Effect of the substitution of fish meal and oyster shell with cockroach meal and hen eggshell on the performance of giant African snails (Swainson, 1821)

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Abstract

The present study aimed to evaluate the effect of substituting fish meal and oyster shell with cockroach meal and hen eggshell on the performance of snails (*Archachatina marginata*). From the control group that received Ration 1 (fish meal: 5%; oyster shell: 10%), the experimental groups each received rations simultaneously substituting these two resources with cockroach meal and hen eggshell at 2.5% and 5% (Ration 2), 5% and 10% (Ration 3). The results revealed that live weights, average daily gains, linear growth in shell, individual feed consumption and feed conversion ratio did not show any significant difference ($p>0.05$) between the groups. The conversion index was lower in snails from batch 2 (1.4 ± 0.3). The diametrical growths were higher in snails from batch 3 ($p<0.05$). The mortality rates were higher in snails from batch 3 (6.7%; $p<0.05$). The results of this study show that these substitutions constitute an alternative to induce similar performances and without consequence in the feeding of *Archachatina marginata*.

Keywords: fish meal; oyster shell; snails; Benin

Introduction

In Africa, snail production units have little visibility compared to those of other species despite strong foreign and local demand. Yet, this activity has the potential to contribute to improving incomes for many families in Africa while providing viable sources of essential food nutrients for other species (Oketoobo et al., 2021; Mvodo Meyo et al., 2021). In West Africa in particular, snails live mainly in humid forest areas, from where they are collected by villagers for consumption and other uses and livestock farms for these animals are not widespread unlike those of other species such as ruminants and poultry (Oladejo et al., 2019; Aminu et al., 2020; Okwuokenye et al., 2022). Faced with rapid population growth and changing eating habits, the consumption of snail meat has progressively become more important. Thus, a certain segment of the population for whom the flesh of this animal was taboo, has crossed the wall of preconceived and scientifically unfounded ideas, to join the large camp of regular consumers. Considering also the shortage of conventional concentrated feed supplies that significantly and continuously affects animal production in the tropics, large-scale snail farming is necessary to meet the animal protein needs of human nutrition (Inemotimineri et al., 2023; Omolara, 2015).

In Benin, the current situation is such that collecting snails in the rainy season is no longer sufficient to satisfy customers. If in the past, it was easy to obtain snails in the rainy seasons in this country, today, the trend is clearly reversed. In fact, under social pressure, wild stocks are threatened by the collection which has become more intense in recent years. In addition, in the dry season, due to environmental destruction, deforestation and bush fires, which continually reduce wild snail populations to the bare minimum, testify to the extent of various forms of threats that hang over the different species of snails found in this country (Ogbolo et al., 2019). Thus, to meet the ever-increasing consumer demand in Benin, it is urgent to promote snail farming and at the same time conduct scientific trials to promote best feeding and breeding practices. Morever, in recent years, the emergence of some scientific work in Africa aimed at addressing the challenge in the snail farming sector (Bouye et al., 2017; Etim and Agida, 2021; Ogbolo et al., 2019) can be considered a glimmer of hope. Improved breeding in a controlled environment may therefore prove to be an alternative for the repopulation of this critically endangered species and the improvement of animal protein availability in Benin (Ogbolo et al., 2019; Toukourou et al., 2022). Large-scale snail production, as a response to better availability and accessibility thus remains a challenge to sustainably preserve a natural resource subject to a double constraint, environmental and anthropogenic; and in this perspective, it seems appropriate to consider food alternatives to reduce dependence on imported or expensive feed resources in the formulation of rations by those locally available or very little used due to lack of knowledge or information by producers. On this, the present study proposes to analyze the impact of a substitution of fish meal (expensive cost) and oyster shell (mainly purchased in feed shop in Benin) respectively by cockroach meal and chicken eggshell on the weight growth performance and shell development of giant African snails of the species *Archachatina marginata* subjected to captive farming conditions.

