

Full Length Research Paper

## Evaluation of African giant snails (*Achatina* and *Archachatina*) obtained from markets (wild) and breeding farms

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In the Greater Accra Region there is high demand in consumption of molluscs, which indicates the need for studies on the possibility of disease transmission. Snail meat is usually susceptible to microbial contamination. Shelling is difficult with possibilities of cross contamination. Slime on the meat becomes a hurdle during commercial processing. The objective of the study was to establish the differences in the microbial load of African land snails (*Achatina achatina* and *Archachatina marginata*) from two sources (market and breeding farm) and to enumerate some consumer concerns about the snail meat. The results found that the total viable count ( $\log_{10}$  CFU/g) ranged from  $6.61 \pm 1.25$  to  $8.29 \pm 1.02$ . The total of coliform count ( $\log_{10}$  CFU/g) ranged from  $8.50 \pm 0.57$  to  $5.61 \pm 1.51$ . *Salmonella* count ( $\log_{10}$  CFU/g) ranged from  $2.91 \pm 3.19$  to  $7.39 \pm 0.45$ . *Staphylococcus*, *Bacillus* and *Pseudomonas* counts ( $\log_{10}$  CFU/g) ranged from  $7.68 \pm 1.40$  to  $2.66 \pm 2.99$ ;  $4.90 \pm 1.07$  to  $1.53 \pm 1.68$  and  $5.66 \pm 0.14$  to  $3.97 \pm 0.74$ , respectively. Most microorganisms identified were from the Enterobacteriaceae family. Shelling, slime removal, contamination, price, packaging were problems associated with snail meat.

**Key words:** Molluscs, consumer behaviour, Enterobacteriaceae, contamination, food safety, Accra Metropolitan Area, Ghana.

### INTRODUCTION

Apart from the conventional sources of protein; which are mainly meat and fish, snails (molluscs) are excellent sources of protein and mineral elements for many families. Snail meat is a nutritious food that is high in protein, low in fat and a good source of iron (USDA, 2006). According to Akinnusi (2002) snail meat is high in

protein, iron, calcium and phosphorus, but low in sodium, fat and cholesterol, and contains almost all the amino acids needed by man. The meat is high in health benefiting essential fatty acids such as linoleic and linolenic acids. A study on a snail species in Brazil estimated that 75% of the fat in snail is unsaturated fatty

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acids. That is 57% polyunsaturated fatty acids, 15.5% of monounsaturated fatty acids and 23.25% of saturated fatty acids (Su et al., 2004), furthermore the African giant snails (*Archachatina marginata* and *Achatina achatina*) are considered as a delicacy in Nigeria and they command high demand in the market (Adeyeye, 1996).

The African giant land snail (*Archachatina marginata*) is the largest known snail in Africa (Olawoyin and Ogogo, 2006). Snails have high rate of productivity or fecundity. Though they are hermaphrodites, they practice sexual reproduction (Akinnusi, 2004). Snails are selective in their mating partners and sometimes uninterested in mating with other snails of the same species originating from a considerable distance away (Omole and Kehinde, 2005).

The natural habitat of snails are mostly found in the forest, farms and gardens where they have unlimited vegetation to feed on. According to Raut and Barker (2002), the most dominant types of vegetation in Africa are the tropical forest and the savannah where a wide variety of the African terrestrial Gastropods inhabit. Most land snails, especially, the African giant land snails that are eaten and exported are usually picked from their natural habitat. However, with the large market for the meat, many concerns have been raised about the reduction in their natural population. With challenges such as depletion of the stock of wild snails, over population, high cost of conventional animal protein, and also for health reasons, the demand for snails has increased such that commercial production is necessary. This led to the introduction of snail breeding farms with the purpose of supplying snails to meet the market demands.

The close contact of wild snails with soil and their uncontrolled feeding pattern make the snail susceptible to microbial contamination. Snails inherently have high populations of indigenous bacteria and coliforms and other poisonous substances which they ingest (ICMSF, 2005). The meat can be easily contaminated by pathogens and serve as vehicle of transferring infectious agents to consumers. Kirkan et al. (2006) reported the presence of *L. monocytogenes* in fresh snail sample which notably could have been contaminants from soil. So, despite rich nutritional values of snail, the involvement of the molluscs in the transmission of infection mostly as secondary host for pathogens makes it necessary to study the microbiology of the resident snail. The fact that consumption of field-collected snails may lead to bacterial infection, the provision of a systemic farming of snails will help solve both the problem of depletion of snail populations as well as provision of a relatively wholesome meat with less microbial contaminations (Upatham et al., 1988). This study therefore seeks to bring out the differences in the microbial quality of snails from two sources (wild and breeding farms) using two species of snails and to enumerate some consumer concerns pertaining the snail meat.

## MATERIALS AND METHODS

### Study area and snail species

The study area for the collection of samples was the Greater Accra Region. This is the capital town of Ghana, where there is high demand for meat. Samples were collected from five markets (Dome, Kaneshie, Madina, Makola and Mallam Atta) and five snail farms (Abokobi, Assin Fosu, Burma Camp, Madina and Nsawam) within the Accra Metropolitan Area and its surroundings. The *A. achatina* and *A. marginata* species were used for the study because they are the most preferred choice by the consumer. The *A. achatina* species are the most preferred and the most expensive amongst the two.

