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Carcass yield of giant African snails of the species Archachatina marginata bred in captivity (Swainson 1821)

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Abstract

The carcass yield of giant African snails, *Archachatina marginata*, subjected to a restrictive diet for 70 days and then re-fed for 70 days, was evaluated. The objective was to determine the ability of the species to compensate for growth retardation. The study took place at the application farm of the Faculty of Agronomy of the Parakou's University between August 15, 2019 and January 22, 2020. A total of 90 snails, with an average live weight of 52.48 ± 9.03 g, were randomly divided into three batches of 30 subjects in semi-buried enclosures made of cement block and fine-mesh wire netting. Three meal rations containing 20.26%, 17.18% and 14.43% crude protein and 2976 kcal, 2540 kcal and 2089 kcal of metabolizable energy per kg of dry matter were distributed ad libitum to batches I (control), II and III respectively. At the end of each feeding period, 8 snails from each batch were randomly selected and slaughtered. The feed consumption indices as well as the carcass yields were respectively 1.94 ± 0.51; 3.44 ± 1.07 and 4.31 ± 1.03 ($p < 0.05$) as well as 38.70 ± 3.12%; 30.35 ± 2.03% and 28.30 ± 1.26% ($p < 0.05$) respectively for batches I (control), II and III at the end of the feeding restriction period. After the re-feeding period, where all the batches of snails were fed at the same level as the control batch, these values were respectively 2.55 ± 0.35; 1.65 ± 0.14 and 1.60 ± 0.14 ($p < 0.05$) as well as 40.44 ± 4.00%; 37.48 ± 2.56% and 36.55 ± 1.75% ($p < 0.05$) respectively for batches I, II and III. It appears from this study that temporary feeding restriction followed by re-feeding significantly improved feed efficiency in *Archachatina marginat*a. The carcass yield, despite a remarkable increase, could not be fully compensated.

Keywords: *Archachatina marginata*; Feeding restriction; Feed efficiency; Carcass yield; Republic of Benin

1 Introduction

The synthesis of body tissues in farm animals is closely linked to the quantity and quality of nutrients contained in their feed rations. The metabolic use of these nutrients is all the more efficient as the animal develops the ability to transform available feed resources into animal products. It can be milk production in mammals, egg production in oviparous animals (case of poultry) or carcass yield in slaughtered animals. According to Cantalapiedra-Hijar *et al.* [5], the efficient use of feed resources can be linked either to better digestibility of the ration, which makes it possible to extract more energy for the animal, or by better metabolic recovery, which in this case reflects better metabolic performance. It is known that animal species direct their food consumption according to the energy and protein density of the ration ([1]; [6]; [27]). The more the ration is rich in these nutrients, the less it is consumed, which contributes to better efficiency of use. Conversely, the less the feed ration is rich in essential nutrients, the more it is consumed up to the limit of the ingestion capacity, which does not offer the animals the possibility of fully expressing their potential for tissue synthesis. Such a mode of feeding has the consequence of delaying young animals in the process of developing their organic material by depriving them of precious resources. Several studies have shown that the level of coverage of nutritional

