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Biochemical and nutritional composition of garden snail (*Limicolaria flammea*) flesh consumed in Côte d'Ivoire

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Abstract: Investigations about biochemical composition and nutritional value of snail meat are few. Research was conducted on flesh flour from snail (*Limicolaria flammea)* collected in Agboville (South, Côte d'Ivoire). The proximate composition showed that snail (*Limicolaria flammea)* flesh flour was rich in protein (46.65±0.05 %) and low in fat (8.64±0.6 %), total carbohydrate (8.20±0.01 %) , total sugars **(**7.8±0.25 %) reducing sugars **(**7.23±0.04 %) and ash (6.23±0.01 %). The major minerals were phosphorus (3365.33±0.33 mg/Kg), calcium (1654.54±0.06 mg/Kg) potassium (1324.54± 4.18 mg/Kg) and sodium (668.69±1.13 mg/Kg). The major vitamins were vitamin B_9 (21.56±0.17 µg/100g), vitamin C (18.34±1.30 µg/100g) and vitamin E (18.12±2.1 µg/100g). The chromatographic profile of amino acids revealed fifteen amino acids of which five are the dominant ones. Those are lysine (2.38±0.01 mg/100g), valine (1.45±0.02 mg/100g), methionine (1.26±0.03 mg/100g), isoleucine (1.24±0.01 mg/100g), leucine (1.05±0.01 mg/100g), the others have contents lower than 1mg /100g. Oxalate and phytate anti-nutritional parameters are non-existent in flour and tannins content was 0.18±0.01 mg/100g.

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INTRODUCTION

Several groups of molluscs are known to be available in the wild, with snails being the largest group (Yoloye, 1984). Snails composed of several species, are invertebrates whose soft body is covered with a hard calcareous shell. They belong to the phylum Mollusca and the class Gastropoda (Barker 2001, Ramzy 2009). They are bilaterally symmetrical with more than 100.000 species known worldwide (Segun, 1995). They spend most of the day under stones, soil litter or decomposing organic matter (Ajayi et al., 1978).

In West Africa, snail meat has always been a major source of protein in the diet of people living in the forest zone (Cobbinah, 1993). People's attitudes towards the consumption of molluscs vary within the sub-region. In southern forest regions, snails are a delight for many people and people are willing to pay for them at high prices. In the northern regions, snails are taboo and many tribes do not touch them, let alone eat them. This may be due to the fact that the majority of the inhabitants of northern Côte d'Ivoire are Muslims and Muslims do not eat snails (Ebenso, 2003). The flesh of the snail is a meat very popular with European populations (Codjia and Noumonv, 2002), West Africa (Agbelusi and Ejidike, 1992) and American (Thompson and Cheney, 2004). This appreciation of snails is usually associated with the quality and flavor of their flesh. Several fields of application (traditional medicine, cosmetics and aesthetics) use snails for certain purposes (Codjia, 2002). Snails are processed by different methods of consumption. While some people eat roast snails, others boil them during cooking or fry them for consumption (Uboh et al., 2014). In the food sector, snails of the genus Archachatina and Achatina are highly preferred by populations that consume them in different forms (Fantodji et al., 2000). The forested areas of Côte d'Ivoire contain several species of molluscs (Otchoumou et al., 2005) and their relative distribution in their living environment is closely linked to the content of certain minerals, notably calcium, as well as to rainfall (Tattersfield et al., 2001). In addition, with some prejudices (small, invasive and devastating), the snail (*Limicolaria flammea)* experiences discrimination inducing very low consumption of this species in spite of its availability in all areas of the country. In order to value snail *Limicolaria flammea* and to find favorable economic prospects, scientific research has been carried out to determine the biochemical and nutritional potential associated with his flesh. The knowledge of their nutritional properties would help to identify the elements useful for their valorization and their promotion on the market.

