majority of processors in Groups 2 and 3 ($p<0.001$) do. In addition, processors have at least specific clothing for their workers (77%), and workers wash their hands (73.8%). However, workers do chat (75.4%) during processing. Processors (91.4%) wash their hands after separating the visceral mass. Hand washing is done with tap water (71.9%), well water (57.9%), sometimes soap (7%) and disinfectant (1.8%). Note that processors in groups 1 and 3 use only tap or well water, while those in group 2 use not only tap or well water, but also soap and disinfectant.

Table 6. Hygiene practices during processing

Variable	General (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Hygiene compliance with regard to:									
The raw material	100a	0	100a	0	100a	0	100a	0	NS
Environment	96,8a	4,4	96,9a	5,8	92,9a	13,5	100a	0	NS
Equipment	100a	0	100a	0	100a	0	100a	0	NS
Manpower	100a	0	100a	0	100a	0	100a	0	NS
Method	100a	0	100a	0	100a	0	100a	0	NS
Specific work clothing									
Yes	38,7b	12,1	9,1b	9,8	85,7a	18,3	60a	24,8	***
No	61,3a	12,1	90,9a	9,8	14,3b	18,3	40b	24,8	***
Special workforce clothing									
Yes	77,1a	10,6	78,8a	13,9	78,6a	21,5	71,4a	23,7	NS
No	23,0b	10,6	21,2a	13,9	21,4a	21,5	28,6a	23,7	NS
Chatting at work									
Yes	75,4a	10,8	78,8a	13,9	78,6a	21,5	64,3a	25,1	NS
No	24,6b	10,8	21,2a	13,9	21,4a	21,5	35,7a	25,1	NS
Washing hands of the workforce									
Yes	73,8a	11,0	78,8a	13,9	78,6a	21,5	57,1a	25,9	NS
No	26,2b	11,0	21,2a	13,9	21,4a	21,5	42,9a	25,9	NS
Hand washing after visceral mass separation									
No	8,6b	7,2	16,1a	12,9	0a	0	0a	0	NS
Yes	91,4a	7,2	83,9a	12,9	100a	0	100a	0	NS
Hand washing technique									
Well water	57,9a	12,8	66,7a	16,9	42,9a	25,9	53,9a	27,1	NS
Tap water	71,9a	11,7	76,8a	15,1	64,3a	25,1	69,2a	25,1	NS
Soap	7b	6,6	0b	0	28,6a	23,7	0b	0	**
Water with disinfectant	1,8b	3,4	0a	0	7,14a	13,5	0a	0	NS
Water, soap and disinfectant	1,8b	3,4	0a	0	7,14a	13,5	0a	0	NS

*NS: p>0,05; *: p<0,05; **: p<0,01; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.7 Management Of By-Products And Waste From Snail Processing

Table 7 shows how waste is managed. Once the giant snail meat has been obtained, all processors discard the visceral mass. The shells are discarded by 88.71% of processors, while 11.29% sell them. This waste is disposed of in the bush, in garbage cans and on garbage heaps. It should be noted that 90.3% of players sell the slime, while 9.7% throw it away. The slime sold is either used medicinally or in the cosmetics industry. The proportion of people selling slime in group 1 (96.97) is significantly higher ($p<0.05$) than in group 2 (78.6%).

Table 7. Management of by-products and waste from snail processing

Variable	Général (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Slime									
Sold at	90,3b	7,36	96,97a	5,8	78,6b	21,5	86,67ab	17,2	*
Use in medicine	100a	0	100a	0	100a	0	100a	0	NS
Use in the cosmetics industry	100a	0	100a	0	100a	0	100a	0	NS
Visceral mass									
Landing	100	0	100a	0	100a	0	100a	0	NS
Shell									
Landing	88,71a	7,88	87,9a	11,1	92,9a	13,5	86,67a	17,2	NS
Sold	11,29b	7,88	12,1a	11,1	7,14a	13,5	13,33a	17,2	NS

*NS: p>0,05; *: p<0,05; **: p<0,01; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.8 MARKETING AND STORAGE OF PROCESSED SNAILS