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needs, mainly in monogastric animal species, can improve or deteriorate the efficiency of feed conversion ([14]; [7]). Gidenne *et al.* [7] analyzed the effects of energy concentration on the feed efficiency of growing rabbits. These authors noted an improvement in feed efficiency with an energy concentration of the feed. This feed conversion, according to the same authors, tends to degrade linearly when the energy concentration of the feed drops. In reality, the rate of feed and nutritional conversion of animals describes a rather complex trajectory. It depends primarily on the mode of feeding which can be surplus (in the case of a highly enriched diet and made available at will), deficit (in the case of a qualitatively impoverished or quantitatively limited diet) or balanced (in the case of a diet allowing the animals to fully express their genetic potential, when sufficiently nourished). With regard to the mode of deficit feeding, also known as the practice of feed restriction, it offers two operating modes: qualitative feed restriction, where the animals are unable to meet their nutritional needs despite a large quantity of feed available to them, and the quantitative feed restriction also called undernourishment. Animals in the latter case are unable to adequately cover their feed needs, despite the nutritional balance of the ration. The practice of feed and nutritional restriction is increasingly used in conventional farming as a strategy to achieve health, zootechnical or zoo-economic productivity objectives. Thus, feed rations are formulated to control the health status and fattening level of animal species such as poultry ([21]) and pigs. With regard to pork, it was, according to [14], to limit feed intake to reduce carcass fatness. In poultry, the reduction of adiposity and the lowering of the feed conversion index can be obtained by protein-enriched feeds, according to the same authors. [8] Subjected post-weaned young rabbits to a 20–40% feed restriction in an effort to improve digestive health and improve feed efficiency. This feeding strategy made it possible, according to the authors, to significantly reduce the mortality and morbidity of the rabbits. Another consequence of feed restriction is the drop in carcass yield as shown by [23] on poultry and [24] on goats. Travel *et al.* [26] also reported a decrease in carcass yield at slaughter and overall carcass fatness in rabbits under feed restriction. In all cases, it appears that prolonged nutritional restriction or deprivation leads to the loss of tissue, first adipose, and then protein. The animal reacts by reducing energy losses linked to production, which translates into better nutritional efficiency, which can be measured by its carcass yield. However, such a reaction is likely to change if the feeding conditions become optimal again. The question we ask is whether *Archachatina marginata*, cold-blooded animal species, are able to fully replenish the decline in their carcass yield after a certain period of feed restriction.

2 Material and methods

2.1 Study environment

The study took place at the application farm of the University of Parakou located in the northern part of Benin. The town of Parakou, which houses the University of the Same Name, is located at 9°21′ North latitude, 2°36′ East longitude and at an average altitude of 350 m. The climate is of the humid tropical type (South Sudanese climate). It is characterized by the alternation of a rainy season (May to October) and a dry season (November to April). The average annual precipitation is 1200 mm.

2.2 Animal material and conduct of the test

The test was conducted on 90 giant African snails of the species *Achachatina marginata* weighing an average of 52.48 ± 9.03 g. The snails are randomly divided into three batches of 30 subjects in semi-buried enclosures made of cement and covered with fine mesh wire netting. Three diets in mealy form containing 20.26%, 17.18% and 14.43% crude protein and 2976 kcals, 2540 kcals and 2089 kcals of metabolizable energy per kg of dry matter were distributed ad libitum, all two weeks at the same time in batches I (control), II and III respectively. The pens are cleared of uneaten feed before a new service. Drinking water is made available ad libitum in siphoid drinkers with a capacity of 5 liters. At the end of each feeding phase, eight snails are randomly sampled from each batch and slaughtered after the live weights have been recorded. The slaughtering process consisted of subjecting the snails to a thermal shock by immersion for two minutes in water previously brought to a boil. The dissection was performed by manual extraction of all the soft part of the shell. Foot mass was separated from the gastrointestinal complex and weighed to determine hot carcass yield. Cold empty carcass weight was also recorded after 24 hours at 4°C to determine water loss.

2.3 Experimental design

The experimental design of the study is presented in table 1 below.

Table 1 Experimental device

Study criteria	Study phases						
	Adaptation	Restriction			Re-feeding		
		Lot1 (control)	Lot2	Lot3	Lot1 (control)	Lot2	Lot3
Trial duration (day)	10	70	70	70	70	70	70
Number of snails at the start of each phase	90	30	30	30	22	22	22
CP* (%)	20.26	20.26	17.18	14.43	20.26	20.26	20.26
ME* (kcal/ kg MS)	2976	2976	2540	2089	2976	2976	2976
Number of snails slaughtered at the end of each phase	--	8	8	8	8	8	8
Number of snails at the end of each phase	90	22	22	22	14	14	14

*CP: Crude protein; *ME: Metabolizable energy.

2.4 Data collected and statistical analysis

The snails are individually identified by a number written on the shell using a permanent marker. Feed consumption and weight gain were recorded every two weeks at the same time. Carcass yield was determined by considering the proportion of foot sole (essentially edible part) of the rest of the slaughter weight. Statistical analysis of the data collected was performed using SAS software version 9.2 (Statistical Analysis System, 9.2). The dependent variables taken into account in the analysis were: daily feed consumption, rate of weight gain and carcass characteristics. These variables were previously subjected to the normal distribution test, in order to ensure their compliance with an analysis of variance which was carried out using the Proc GLM (General Linear Model) procedure. The statistical model that was used for the analysis of variances was as follows:

$$Y_{ijk} = \mu + A_i + B_j + e_{ijk}$$

With:

Y_{ijk} = Observed value of the dependent variable studied Y;
μ = Overall mean of the dependent variable studied Y;
A_i = Fixed effect of feed consumption level (lot) (i = 1, 2, 3);
D_l = Fixed effect of the live weight of snails at the end of the adaptation phase;
e_{ijk} = variance residual.