MATERIAL AND METHODS

Biological material

The biological material used is the garden snails (*Limicolaria flammea*) collected in Agboville (South, Côte d'Ivoire). The taxonomic identification of species was carried out at Entomology Laboratory of Felix Houphouët-Boigny University (Abidjan, Côte d'Ivoire). Put in a cooler to preserve their fresh state, they were transported to the Laboratory of Biochemistry and Food Technology of University of Nangui Abrogoua (Abidjan, Côte d'Ivoire) where study was conducted.

Preparation of snail flour

The snails collected, were sorted and washed before being broken up. The shelled snails were dried in an oven at 80 °C for 72 hours. The dry samples obtained were crushed and sieved. A fine powder is thus obtained which is the meal of snails.

METHODS

Proximate analysis

Moisture content (on dry weigh basis) was determined on fresh sliced samples after oven drying at 105ºC for 24 h according the procedure of AOAC (1990). Sugars were extracted from flours using 80% aqueous ethanol. Total sugars were determined using the method of phenol-sulfuric (Dubois *et al.*, 1956). Reducing sugars were determined according to the method of Bernfeld (1955) using DNS. Crude fat was determined exhaustively extracting sample of flours in a soxhlet apparatus using anhydrous hexan as solvent. Nitrogen was determined by the Kjeldahl method reported by AOAC (1990) and crude protein content was subsequently calculated by multiplying the nitrogen content by a factor of 6.25. Ash content was determined by measurement of residues left after combustion in a furnace at 550ºC for 8 h (AOAC, 1990). Fiber estimate was obtained from the loss in weight of dried residue following the digestion for fat-free samples with 1.25% each of sulfuric acid and sodium hydroxide solutions. pH was determined according to the AOAC method (1990)**.** Energy values were obtained by the summation of multiplied mean values for protein, fat and carbohydrate by their respective Atwater factors, 4, 9 and 4 (Udosen, 1995).
Carbohydrate were calculated using the following formulas (FAO, 2002): Carbohydrates (dry matter basis) = 100 - (% moisture + % proteins + % lipids + % ash + % fibers)

Minerals analysis

The mineral elements were analyzed after wet-ashing using the scanning electron microscope (SEM) with variable pressure (SEM FEG Zeiss Supra 40 VP). This SEM is equipped with an X-ray detector (Oxford Instruments) connected to an energy diffusion spectrometry (EDS) microanalyzer platform (Inca Cool Dry, without liquid nitrogen). About 10 mg of the sample ash residue were applied evenly to a primed platform with double-sided adhesive carbon for analysis to measure the content of chemical elements, the device performs a measurement of the transition energy of the electrons from electronic clouds of the K, L and M series of atoms of the sample.

Determination of phosphorus

Phosphorus determination was carried out by the molybdenum blue method (Hanson, 1973). Two (2) grams of sample was dry-ashed and 5.0 ml of 5 M H2SO4 and 5 ml of 4% molybdate solution (25.0 g/l sodium molybdate in 5 ml H) added in a 100.0 ml volumetric flask. This was followed by the addition of 4 ml of 2% ascorbic acid. The mixture was then heated until a deep blue colour was developed. Deionised water was added to reach the 100 ml mark and the absorbance read at 655 nm using the atomic absorbance spectrophotometer (Perkin Elmer ASS, 5100 PC) against a blank. A standard curve was drawn by measuring absorbances at 655 nm of standard solutions containing 0.0 mg, 1.0 mg, 2.0 mg, 3.0 mg, 4.0 mg, and 5.0 mg of phosphorus in 100.0 ml deionised water. The phosphorus content of the snail sample was obtained from the standard curve.