Materials and methods

Study environment

The experiment was conducted at the application farm of the Faculty of Agronomy of the University of Parakou, located in the town of Parakou. The regional capital of Northern Benin, Parakou is located in the center of the Republic of Benin, 407 km from Cotonou. The town of Parakou is located at 9° 21' North latitude, 2°36' East longitude at an average altitude of 350 m and has a fairly modest relief. The climate is tropical humid (South Sudanese climate) characterized by the alternation of a rainy season (May to October) and a dry season (November to April) with an average annual precipitation around 1200 mm. The building housing the Snail Breeding Unit (Figure 1) of the said farm consists of 9 cubic-shaped concrete block snail farms (1m x 1m x 1m) with fine mesh wire mesh covers. The bottom of each snail farm is entirely cemented and backfilled with a depth of 5 cm of sand containing organic matter to prevent the intrusion of pests and at the same time allow greater water retention for greater comfort for the snails.

Experimental device

Process of obtaining cockroach meal

The cockroach meal used in this study was produced in the production unit. Adult cockroaches of the species *Periplaneta americana* (Linnaeus) were collected from the natural environment mainly in latrines and used to inoculate the production medium prepared for this purpose. They were then placed in plastic trays (1.5m x 1m x 1.8m) for reproduction at a density of 50 adult cockroaches per m^2. The trays were previously perforated in several places and then wood shavings and egg cells (superimposed) (Fig 2 A) were placed there before being covered with mosquito netting. The cockroaches were fed with kitchen scraps, parts of cereals, fruits and vegetables destined for the garbage. Water was also placed in a sufficient quantity in a drinking trough. The cockroaches benefited from the natural photoperiod with an average temperature of 30°C in the production environment. After 6 months of production, a large population of cockroaches was obtained, killed by soaking in hot water. The cockroaches were then dried, roasted (Fig 2 B) then ground and dried (Fig 2 C) before being packaged for laboratory analysis. The rations were served in plastic dishes that had been used as feeders (Fig 2 D).

Figure 1: Intern view of the Snail Breeding Unit

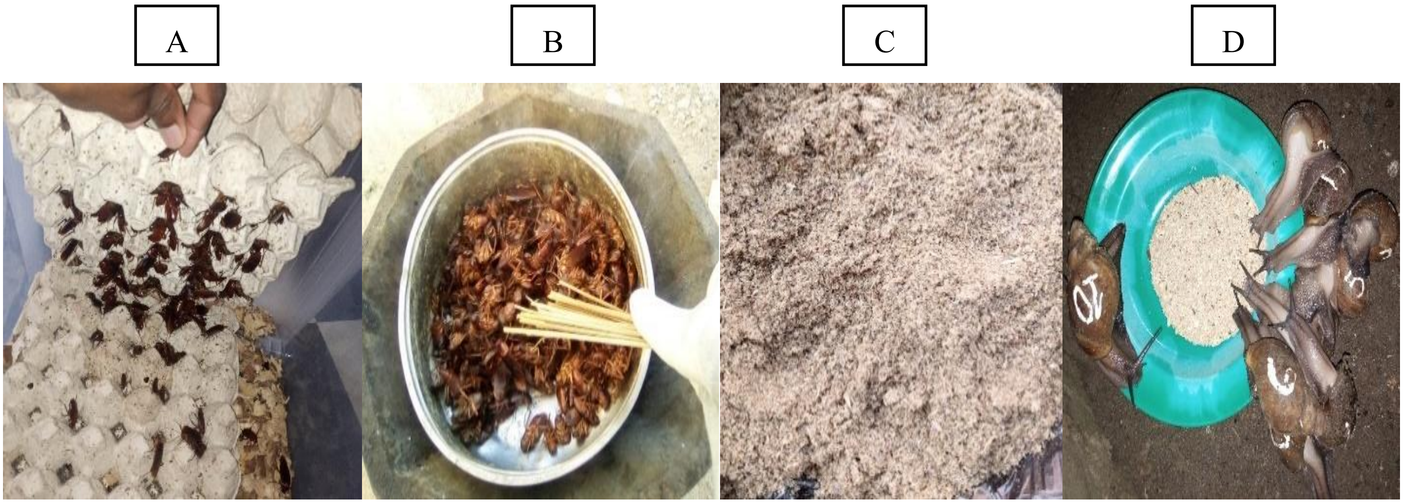

Figure 2: Stages of production and inclusion of cockroach flour in the snail diet

Composition of rations

Bromatological analyses of the three rations were carried out at the Food Sciences Laboratory (LaSA) of the University of Abomey-Calavi (UAC). The chemical composition of the rations and the quantity of nitrogenous matter contained in the excrement were obtained according to the official methods approved by the AOAC (AOAC, 2005). The percentage composition of the 3 rations as well as their nutritional values are presented in Table 1.

