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(Research Article)

Effect of dietary sodium chloride on growth, feed intake, and survival of the African giant snail *Archachatina marginata* in a farming system

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Abstract

This study aimed to evaluate the effect of different dietary sodium chloride (NaCl) levels on several zootechnical performance parameters of the African giant snail, *Archachatina marginata*. Sixty juvenile snails, with a mean initial live weight of 9.26±0.06 g, were divided into five groups receiving isoenergetic and isoprotein diets containing 0%, 0.2%, 0.5%, 1% and 1.1%\ NaCl. The experiment lasted eight weeks under controlled conditions. Measured parameters included feed intake, weight gain, shell growth (length and diameter), and mortality. The results showed that feed intake was significantly higher for the 0% and 0.2% NaCl diets. The highest weight gain (27.17±3.5 g) was observed with the salt-free diet, while the 1.1% NaCl diet resulted in the lowest growth (17.61±4.5 g). Shell growth followed the same trend. No mortality was recorded with the 0.2% NaCl diet, compared to 4 deaths with the salt-free diet and 2 deaths with the 0.5% and 1.1% diets. Moderate NaCl supplementation (0.2%) optimises survival and allows for satisfactory growth, whereas the absence or excess of salt are unfavourable. These results highlight the importance of ionic balance in snail diets to improve farming performance.

Keywords: Snail; Sodium chloride; Growth; Survival; Achatiniculture

1. Introduction

Côte d'Ivoire, a West African country, is known for its diversified economy, primarily based on agriculture. With a rapidly growing population and accelerated urbanisation, the demand for animal protein has increased considerably [1]. To meet this demand, Côte d'Ivoire has developed several types of farming, both conventional and emerging, to ensure the country's food security [2]. Conventional livestock farming, such as poultry, cattle, pigs, and small ruminants (sheep and goats), is essential for providing animal protein to the population. However, these farming systems often face challenges such as high animal feed costs, diseases, and environmental impacts [3]. Faced with these limitations, Côte d'Ivoire is exploring sustainable alternatives, such as farming edible insects, fish (aquaculture), rabbits, bees, and snails. These developing farming systems are considered promising solutions for diversifying protein sources and reducing pressure on natural resources [4]. Among these alternatives, farming African giant snails, such as *Achatina achatina* and *Archachatina marginata*, holds an important place in the diet of Ivorian populations [5]. However, the species *Archachatina marginata* stands out due to its unique characteristics and exceptional nutritional value [6]. Native to West Africa, *Archachatina marginata* is one of the largest species of land snails, reaching a size of 20 cm and a weight of around 500g **[7]**. This species is particularly appreciated for its tender and tasty flesh, rich in protein (up to 43.7% depending on the diets studied) and essential minerals [8]. The meat of *Archachatina marginata* is rich in protein while being low in fat and cholesterol, making it a healthy, nutritious food considered a delicacy in many regions of the country

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due to its high nutritional value [9]. However, the scarcity of wild snails due to overexploitation, destruction of natural habitats, and climate change has led to a decrease in their availability in local markets [10]. This situation has prompted agricultural stakeholders to consider snail farming in response to the growing demand for protein [11]. In snail farming, nutrition plays a crucial role in ensuring optimal growth and good health of the animals. Among the many nutrients necessary for their development, some, although less often mentioned, are nevertheless essential. This is the case for common salt (NaCl), an often overlooked but essential element in snail diets. Sodium and chloride, components of salt, are electrolytes essential for maintaining the water and electrolyte balance of snails. They also participate in the regulation of nervous and muscular functions [12]. Studies have shown that moderate salt supplementation in snail diets can improve their growth, reproduction rate, and disease resistance. However, excess salt can be harmful, leading to osmotic imbalances and increased mortality. In snail farms in Côte d'Ivoire, adding small quantities of common salt (NaCl) to the feed, for example in vegetables or compound feeds, could optimise zootechnical performance, such as growth, reproduction, and disease resistance, while contributing to the profitability of this activity [13].