The marketing and preservation of giant African snails processed in South Benin is specific to each group (Table 3.8). Giant African snail meat is marketed in South Benin as boiled, fried, smoked, dried or grilled. Most snail meat is sold fried (95.2%), followed by boiled (2.4%) and smoked, dried or grilled (2.4%). The proportion of respondents selling fried meat in groups 1 (100%) and 3 (100%) was significantly higher ($p<0.05$) than in group 2 (77.8%). It is sold to direct consumers, intermediaries, hotels and restaurants, processors, supermarkets, small retailers, large distributors and on the international market. In terms of purchase levels, direct consumers (100%) lead the way, followed by intermediaries (93.1%) and then hotels and restaurants (51.7%). Processors, supermarkets, small retailers, large distributors and the international market are supplied to a lesser degree. The meat is grilled at the request of certain direct consumers. Boiled meat is more commonly sold to hotels or restaurants, processors, supermarkets and internationally. The proportion of people selling meat to hotels and restaurants in groups 3 (84.6%) and 2 (53.8%) was significantly higher ($p<0.05$) than in group 1 (37.5%). Fried meats are the most commercialized. They are packaged more in skewers (94.4%) and less in batches of 5 to 15 (7.4%). Achatine meat is sold at bus stations, crossroads, at on-site processors in towns and elsewhere. The proportion of people selling meat in town in group 1 (96.7%) was significantly higher ($p<0.05$) than in groups 2 (69.2%) and 3 (76.9%). The majority of respondents (95.2%) acknowledged that they had often experienced poor sales. Unsold products are mostly preserved (77%) by soaking in water, then re-seasoned and fried the following day. The proportion of processors in groups 2 (100%) and 3 (92.3) using this preservation technique was significantly higher ($p<0.01$) than in group 1 (61.3%). Other processors left the remaining products in the lee or in open plastics (43.1%). The proportion of processors in groups 1 (58.1%) and 2 (42.9%) using this preservation technique was significantly higher ($p<0.01$) than in group 3 (7.7%). Very few processors (3.4% and 5.2% respectively) put unsold products in cool storage (in a freezer or refrigerator) or in food storage units. The proportion of processors using the chilling technique in group 3 (15.38%) was significantly higher ($p<0.05$) than in groups 1 and 2 (0%).

Table 8. Marketing and storage of processed snails

Variable	Général (N=42)		G1 (N=22)		G2 (N=9)		G3 (N=11)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Products sold									
Fresh or boiled meat	2,4b	4,6	0a	0	11,1a	20,5	0a	0	NS
Fried meat	95,2a	6,4	100a	0	77,8b	27,2	100ab	0	*
Smoked, dried or grilled meat	2,4b	4,6	0b	0	11,1a	20,5	0a	0	NS
Buyers									
Direct consumer	100a	0	100a	0	100a	0	100a	0	NS
Local market consumer	93,1b	6,5	96,9a	6,0	92,3a	14,5	84,6a	19,6	NS
Hotels and restaurants	51,7c	12,9	37,5b	16,8	53,8ab	27,1	84,6a	19,6	*
Processor	8,6d	7,2	6,2a	8,4	15,4a	19,6	7,7a	14,5	NS
Supermarket	5,2d	5,7	3,1a	6,0	15,4a	19,6	0a	0	NS
Small retailer	10,3d	7,8	3,1a	6,0	23,1a	22,9	15,4a	19,6	NS
Large distributor	5,2d	5,7	3,1a	6,0	15,4a	19,6	0a	0	NS
International market	5,2d	5,7	3,1a	6,0	15,4a	19,6	0a	0	NS
Other customers	5,2d	5,7	3,1a	6,0	7,7a	14,5	7,7a	14,5	NS
Conditionally for sale									
Batch of 5 to 15	7,4b	6,9	6,7a	8,9	15,4a	19,6	0a	0	NS
Skewer	94,4a	6,1	96,7a	6,4	84,6a	19,6	100a	0	NS
Points of sale									
Bus station	71,4a	11,8	73,3a	15,8	76,9a	22,9	61,5a	26,4	NS
Carrefour	85,7a	9,2	83,3a	13,3	76,9a	22,9	100a	0	NS
On site	82,1a	10	93,3a	8,9	69,2a	25,1	69,2b	25,1	NS
In town	87,7a	8,6	96,7a	6,4	69,2b	25,1	76,9b	22,9	*
Other point of sale	17,9b	10	20a	14,3	15,4a	19,6	15,4a	19,6	NS
Unsale									
No	4,8b	5,3	9,1a	9,8	0a	0	0a	0	NS
Yes	95,2a	5,3	90,9a	9,8	100a	0	100a	0	NS
Managing unsold products									
Cool storage	3,4c	4,7	0b	0	0ab	0	15,4a	19,6	*
Leave in lee or open plastic	43,1b	12,7	58,1a	17,4	42,9a	26,9	7,7b	14,5	**
Leave in food racks	5,2c	5,7	3,2a	6,24	7,14a	14	7,7a	14,5	NS
Preservation (of remaining products)	77,6a	10,7	61,3a	17,1	100b	0	92,3b	14,5	**

