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Research Article

Effects of Dietary Level of Calcium on Body Proportion and Nutritional Value of African Giant Snail (*Archachatina marginata*)

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Abstract

The study was designedto evaluate the effect of dietary level of calcium on meat yield and nutritional value of the African giant snail (*Archachatina marginata*). The snails were fed on diet containing 12%, 14%, 16% and 18% calciumfor thirty-two weeks.The results revealed that the final live body weight, the proportion of meat and shell increased with the increasing level of calcium in the ration. The highest shell yield (36.5%) and the lowest proportion of soft tissue (59.87%) were recorded with the highest content of calcium (18%). The highest viscera yield was recorded with the lowest calcium level (24.48%), while the proportion of the shell increased with increasing level of calcium (R^2=0.9752). The highest meat yield (45.70%) was achieved with 16% calcium, while the lowest meat (38.47%) and the highest shell yield (36.50%) were achieved with 18% calcium. Meat content in proteins increased (p<0.05) with increasing level of calcium from 45.85, 50.52, 55.22 to 57.30% respectively with 12%, 14%, 16% and 18% calcium. Meat content in fat and carbohydrates significantly (p<0.05) decreased with increasing level of dietary calcium. Thevariation of calcium level had no significant effect (p>0.05) on the mineral composition of the shell.It was concluded that the calcium needs for a better growth, and nutritional value of *Archahatina marginata* is 16%.

Keywords: *Archachatina marginata*; Calcium; Carcass yield; Nutrient content

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Introduction

In Sub-saharan Africa, forest food resources provide rural households with a very important part of animal protein [1]. Among these forest resources, snails are highly appreciated for the quantity, flavour and quality of meat that they provide [2]. In fact, their flesh is an excellent source of crude protein that varies between 40% and 82.87% [3,4] and contains almost all the essential amino acids, energy and minerals [3,5-7]. The flesh of snails has low fat [2] and is highly recommended for dietetics in low-fat diets [8].

The portions of meat traditionally consumed by humans represent about 1/3 of the live weight of the giant snail compared with almost half of the live weight for the uneaten shell and viscera [9,10]. One kilogram of giant snail destined for human consumption can be recovered for almost half a kilogram of high-value animal feed (calcium and protein) [2]. Indeed, snail shell powder is used in animal feeds such as broilers and layers, small livestock and cattle as a source of calcium [11]. The shell can also be used in crop production to reduce soil acidity [12]. The results of Sika et al., [2,13] have shown that the meat yield and nutritional value of *Achatina fulica* was improved with the increasing level of protein in the diet. However, no in-depth study has yet been conducted on the minimum level of calcium to be included in the diet of *Archachatina marginata* snails to ensure better meat yield and better nutritional value. The present study was designed to evaluate the effect of dietary calcium level on the meat yield and nutritional value of the giant African snail *Archachatina marginata* [14].

Materials and Methods

Period and site of study

This study was conductedat the Teaching and Research Farm of the University of Dschang, Cameroon between March and October 2018. The breeding took place in bins arranged along the walls inside a building in hard closed on all sides. The average temperature in the building was 19.7°C, the relative humidity 62.4%, the temperature of the substrate 16°C, and its humidity 84%. The photoperiod was natural (12h/12h).

Animals and experimental design

A total of 180 snails with average weight 10.00±1.00g, 33.00±1.00mm length and 24.00±1.00 mm width were randomly assigned to four experimental diets in a completely randomized design

with 45 snails per treatment. Each group was subdivided into 5 replicates of 9 snail's eachcorresponding to a density of 75 snails/m². They were collected in cocoa plantations in the Moungo subdivision (Njombé). The snails were selected based on their morphology and behavior: live weight, shell shape with no breakage, free from visible and active trauma.

The snails were raised in plastic tanks with 45cm, 30cm and 25cm respectively for length, width and depth. A fine mesh (2 mm mesh) was placed above each tank to prevent snails from escaping. The substrate was made up with 10cm deep white sawdust. The moisture content of the substrate was maintained above 85% by watering each tank after 2 days with 120 ml of water. The experimental diets consisted of rations containing 12, 14, 16 and 18% calcium (Table 1). Snails were weighed at the beginning of the trail and on a two weeks basis thereafter, for a period of eight months. Throughout the experiments trails, the snails received feed and water ad libitum every day.