### Survey on the preferences of snails

A study was conducted on consumer preferences of snails. Mixed questionnaires comprising both open ended and closed ended questions were administered to fifty consumers concerning the species and type of snails they preferred. Other questions were about the packaging, price, availability and the wholesomeness of the snails they buy. There were also questions relating to the problems associated with the preparation and cooking of the meat. A face-to-face interview technique was used in the administration of the questionnaires especially where the respondents could not read or write (Adeniyi et al., 2013).

### Sampling procedure and microbiological analysis

Thirty matured live snail samples each in total of the two species were obtained from various markets in Accra. The samples were bought from market women who sold snails collected from the forest. Similarly, the same quantity of snails for each species, were obtained from breeding farms in Accra. Five snail samples each for both species were sampled from the total quantity and used for the study. The experiment was replicated three times. The snail samples were collected in a sterile bag and labelled according to its source. The samples were scrubbed, rinsed with water to remove surface dirt. They were then washed with sterile distilled water and scrubbed with ethanol to remove external microorganism, the meat was aseptically extracted and homogenized. Sample preparation was done under sterile conditions in the laboratory under the laminar flow cabinet. A 10 g of sample (snail) was immediately transferred into 90 ml peptone water for analysis. Standard pour plates were prepared from 10-fold dilutions into nutrient agar medium for total bacteria counts, Violet red bile agar for total coliform counts, Xylose Lactose Desoxycholate (XLD) agar for total *Salmonella/Shigella* counts, Baird-Parker agar enriched with egg - yolk emulsion for *Staphylococcus* count, *Bacillus cereus* select agar for *Bacillus* count and *Pseudomonas* agar for total *Pseudomonas* count.

The bacterial plates were incubated at 37°C for 24 to 48 h. Colonies were selected randomly and were characterized using morphological and biochemical tests such as gram stain, spore stain, motility, catalase, oxidize, coagulase, indole, MR-VP, urease and sugar fermentation tests. Bacterial isolates were identified with reference to Cowan and Steel's Manual for the Identification of Medical Bacteria (Cowan, 1985) and Bergey's Manual of Determinative Bacteriology (Holt et al., 1994). Identification for this and other microorganisms were further done using the API 20E (BioMerieux, Boston, USA).

### Data analysis

The means of each result was calculated for each source from

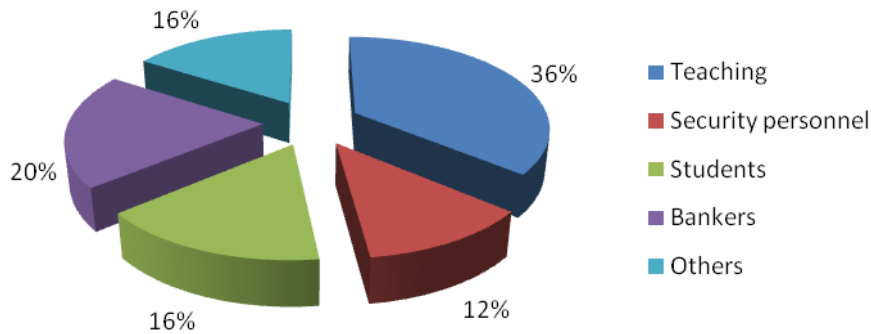


Figure 1. Occupation of respondents.

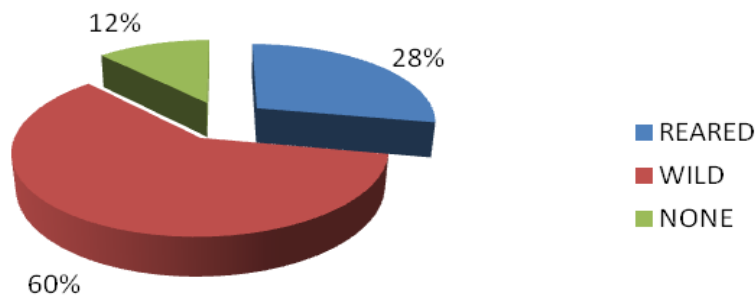


Figure 2. Preference for wild or reared snails.

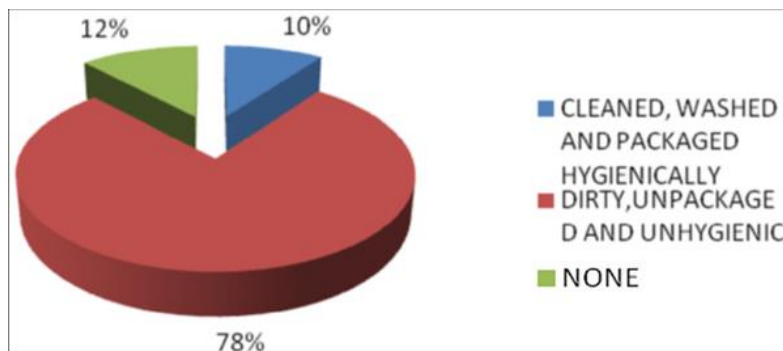


Figure 3. Presentation of fresh snails for sale.

triplicate plate counts and from the repeated survey. The means obtained from each source was separated using *t*-test. Data obtained from samples were analyzed using Microsoft Excel and Statgraphics Centurion XVI (Stat-point Technologies, Inc., Warrenton, Virginia, USA). Means were separated using Duncan's multiple range test.