Determination of vitamins

Vitamins (A and E) contents were determined according the method (Bonvehi et al., 2000). The flour sample (1 g) was diluted in 10 ml of hexane. Thereafter, 200 µl of this mixture was transferred into a screw-capped tube where 800 µl of methanol were added. After being votex-mixed and centrifuged (3000 rmp for 5 min), the samples were filtred though a 0.45 µm pore size filter and used for ultraperformance liquid chromatography (UPLC) analysis. Separation by UPLC was carried out using a liquid chromatography system (ACQUITY WATERS, USA) equipped with an optical detector TUV system and a BEH C column (150x0.25mm i.d., 1.7 µm particle size). The injection volume was 10ul. The mobile phase was methanol-water (98:2, v/v) and the elution was performed at a flow rate of 2 ml/min. The analytical column was kept at 45°C. Vitamin A of snail flour sample was detected at 325 nm and identified by comparing its retention time with this of authentic standard. Quantification of vitamin A identified in flour sample was done by using a standard curve (concentration versus peak area) of retinol palmitate. Detection of vitamin E was done at 292 nm using an optical detector TUV system. Vitamin E of oil sample was identified by comparing its retention time with of authentic standard. Quantification of vitamin A identified in oil sample was done by using a standard curve (concentration versus peak area) of a-tocopherol acetate. All the data obtained were stored and

processed by Empower software (WATERS, USA).

Determination of B group vitamins

The determination of the vitamin content of group B was highlighted according to the method described by (Rougereau, 1984**).** 5g of previously dried and dehydrated fine flour were collected from a 100 mL volumetric flask. 50 mL of distilled water are added and the pH of the mixture is adjusted to 4.5. The mixture is then delipidated by means of a solution of sulphur ether and petroleum ether. The newly obtained mixture is filtered and neutralized to a pH of 6.9. The solution obtained is lyophilized and the lyophilisate is reduced to a minimum volume. The determination of group B vitamins was carried out after calibration of the standards of each vitamin under the following technical conditions: solvent: acetonitrile 72; k H_2 PO_4 0,005. 28, column: Lichrosorb M H2 25× 4.6. 10µm, Temperature acetonitrile: 30°C, Temperature; K H_2 PO_4 25°C, Pressure column: 90-100 bar, Flow: 2.5 to 3 ml /minute Wavelength 234; 272; 218 ; 286 212; for the respective vitamins B1, B2, B3 and B5 (for 100 bar pressure), B6, and B12.

Determination of vitamin C

5g flour sample were weighed and placed in an aqueous solution of 5% glacial acetic acid and 1% thiourea. This mixture was placed in the oven for 20 hours at 60°C, then 50 ml of 2% oxalic acid was added. The mixture was filtered and its pH readjusted to 4.5 by addition of NaOH N. Finally, this solution was washed in a separating funnel twice its volume in petroleum ether. The pale yellow organic phase is rejected. The aqueous phase is retained (Holzhauer, 1986). This method allowed the determination of ascorbic acid and, with the following conditions: Lichrosorb MH2 column 25 × 4.6. 10 µm. Acetonitrile solvent: 73; buffer: KH_2 PO_4 0.005 M 27. Solvent temperature: 40°C. Flow rate: 2ml/min. Pressure: 50 to 70 bar Wavelength: 268 nm (Rougereau, 1984).

Determination of amino acids

Amino acid analysis was determined using high performance liquid chromatography (HPLC) (Shimadzu, Kyoto, Japan) (Erkan *et al.,* 2010).The amino acids of snail flour were determined by reverse phase high performance liquid chromatography (PTC RP-18 column, 220 mm long, 2.1 mm internal diameter) with a pre-column (SHIMADZU SPD 20A). The sample was hydrolyzed under vacuum at 150°C for 60 minutes in a Pico-Tag station (Waters, Milford, MA, USA) in the presence of HCl 6 N at 1% phenol. It was then taken up again in ultrapure water and automatically derived thanks to a self-derivator-analyzer-420 a (SHIMADZU SPD 20A). The amino acid derivatives in the form of phenyl-isothiocyanates (PITC) were separated by buffer A (sodium acetate 45 M at pH 5.9) and buffer B (30% sodium acetate 105 mM, pH 4.6; 70% acetonitrile) under an elution gradient. The detection was set at 254 nm and the total analysis time was 31 minutes. The results were acquired and evaluated using the Model 600 Data Analysis System (SHIMADZU SPD 20A) software Déguine and Hau (2001).