Carcass characteristics

After 8 months, 6 snails from each treatment group were randomly selected, fasted for 24h, then marked and weighed before being euthanized by scalding (immersion in boiling water for 10 min). After cooling, the soft tissues were removed from the shell and drained in a colander. Empty shells were also drained. A set of organs (foot, head, distal edge of the mantle bearing the last centimeter of the rectum and anus, pneumostome, pallial bead, distal part of the genital tract including the penile sleeve, the anterior part of the digestive tract until the first half of the crop) were separated from the rest of the visceral organs (digestive glands, gonads, albumin glands, genital tract, heart and hepatopancreas). For each snail, the weight of the edible flesh, the visceral mass and the weight of the empty shell were determined. From these parameters, the proportions of the various parts of the body of the snails were calculated with the following formulas:

Proportion of empty shell (%) = PEs × 100 / LW
Proportion of visceral mass (%) = PVm × 100 / LW
Proportion of soft tissue (%) = PSt × 100 / LW
Proportion of edible flesh (%) = PCf × 100 / LW

PEs: Empty shell weight; LW: Live weight of the snail; PVm: Weight of the visceral mass; PSt: Soft tissue weight; PCf: Weight of edible flesh.

Proximateanalysis of the flesh

After the evaluation of the meat yield, 20 snails were samples from each treatment group, weighed and dried in a ventilated oven at 60˚C till constant weight forproximate analysis. Dry matter, crude protein, fat content, total carbohydrates and minerals (calcium, phosphorus, potassium, magnesium and iron) were determined by the procedure described by AOAC (1990) [15]. Shell samples were collected for mineral content determination. Carbohydrates were obtained by the following formula:

Carbohydrates (% MS) = Organic Matter - (Fat + Crude Proteins)

Statistical analysis

Data collected on the different parameters were submitted to one-way analysis of variance test by General Model procedure of Statistical Package for Social Science (SPSS 20.0) software. The different were tested using Duncan's multiple range's test and probability values less than 0.05 were considered as significant. The Pearson regressions established the links betweenthe growth and reproduction parameters.

Ingredients (kg)	Experimental diets			
	R1(12%Ca)	R2(14%Ca)	R3(16%Ca)	R4(18%Ca)
Maize	15	15	18	20
Soybean cake 49	20	20	20	13.5
Cotton cake	14.75	14.75	9	0
Palm kernel cake	6	0	0	0
Fish meal	0	0	5.5	17
Wheat bran	12	5	0	0
Seashell	31	32.5	37.5	40.5
Palm oil	0.5	0.5	0.5	0.5
Salt	0.25	0.25	0.25	0.25
Premix 0.5%	0.5	0.5	0.5	0.5
Agar-agar	0	11.5	6.25	7.75
Total (kg)	100	100	100	100
Analysed chemical composition				
Crude protein (%)	18.86	18.93	19.13	19.21
Crude energy (Kcal)	4193.00	4361.14	4315.82	4331.17
Fat (%)	1.12	2.23	1.48	2.28
Calcium (%)	11.85	13.57	16.01	17.76
Phosphorous (%)	0.28	0.26	0.21	0.23
Potassium (%)	0.17	0.20	0.30	0.20
Magnesium (%)	0.56	1.02	1.04	1.04
Natrium (%)	0.10	0.07	0.10	0.07
Iron (%)	0.22	0.25	0.23	0.25

Table 1: Proximate composition of the experimental diet.

Results

The body proportions of *Archachatina marginata* as affected by the calcium content of the ration is summarized in table 2. The final live body weight, the proportion of meat and shell increased (P<0.05) with the increasing level of calcium in the ration until 16% but meat proportion decrease beyond 16% calcium. The soft tissue and were not affected by the level of calcium.

Table 3 summarized the carcass proportions of *A. marginata* as affected by the calcium content of the ration. The highest shell yield (36.5%) and the lowest proportion of soft tissue (59.87%) were recorded with the highest content of calcium (18%), and the soft tissue yield decreased with increasing calcium levels (R^2=0.9829). The highest viscera yield was recorded with the lowest calcium level (24.48%), the proportion of the shell increased with increasing level of calcium (R^2=0.9752) while the meat proportion was significantly (p<0.05) higher with 16% calcium as compared to all other treatments.