**RESULTS**

**Problems associated with the sale and consumption of the snail meat**

Respondents used for the study had different occupational background ranging from teaching, security, banking, among others (Figure 1).

There was high preference for wild snails than the reared ones. Respondents admitted buying snails which are unpackaged and in an unhygienic state, some of the respondents agreed to a possible contamination of the snail meat presented for sale on the market. Most of the respondents indicated their preference for processed and packaged fresh snails. Consumers enumerated various problems associated with preparation of snails, ranging from the slime, shelling and dirt (Figures 2 to 7).

**Mean count of microorganisms of snails from two sources (breeding farms and wild)**

The microbial load of snail from both sources is shown in

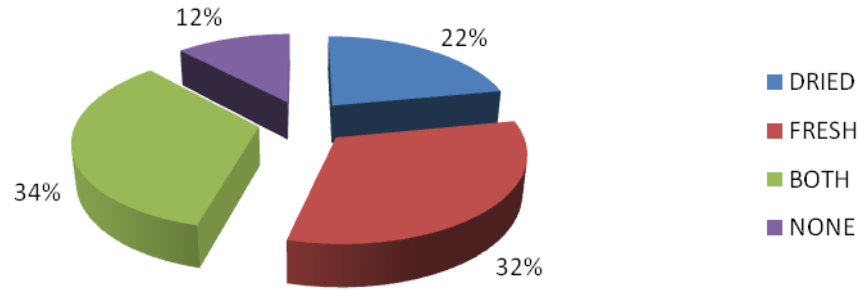


Figure 4. Type of snails preferred.

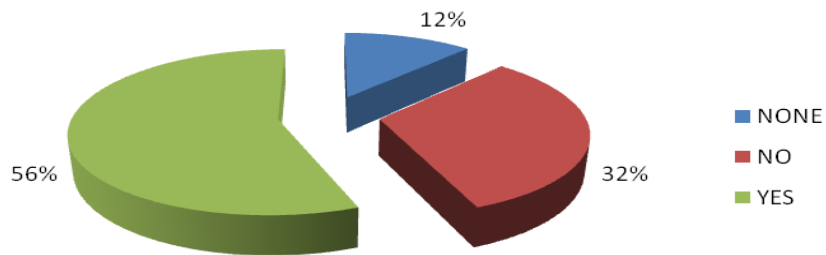


Figure 5. Possibility of contamination.

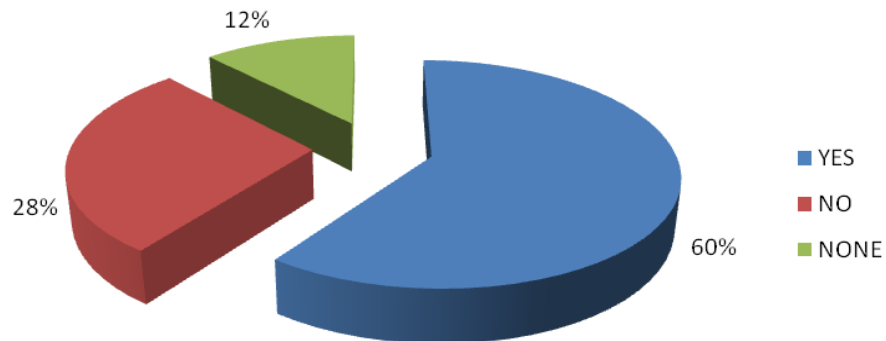


Figure 6. Preference for processed and packaged snails.

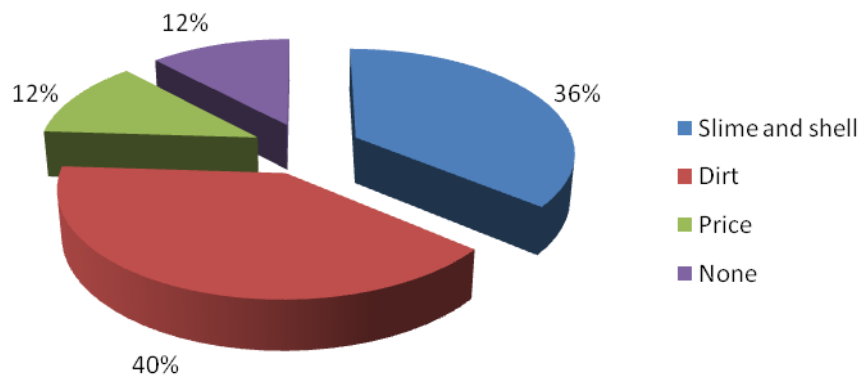


Figure 7. Problems associated with purchasing, preparation and cooking of snails.