The general objective of this study is therefore to determine the impact and importance of sodium chloride (NaCl) in the diet of African giant snails, by evaluating its effects on their growth, shell formation, and overall health. Specifically, it aims to :

- Evaluate the effect of different NaCl levels on feed intake and feed conversion ratio of *Archachatina marginata* ;
- Analyse the influence of dietary NaCl on live weight gain and shell growth (length and diameter).
- Determine the effect of NaCl concentration on the survival rate of snails during the rearing period.Identify the optimal NaCl level for rearing *Archachatina marginata* in terms of growth performance and survival.

2. Material and methods

2.1. Material

2.1.1. Study Site

The study was conducted on a snail farm located in the Toumodi department, 164 km north of Abidjan. The farm is situated 1.6 km from the village of Oussou and 36.6 km from Toumodi. The locality of Oussou is characterized by vegetation that transitions between the southern dense humid forest and the northern open savanna, providing a favorable environment for snail farming.

2.1.2. Biological Material

The biological material consisted of 60 juvenile African giant snails (*Archachatina marginata*) (Figure 1), of the same generation, purchased from the Adjamé market in Abidjan. The snails had an average initial live weight of 9.26±0.06 g and were approximately three months old. They were acclimatised for one week under the experimental conditions before the start of the trial.

Figure 1 *Archachatina marginata* (Swainson, 1821)

2.1.3. Feeds

Five isoenergetic and isoprotein experimental diets were formulated, differing only in their sodium chloride (NaCl) content (Table 1). The basic mash served as the basis for formulating these five diets, enriched with different levels of NaCl: 0% (R1, control), 0.2% (R2), 0.5% (R3), 1% (R4), and 1.1% (R5).

Table 1 Sodium Chloride Content Of Diets

Diet	**NaCl concentration**
R1 (Control)	**0%**
R2	**0.2%**
R3	**0.5%**
R4	**1%**
R5	**1.1%**

2.1.4. Rearing Equipment

The snails were reared in plastic boxes (60 cm x 40 cm x 35 cm), with perforated lids for ventilation, placed inside a shelter (Figure 2 and Figure 3). A Digital Kitchen Scale brand balance, with a sensitivity of 0.1 g and a capacity of 5 kg, was used to weigh the snails (Figure 4). To measure the length and diameter of the snail shells, an electronic calliper (Digital Cailer model) with an accuracy of 0.1 mm was used (Figure 5). Additionally, an improvised watering can was made from a 50 cl plastic bottle, the cap of which was perforated using a pointed tool. This homemade tool ensured adequate humidification of the rearing enclosures (Figure 6).

Figure 2 Rearing tank

Figure 3 Shed housing the breeding enclosures

Figure 4 Electronic scale of the Digital Kitchen Scale brand

Figure 5 Electronic caliper

Figure 6 Can used as a watering

2.2. Methods

2.2.1. Design and experimental plan

The bottom of the boxes was lined with a substrate based on potting soil previously heated to eliminate insect eggs, insects, and bacteria that could attack the snails. The substrate was covered with disinfected cocoa leaves by immersion in boiling water, to guarantee the snails a healthy environment.

The formulation of the experimental diets was based on a mixture of cereal flours (ground maize, wheat bran), proteinaceous plants (soybean meal), minerals (calcium bicarbonate, dicalcium phosphate), and a vitamin supplement (meat premix). The basic mash (Figure 7) was used to formulate five diets, enriched with different levels of NaCl (Table 1).

A ration of 10 g of feed was distributed per box (containing 10 snails) for a period of three days. After this period, the leftover feed was collected and weighed to determine the quantity consumed.

The substrate moisture was maintained by watering twice a day (morning and evening).

To evaluate the growth of snails under the different diets, weekly measurements were taken, including weight as well as shell length and diameter. During the experiment, each case of mortality was systematically recorded. To maintain the initial stocking density, dead snails were replaced by reserve individuals. These replacement subjects were marked for identification and were not included in the evaluation of growth parameters.