Biochemical composition of meat

The information's on the nutritional value of *Archachatina marginata* meat as affected by the calcium content of the rations are presented in table 4. The ash and protein content of snail's meat increased (R^2=0.995) with the increasing level of calcium in the ration. Fat and carbohydrates content significantly (p<0.05) decreased with increasing level of dietary calcium level.

Minerals content in meat

Table 5 summarizes the mineral composition of Archachatina marginata meat as affected by dietary calcium level. The highest calcium and iron content of meat wererecorded with 16% calcium in the ration. The K; Mg and Fe content of snail meat doubled with 18% calcium in the ration as compared to ration containing 12% calcium.

Minerals content in shell

Table 6 summarizes the mineral composition of Archachatina marginata shell as affected by the graded level of calcium in the ration. The variation of the calcium level of the ration did not have any significant effect (p>0.05) on the mineral composition of the snail shell. However, it is noticed that calcium is the most abundant mineral in the snail shell, while the phosphorous is found in trace.

Body proportions (g)	Experimental Diets				*P*
	R1 (12%Ca)	R2 (14%Ca)	R3 (16%Ca)	R4 (18%Ca)	
Live weight	40.21±1.02^a	40.95±1.93^a	44.97±3.5^b	47.99±2.00^b	0.000
Shell	10.11±0.71^a	11.33±0.81^a	13.24±0.82^b	17.52±1.38^c	0.000
Soft tissue	27.01±0.80	28.57±2.71	29.63±3.13	28.75±2.31	0.411
Meat	17.15±0.72^a	17.42±1.14^a	20.58±2.07^b	18.45±0.76^a	0.005
Visceral mass	9.83±0.67	9.82±0.90	8.93±1.65	9.83±1.45	0.588

Table 2: Effects of calcium level on body proportions of Archachatina marginata.

a, b, c: On the same line, values affected withthe same letters are not significantly different (p>0.05);
R1: Diet containing 12% calcium; R2: Diet containing 14% calcium; R3: Diet containing 16% calcium; R4: Diet containing 18% calcium.

Carcass components (%)	Experimental Diets				*P*
	R1 (12%Ca)	R2 (14%Ca)	R3 (16%Ca)	R4 (18%Ca)	
Shell	25.13±1.43^a	27.68±1.88^b	29.49±1.05^b	36.50±2.42^c	0.000
Soft tissue	67.21±2.32^b	69.65±3.73^b	65.80±2.77^b	59.87±3.62^a	0.001
Meat	42.66±1.55^b	42.51±2.60^b	45.70±1.12^c	38.47±1.44^a	0.000
Visceral mass	24.48±1.97^b	23.94±1.44^b	19.81±2.78^a	20.44±2.64^a	0.009

Table 3: Effects of dietary calcium level on the carcass proportions of *Archachatina marginata*.

a, b, c: On the same line, values affected withthe same letters are not significantly different (p>0.05);
R1: Diet containing 12% calcium; R2: Diet containing 14% calcium; R3: Diet containing 16% calcium; R4: Diet containing 18% calcium.

Biochemical components (%)	Experimental Diets				*P*
	R1 (12%Ca)	R2 (14%Ca)	R3 (16%Ca)	R4 (18%Ca)	
Dry matter	90.40±0.28	90.59±0.27	90.41±0.12	90.50±0.17	0.715
Organicmatter	86.12±0.32b	86.15±0.35b	84.60±0.23a	85.10±0.41a	0.001
Proteins	45.85±0.16a	50.52±0.16b	55.22±0.26c	57.30±0.34d	0.000
Fat	3.73±0.25b	1.43±0.010a	1.49±0.33a	1.35±0.05a	0.000
Carbohydrates	36.52±0.087d	34.20±0.14c	27.89±0.31b	26.44±0.39a	0.000
Ash	4.26±0.10a	4.43±0.11a	5.46±0.37b	5.38±0.33b	0.001

Table 4: Effects of dietary calcium level on biochemical components of *Archachatina marginata* meat.

a, b, c: On the same line, values affected withthe same letters are not significantly different (p>0.05);
R1: Diet containing 12% calcium; R2: Diet containing 14% calcium; R3: Diet containing 16% calcium; R4: Diet containing 18% calcium.