Determination of oxalates

The oxalate assay of the samples was performed according to the method described by Dayand Underwood (1986). A sample of 1g of finely ground sample was homogenized in 75 mL H_2SO_4 (3M) under magnetic agitation for 1 hour. The mixture is filtered with Whatman filter paper and then 25 mL of the filtrate are sampled and hot titrated with a solution of KMO_4 (0.05M) until the persistent pink turn. The oxalate content is given by the following mathematical formula:

Determination of tannin

The tannin content was determined according to the method described by (Bainbridge *et al*., 1996). A sample of 1 ml of the methanolic extract is introduced into a test tube. 5 ml vanillin reagent (0.1 mg/ml vanillin in 70% (v/v) sulphuric acid) is added to the contents of the tube. The tube is left at rest for 30 min in darkness and the optical density (OD) is read at 500 nm against a white. The tannin content of the samples is determined using a standard range established from a stock tannic acid solution (2 mg/mL) under the same conditions as the test.

Determination of phytate

The determination of phytates in flour is carried out according to the method described by Latta and Eskin (1980). 1 gram of each finely ground sample is weighed and ground and homogenized in 20 mL HCl 0.65N under stirring for 12 hours at room temperature. The mixture is then centrifuged at 12000 rpm for 40 min. 0.5 mL of each supernatant is collected from the test tubes and 3 mL Wade reagent is added to each tube. The mixture is left at rest for 15 min and the optical density is read with a spectrophotometer at 490 nm against the control. The determination of the amount of phytates is established using a calibration line established from a 10 µg/m sodium phytates stock solution.

Statistical analysis

All analyses were performed in triplicates. Results were expressed by means of ± SD. Statistical significance was established using Analysis of Variance (ANOVA) models to estimate the biochemical and Nutritional Composition of garden snail flour. Means were separated according to Duncan's multiple range analysis ($p<0.05$), with

the help of the software Statistica (StatSoft Inc, Tulsa USA Headquarters).

RESULTS AND DISCUSSION

Biochemical parameters of snail (*Limicolaria flammea*) flesh flour are shown in table 1. Moisture content (9.44±0.01%) of snail flesh flour would involve a cellular or bilayer structure rich in highly hydrophobic lipid molecules that would maintain water on the surface of the cells likely to evaporate rapidly upon cessation of all biological activities (Tarek, 2009). This moisture content was lower than *Limicolaria flammea* snail meal (21.33%) reported by Sea *et al*., (2008) but higher than *Archatina marginata saturilis* snail, which is 6.17% (Okon, 2016). However, this moisture content in snail (*Limicolaria flammea)* flour would be less likely to induce a corruptible microbiological activity of the flour quality and capable of increasing a priori the shelf life of this flour.

Table 1: Biochemical parameters of garden snail (*Limicolaria flammea*) flesh flour

Parameters	Contents (%)
Humidity	9.44 ± 0.01
Ash	6.23 ± 0.01
Fiber	1.2 ± 0.25
pH	7.2 ± 0.36
Total Carbohydrate	8.20 ± 0.01
Total sugars	7.8 ± 0.25
Reducing sugars	7.23 ± 0.04
Protein	46.65 ± 0.05
Fat	8.64 ± 0.64
Energy values (Kcal/100g)	301.18