Figure 7 Basic mash

2.2.2. Expression of Results

At the end of the experiment, the data collected (weight and dimensions) were used to evaluate, for each diet, the following zootechnical parameters:

Live weight gain (ΔP, g) : $\Delta P = Flw - Ilw$;

Length gain (ΔL, mm) : $\Delta L = Fsl - Isl$;

Diameter gain (ΔD, mm) : $\Delta D = Fsd - Isd$;

Feed intake (FI, g/day/snail) : $FI = (DF - RF) / (Nbre \times \Delta t)$;

Feed conversion ratio (FCR) : $FCR = TQFI / \Delta P$;

Average daily gain (ADG, g/day) : $ADG = (Fw - Iw) / \Delta t$;

Where:
- Flw/Ilw : Final/initial live weight (g)
- Fsl/Isl : Final/initial shell length (mm)
- Fsd/Isd: Final/initial shell diameter (mm)
- Δt : Total rearing duration (days)
- TQFI : Total quantity of feed ingested (g)
- Nbre : Number of snails per batch
- Wfd/Rf : Weight of feed distributed/refused feed

2.2.3. Statistical Analysis

The data were processed using STATISTICA software (version 7.1). An analysis of variance (ANOVA) followed by a post-hoc Tukey (HSD) test at a significance level of 5% was applied to compare, between the diets, body weight gains; shell length and diameter growth, quantities of feed ingested, and feed conversion ratios. Furthermore, mortality rates were analysed using a non-parametric statistical test (Fisher's Test at $P < 0.05$).

3. Results

3.1. Effect of Sodium Chloride on Snail Feed Intake

Table 2 presents the feed intake and feed conversion ratio values of the snails according to the sodium chloride content of their diet. The daily quantity of feed consumed per snail depending on the sodium chloride level in the mash varied between 0.68 ± 0.03 g/day (R5) and 0.89 ± 0.05g/day (R2). Analysis of the results shows a progressive decrease in intake from diet R1 (0.85 ± 0.040) to diet R5 (0.68 ± 0.03), suggesting a negative effect of increased NaCl on the appetite of the snails. The lowest feed conversion ratios were recorded with the with diets R1 (0.88 ± 0.02) and R2 (1.08 ± 0.06), and the highest (1.05 ± 0.04, 1.08 ± 0.05) with diets R3, R4, and R5. The feed intake index recorded with diet R1 is lower than that observed with diet R2. Analysis of the results indicates a decrease in the feed intake index with the increase in NaCl content of the feed.

Table 2 Intake and food consumption index of snails according to the NaCl content of their diet

Diet	Food intake (g/day)	Consumption index
R1	0.85 ± 0.04[b]	0.88 ± 0.02[b]
R2	0.89 ± 0.05[a]	0.98 ± 0.03[b]
R3	0.76 ± 0.03[c]	1.08 ± 0.05[a]
R4	0.71 ± 0.05[d]	1.05 ± 0.04[a]
R5	0.68 ± 0.03[e]	1.08 ± 0.06[a]

The values in the same column indexed with the same letters are not statistically different according to Tukey's HSD test at P < 0.05.

3.2. Growth Performance of Snails According to the NaCl Content of the Feed

3.2.1. Weight Growth

Table 3 presents the weight growth performance of the snails according to the NaCl level in their feed. The snails, with statistically identical initial live weights varying between 9.24±0.08 g and 9.27±0.05g, presented final weights after 2 months of rearing ranging between 26.89±6.11 and 36.4±2.7g, which were statistically different. Indeed, the analysis of the results shows that the weight growth of the snails decreases significantly when the NaCl content in their ration is increased. The snails fed with diet R1 (0% salt) acquired an average live weight of 36.4±2.7g at the end of rearing period with a total weight gain of 27.17±3.5g, compared to 17.61±4.5g for those on diet R5 (1.1% salt) which acquired a final live weight of 26.89±6.11g. The difference between the two diets is statistically significant, indicating that NaCl negatively impacts the weight growth of snails (excess NaCl hinders body growth).

Table 3 Weight gain of snails according to the salt content of the diet

Diet	Initial live weight (g)	Final live weight (g)	Total weight gain (g)
R1	9.23 ± 0.04[a]	36.4 ±2.7[a]	27.17 ± 3.5[a]
R2	9.27 ± 0.03[a]	34.63 ± 1.21[b]	25.36 ± 5.1[b]
R3	9.24 ± 0.08[a]	29 ± 4.18[c]	19.76 ±4.55[c]
R4	9.27 ±0.05 [a]	28.28±7.83[d]	19.01 ± 5.12[d]
R5	9.28± 0.06[a]	26.89± 6.11[e]	17.61 ± 4.5[e]

The values in the same column indexed with the same letters are not statistically different according to Tukey's HSD test at P < 0.05.