3 Results

3.1 Consumption and feed efficiency of snails

The consumption and feed efficiency values for snails are recorded in Table 2 below.

Table 2 Consumption and feed efficiency of snails

Feeding phases	Mean feed intake (g DM/head/day)			Consumption index		
	Lot1 (control: 100%)	Lot2: (85%)	Lot3: (70%)	Lot1 (control: 100%)	Lot2: (100%)	Lot3: (100%)
Restriction	1.04^{a*} ± 0.12	1.09^{a} ± 0.13	1.13^{a} ± 0.14	58.28^{a} ± 15.41	103.30^{b} ± 32.07	129.30^{b} ± 30.86
Re-feeding	1.48^{a*} ± 0.07	1.49^{a} ± 0.07	1.49^{a} ± 0.07	56.24^{a} ± 7.89	36.32^{b} ± 3.28	35.28^{b} ± 3.21

* Values with the same superscript letters on the same line are not significant at the 5% level.

It appears from the table 2 that the snails ingested daily on average a little more than 1 g of dry matter of feed per head during the feed restriction phase. However, it appears that feed consumption during this period tends to be inversely proportional to the energy and protein concentration of the ration. To produce a live weight gain of 1 g, the snails ingested on average during the feed restriction period, 58.28 g, 103.3 g and 129.3 g of dry matter, respectively for lot I, II and III, with a significant difference ($p \leq 0.05$) between the control group on one side and the other two. Mean feed intake during the re-feeding phase increased in all batches of snails to about 1.5 g/head/day. The feed consumption index was significantly more favorable ($p \leq 0.05$) in the batches of snails previously subjected to a feeding restriction, with 56.24, 36.32 and 35.28, respectively for batches I, II and III.

3.2 Carcass characteristics

Figures 1 and 2 below successively show the outline of the carcass of *Archachatina marginata* stripped off its shell and snails feeding. We distinguish the particularly fleshy foot mass representing the edible part and the gastro-intestinal complex considered as the part of the carcass usually unsuitable for consumption.

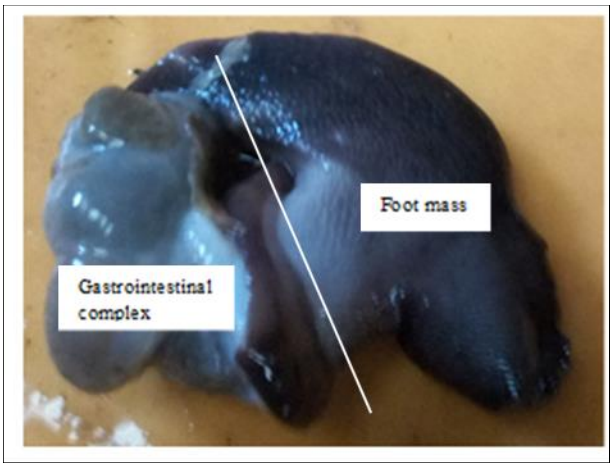

Figure 1 Carcass of Archachatina marginata stripped off its shell

Figure 2 Snails feeding

The results from the snail carcass analysis are shown in Figure 3 below. At the end of the feed restriction period, the average live weight at slaughter was found to be significantly different ($p \leq 0.05$) between the control batch on one side with 79.6 g and batches II and III with respectively 68.86 g and 66 g on the other side. The average weight of the empty shell was 12.37 g, 11.87 g and 9.87 g, representing a respective proportion of 15.54%, 17.24% and 14.95% of the live weight at the time of slaughter, respectively for batches I, II and III, with a significant difference ($p \leq 0.05$) between batches I (control) and II on the one hand and batch III on the other. The foot mass showed an average weight of 30.25 g, 21.12 g and 17.5 g respectively in batches I, II and III representing a proportion of 38%, 30.67% and 26.52% of live weight at slaughter with a significant difference ($p \leq 0.05$) between batches II and III on the one hand and control batch I on the other hand.