*NS: p>0,05; *: p<0,05; **: p<0,01; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

3.9 Difficulties Encountered By Snail Processing Units

The difficulties encountered by processing units are of three kinds: processing problems, marketing and conservation. Our survey revealed that processing materials is inadequate (96.8%). This inadequacy is particularly noticeable in groups 1 and 2 ($p<0.05$) compared to group 3. Processing time is very long in all three groups (table 3.9). Other processing-related problems (injuries caused by shell residues, the knife and stick used to remove the flesh from the shell, frequent illnesses caused by putting one's hand too far into the water, panic attacks, and as we are used to being in contact with wood fires, eye problems, etc.) were more frequent in group 3 ($p<0.001$) than in groups 1 and 2. Several problems are linked to the sale of the product, such as: distant market, plethora of processors and inaccessibility of the channels in the rainy season or in any season and others (passage of customers who consume it, holidays, weekends, etc.). The plethora of processors is more noticeable ($p<0.05$) in groups 2 and 3 than in group 1. With regard to conservation, we note a lack of adequate conservation materials, ignorance of appropriate conservation techniques and other factors.

Table 9. Problems registered during survey

Variable	Général (N=62)		G1 (N=33)		G2 (N=14)		G3 (N=15)		Chi²
	%	IC	%	IC	%	IC	%	IC	
Problems related to processing									
Inadequate processing materials	96,8a	4,40	100a	0	100a	0	86,67b	17,20	*
Long processing time	4,84b	5,34	3,03a	5,8	0a	0	13,33a	17,20	NS
Other	6,56b	6,21	0b	0	0b	0	28,57a	23,66	***
Flow-related problems									
No problem	35,5a	11,91	48,5a	17,1	28,6a	23,7	13,33a	17,20	NS
Distant market	9,68b	7,36	15,15a	12,2	0a	0	6,67a	12,63	NS
A plethora of transformers	43,6a	12,34	30,3b	15,9	71,4a	23,7	46,7ab	25,25	*
Inaccessible roads in the rainy season	6,45b	6,11	9,1a	9,8	0a	0	6,67a	12,63	NS
All-season track inaccessibility	1,61b	3,13	3,03a	5,8	0a	0	0a	0	NS
Other	36,1a	12,05	30,3b	15,7	21,4b	21,5	64,3a	25,10	*
Conservation problems									
None	3,3b	4,47	0a	0	7,1a	13,4	7,14a	13,5	NS
Lack of adequate storage materials	96,7a	4,47	100a	0	92,9a	13,4	92,9a	13,5	NS
Lack of knowledge of appropriate preservation techniques	96,7a	4,47	100a	0	92,9a	13,4	92,9a	13,5	NS
Other	1,6b	3,16	0a	0	0a	0	7,14a	13,5	NS

*NS: p>0,05; *: p<0,05; **: p<0,01; [a, b,c]: percentages on the same line followed by different letters differ significantly at the 5% threshold (between groups) and intra-class percentages on the same column followed by different letters differ significantly at the 5% threshold (overall).*

4 DISCUSSION

4.1 GENDER AND LOCAL AND MATERIALS FOR SNAIL PROCESSING

The survey shows that women are more involved in the processing and marketing of giant snails in southern Benin. This finding was corroborated by [6] and [8] in Benin. This large female presence is due to the fact that food processing is often reserved for the female gender in Benin.