3.2.2. Shell Growth

Table 4 presents the shell growth performance of the snails according to the sodium chloride content of their diet. The results in this table indicate a variation in the final shell length of the snails with the increase in NaCl level in their feed. Indeed, the shell length gain decreased from 23.78±4.5 mm (R1) to 12.66±3.5 mm (R5). This decrease in shell length gain is statistically very significant. The increase of NaCl in the feed thus hinders the shell growth of the snail, which can affect its overall physiology or limit its growth.

Table 4 Shell growth performance of snails according to the salt content in their feed

Diet	Initial shell length (mm)	Final shell length (mm)	Total shell length gain (mm))
R1	35.46 ± 0.79[a]	59.24 ± 2.78[a]	23.78±4.5[a]
R2	35.38 ± 0.19[a]	54.65 ± 1.38[b]	19.27 ± 4.5[b]
R3	35.45± 0.48[a]	50.67 ± 3.14[c]	15.22 ± 3.7[C]
R4	35.33 ± 0.82[a]	49.25 ± 6.51[d]	13.92 ± 3.3[d]
R5	35.42 ± 0.5[a]	48.08 ± 4.34[e]	12.66 ± 3.5[e]

The values in the same column indexed with the same letters are not statistically different according to Tukey's HSD test at P < 0.05.

Figure 8 illustrates the evolution of shell length of snails according to the NaCl content of their diet. Diet R1 showed continuous and superior growth compared to the other diets throughout the 8 weeks of the experiment. Diet R2 showed performance comparable to R1 until the 4th week, before recording a gradual slowdown. Diet R3 was characterised by more moderate growth, being temporarily overtaken by R5 in week 3, then regaining its position in week 6. Finally, diet R4 gave the least favourable results, with a marked decrease in growth between weeks 7 and 8.

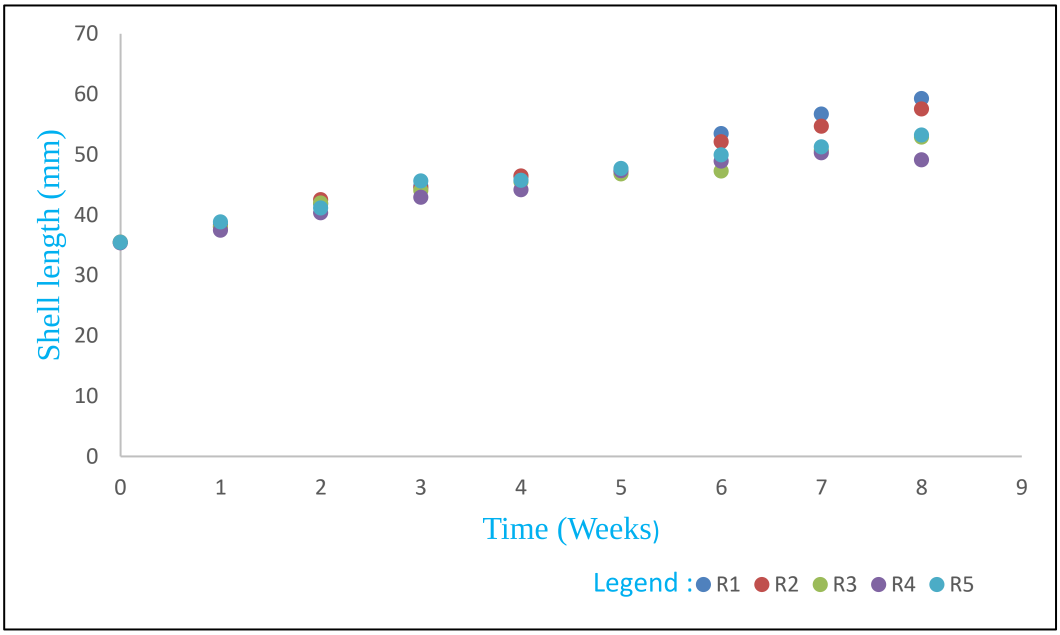

Figure 8 Evolution of snail shell length according to the NaCl content in the feed

Analysis of the data in Table 5 indicates, as in the case of shell length growth, an influence of the dietary NaCl level on the shell diameter growth of the snails. The shell diameter gain experienced a progressive decrease from 12.52 ±1.02 (R1) to 9.14±4.33 (R5). The high level of NaCl also acted negatively on the shell growth of the snails.