**Table 1.** Total microbial count (log<sub>10</sub> CFU/g) in fresh land snail samples from different farms and markets.

Market of snail samples	Sample code	Total bacterial count	Total Coliform count	Total <i>Salmonella</i> / <i>Shigella</i> count	Total <i>Staphylococci</i> count	Total <i>Pseudomonas</i> count	Total <i>Bacillus</i> count
Makola	MK	6.79±0.97 <sup>A</sup>	6.32±0.05 <sup>A</sup>	5.13±0.47 <sup>A</sup>	5.69±0.22 <sup>A</sup>	5.24±0.36 <sup>A</sup>	4.18±0.417
Madina	MD	7.13±0.40 <sup>A</sup>	7.07±0.61 <sup>AB</sup>	5.47±0.43 <sup>A</sup>	6.18±1.81 <sup>A</sup>	4.80±0.32 <sup>A</sup>	4.17±0.09
Kaneshie	KN	7.86±0.72 <sup>B</sup>	8.26±0.56 <sup>C</sup>	6.86±0.49 <sup>B</sup>	7.68±1.40 <sup>A</sup>	4.64±0.11 <sup>A</sup>	4.69±0.09
Dome	DM	8.04±0.48 <sup>B</sup>	7.17±0.93 <sup>B</sup>	6.40±0.43 <sup>BC</sup>	5.85±0.10 <sup>A</sup>	5.17±0.33 <sup>B</sup>	4.77±1.07
Mallam Atta	MA	8.19±0.30 <sup>B</sup>	8.50±0.57 <sup>C</sup>	7.39±0.45 <sup>C</sup>	5.91±0.05 <sup>B</sup>	4.86±0.08 <sup>B</sup>	4.90±1.07
Average		<b>7.60±0.79</b>	<b>7.46±1.02<sup>B</sup></b>	<b>6.25±0.95<sup>B</sup></b>	<b>6.26±1.21<sup>B</sup></b>	<b>4.94±0.31<sup>B</sup></b>	<b>4.65±0.72<sup>B</sup></b>
<b>Breeding farms</b>							
Abokobi	AB	6.61±1.25 <sup>A</sup>	6.71±1.9 <sup>A</sup>	2.91±3.19 <sup>A</sup>	3.39±3.72	5.39±0.39 <sup>A</sup>	2.78±0.56
Madina	MD	6.84±0.83 <sup>A</sup>	5.61±1.51 <sup>AB</sup>	3.30±0.50 <sup>A</sup>	3.90±2.46	4.74±0.13 <sup>B</sup>	1.53±1.68
Assin Fosu	AF	7.54±0.01 <sup>AB</sup>	7.17±0.33 <sup>AB</sup>	5.51±0.17 <sup>A</sup>	3.26±3.57	6.13±0.34 <sup>C</sup>	3.32±3.48
Nsawam	NS	7.12±1.47 <sup>AB</sup>	7.38±1.75 <sup>C</sup>	3.38±3.70 <sup>AB</sup>	2.80±3.07	5.66±0.14 <sup>CD</sup>	3.76±0.01
Burma camp	BC	8.29±1.2 <sup>C</sup>	6.92±0.02 <sup>C</sup>	6.79±1.21 <sup>B</sup>	2.66±2.99	3.97±0.74 <sup>D</sup>	2.37±2.60
Average		<b>7.28±1.14</b>	<b>6.76±1.25<sup>A</sup></b>	<b>4.38±2.60<sup>A</sup></b>	<b>3.20±2.99<sup>A</sup></b>	<b>5.17±0.86<sup>A</sup></b>	<b>2.75±2.16<sup>A</sup></b>

Markets, MK- Makola, MD- Madina; KN, Kaneshie; DM, Dome; ML, Mallam Atta; Farms AB- Abokobi; MD, Madina; AS, Assin Fosu; NW, Nsawam; BC, Burma Camp. Different uppercase subscripts within the same columns are significantly different ( $P \leq 0.05$ ).

**Table 2.** Pooled mean count of microorganisms from two species of snails.

Species	Total bacterial count	Total coliform count	Total <i>Salmonella</i> count	Total <i>Staphylococcus</i> count	Total <i>Pseudomonas</i> count	Total <i>Bacillus</i> count
<b>Log<sub>10</sub> CFU g<sup>-1</sup></b>						
A.A	7.87±1.07 <sup>B</sup>	7.47±1.28 <sup>B</sup>	4.38±2.61 <sup>B</sup>	4.96±2.77	5.24±0.57 <sup>B</sup>	2.90±2.13 <sup>B</sup>
A.M	7.01±0.66 <sup>A</sup>	6.75±0.79 <sup>A</sup>	5.98±1.32 <sup>A</sup>	4.51±2.72	4.87±0.68 <sup>A</sup>	4.51±1.08 <sup>A</sup>

Values are mean count ± standard deviation. \*Different uppercase subscripts within the same columns are significantly different ( $P \leq 0.05$ ). A.A, *Achatina achatina*; AM, *Archachatina marginata*.