The biological material consisted of 90 giant African snails of the species *Archachatina marginata*, weighing on average 50 ± 0.8 g (at the start of the trial), of the same age and from the Production Unit. The snails selected were those with a well-formed shell (without breakage) and free of trauma. The snails were individually tagged (numbered on the shell) to facilitate both their identification and data collection. They were then randomly divided into 3 batches of 10 individuals with 3 replications following each diet. Batch 1 (control batch) received a ration containing 0% cockroach flour and 0% eggshell. Batch 2 received a ration that substituted fish meal with cockroach flour (2.5%) and oyster shell with chicken egg flour (5%). The snails in Batch 3 received a ration that substituted cockroach meal (5%) for fish meal and oyster shell meal for chicken egg meal (10%). The feed was weighed before being served to the snails at 2-day intervals. Feed refusals were regularly weighed and the feeders were thoroughly washed before being reused. The average quantity of feed served each time was 30g. The rearing substrates were also watered at 2-day intervals with tap water at a rate of 0.5 liters/substrate/watering, to ensure good humidity in the pens. In addition, the substrates were regularly cleaned of food refusals, snails that died during the test and feces to prevent the development of possible pathogens.

Final live weights were determined using a sensitive digital scale. Average daily gains were determined by dividing the weight gain (difference between the final live weight and the initial live weight) by the corresponding time. Average daily shell diameter gain was determined by dividing the shell diameter gain (difference between the final diameter and the initial diameter) by the corresponding time. Linear shell growth was determined by dividing the shell linear gain (difference between the final length and the initial length) by the corresponding time. Feed intake was determined by subtracting leftover feed from the amount of feed distributed. Feed conversion was determined by the ratio between the average amount of feed consumed during a period and the weight gain during the corresponding period. Mortality rates were determined by the ratio (in percentage) of the number of dead snails to the total number of snails.

Statistical analysis

The collected data were entered using Excel 2013 spreadsheet and then imported into R 4.3.1 software (R Core Team, 2023) for statistical analyses. The mean values of the different variables (live weight, average daily gain, linear growth of the shell, diametrical growth of the shell) of the snails of the three batches were subjected to an ANOVA analysis of variance at the 5% threshold. The means were compared by the Tukey test when the ANOVA indicated significance ($p<0.05$). The values are presented as mean ± Standard error (Mean ± SE).

Result

Live weight and average daily gains of snails

The weights and ADG of the snails were recorded following their evolution during the 12 weeks of the experiment (Table 2). The results showed that the weights recorded in the snails at the level of the three rations did not present any significant difference from the first to the sixth week ($p>0.05$). On the other hand, the weights recorded at the 7th week revealed a superiority of ration 3 (71.9 ± 2.3g) and lower weights recorded in the level of the snails having received Ration 1 (62.2 ± 2.0) ($p<0.05$). However, from the 8th to the end of the experiment, the weights of the snails did not present any significant difference between the three batches ($p>0.05$).

The ADG of the snails of the 3 batches also did not show any significant difference between the 3 batches at the end of the second week of the experiment ($p>0.05$). Between the end of the 3rd week and that of the 5th week, the lowest ADG were recorded for the snails of batch 1 ($p<0.05$). Furthermore, the weights were significantly different between the three batches of snails from the 7th to the 11th week of the experiment ($p<0.05$) with lower ADG for the 8th, 9th and 11th weeks in the snails that received Ration 3. The ADG recorded during the last week of the experiment as well as for the entire duration of the experiment (1st week to the 12th week did not show any significant difference between the snails of the 3 batches ($p>0.05$).