Table 5 Shell diameter growth of snails according to the salt content of their diet

Diet	Initial shell diameter (mm)	Initial shell diameter (mm)	Total gain in shell diameter (mm)
R1	18.28 ± 0.39[a]	30.80 ± 0.54[a]	12.52 ± 1.02[a]
R2	18.23 ± 0.26[a]	29.36 ± 0.56[b]	11.13 ± 3.1[b]
R3	18.25 ± 0.33[a]	27.97 ± 0.61[c]	9.72 ± 4.02[c]
R4	18.24 ± 0.35[a]	27.68 ± 0.59[cd]	9.44 ± 4.11[c]
R5	18.25 ±0.40[a]	27.39 ± 0.60[d]	9.14 ± 4.33[ec]

The values in the same column indexed with the same letters are not statistically different according to Tukey's HSD test at P < 0.05.

Snails fed diet R1 show exponential growth in shell diameter up to the 6th week, followed by a notable slowdown thereafter (Figure 9). From the first week, their growth is significantly distinct from that of the other groups. With diet R2, growth remains regular, but its magnitude is less compared to R1. Diets R3 and R4 lead to very similar evolutions, although R4 takes a slight advantage from the 5th week. Finally, diet R5 is characterised by the weakest growth throughout the rearing period.

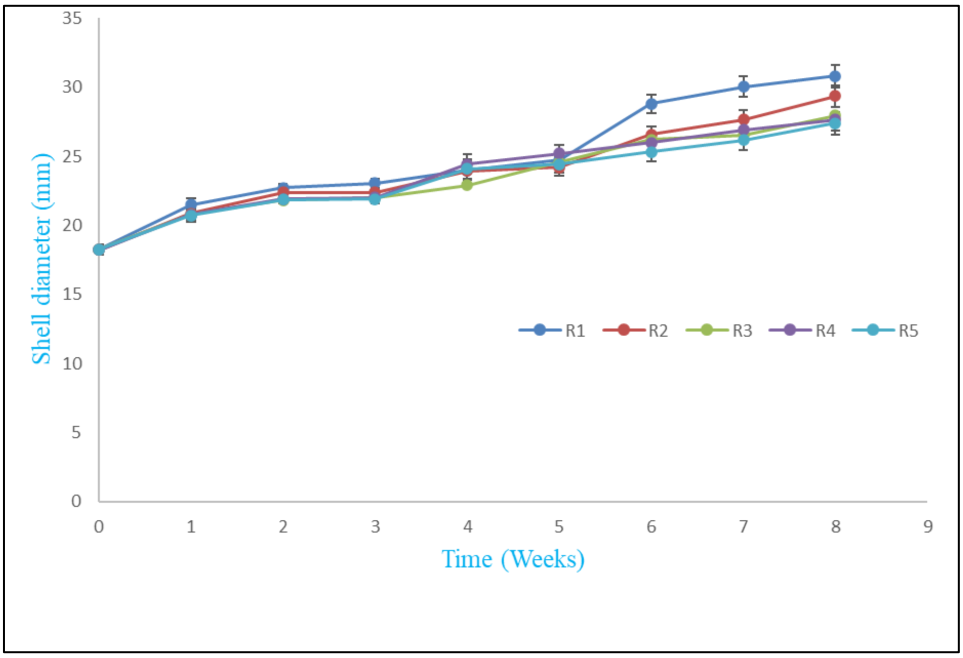

Figure 9 Evolution of snail shell diameter according to the NaCl content of the feed

3.3. Effect of the NaCl Content of the Feed on Snail Survival

Throughout the entire experiment, diet R2 (0.2% salt) resulted in no mortality in the snails, while the highest mortality (4 deaths) was observed with diet R1 (0% salt). Diets R3 (0.5% salt), R4 (1% salt), and R5 (1.1% salt) each recorded two (2) cases of mortality (Table 6).