Snail meat is reported to be a high quality food that is rich in protein, low fats and a source of many vital minerals required for normal tissue development and maintenance (Orisawuyi, 1989; Ademolu et al., 2004; Fagbuaro et al., 2006; Funmilayo, 2008). Protein content (46.65±0.05 %) of snail (*Limicolaria flammea*) flour relatively high protein content and this would be associated with amino acid-dependent biogenesis. Similarly, this high protein content would be due to a rich plant spectrum, constituting the diet of these snails (Kouadio et al., 2015). Protein content of snail (*Limicolaria flammea*) flour is lower than that of the snail (*Helix pomatia*) (50.6%) reported by Daina et al., (2014) and remains below that of the snail *Archachatina marginata* whose content was 62.66% (Kouadio et al., 2015). The protein content of snail (*Limicolaria flammea*) would al low their incorporation in protein-poor flours, particularly cereals, in order to contribute to the fight against child malnutrition (FA0, 2004). Moreover, protein content of snail *Limicolaria flammea* flour gives this species the advantage of being an ideal substitute for meat to combat gout disease which would be the consequence of the metabolism of proteins from red meat by the production of uric acid which is deposited in the form of crystals at the joints and manifests itself by severe chronic or spontaneous pain.

The incineration of the snail flour (*Limicolaria flammea*) quantitatively revealed a mineral profile confirming that this species remained a source of minerals. This ash content (6.23%) remained higher than that of *Limicolaria flammea* snails which was 3.86% (Sea et al., 2008), and *Lunella undulatta* species which (1.97%) (Roslizawati et al., 2017). This protein content is similary with that of garden snails (6.5%) (Sogbessan and Ugwumba, 2008). The snail (*Limicolaria flammea*) flesh flour had a high fat level compared with the range values of 3.75–4.5 %, 3.98±0.11 % , 4.50–4.91 % and 1.64 % reported by Eneji et al. (2008), Engmann et al. (2013), Soniran et al. (2013), Imevbore and Ademosun (1988).

Mineral composition of snail (*Limicolaria flammea*) flesh flour are shown in table 2. The current study provides information on mineral elements that compared favourably with the mineral contents of some lean domestic livestock meats (Aganga et al., 2003). The mineral profile of the flour flesh snail (*Limicolaria flammea*) shows a flour rich in macroelements (Potassium, Calcium and Phosphorus) and could be useful for children, pregnant women or athletes (Omotoso, 2006). High levels of these minerals are thought to be associated with the diet of these snails (Karamoko et al., 2014). The phosphorus content (3365.33±0.33 mg/Kg) is much higher than that of the *Archachatina marginata* and *Archachatina achatina* snails (Friday et al., 2014). Compared to data obtained by Oduro et al. (2002) (239.89–264.99 mg/100 g) on mineral composition of Snail (*Achatina achatina*) meat, the value obtained for phosphorus in this work was very higher. The snail *Limicolaria flammea* is a good source of phosphorus. Both phosphorus and calcium are involved in the calcification of bones and teeth. It also plays an essential role in the oxidation of nutrients in the form of phosphate groups in ATP (Khlyntseva et al., 2009). Phosphorus has more functions than any other mineral element in the body. It forms a complex with calcium that lends rigidity to bones and teeth (Food and Nutrition Board, 1997). The high calcium content (1654.54± 0.06 mg/Kg) of snail *Limicolaria flammea* is thought to be due to a high distribution of this mineral in the natural biotope of these snails (Otchoumou et al., 2011). In the same way, these minerals would be precursors of the synthesis of amino acids which would be at the base of the installation of the organs of the snails (Callen, 2006). Thus, the bioavailability of calcium would result in protection against increased blood pressure and other cardiovascular risks (Langford, 1983). Potassium is the principal intracellular cation and in conjunction with sodium plays a very important