Table 1. The total viable count (log<sub>10</sub> CFU/g) ranged from 6.61 to 8.29. The highest count was observed at samples from Burma Camp. The total coliform count (log<sub>10</sub> CFU/g) ranged from 5.61 to 8.50; samples from Mallam Atta market had the highest count. *Salmonella* count (log<sub>10</sub> CFU/g) also ranged from 2.91 to 7.39 with Mallam Atta recording the highest count. The total Staphylococcal count (log<sub>10</sub> CFU/g) also ranged from 2.66 and 7.68 with Kaneshie recording the highest count. *Pseudomonas* and *Bacillus* count (log<sub>10</sub> CFU/g) ranged from 6.13 to 3.97 and 1.53 to 4.90 and the highest counts were seen at Nsawam and Mallam Atta, respectively (Table 1).

There were no significant differences ( $P \geq 0.05$ ) in the total mean obtained for the total viable count, from both sources (Table 1). However, there were significant differences ( $P \leq 0.05$ ) in the total mean counts obtained for coliform, and a highly significant differences ( $P \leq 0.001$ ) in the total mean counts for *Salmonella*. A highly significant differences ( $P \leq 0.000$ ) in total mean counts for both sources were recorded for *Staphylococcus*, and similarly, for *Pseudomonas* and *Bacillus* (Table 1).

### Mean count of microorganisms from two species of snails

The microbial load of two species of snail samples is shown in Table 2. *A. achatina* samples had the highest count for total viable count, coliform, *Staphylococcus* and *Pseudomonas* and a lower count for *Salmonella* and *Bacillus cereus*.

### Microorganisms identified from the breeding farms and the wild samples using API and some Biochemical Tests (BT)

Most of the microorganisms isolated from the wild samples were enteric bacteria (Table 3).

## DISCUSSION

### Problems associated with purchasing and consumption of snail meat

Even though snail meat is known to be highly nutritious,

**Table 3.** Phenotypical characterization of the most representative microorganisms isolated from fresh land snail samples from different breeding farms and markets.

Isolates	Snail samples									
	Market				Breeding farms					
	MK	MD	KN	DM	ML	AB	MD	AS	NW	BC
<i>Citrobacter freundii</i>	+	+	-	+	-	-	+	+	+	+
<i>E. coli</i> spp	+	+	+	-	+	-	-	-	+	-
<i>Enterobacter aerogenes</i>	-	-	+	-	-	-	-	-	+	-
<i>Enterobacter clocae</i>	-	-	-	-	+	+	+	+	-	-
<i>Klebsiella pneumonia</i>	-	-	-	+	-	-	+	-	+	-
<i>Micrococcus</i> spp.	+	+	-	+	-	-	-	-	-	-
<i>Proteus</i> spp.	-	+	+	+	+	-	-	+	+	+
<i>Salmonella</i> spp.	+	+	+	-	+	-	+	-	+	-

MK, Makola; MD, Madina; KN, Kaneshie; DM, Dome; ML, Mallam Atta; AB, Abokobi; MD, Madina; AS, Assin Fosu; NW, Nsawam; BC, Burma Camp.

several problems associated with the snails prevent a number of people from patronising it, especially, consumers who engaged in sedentary work with little time at their disposal.

The percentage of individuals who do not eat snails may be due to traditional, religious and cultural beliefs associated with the meat, health problems such as allergies among others (Ebenso, 2003). According to Ogbuagu and Okapara (2011), eating of snail is forbidden in some local communities and amongst some individuals due to cultural/religious beliefs or because of the feeding habit of snails. This is contrary to some beliefs that the meat has traditionally been a major ingredient in the diet of people living in high forest zone and the rural communities (Agbogidi and Okonta, 2011). Recently, snails are now consumed by a large number of people in the urban areas. This upsurge resulted from studies on their nutritive value which showed the 'foot' (the part eaten by people) to be rich in essential fatty acids such as linoleic and linolenic acids, required for normal tissue development and maintenance (Malik et al., 2011).

There are basically two types of snails on the Ghanaian market. There are the fresh snails, sold with the shell and the smoked- dried snails, shelled and skewed on a stick. Of these two types, the most preferred is the fresh snails. Respondents preferred the fresh snails because they claimed the fresh ones are more nutritious (Figure 4). A part from the high preference for fresh snails, traditionally preserved foods like smoked dried bush meat (game), stink fish are relished by Ghanaians for their peculiar taste and aroma. For this reason, there is high preference for the smoked- dried snails as well. Smoke drying the snails not only provides a different type of snails on the market but leads to the preservation of the snails against the lean seasons.

Snails that are usually sold on the market are hand-picked from the forest or their natural habitat where they live naturally and are considered as wild. These ones constitute a large percentage of those sold on the market.

