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Original article

Rearing density effect on the production performance of the edible snail *Helix aspersa* Müller in indoor rearing

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Abstract — Six different indoor rearing densities (250 to 500 animals per m^2) were tested. Three repeats were carried out for each density. The following were recorded: feed intake, weight and number of adult individuals (animals with a reflected peristome), non-adult weight at the end of the experiment, and mortality. A simplified calculation of gross margin is also presented. It was observed that, at low densities, the animals consumed more, were bigger and more of them became adults. However, the total amount of biomass produced is greater at higher densities. If the breeder merely fattens the snails, then the gross margin is maximal at a density of 250 animals per m^2. If the breeder fattens and cooks his own produce, then the gross margin is maximal at high densities. Compared to the mixed rearing method currently used, the performances observed in this indoor rearing experiment could be improved further (particularly in terms of the percentage of adult animals obtained).

***Helix aspersa* / indoor rearing / density / growth / gross margin**

Résumé — **Influence de la densité sur les performances zootechniques d'escargots Petit-Gris (*Helix aspersa* Müller) en élevage hors sol.** L'effet de six densités d'engraissement (250 à 500 animaux par m^2) sur les performances d'élevage hors-sol est étudié. Trois répétitions pour chaque densité sont formées. On mesure la consommation alimentaire, le poids des individus bordés et leur nombre, le poids des individus non bordés en fin d'expérience et la mortalité. Un calcul simplifié de marge brute est aussi présenté. On constate que pour les faibles densités, les animaux consomment plus, sont plus gros et qu'il y a plus d'individus bordés. Cependant, si l'on s'intéresse à la biomasse totale produite, les fortes densités fournissent de meilleurs résultats. La marge brute est maximale pour une densité de 250 individus par m^2 si l'éleveur est engraisseur seulement.

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Si l'éleveur transforme lui-même sa production, la marge brute est maximale pour les fortes densités. En comparaison avec l'élevage mixte actuellement pratiqué, les performances observées dans cet essai d'élevage hors-sol, en particulier le pourcentage d'animaux bordés obtenu, peuvent être encore largement améliorées.

***Helix aspersa* / élevage hors-sol / densité / croissance / marge brute**

1. INTRODUCTION

Snail farming has been expanding rapidly in Europe since 1990, particularly in France where production has increased from a few dozen tons in 1990 to approximately 700 tons in 1998. The rearing method used, referred to as the mixed method, is a seasonal one. Reproduction and nursery take place in buildings, under controlled ambient conditions. Fattening takes place in outdoor greenhouses, climatic conditions permitting, i.e. between the end of March and September in France. The advantage of this kind of rearing is that it requires little investment, but it only allows for the production of one generation of animals annually. Indoor rearing, entirely in buildings, enables animal production throughout the year, but the cost (building, heating, etc.) is much greater. A large number of studies report on continuous snail production experiments in the laboratory. Nonetheless, few studies on economically viable indoor production techniques have been undertaken, other than by the team of Prof. Gomot ([12], for a review). But their studies date back to the beginning of the eighties and, since then, there has been considerable progress in animal production which means that control in rearing has improved. Indoor rearing methods have been considered rather unprofitable, and consequently few in-depth studies have been carried out on them in contrast to mixed rearing [1, 5–7]. Recently, only De Grisse [9] has described a battery rearing method in detail, but the growth results given are brief and only concern the early growth stage (6 to 7 weeks).

Our aim here was to test the effect of density on rearing performance (production and profitability). We decided to test densities of between 250 and 500 individuals per m^2, i.e. about the optimal density for fattening under mixed rearing conditions (350 individuals per m^2).

2. MATERIALS AND METHODS

2.1. Biological materials

The snails (*Helix aspersa* aspersa) were born at the INRA (Domaine du Magneraud, France). They were all taken from clutches which had all hatched in the same week, so that the maximal age difference between two individuals was of one week. They underwent a nursery period for 9 to 10 weeks and then a fattening period for 9 weeks (see below).

2.2. Rearing method

2.2.1. Nursery

The snails were reared in watertight plywood boxes as described by Daguzan [6], at a rate of 350 individuals per box. They were placed in a rearing pen where the ambient conditions were regulated as such:

– temperature: 20 °C during the day; 17 °C at night
– humidity: 70% during the day, 90% at night
– photoperiod: 16 h day, 8 h night.