role in the regulation of water and electrolyte balance as well as acid-base balance in the body (Otten, et al., 2006). This may explain the use of snail meat in the suppression of hypertension among rural people. Besides, potassium lowers blood pressure, when it is consumed in our foods (Institute of medicine, 2004; He and macGregor, 2008). Potassium influences the contractility of smooth, skeletal, and cardiac muscles and profoundly affects the excitability of nervous tissue (Burton and Foster, 1988, Moczydlowski, 2009). Thus, the bioavailability of potassium would result in protection against increased blood pressure and other cardiovascular risks (Langford, 1983). The important sodium content (668.69 ± 1.13 mg/Kg) of snail *Limicolaria flammea* involved in controlling the osmotic pressure that develops between blood and cells due to unequal ionic concentrations (Stachenfeld et al., 2001). Consumption of snail flesh *Limicolaria flammea* given its high calcium content, would play an important role in the diets of children and adults by intervening in bone fortification and tooth development (Nelson, 1987). It is also useful in the formation of muscles, heart and digestive system (Paiko et al., 2013).

Table 2: Mineral composition of garden snail (*Limicolaria flammea*) flesh flour

Minerals	**Content (mg/Kg)**
Mn	64.77 ± 0.60
Na	668.69 ± 1.13
K	1324.54 ± 4.18
Mg	135.67 ± 1.16
Cu	25.25 ± 0.08
Zn	29.18 ± 0.68
P	3365.33 ± 0.33
Fe	42.39 ± 0.39
Ca	1654.54 ± 0.06

Vitamin composition of snail (*Limicolaria flammea*) flesh flour are shown in table 3**.**The vitamins composition of snail flesh flour gives a presence of water-soluble vitamins (B_1, B_2, B_6, B_9, B_{12} and C) and fat-soluble vitamins (A and E). The presence of these vitamins would be due to important biological reactions which would involve both biochemical molecules in this case hexoses and minerals such as copper (Cu) and manganese (Mn) with the presence more or less important of ultraviolet rays catalysed by an optimal temperature for each vitamin Sivadjian (1953). The vitamin B_9 content of snail (*Limicolaria flammea*) flour was higher than that obtained in beef (6 µg/100g), steamed African carp (11 µg/100g) (Finke, 2002; FAO, 2012). The vitamin potential of the snail *Limicolaria flammea* flesh would give this species a great capacity to combat diseases associated with vitamin deficiency (avitaminosis). The vitamin B_1 content of the *Limicolaria flammea* snail is higher than that found by Eruvibetine (2012) in the giant African snail. Similarly, vitamin B_2, B_6 and B_{12} contents were lower than those found by Okon et al, (2016) in *Archachatina marginata saturalis* which respectively concentrated less than 130 µg/100g. When consumed by humans, vitamin E promotes healing of wounds with much less scar tissues, assists in breaking down blood clots in the circulating system, reduces the incidence of heart diseases or cancer (Okon et al., 2016). Vitamin B1 assists human body cells to produce energy for carbohydrates, it is essential for functioning of the heart muscles, nervous system and muscle contraction (Ruthenberg, 1991). Vitamin B12 plays a key role in normal functioning of the brain, nervous system and blood formation (Ruthenberg, 1991).

Table 3: Vitamin composition of garden snail (*Limicolaria flammea*) flesh flour

Vitamins	Values (µg / 100g)
A	0.11 ± 0.94
C	18.34 ± 1.30
E	18.12 ± 2.1
B_1	0.11 ± 0.46
B_2	0.17 ± 0.51
B_6	0.88 ± 1.2
B_9	21.56 ± 0.17
B_{12}	0.92 ± 0.24

Amino acids composition of snail (*Limicolaria flammea*) flesh flour are presented in table 4. Amino acids profile of snail flour (Limicolaria flammea) revelead mainly eight essential amino acids. The results of this profile indicate that lysine (2.38 mg/100g) valine (1.45±0.02) and methionine (1.26 mg/100g) as well as isoleusine (1.24 mg/100g) are the predominant essential amino acids in snail flour. The presence of amino acids in the flour of the snail (*Limicolaria flammea*) would be linked to the process of organogenesis which would depend on growth factors in this case EFG (epidermal growth factor) which is a polypeptide composed of fifty three amino acids and which would stimulate the proliferation of ectodermal, mesodermal and endodermal cells (Stoscheck and King, 1986). These respective amino acid levels are well above those observed in the white-fleshed *Helix pomatia* snail for the corresponding values of 0.567; 0.131 and 0.408 mg/100g respectively (Daina et al., 2014). The presence of essential amino acids in the flesh flour would be significant for human consumption because of the impossibility that the human organism presents in the synthesis of these. Researchers believe that the snail meat contains very high quality protein (Ferhat et al., 2011). The isoleucine, leucine, lysine, phenylalanine, valine and methionine values in snail suggests that the meat may meet the minimum daily requirements and contains balanced essential amino acid highly suitable for the fortification of maize food products which are