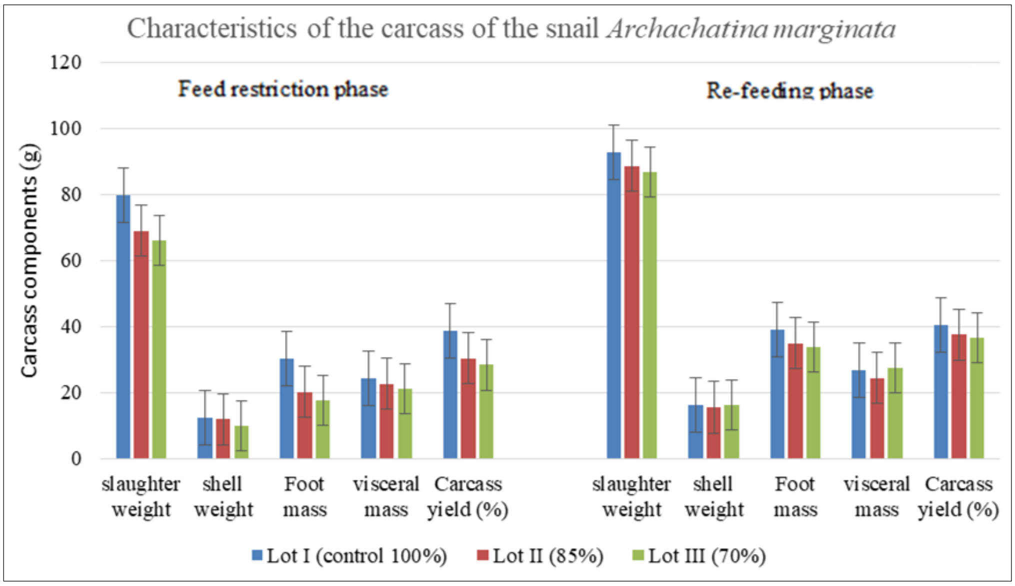

Figure 3 Carcass characteristics of re-fed *Archachatina marginata* after a period of feeding restriction

The carcass yield at the end of the feeding restriction period was 38.70%, 30.35% and 28.30% respectively for the snails of the control batch (without feed restriction), of batch II (15% restriction) and Lot III (30% restriction). A significant difference ($p \leq 0.05$) was recorded between control batch I on one side and batches II and III on the other.

At the end of the re-feeding period, where all the batches of snails had been fed at the same level as the control batch, the average weight at slaughter was 92.59 g, 88.5 g and 86.63 g respectively for control batches I, II and III with a significant difference ($p \leq 0.05$) between the control batch on one side and batches II and III on the other. Other carcass characteristics showed mean values of 16.12 g, 15.5 g and 16.25 g for shell weight, 39 g, 34.87 g and 33.62 g for foot mass and 26.62 g, 24.37 g and 27.37 g for visceral mass, respectively for batches I, II and III without any significant difference ($p \geq 0.05$) between batches. The average carcass yield was 40.44%, 37.48% and 36.55% respectively for batches I, II and III with a significant difference ($p \leq 0.05$) between batches I and III.

Figure 4 below illustrates the evolutionary dynamics of the carcass characteristics of *Archachatina marginata* at the end of the two feeding periods.