In the context of snail processing hygiene in southern Benin, the majority of processors surveyed, especially in groups 1 and 3, have no processing premises and processing is carried out in the open air, exposing the meat to external sources of contamination (air, flies, insects, etc.). These same practices are reported by [16] in slaughterhouses and dibiteries in Dakar, Senegal. He stresses that to guarantee meat quality, the construction of processing facilities must be encouraged. This is essential because consumers are exposed to contamination, as these animals and insects carry parasites and microbes harmful to humans. Moreover, the lack of buildings could lead to rapid contamination of the meat, as the air could carry and deposit on the meat various bacteria including pathogenic *Eicheria coli, Salmonella enterica, Staphylococcus aureus, Clostridium botulinium, Clostridium perfringens, Bacillus cereus, Listeria monocytogenes,* etc. ([17], [18]). The materials used for processing (basins, buckets, knives, etc.) is well cleaned, which limits the risk of contamination of the meat. Unfortunately, such equipment is often stored in inappropriate locations. The poor maintenance of equipment observed among some processors can also promote contamination of meat by *Salmonella enterica, Bacillus cereus, Clostridium botulinum, Clostridium perfringens, Listeria monocytogenes,* etc. ([17], [18]).

4.2 SNAIL PROCESSING IN SOUTHERN BENIN

In this study, snails are slaughtered by breaking the shell or by placing in hot water for a few minutes. These methods of obtaining snail meat have already been described by [19], [20] in Africa. Breaking the shell, as practiced by most processors, appears to be more hygienic, as the viscera and meat are separated before cooking, whereas scalding can lead to contamination of the meat by the visceral mass. Scalding was recorded on very few processors; this proves that the majority of processors perceive this risk. The minority who do so should opt for shell-breaking, especially as consumers find the organoleptic quality

of meat obtained by shell-breaking better than that obtained by scalding. However, shell breaking can be an obstacle to its use. Solutions should therefore be found to obtain snail meat without breaking or boiling. Other slaughtering techniques have been reported in the literature. According to [6], in addition to fasting and breaking the shell, snails are asphyxiated in a hermetically sealed box or grilled over charcoal fires during slaughter. The flesh is washed with water containing alum or lemon. The use of lemon and alum in the washing of snail meat has already been reported in Benin and other African countries ([6], [19], [20], [21]). Other solvents such as fermented cassava juice, water containing ash, water containing potassium or ammonium aluminum sulfate or salt ([19], [21]) have already been reported as solvents used to separate flesh from slime. These solvents are not used by processors because they are not informed of their potential power to rid the snail of slime. In the case of roasted or asphyxiated purchases, the flesh is directly transformed into a consumable product [6], whereas in the case of our study, whatever the form of slaughter, the flesh is always cleaned of mucus by washing with water and alum or lemon. [22] have shown that to reduce the bacteria present in the flesh of giant African snails, it is preferable to use lime, which reduces by 34.7%, followed by salt, which reduces by 34.7%. As for ash, it reduces by 16.1%, followed by vinegar, which reduces by 10%. Alum, used by the majority of processors in our study, reduces bacteria by 18.5%. Flesh purchaseine reserved for boiling was first washed several times with water and alum. Alum is a hydrated double sulfate of potassium and aluminum, widely used by local populations to remove not only dirt, but also the slimy substance from achatine flesh [23].

4.3 Snail Origin And Processed Species

The snail species identified in this study are: *Archachatina marginata, Archachatina ventricosa, Achatina achatina, Achatina fulica*. [24] have already shown that the edible giant African snails in Africa are *Archachatina marginata* black, *Archachatina marginata* white, *Archachatina ventricosa* and *Achatina achatina*. The snails processed in this study were purchased from collectors and resellers. These results are in line with the findings of [6], who state that the snail trade circuit is relatively simple, with three main players: collectors, wholesalers and traders. They go on to point out that the marketing margin is relatively low for collectors and wholesalers, while it is high for traders and very high for gatherers, which encourages gathering and may lead to the disappearance of giant African snails. Hence the need to set up breeding programs. Processors here feel that snails are excessively expensive to buy from breeders, which is why they prefer to buy from collectors and then from retailers, since cheaper raw materials have a positive impact on the quantity sold and on profits. The processors surveyed, on the whole, have no preference for any one species, except for those in group 3 who, like [21], point out that consumers have a higher preference for larger snails. This is why they prefer *Archachatina maginata*. This statement confirms that of [25], who state that the most prized of all African giant snail species is *Archachatina marginata*. The strong preference for this species is due not only to its size, but also to the succulence of its flesh. It is also the most expensive species on the southern Benin markets.