They are also the preferred choice by consumers (Figure 5). The high preference for the wild snails comes from the belief that these have a better taste; however, their availability on the market is threatened in the near future. High demand of the wild snails had led to massive collection of the meat from the forest and the wild, depleting their population and possibly resulting in extinction of some of the species. Hence the few remaining species are captured before they reach maturity. The need to promote the domestication and rearing of these animals therefore cannot be overestimated.

Production and the sale of snails has remained a traditional and indigenous work. Right after they have been collected from the forest or from the farm, they are usually sold in the same state in which they were collected, that is, together with their shell. This product is yet to be processed into an attractive and a more hygienic form. The sale of both fresh and smoked dried snails in Ghana has been an indigenous work mostly preserved for market women who engaged in its trade. There has been no regulation concerning how the meat should be sold or presented to consumers. Traditionally smoked dried snail meat is not packaged but displayed on open trays for sale and at the end of the day; the unsold ones are packed into wooden boxes or sacks introducing various sources of contamination through human handling and other environmental factors (Tetty et al., 1997).

Due to the natural habitat of snails and their feeding habits, there is a high possibility of the meat being contaminated with lots of microorganisms. Snails are usually picked from the soil where they live, feed and breed, however, the soil is a host of several microorganisms most of which are pathogenic. There are growing interests to the extent to which edible land snails may present a threat to the health of humans (Ekundayo and Fagade, 2005). Efuntoyey et al. (2011) isolated approximately two species of *Staphylococcus* in the

intestines of different types of snails, with *S. aureus* being isolated from 27 individual *A. marginata* and 7 from *A. achatina*. Lack of accessible information and ignorance of the consumers may account for their perception of no contamination for the snails.

There was high preference for processed, packaged snails. Respondents explained the preparation of snail is difficult, time consuming and require additional resources to get them ready for use. A processed and well packaged fresh snail not only becomes handy for use but reduces its preparation time and is much more hygienic.

In the era of global change and massive technological advancements, efforts are targeted at improving the quality and adding value to existing products. Changes in family lifestyle, and increased ownership of freezers and microwave ovens, are reflected in demands for foods that are convenient to prepare, are suitable for frozen or chilled storage, or have a moderate shelf life at ambient temperatures (Fellows, 2000). The acceptance of these newly improved products on the other hand, usually prevents the possibility of developing them.

Respondents reported slime and shelling of snails, dirt, and price of the snails as some problems associated with the meat (Figure 7), however, there is an inverse relationship between the high cost (price) of snails and its consumption rate due to the high demand for snails. Unlike meat or fish, snail preparation could be very complex. In addition to the fact that snails need to be shelled, which required some skills in doing so, there are also problems associated the slime found on them. One complication in commercial processing of snail meat has been the mucus or "slime" secreted by the snails, used in their locomotion, defence, water retention and other physiological activities (Gallo, 2002). Snails are also dirty and covered with mud since they are mostly on the ground. All these, prevents consumers from patronising it. Consumption of snail meat is continuously increasing because many consumers eat snails for various reasons (Ogogo et al., 2011). While some consumers patronise the meat for health reasons, others harness its believed medicinal values. The low content of fat (1.3%) and low cholesterol level makes snail meat a good antidote for vascular diseases such as heart attack, cardiac arrest, hypertension, stroke, high blood pressure and other fat related ailments (Akinnusi, 2002). Medicinally, Ayodele and Ashimolowo (1999) reported that, among the people of West Africa specifically, the Yoruba speaking people of the South Western Nigeria, snail is a requirement in several preparations in traditional medicine. At the household level, nursing mothers depend on the snail mucus for treating wounds from the umbilical cords. All these medicinal attributes are however yet to be proven.

### Microbiological quality of snails from two sources

The TVC ( $\log_{10}$  CFU/g) from the microbial survey ranged

from 6.61 to 8.29, however, higher values of 10.41 of *A. achatina* were obtained before purging (Antwi, 2009) and 8.16, 8 and 8.17 for *Achatina fulica*, *Limicolaria* and *Helix pomatia* species of land snails (Adegoke et al., 2010). The value was close to 6.85 for *Helix aspersa*, a land snail popular to the European (Temelli et al., 2006). The TVC from the different markets and farms were also higher than the recommended levels acceptable of  $5 \times 10^5$  CFU/g for shell fish and fishery product (ICMSF, 1980). According to ICMSF (2005), snails may contain some parasites and other pathogenic bacteria which cannot be gotten rid of even after purging. This is due to the swamps and marshes in which they are found. A study conducted on the microbial load of snail farm soil reported a count of 5.35 to 5.85 ( $\log_{10}$  CFU/g) of different snail farms in Nigeria (Ekundayo and Fagade, 2005). The same study revealed a count ( $\log_{10}$  CFU/g) of 5.43 and 5.08 in the visceral mass of snails obtained from different snail farms. This indicates some relationship between the microbial load of snail and the soils they have contact with. The visceral fluid and excretion process of the snail can result in cross contamination of the meat. Efuntoye et al. (2011) isolated several species of *Staphylococcus* from the intestines of snails of both *Achatina* and *Archachatina* species. Total viable count is used to indicate the level of microbial contamination of a product (Maturin and Peeler, 1998). Although this may not directly relate to food safety hazard, it can be used to indicate the quality, shelf life and post-harvest contamination of these foods.