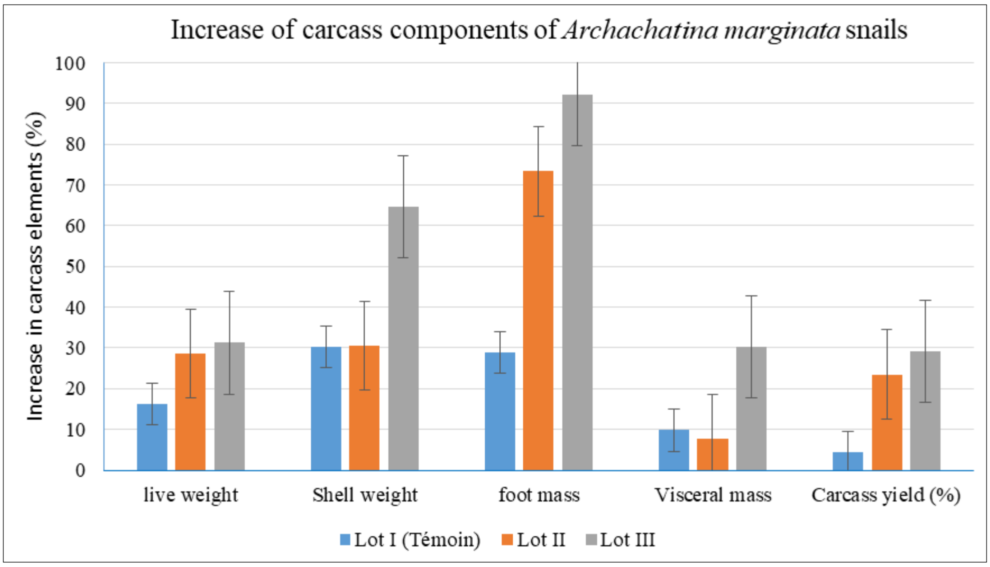

Figure 4 Evolutionary dynamics of the carcass of re-fed *Archachatina marginata* after a period of feed restriction

Figure 4 shows that the snails recorded an average increase in live weight of 16.32%, 28.52% and 31.27% respectively for control batches I, II and III between the end of the period of feed restriction and that of the re-feeding period. In the same order, the weight of the shell increased by 30.32%, 30.58% and 64.64%, that of the foot mass, 28.93%, 73.31% and 92.11%. , visceral mass recorded an increase rate of 9.77%, 7.74% and 30.33% and carcass yield increased by 4.5%, 23.49% and 29.15%.

4 Discussion

4.1 Consumption and feed efficiency of snails

Feed consumption of captive-bred *Archachatina marginata* snails tends to be inversely proportional to the energy and protein concentration of the diet. The less the feed intake was concentrated in metabolizable energy and digestible protein, the more the snails tried to consume. Such feeding behavior can be explained by the fact that the snails, constantly seeking to meet their nutritional needs, began to ingest as much feed and as long as their ingestion capacity allowed. A similar feeding behavior was observed by [2] on growing rabbits. The authors recorded a daily feed consumption of more than 10% between subjects fed a low-energy diet and controls. The nutritional value of the ration being the main determinant of tissue synthesis and growth, it is obvious that snails subjected to a qualitative feeding restriction record a delay in weight growth. This is exactly what observed [20] and [11]. The first on baby snails and the second on juvenile snails of the same species, *Archachatina marginata*, subjected to different feed rations. The batches of snails fed with complete compound feed recorded, in the trial conducted by these authors, a significantly greater weight gain than those fed with fruits, leaves and vegetables, which are clearly less rich in energy and proteins.

The tendency to a high consumption of dry matter associated with a significantly low weight gain, translates in the snails having received a poor ration, the feed inefficiency which is expressed in the present study, by a consumption index clearly on the rise. The feed consumption index of snails from the control group, without feed restriction, in the present study, is close to that obtained by [11] with snails of the same species fed with ripe papaya supplemented with sea shells in mealy form. However, these authors obtained markedly lower values with snails fed on a concentrated compound feed richer in crude protein and metabolizable energy. It is likely that the considerable difference observed between the two studies with the same species of snails fed with a compound feed concentrate is due to a difference in physiological stage. The snails used in the present study being more mature than those used by the aforementioned authors. In fact, it has been shown ([13]; [3]) that the younger the animals are and are properly fed, the faster the growth rate is, which translates into better feed efficiency.

The consumption index in the present study was considerably degraded with the qualitative feed restriction. An energy and protein restriction of around 15% caused a deterioration in the feed consumption index of more than 77%. When the restriction is increased to 30%, there is an aggravation of the degradation of the feed consumption index which goes beyond twice that of the control group. For their part, [9] observed a poor feed consumption index of more than 12% in growing pigs subjected to intermittent feed deprivation for 3 days per week over the entire study period. Similarly, a deterioration in the feed conversion ratio proportional to the intensity of feed restriction in broiler chicks has been documented by [4]. The authors recorded during the third and last week of the test, degradations of the order of 121%, 68% and nearly 7% for respective levels of feed restriction of 30%, 20% and 10%.