Mineral content in the meat (%)	Experimental Diets				*P*
	R1 (12%Ca)	R2 (14%Ca)	R3 (16%Ca)	R4 (18%Ca)	
Ca	2.64±0.21^{a}	2.58±0.10^{a}	3.40±0.49^{b}	2.97±0.30^{ab}	0.042
P	0.24±0.04^{ab}	0.20±0.02^{a}	0.23±0.023^{ab}	0.27±0.02^{b}	0.074
K	0.22±0.017^{a}	0.21±0.020^{a}	0.21±0.04^{a}	0.36±0.015^{b}	0.000
Mg	0.42±0.020^{a}	0.78±0.028^{c}	0.62±0.026^{b}	0.91±0.010^{d}	0.000
Na	0.066±0.0057^{a}	0.066±0.015^{a}	0.077±0.0057^{a}	0.096±0.057^{b}	0.012
Fe	0.037±0.005^{a}	0.067±0.005^{b}	0.083±0.005^{c}	0.066±0.01^{b}	0.000

Table 5: Effects of calcium level in mineral content of *Archachatina marginata* meat.

a, b, c: On the same line, values affected withthe same letters are not significantly different (p>0.05);
R1: Diet containing 12% calcium; R2: Diet containing 14% calcium; R3: Diet containing 16% calcium; R4: Diet containing 18% calcium.

Mineralscontent of shell (%)	Experimental Diets				*P*
	R1 (12%Ca)	R2 (14%Ca)	R3 (16%Ca)	R4 (18%Ca)	
Ca	22.54±0.12	22.48±0.21	22.59±0.61	23.25±0.54	0.176
K	0.043±0.0057	0.0367±0.011	0.033±0.0057	0.036±0.0057	0.480
Mg	0.91±0.015	0.89±0.036	0.92±0.020	0.79±0.12	0.129
Na	0.020±0.00	0.023±0.0057	0.023±0.0057	0.020±0.00	0.596
Fe	0.0010±0.0010	0.0013±0.0015	0.0013±0.0011	0.0010±0.0010	0.970
P	Trace	Trace	Trace	Trace	-

Table 6: Effects of dietary calcium level on mineral content of Archachatina marginata shell.

Discussion

Feeding snails with a compounded balanced feed improved growth performance and nutritional value especially in calcium, protein, energy and vitamins [2,4,16]. The carcass proportion of *Archachatina marginata* as affected the level of dietary calcium show that the meat yield was higher (45.70%) with 16% of calcium. The lowest proportion of soft tissue was recorded in snails fed on diet containing the highest calcium (18%) and the soft tissue yield was observed to decrease with increasing calcium levels. This result agrees with the finding of Otchoumou [10] which state that weight and shell growth of snails are closely related to the content of certain nutrients such as calcium and protein. When calcium contentexceeds 16%, this snail tends to develop much more shell than meat. The same phenomenon was reported by Ireland [17] on *Achatina fulica* and by Otchoumou [10] on *Achatina achatina*. In fact, the Pearson regression have shown that the increase in shell yield is closely related (R^2 = 0.975) to the increase in calcium level of the diet. The same tendency was observed with the variation in soft tissue yield that was closely related (R^2 = 0.982) to the increase in calcium level of the diet. The highest proportion of meat produced by snails in this study was 45.70% which is much higher than the 26.6% reported by Otchoumou et al., [7] in *Achatina fulica*, but not far from the proportions (42.2 to 43.97%) obtained by Sika et al., [2] with the same species as well as the results (41.3%) obtained by Kana et al., [4] with *Archachatina marginata.* These differences could be explained by the portion considered consumable in each study, the conditions of rearing and probably the live weight of the snail at slaughter. Fagbuaro [18] recorded a percentage of 41.18% by considering only the pedal mass (foot) of *Archachatina marginata* having a live weight of 324.13g. In the present study, the portion consisting of the foot, the head, the distal edge of the mantle bearing the last centimeter of the rectum and anus, the pneumostome, the pallial bead, and the distal part of the genital tract including thepenis sleeve, the anterior digestive tract to the first half of the crop were considered as edible as recommended by Aman [19].