The total coliform count ( $\log_{10}$  CFU/g) from both sources were however higher than 2.77 (Temelli et al., 2006) for *H. aspersa* and 5.25 for aquatic snails (periwinkles) (Adebayo-Tayo et al., 2006). Similar findings were made by Adegoke et al. (2010) with counts ( $\log_{10}$ ) of 7.30, 7.22 and 7.34 for *A. fulica*, *Limicolaria* spp. and *H. pomatia*. High levels of coliform indicate faecal contamination of the natural habitat of these snails. This could be due to negative human activities carried out in the wild (forest) where these snails are particularly picked from and sold in the market. In addition, organic manure applied on farms where these snails are picked can also increase the coliform counts and other microbial counts of snails obtained from such areas. According to Adagbada et al. (2011), there is a close association between snails and microorganisms because their habitat is made up of filth, sewage, manure, rotten materials and poor latrine system which increase the microbial load of land snails.

High coliform counts from snails of the breeding farm samples could result from contaminated water and feed used since there are no regulations governing rearing of snails. The practice of domesticating and rearing snails has now been taken over by individual farmers with some assistance and training from the Ministry of Food and Agriculture, Ghana. This assistance however does not include regulating the quality of feed and water, or the

general sanitary conditions practiced. Another possible source of contamination among the breeding farm samples is the presence of other decomposed snails or their faecal material which had become part of the soil. Ekundayo and Fagade (2005) reiterated the fact that, high coliform, bacteria counts and pathogenic organisms associated with reared snails are due to the faecal materials and dead snails which decompose in the farm soil. Their findings also indicated that, as a result of snails licking the slime of infected snails or dead rotten snail, the microbial flora of the meat could be high.

Regarding *Salmonella*, similar counts ( $\log_{10}$ ) of 7.77, 7.96 and 7.71 were reported for three different species of land snails (Adegoke et al., 2010). Adebayo-Tayo et al. (2006) also enumerated *Salmonella* count of 6.04  $\log_{10}$  from aquatic snail (periwinkles) which were also within similar range, however, lower count ( $\log_{10}$ ) of 4.30 and 5.65 were reported for aquatic snail and oysters, respectively (Adebayo-Tayo et al., 2008). The level of shell fish contamination is directly dependent on the level of pollution in their habitat (Ekanem and Adegoke, 1995). According to Huss et al. (2000), *Salmonella* species are reported to form a natural micro flora in farms and pools of shell fish where they are raised and their presence in all snail samples indicates their contact with faecal matter originating from humans, animals or the snails themselves. Since *Salmonella* causes food poisoning in human, their presence in food should be totally eliminated. Efficient processing methods should be done to eliminate the organism totally from the cooked snail meat (Parlapani et al., 2014).

Similarly, *Staphylococcus* counts of 3.96  $\log_{10}$  was reported for life snails before boiling by Temelli et al. (2006). In another study conducted on the microflora of snail farm soil, an average range ( $\log_{10}$ ) of 3.17 and 3.41 was obtained for Staphylococcal count (Ekundayo and Fagade, 2005).

There are various strains of *Staphylococcus*, but the most important strain responsible for food intoxication and of public interest is *S. aureus*. This bacterium is heat sensitive and can be eliminated by cooking; however, its toxins are relatively heat stable and may continue to remain in food after cooking. According to Brooks et al. (2004), *S. aureus* may be easily killed by boiling but they produce enterotoxin that is stable to heat at 100°C for 30 min and this toxin is known to cause food poisoning.

Adagbada et al. (2011) revealed a 4.4% of *Pseudomonas* species isolated from different species of snails. One major source of *Pseudomonas* is the soil therefore; *Pseudomonas* is a likely microflora of the meat due to their close association with the soil. According to Bibek (2005), many types of moulds, yeast and bacterial genera such as *Pseudomonas* can enter food through the soil or through animals that are reared on the soil. According to a research conducted by Ekundayo and Fagade (2005), *Pseudomonas* was isolated from the snail farm soil (3.32  $\log_{10}$ ) and from the visceral mass of

the snail (2.50  $\log_{10}$ ). *Pseudomonas* spp. can be found in a lot of food commodities such as meat and fish including shellfish both of aquatic and terrestrial origin. They are mostly associated with food spoilage even at lower temperatures such as refrigeration temperatures. Yagoub (2009) isolated 62% of *Pseudomonas* spp. from 150 collected samples of shellfish. This is of much concern because *Pseudomonas* is an important indicator of quality control in food processing.

*Bacillus* species are widely distributed in the environment and can be found in the soil, dust, plants and on animals. Most *Bacillus* species have been isolated from different species of snails. Adagbada et al. (2011) *Bacillus cereus* is a spore forming bacteria associated with many foodborne illnesses. They can be present in undercooked meals since their spores are heat resistant. The bacteria are able to produce more cells under favourable conditions (Wang et al., 2010), therefore, this organism becomes an important concern especially in situations where snails are grilled for the preparation of kebab without adequate cooking to eliminate the spores. The differences in the microbial load of the two species might have resulted from the peculiar habitat of the species. According to Hodasi (1984), the Central and West African species of *Achatina* are confined to humid areas whilst the *Archachatina* species are distributed in less humid areas. This may contribute to the difference in the microbial load observed.