The lifting of the feed restriction was marked by an almost identical average daily consumption of dry matter between all the batches of snails. The increase in feed consumption between the two feeding phases was, however, less significant in the batches of snails previously subjected to feed restriction. The more severe the feed restriction, the less the average daily consumption of dry matter increased at the end of the re-feeding period. At the same time, the increase in live weight followed a trajectory inversely proportional to the intensity of feed restriction. The more severe the feed restriction, the greater the increase in live weight after the re-feeding period. Such a phenomenon known as compensatory growth has been sufficiently documented on different animal species ([15]; [10]; [12]; [23]; [25]) and finds its foundation in an efficient use of the feed ration. The values of the feed consumption index at the end of the re-feeding period clearly illustrate the superiority in the feed efficiency of the re-fed snails over the regularly fed controls. While the feed consumption index of the snails from the control batch, without feeding restriction, remained almost unchanged over the entire duration of the test, that of the re-fed snails experienced from single to triple, regardless of the intensity feeding restriction.

4.2 Characteristics of the carcass of snails

Just like the weight at slaughter, the carcass of snails and its various components were influenced by the energy and protein restriction of the ration. The more severe the restriction, the more the carcass and its various components, with the exception of the shell, decreased in weight at the end of the feeding restriction period. Of all the carcass components evaluated, the shell appears to have the lowest proportion, with less than 18%, of slaughter weight. In the trial conducted by [11] on *Archachatina marginata* juveniles weighing an average of 10 g, the shell showed a proportion between 20% and 30% depending on the type of ration given to the snails. It is not excluded that the weight of the shell in the snail can be strongly influenced by the calcium content of the ration. The relatively low shell weight recorded in the present study is certainly related to the moderate calcium content of the ration. Moreover, the iso calcic character of the different rations explains the almost similarity of the weight of the shell in all the batches of snails, independently of the level of feed. Kana *et al.* [11] obtained a significantly high shell proportion in snails fed a diet particularly rich in calcic substances.

The tissue synthesis of the different components of the snail carcass did not appear to be linearly proportional to the intensity of the energy and protein restriction of the ration. The effect of the first level of restriction of 15% was generally much more marked than that of the second level which brings the cumulative restriction to 30%. This is illustrated by a non-significant gap in the different components of the carcass between the snails of batches II and III fed respectively at 85% and 70% of the energy and protein level of those of the control batch. Presumably the energy and protein restriction increased to 30% proved to be more strategic because it made it possible to save 15% of these resources without significantly altering the performance of the snail carcass.

The reaction of the snails previously subjected to the energy and protein restriction of the ration was highly perceptible through the development of their carcass and its various components, after the feed standards had been restored. The re-fed snails considerably reduced the gap which kept them away from their congeners in the control group under strictly identical feeding conditions with the latter. Such an intensification of tissue synthesis reflects, in re-fed subjects, a capacity for efficient use of the feed ration. This is all the more visible as the rate of increase in the carcass and its various components between the two feeding phases was markedly higher in the re-fed subjects. This so-called compensatory growth phenomenon has been the subject of studies on different farmed animal species ([19]; [18]; [16]; [21]; [17]). The re-fed subjects have often shown in their great majority an accelerated growth, which allows them to partially or totally catch up the delay recorded during the previous phase of feeding restriction.

5 Conclusion

The strategy of a diet based on energy and protein restriction of the ration in giant African snails of the species *Archachatina marginata* bred in captivity has made it possible to significantly improve feed efficiency during subsequent re-feeding. The growth rate of the carcass and its components, which proved to be significantly higher in the re-fed snails, testifies to the intense activity of tissue synthesis induced by the phenomenon of compensatory growth. Despite such superiority of the re-fed snails over the controls in the development of the carcass and its components, the delay incurred during the previous phase of feeding restriction could not be fully compensated. However, it cannot be ruled out that an extension of the make-up time may lead to complete compensation. It has been proven that an energy and protein restriction threshold of the order of 30% is strategically more effective compared to that of 15%, because the compensation effort is greater.

Compliance with ethical standards

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Disclosure of conflict of interest

All the authors who contributed to the development of this manuscript declare that there is no conflict of interest between them.

Statement of ethical approval

This work was carried out on animals (giant African snails) whose use for human consumption and scientific research is not prohibited by the legislation in force.

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