Table 1: Composition of the different rations

Feed ingredients	Composition (%)		
	Ration 1	**Ration 2**	**Ration 3**
Corn	35	36	35
Fish meal	5	2.5	0
Cockroach flour	0	2.5	5
Roasted soybeans	18	20.6	23
Palm kernel cake	15	15	14
Wheat bran	10.6	9	9
Rice bran	5	3	2.6
Lysine	0.25	0.25	0.25
Methionine	0.15	0.15	0.15
Oyster shell	10	5	0
Chicken eggshell	0	5	10
Vitamin-mineral concentrate	1	1	1
Total	100%	100%	100%
	Chemical composition		
Metabolizable energy (Kcal/kg DM)	2707.3	2720.5	2705.5
Crude protein (% DM)	16.9	17.0	17.1
Calcium (g/kg DM)	45.3	43.4	41.5
Phosphorus (g/kg DM)	7.9	7.2	6.7
	Price per kg		
	309,38 FCFA ~ 0.6$	326,75 FCFA ~ 0.6$	338 FCFA ~ 0.6$

Diametrical growth and linear growth of snails

The performance recorded on the snails on the diametrical growth of the shell and the linear growth of the shell are presented in Table 2. The results showed that the substitutions had no effect on the linear growth of the shell of *Archachatina marginata* among the 3 batches during the entire experimental period (p>0.05). Furthermore, the type of ration had a significant effect on the diametrical growth of the shell of the snails (p<0.05). The lowest values of diametrical growth were recorded on the snails that received Ration 1 throughout the experimental phase. The snails of batches 2 and 3 presented higher diametrical growth from the 1st to the 4th week.

Consumption index and mortality of snails

Individual feed consumption, feed conversion ratio, and mortality recorded in each of the three batches are presented in Table 4. The results showed that individual feed consumption was lower in animals fed the R1 ration. The quantities of feed consumed by snails in batches 2 and 3 were not statistically different (p>0.05) (Table 3). However, feed conversion ratio was lower in snails in batch 2. Snails fed with R1 and R2 rations had similar mortality rates (3.3%; p>0.05) and lower mortality rates compared to those fed with R3 ration (p<0.05).

Table 2: Live weights and average daily gains of experimental snails

Weeks	Weight (g; Mean ± SE)				ADG (g; Mean ± SE)			
	Batch 1	Batch 2	Batch 3	Sig	Batch 1	Batch 2	Batch 3	Sig
1	50.0 ± 1.5	50.07 ± 1.5	50.1 ± 1.3	NS	-	-	-	-
2	53.1 ± 1.5	50.7 ± 1.1	55.0 ± 1.5	NS	0.4 ± 0.2	0.1 ± 0.07	0.7 ± 0.2	NS
3	54.9 ± 1.4	55.2 ± 1.6	58.5 ± 1.7	NS	0.3 ± 0.2a	0.6 ± 0.2c	0.5 ± 0.1b	*
4	57.9 ± 1.4	60.8 ± 1.6	62.4 ± 1.8	NS	0.4 ± 0.1a	0.8 ± 0.1c	0.6 ± 0.1b	*
5	60.4 ± 1.7	64.0 ± 1.9	66.2 ± 1.9	NS	0.4 ± 0.1a	0.5 ± 0.1b	0.5 ± 0.2c	*
6	64.3 ± 1.9	68.4 ± 1.8	70.3 ± 2.1	NS	0.6 ± 0.1	0.6 ± 0.1	0.6 ± 0.1	NS
7	62.2 ± 2.0a	67.0 ± 1.9ab	71.9 ± 2.3b	*	-0.3 ± 0.1a	-0.2 ± 0.1a	0.2 ± 0.1b	*
8	67.7 ± 2.1	72.4 ± 1.9	73.3 ± 2.2	NS	0.8 ± 0.1a	0.8 ± 0.1a	0.2 ± 0.1b	*
9	73.7 ± 2.0	78.0 ± 1.9	76.0 ± 2.1	NS	0.9 ± 0.2a	0.8 ± 0.1ab	0.4 ± 0.1b	*
10	78.8 ± 2.0	79.8 ± 1.8	81.1 ± 2.5	NS	0.7 ± 0.1a	0.3 ± 0.1b	0.7 ± 0.1a	*
11	84.6 ± 2.1	81.5 ± 2.1	83.5 ± 2.3	NS	0.8 ± 0.2a	0.2 ± 0.1b	0.3 ± 0.1b	*
12	85.7 ± 2.1	82.8 ± 2.1	84.3 ± 2.3	NS	0.2 ± 0.1a	0.2 ± 0.1a	0.2 ± 0.1a	NS
1-12	-	-	-	NS	0.4 ± 0.0	0.4 ± 0.0	0.4 ± 0.0	NS