4.4 Hygiene Practices During Snail Processing

The majority of processors in groups 2 and 3 have specific processing clothes. Group 1 processors should introduce this practice into their routines, because processing food in street clothes or clothes intended for other uses can be a source of food contamination [18]. The problem of hygiene in snail processing is mainly due to a lack of awareness of certain hygienic measures and poor application of these measures. A minority of processors put snails down for a few days before slaughter, while the majority do not observe a diet. According to [26], snails must fast for at least 48 hours to eliminate unabsorbed food and faeces from their digestive tract. Before slaughter, snails are washed with plain water by the majority of processors against a minority who wash them with bleach, while [27] point out that the environment (soil, plants, human dejecta and others in direct contact with snails) in Benin is highly polluted with toxic metals (Pb, Al, Cd, Cu, Cr, Zn, Mn), and as the snail eats the soil, the plant the dejecta and breathes the same environment, this favors the bioaccumulation of metals in its organs and could present an immediate or long-term risk to consumers. The majority of processors understood the importance of washing their hands to avoid contamination of snail meat. Indeed, according to [28], hand hygiene for food handlers is a very important element in ensuring the microbiological protection of food. Nevertheless, in this study, washing was done with tap water, well water, sometimes soap and rarely with disinfectant while the food code states for a hand to be said to be appropriate, washing must take at least 20 seconds and include: warm running water, soap, friction between hands for 10 to 15 seconds, rinse and dry with clean water towels or warm air [29].

4.5 Management And Marketing Of Processed Snails

The visceral mass in our study is discarded by processors. In contrast, [30] proved that the digestive (albumin gland) and genital (common hermaphroditic duct) organs of the visceral mass are not only edible, but also nutritious for consumption by humans and livestock. In our study, the shell is discarded by processors. On the other hand, according to [31], supplying additional snail shells to hens fed a feed already containing shells increases calcium intake and egg weight of the hens fed.

Giant African snail meat is marketed in South Benin mainly in fried and rarely boiled and smoked forms. According to [23], the flesh of giant African snails is consumed by the population in boiled and fried form. [32] also pointed out that these two processing methods (boiling and frying) of African giant snail meat have a positive effect on lead reduction and a negative effect on cadmium reduction. Therefore, populations should consume African giant snail meat in moderation, but favoring the fried form over the boiled form, as cadmium concentrations increase from raw to fried while lead concentrations decrease from raw to fried [32]. In the Equateur region of the Central African Republic, according to [33], there are two snail processing techniques: smoking and drying. Smoking is the most widely used technique, due to its speed and efficiency. It consists of spreading the scalded snails on a wire mesh under which a fire is lit to dry them. The advantage of smoking is that it can be carried out at any time, and the snails can be kept for over a month. Drying, on the other hand, is a technique less and less practiced, and involves exposing the scalded snails to the sun. Its disadvantage is that it requires a fairly long drying time, which poses a real problem in forest areas where the rainy season is longer. With this technique, snails have a shelf life of less than a month. These forms of snail preservation are little recorded in this study because processors do not preserve snail meat over a long period, and consequently smoking is done at the customer's request. However, [21] found that smoke-dried snail meat was generally preferred by consumers to oven-dried snail meat. The need to study the nature of the wood used for smoking is also highlighted.

5 CONCLUSION

This study confirms that the most processed giant snails are *Archachatina marginata, Achatinia achatina Archachatina ventricosa* and *Achatina fulica*. Most of their meat is processed by women, who use either a process that allows them to obtain the meat after breaking the shell, or a process that allows them to obtain the meat after scalding. The hygienic quality of the snail meat obtained can be adversely affected by processing the meat in the open air, and by wearing clothing not reserved for processing. Although snails are washed with bleach before boiling, this cannot prevent the meat from being contaminated by the contents of the visceral mass, especially as most processors do not observe a diet. Not all the meat obtained is sold in a single day. So poor preservation can be detrimental to consumers. It would therefore be advisable to preserve snail meat properly, either by smoking or sun-drying, or with natural preservatives such as salt. Since there is no difference between the flesh of different processed species, does this mean that they taste the same? And do they provide consumers with the same nutritional elements?

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