widely used as weaning food for children in most African countries.

Table 4: Amino acids composition of garden snail (*Limicolaria flammea*) flesh flour

amino acids	Content (mg /100g)
Valine	1.45 ± 0.02^{a}
Leucine	1.05 ± 0.01^{a}
Isoleucine	1.24 ± 0.01^{a}
Phenylalanine	0.51 ± 0.02^{b}
Lysine	2.38 ± 0.01^{c}
Threonine	0.25 ± 0.01^{e}
Methionine	1.26 ± 0.03^{a}
Tryptophan	0.40 ± 0.46^{b}
Arginine	0.31 ± 0.44^{e}
Aspartic acid	0.56 ± 0.20^{f}
Serine	0.15 ± 0.01^{g}
Glutamic acid	0.13 ± 0.12^{g}
Alanine	0.9 ± 0.54^{a}
Proline	0.09 ± 0.12^{h}
Tyrosine	0.30 ± 0.03^{e}

Data in the same column with different superscript letters (a, b…) are significantly different ($p<0.05$)

Anti-nutritional parameters of snail (*Limicolaria flammea*) flesh flour are presented in table 5. Oxalates or phytates was not detected in the flesh flour of *Limicolaria flammea* snail. This absence of phytate and oxalate would be consistent with the study reported by Okon *et al*, (2016) in *marginata* and *achatina* species. Moreover, the synthesis of these factors would be an almost exclusive property of plants. Consumption of large doses of oxalate leads to corrosive gastro enteritis which may result in renal damage and low plasma (Kelsely, 1985). According to Monago and Akhidue (2002), and Osabor et al. (2008), the lethal dose of oxalate for human beings was 2-5g/100g of sample. Therefore, the consumption of snail (Limicolaria flammea) flesh make the snail perfectly safe and without threat of exposure to high levels of toxicant. Phytate has a strong affinity for calcium, magnesium, iron, copper and zinc making these minerals unavailable for absorption in the intestine (Cheryan and Rackis, 1980, Ekhol et al., 2013). Tannins can also interfere with protein digestibility by enhancing excretion of endogenous protein, and they increase fecal fat excretion (Bravo et al., 1993; Bravo, 1998).

Table 5: Anti-nutritional parameters of garden snail (*Limicolaria flammea*) flesh flour

Parameters	Content (mg/100g)
Tannins	0.18 ± 0.01
Oxalates	ND
Phytates	ND

ND: Not Determined

CONCLUSION

The biochemical and nutritional study of snail flesh (*Limicolaria flammea*) revealed a wealth of proteins, minerals (phosphorus, calcium, potassium and sodium) and the presence of many vitamins (water-soluble and fat-soluble) and fifteen amino acids including essential amino acids. These results could attract population's attention because of their prejudices about this snail of so-called garden snails. Its consumption could solve some problems of protein, vitamin and mineral deficiencies in our foods. Hence, consumption of *Limicolaria flammea* snails should be encouraged for both the young and old, as an alternative source of essential nutrients at a lower cost. Results of this study reconfirm the nutritional status of snail, which could be used as food for humans. *Limicolaria flammea* snail production and consumption would go a long way in enhancing nutritional balance of diet. The levels of anti-nutritional factors present in meat samples were not toxic to snails and hence humans.

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