.**Table 3**: Linear and diametric growth of snails

Week	Linear growth (mm; Mean ± SE)				Diametric growth (mm; Mean ± SE)			
	Batch 1	Batch 2	Batch 3	Sig	Batch 1	Batch 2	Batch 3	Sig
1	69.4 ± 0.6	69.4 ± 0.8	70.8 ± 0.8	NS	39.9 ± 0.3a	41.0 ± 0.3b	40.2 ± 0.3ab	*
2	72.6 ± 0.6	72.7 ± 0.8	73.8 ± 0.8	NS	40.5 ± 0.3a	41.9 ± 0.3b	41.0 ± 0.3ab	*
3	73.9 ± 0.6	74.6 ± 0.9	75.7 ± 0.8	NS	41.3 ± 0.3a	42.4 ± 0.3b	42.0 ± 0.3ab	*
4	75.1 ± 0.6	75.7 ± 0.9	78.3 ± 0.9	NS	41.6 ± 0.3a	42.9 ± 0.3b	42.7 ± 0.3ab	*
5	76.1 ± 0.7	77.0 ± 0.9	78.3 ± 0.9	NS	42.5 ± 0.3a	43.2 ± 0.3ab	43.6 ± 0.3b	*
6	77.1 ± 0.7	78.1 ± 0.9	79.2 ± 0.9	NS	42.6 ± 0.3a	43.5 ± 0.23ab	44.0 ± 0.4b	*
7	78.1 ± 0.7	79.1 ± 0.9	80.0 ± 0.9	NS	43.0 ± 0.3a	44.0 ± 0.3ab	44.4 ± 0.4b	*
8	79.2 ± 0.7	80.0 ± 0.9	81.0 ± 0.9	NS	43.5 ± 0.3a	44.6 ± 0.3b	44.9 ± 0.3b	*
9	79.9 ± 0.7	80.7 ± 0.9	81.6 ± 0.9	NS	43.9 ± 0.3a	45.0 ± 0.3ab	45.3 ± 0.4b	*
10	80.8 ± 0.7	81.2 ± 0.9	82.4 ± 0.9	NS	44.1 ± 0.3a	45.4 ± 0.3b	45.6 ± 0.3b	*
11	81.8 ± 0.7	82.0 ± 0.9	83.2 ± 1.0	NS	44.6 ± 0.3a	45.7 ± 0.3b	45.8 ± 0.3b	*
12	82.3 ± 0.6	83.0 ± 0.7	84.0 ± 0.9	NS	45.0 ± 0.2	46.0 ± 0.3b	46.3 ± 0.3b	*
1-12 (avg/d)	1.1 ± 0.0	1.1 ± 0.0	1.1 ± 0.0	NS	0.4 ± 0.0a	0.4 ± 0.0a	0.5 ± 0.0b	*

*abc; Mean ± SE: Mean ± Standard Error; Sig: Significance; *: p<0.05*

Table 4: Individual consumption, consumption index and mortality of snails

Parameters	Ration			
	Batch 1	Batch 2	Batch 3	Sig
IC (g/day)	0.6 ± 0.1a	0.6 ± 0.1b	0.6 ± 0.1b	NS
CI	1.7 ± 0.1b	1.4 ± 0.3a	1.6 ± 0.2b	*
Mortality (%)	3.3	3.3	6.7	-