Table 6 Effect of salt content on snail mortality

Diet	Number of deaths
R1 (0 % salt)	4
R2 (0.2 % salt)	0
R3 (0.5 % salt)	2
R4 (1 % salt)	2
R5 (1.1 % salt)	2

4. Discussion

The data analysis showed that the snails consumed more of diets R1 (0% salt) and R2 (0.2% salt) than diets R3 (0.5%), R4 (1%), and R5 (1.1%). Furthermore, there is no significant difference between the feed conversion ratio observed in R1 and R2, and that observed with diets R3, R4, R5. Although diet R2 (0.2% salt) had the highest intake, its conversion ratio is worse than that of diet R1 (0% salt). Because a high conversion ratio indicates poorer feed utilization. It is likely that excess salt alters the palatability of the feed (an increase in the salt level in the feed causes a decrease in appetite), thereby reducing their willingness to feed. This could be due to physiological stress, a digestive or metabolic disorder. Our results are in agreement with those of the National Research Council [14] which states in its nutritional recommendations for animals that high levels of sodium can lead to a reduction in feed intake, especially in sensitive young animals. As well as [15] who, having studied fish, showed that an excess of salt in the ration causes a drop in feed intake.

The statistical analyses also revealed better growth performance with diet R1. The results show that weight growth, shell length gain, and shell diameter gain of the snails decrease significantly when the salt content is increased. Indeed, snails fed diet R1 (0% salt) achieved an average weight gain of 27.17±3.5 g, compared to 17.61±4.5 g for those on diet R5 (1.1% salt), a shell length gain decreasing from 23.78±4.5 mm (R1) to 12.66±3.5 mm (R5), and a diameter gain progressively falling from 12.52±1.02 mm (R1) to 9.14±4.33 mm (R5). All the results (weight, length, and diameter) allow us to state that the increase in salt content in snail feed exerts a negative effect on their overall growth. This means that salt, beyond a certain threshold, constitutes a limiting factor for snail growth. These results corroborate those of [16] who state that salt, at a high dose, significantly reduces weight gain and shell development. Furthermore, [17] similarly reports that snails are sensitive to excessive salinity, which affects their feeding activity, growth, and survival. The same observation was made by [18], in a study on snails that growth performance decreases beyond a certain threshold of minerals, including salt, due to an alteration of water balance.

The data relating to mortality show that the salt content of the ration influences the survival of the snails. The absence of mortality observed with diet R2 (0.2% salt) suggests that this concentration represents the optimal tolerance threshold for the species *Archachatina marginata*. Conversely, diet R1, the control feed with 0% salt, presents the highest mortality (4 deaths), which could be due to an ionic imbalance or a sodium deficiency.

Diets R3 (0.5% salt), R4 (1% salt), and R5 (1.1% salt) containing 0.5%, 1\%, and 1.1\% salt respectively, each record two (2) deaths. This consistency could indicate a form of moderate stress induced by salt overload, without however causing massive mortality.

5. Conclusion

The diets without Sodium Chloride (R1) and with low NaCl content (R2: 0.2%) were better ingested by the snails than the more concentrated diets (R3 to R5: 0.5–1.1%). Excess NaCl reduced the appetite of the snails, probably by altering the palatability of the feed or inducing physiological stress. Diet R1 (0% salt) allowed the highest weight gain (27.17 g), while R5 (1.1% salt) showed the weakest growth (17.61 g). Gains in shell length and diameter also decreased with the increase in NaCl level, confirming the inhibitory effect of excess salt on overall development. Diet R2 (0.2% salt) recorded zero mortality, unlike the control diet R1 (4 deaths) and the saltier diets (2 deaths each), suggesting that moderate NaCl supplementation could improve the resistance of snails. A salt content of 0.2% (R2) seems ideal for reconciling growth, health, and survival, while diets without NaCl or too rich in NaCl prove to be counter-productive.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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