### Some microorganisms identified from the snail samples

The results reinforce the importance of the analyses regarding the presence of enteric bacteria. Brenner (1984) described enteric bacteria as facultative aerobic gram negative non spore formers from the family of Enterobacteriaceae. Their presence in food usually indicates faecal contamination or insanitary conditions. Most of these organisms are pathogenic while others produce toxins responsible for intoxication.

*Salmonella* spp. which was identified in the samples, were also isolated from snails sampled from different markets in Nigeria (Adagbada et al., 2011).

*E. coli* was mostly isolated from the market samples because these were much exposed to faecal contamination. In another study conducted by Adebayo-Tayo et al. (2011), *E. coli* was isolated from *A. achatina* and other aquatic snails. Periwinkles and oysters also had *E. coli* isolates identified in them (Adebayo-Tayo and Ogunjobi, 2008). Evans and Evans (1995) classified *E. coli* as gram negative bacilli of the family Enterobacteriaceae and normal flora of the large intestines. According to them, strains that acquire bacteriophage or plasmid DNA encoding enterotoxins usually become virulent causing major health problems. It



is to be noted that *E. coli* infections in human results from oral ingestion of food contaminated with the pathogenic strains shed by the infected persons.

*Citrobacter freundii*, *Klebsiella pneumonia* and *Proteus* spp. are microorganisms responsible for many nosocomial infections in man. While *Proteus* spp. and *Klebsiella* are commonly responsible for urinary tract infection, *Klebsiella pneumonia* causes severe pneumonia in humans. *Citrobacter freundii* and other *Citrobacter* spp. are also known to cause urinary and respiratory tract infections, meningitis, septicemia and pulmonary infections in neonates and young children (Barons, 1996).

Other research by Adagbada et al. (2011) identified *Enterobacter* spp. in different species of snails. Different species of *Micrococcus* were also isolated from aquatic snails and *A. achatina*. Even though these organisms were not of much public concern, recently, they have been involved in a number of health problems. *Enterobacter* spp. is known to be responsible for urinary tract infections and can cause lethal effects in immunocompromised patients.

## Conclusions

Consumers had enumerated many problems associated with fresh snails. Some of these problems were difficulty in shelling, the presence of the mucus or slime found on the meat and its interference during meal preparation, possibility of contamination of the meat, packaging and the price of the snails. Shelling of the meat by sellers may cause cross contamination of the meat. Shelling the snail can be time consuming and injurious to consumers. The slime or mucus found on the meat interfered with preparation and gave some consumers 'cold feet'. All these problems render the meat unattractive for consumers. The two species of snails obtained from the market (wild) and the breeding farms had high counts of microorganisms. Samples obtained from the market sources however had higher counts. Most microorganisms isolated from the snails were from the Enterobacteriaceae family. Some of the isolates include *Salmonella*, *Escherichia coli*, *Klebsiella pneumonia*, *Enterobacter cloacae*, *Micrococcus* spp. and *Proteus* spp. whilst some of these microorganisms are pathogenic, others are spoilage microorganisms. Some of these microorganisms were opportunistic organisms responsible for a host of human nosocomial infections.

## Conflict of Interests

The authors have not declared any conflict of interest.

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**QUESTIONNAIRE FOR CONSUMERS**

This survey is part of an ongoing scientific study carried out to research into various processes, methods and storage conditions of snails before packaging and distribution. It is therefore to be treated as highly confidential as possible. You must tick where appropriate. Thank you for your co-operation.

DATE.....

**A. PERSONAL DATA OF THE RESPONDENT**

SEX: M  F

AGE:

Occupation .....

Level of education Primary Secondary Tertiary

Language spoken Ewe  Twi  Ga  Others

**B. QUESTIONS RELATING TO PRODUCT**

1. Do you eat snails? Yes  No

2. If Yes, which type do you prefer? Dried  Fresh  Both

3. Give reasons for your answer.

.....  
.....

4. Which type of snails do you buy? Reared wild

5. How is the snail presented for sale?

a. Clean, washed and packaged under hygienic conditions

b. Usually dirty, unpackaged and unhygienic

6. How much do you buy the snails?

Quantity..... Price, .....C

7. Do you think the snails sold in the market may be contaminated?

Yes  No

8. How would you prefer them being sold?

.....  
.....

9. Would you prefer processed and packaged fresh snails without shells?

Yes  No

10. If Yes, why?

.....  
.....

11. Will you prefer processed and packaged dried snails? Why?

.....  
.....

12. Are snails available for purchase all year round? Yes  No

13. If No, indicate which month/months they are in season.

.....  
.....

14. Why do you eat snails?

.....  
.....

15. What do you dislike about the purchasing, preparation and cooking of snails bought from the market?

.....  
.....