Individual consumption: Individual consumption; CI: Consumption index; Sig: Significance; *: p<0.05

Discussion

Composition of the ration

Giant African land snails are mainly phytophagous and require a balanced diet rich in energy, protein and minerals to ensure optimal and regular production (Ogbolo et al., 2019; Tchowan et al., 2022). The energy concentrations obtained in the present study (2705 – 2720 Kcal/kg DM) are higher than those obtained by (Popoola et al., 2021) (2384 – 2429 Kcal/kg DM) for snails of the same species fed various proportions of yam peels in Nigeria. On the other hand, the protein levels obtained by these authors (23.72% - 24.53%) are higher than ours. On the other hand, the energy values recorded in the present study are also higher than those of the compound feed recorded by Kana et al. (2018) on the same species (1946 Kcal/kg DM) with, however, similar protein proportions. Furthermore, the energy and protein concentrations obtained in the present study are lower than those recorded by Ogbolo *et al.* (2019) (2958 – 3013 Kcal/kg DM for energy and 16.04 – 20.26% for protein) for subjects of the same species on the same experimental site. In addition, the calcium values recorded in our study are much higher than those recorded by these same authors (4.64 to 4.83%). These variations in nutritional composition could be explained by experimental objectives that differ from one author to another and according to the availability of food resources.

Growth performance

In the present study, the growth performance displayed by the snails of the different batches were similar despite some variations observed halfway through the experiment. The final weights obtained in the snails at the end of this study (82.8 ± 2.1 to 85.7 ± 2.1g) are higher than those of the snails that were subjected to a 70-day food restriction by Toukourou et al. (2022) (66 ± 10.6 g to 79.6 ± 7.3g). On the other hand, these final weights obtained in the present study are lower than those of the snails that were subjected to a 70-day refeeding phase by Toukourou et al. (2022) (86.6 ± 7.3 g to 92.6 ± 3.3g). The results of this study revealed that after three months of experiment, the average daily gains of snails fed rations R1, R2, R3 containing respectively 0%, 2.5% and 5% cockroach flour are similar to those of Adeola et al. (2010) and Kouassi et al. (2010) in the same species with the same phenotype. However, these authors observed a breeding density of 100 individuals/m^2, ten times the breeding density applied during this study (10 individuals/m^2). Furthermore, our results are in the range of those obtained by other authors Ogbolo et al. (2019) who obtained for the same species average daily gains varying between 0.29 g/day and 0.61 g/day depending on the protein content of the concentrated feed. The similarities in weight growth obtained by the snails during the different experiments would thus be due to the nature of the feed and its composition.

Feed intake and consumption ratio

In the present study, ingestion was higher in snails from batches 2 and 3. It can be deduced that the substitution of fish meal and oyster shell with cockroach meal and hen eggshell induced better feed intake in snails. The feed conversion ratios recorded on snails from batches 1 and 3 are similar to those recorded by (Babalola and Olaleye, 2010) on snails fed whole lettuce (1.67), lettuce waste (1.52) and cabbage waste (1.58). However, the feed conversion ratios recorded on snails in the present study are lower than those reported (2.39) by the same authors on snails of the same species fed papaya leaves. On the other hand, our results differ from those recorded by Popoola et al. (2021) on snails that displayed indices ranging from 4.38 to 5.12 following feeding with various proportions of yam peels. Furthermore, the individual daily consumption obtained in the present study (~0.6) is much lower than that recorded by Toukourou et al. (2022) on snails of the same species *Archachatina marginata* fed with rations containing between 14.43 and 20.26% crude protein and 2089 kcal to 2976 kcal where the snails presented individual consumptions of the order of 1.48g during the 70-day refeeding phase. Our results obtained on the individual daily feed consumption of snails from the batches are similar to those reported by Oketoobo *et al.* (2021) on snails fed with *Luffa cylindrica leaves (vegetable sponge) and Carica papaya* leaves (papaya) (0.51 and 0.52 respectively). In addition, these authors recorded a higher individual daily consumption on snails fed a commercial poultry feed in the same study and on the same species.