This study also showed a variation in the chemical composition of the flesh of the snails as affected by the calcium level of the diet. Snail's meat fed on 18% calcium is richer in protein (57.30%) than snails fed on the other three rations, with the lowest content of protein (45.85%) being recorded with the lowest calcium level (12%). The same trend was recorded with the ash content of meat suggesting that the biochemical composition of snails depend on thecomposition of diet consumed [2]. In fact, the Pearson regressions show that the increase in the protein content of snail meat depends strongly (R^2 = 0.995) on the calcium level of the ration. The protein content of snail flesh increases linearly with the increasing rate of calcium in the diet. Many authors noticed the importance of calcium in improving the biological performance of farmed snails [10,16,20-22,]. Several studies also reported the synergistic action of mineral elements andorganic matter such as proteins on growth and even reproduction of snails [23]. Thus, we can note the presence of other minerals such as magnesium, which is essential for the assimilation of vitamin B2 (Thianine), essential for protein synthesis, carbohydrate metabolism and would also facilitate the absorption of calcium and phosphorus [24]. Sika et al., [2] revealed that the snails' meat is enriched with the protein of diet that they consumed. These observations corroborate the findings of Kana et al., [4] on *Archachatina marginata.*

The higher lipid content was recorded with the lowest calcium level (12%) and the lowest (1.35%) with the highest calcium level (18%). Similarly, the meat of snails fed on the smallest calcium (12%) was richer in carbohydrates (36.52%) which decrease linearly with the increasing rate of calcium in the diet. The chemical composition of snail meat varies with species, breeding conditions and many other factors. Indeed, Kouadio et al., [25] studied some of the growth

and nutritional value parameters of two wild-grown varieties of *Archachatina marginata* snail. The results showed that the flesh had a protein level of 62.66%; fat content of 2.98%; and total carbohydrates of 4.29%. The values recorded in the present study are much higher than those obtained by Fagbuaro [18] who reported 1.36%; 4.27%; 14.48%; and 0.78% for ashes, fat, crude protein, and total sugars respectively. The present crude protein is also higher than the values of 20.50; 25.68 and 48.85% respectively recorded by Fagbuaro et al., Adeola et al., and Sea et al., [5,26,27] . These differences could be explained on one hand by the potentially different genetic characteristics of the strains used by each of the authors because of the existence of several subspecies not yet identified [28] and on the other hand, by the experimental conditions and techniques.

Regarding the mineral analysis, it appears that the meat of the snails fed on diet containing 16% calcium is richer in calcium (3.40%) than that of the snails fed on three other rations. and the lowest calcium content (2.58%) was recorded with the ration containing 14% calcium. This study also revealed that, the most important mineral element in the flesh of snails is calcium. Kouadio et al., [25] revealed that, particularly with regard to calcium, its rate is higher in the white-fleshed variety (20.34%) than in the black flesh (17.38%) of *Archachatina marginata* grown in the wild. These calcium levels recorded from different varieties of *A. marginata* are higher than the value recorded in this study and also higher than the values estimated in the flesh of snails of the same species fed by different nitrogen sources as reported by Ademolu et al., [29]. The amount of calcium is estimated in this different flesh between 46.75 and 941.75mg/100g of dry matter. In the present study, the highest mineral values were recorded with 18% calcium in the diet while the highest iron level (0.083) was recorded with 16% calcium. All these minerals were also found in the flesh of the wild-caught *Archachatina marginata* snails [25] and *Helix promatia* [30] harvested in southern Turkey [31]. With regard to iron, the rate is lower in the flesh of the snails studied in the present research (0.037-0.083%) compared to the rate of 0.09% reported by Kouadio et al., [25] in the same species. These values are much higher than those recorded by Sea et al., [27] in *Limicolaria flammae.*

Calcium is the most abundant mineral with a higher rate recorded in snails fed on 18% calcium. This result is in agreement with other studies [28], which showed that calcium is the essential mineral in the shell of the snail. However, the calcium content recorded in the present study is lower than the valuerecorded by Kouadio et al., [25] in the same species (35.34%). Similar results were recorded with *Archachatina ventricosa* (36.84%), *Achatina achatina* [32] (36.13%) and *Achatina fulica* (36.86%). The high calcium content of the *A. marginata* shell may justify its utilization as a calcium source in animal feed formulations. Indeed, snail shell powder can be used in animal feeds such as broilers and layers [11].

Conclusion

This study revealed that calcium is one of the essential nutrients to be considered in snail production. Increasing calcium content in the ration improves growth, carcass yield and nutritional value of *A. marginata*. Definitely, the calcium need for better meat proportion and nutritional value of *A. marginata* is 16% in ration.

Conflict of Interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work; there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the content of this paper.

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