The results of this study revealed that after three months of testing, the feed consumption indices of snails fed rations R1 (0% cockroach flour and 0% chicken eggshell), R2 (2.5% cockroach flour and 5% chicken eggshell) and R3 (5% cockroach flour and 10% chicken eggshell) are higher than those obtained by Ogbolo et al. (2019) on the same species. However, it should be noted that these authors, although they carried out their test on the same species of the same phenotype, did not use snails of the same age or rather of the same physiological stage.

Shell growth

The linear growths of the shell obtained for the 3 batches at the end of this study (82.3 to 84.0 mm) are similar to those obtained by Toukourou *et al.* (2022) on these same species (88 mm) at the end of the refeeding phase of these animals. The linear growth performance of the shell of the snails used in our study are lower than those by Oketoobo et al. (2021) on snails fed with *Luffa cylindrica leaves (vegetable sponge) and Carica papaya* leaves (papaya) (with values varying from 8.73 to 11.23 cm). However, it should be mentioned that the initial live weights of the snails taken into account in our study differ from those of the snails of these authors (82.66 to 83 g); this could therefore explain the superiority of their values over ours. As for the diametrical growth obtained in the present study (45.0 to 46.3 mm), they are lower than those reported by these same authors at the end of the refeeding phase of these animals (54.3 to 55 mm). However, the snails used in the present study are not yet eight months old. Furthermore, our results are in the range of those obtained by other authors (Ogbolo et al., 2019) who obtained average daily growths varying between 0.15 mm/day and 0.28 mm/day depending on the protein content of the concentrated feed. This can be justified by the calcium content of the feed used.

Mortality

Our study revealed a similar mortality rate between snails in batches 1 and 2 but twice as high in batch 3. It should be noted that during the experiment, one case of mortality was recorded due to poor handling (resulting in shell damage) after the last data collection. It can be deduced that this mortality is not attributable to the quality of the rations served to the snails and that the different mortality rates obtained are relatively low. Low rates of 0%, 2.22%, 4.44% and 6.67% were also reported by Babalola and Olaleye (2010) *Archachatina marginata* snails fed with cabbage waste, lettuce waste, whole lettuce and papaya leaves respectively. The rates recorded in the present study (regardless of the type of ration) are lower than those obtained (0%) on snails of the same species in Nigeria by Popoola et al. (2021). Mortality rates of 0% were also reported by Oketoobo et al. (2021) on three batches of *A. marginata snails* fed with commercial poultry feed, *L. cylindrica leaves* (vegetable sponge) and papaya leaves. On the other hand, the cumulative mortality rate of snails subjected to the different rations R1, R2 and R3 which is 13.68% is lower than that reported by (Otchoumou, 2005) who recorded a cumulative mortality rate of 20% for a concentrated diet in flour form with a calcium content of 12%. This low rate could be related to the combined effect of all the minerals, proteins and vitamins provided by these diets, the stocking density, hygiene in the farm and many other factors. On the other hand, the mortality rates obtained in the present study are significantly lower than those recorded by Kana et al. (2018) (10.4% to 29.2%) on individuals of the species *Archachatina marginata* having received diets composed of papaya fruit (R0); powdered papaya fruit and marine shellfish (R1) and compound feed in the form of prod.

Conclusion

This study highlights the possibility of substituting commonly purchased feed resources in the commercial animal feed industry with other locally more available and accessible resources. The gradual substitutions made allowed to obtain similar performances at the experimental batch levels at the end of the experiment in the snail species *Archachatina marginata.* The findings of this study suggest that substitution of fish meal and oyster shell with cockroach meal is an alternative for obtaining good performance while reducing the dependency in imported feed resources. Futhermore, it would also be interesting to carry out other substitutions in order to obtain rations consisting largely of local feed resources for snails.

Authors' contribution

YT, HSSW participated in the design and planning of the study and writing of the document. RK, ED, COOO, CADA, MK participated in data collection, processing and analysis. I.T.A. participated in the design of experiment and the revision of the manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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