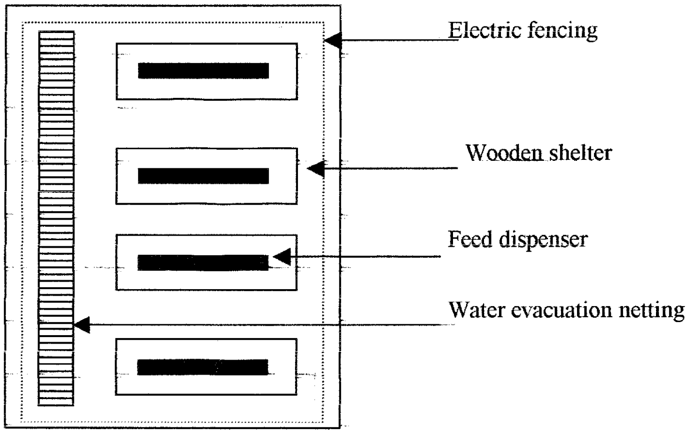

Figure 1. Diagram of a fattening container.

The animals were fed ad libitum, with an artificial feed presented in the form of flour and which mainly contained: crude protein, 15%; crude fat, 2%; cellulose, 3%; ashes, 37% (including calcium carbonate, 30%); gross energy, 2600 kcal·kg^{-1} [4]. The feed was renewed once a week when the boxes were cleaned. This nursery period is described in detail by Bonnet et al. [1].

2.2.2. Fattening

The animals were fattened in black plastic containers (Fig. 1) with a surface of 2 m^2 for the animals to explore. Around the perimeter, the containers were equipped with an electric fence which prevented the animals from escaping. A sprinkler system (two minutes, four times a day), installed on each container maintained the moisture levels. At the bottom of each container there was netting to allow excess water to pass through. Four wooden shelters were placed in each container and PVC feed dispensers below them. The shelters are used as a surface which the animals can stick to and protect the feed from being directly sprayed with water. The containers were arranged one on top of the other in groups of three onto a metal framework. The metal frameworks were lit up by daylight neon lights situated above the frameworks.

The same ambient temperature, humidity and photoperiod conditions as in a nursery were maintained. The containers were cleaned once a week, and the same feed as in a nursery was distributed ad libitum.

2.3. Study on the density effect

For the fattening period, the animals were divided into groups at six different densities: 250, 300, 350, 400, 450 and 500 individuals per m^2. Each density was repeated three times. The different batches were divided up in order to eliminate biases due to any possible stage effect and to minimise biases due to any possible framework effects. Thereby, each density was represented by one repeat for each of the three stages. The distribution of batches for a same stage was randomised.

In order to have batches with the same mean weight at the beginning of the experiment, the batches were formed as follows: the nursery animals were mixed, then 25 snails were sampled from each batch with a density of 250, 30 from each batch with a density of 300, … 50 from each batch with a density of 500, and this was done 20 times. The animals were then counted once more and weighed overall in order to ensure that allocation had indeed been random. The mean animal weight per batch at the beginning of the fattening period was on average 1.98 grams and varied between 1.92 and 2.12 grams.

This fattening period lasted nine weeks.

2.4. Studied performances

2.4.1. Feeding

Each week, the distributed feed and the refused feed were weighed (Mettler balance, accuracy: hundredth of a gram). A sample of the distributed feed and the refused feed were dehydrated (24 hours in the oven at 104 °C), which enabled us to improve our knowledge of the overall weekly intake of each container (in dry matter). The mean individual intake for each container per week was estimated by dividing the overall intake by the number of animals present at the beginning of the week.

A feed conversion index was calculated for each container. It was, however, overestimated since the weight of the dead snails was not taken into consideration.

2.4.2. Growth

During rearing, snails are sold when they are adult, i.e. when the edge of the shell (the peristome) is reflected. The shell's growth has then come to an end. The adult animals should be removed from the rearing cells – otherwise they will consume feed unnecessarily and, above all, they risk reproducing and dying. Non-adult animals can also be sold, but they are generally valued less.

Every three weeks, the adult animals were removed from the containers, counted and weighed individually (Mettler balance, accurate to the nearest hundredth of a gram). At the end of the experiment, the non-adult animals were counted and weighed overall for each container (Mettler balance, accurate to the nearest hundredth of a gram).

2.4.3. Simplified calculation of the gross margin

Besides Daguzan [7], the authors [2, 8, 13, 15] who have studied the effect of density on snail growth have limited themselves to analysing raw variables such as adult animal weight, number of adult animals and occasionally feed intake. Yet the aim of a breeder is not necessarily to maximise these variables individually but rather to obtain maximum profits. In the case of snail farming, a distinction should be made between two types of breeders:

– those who fatten the animals to sell them live or simply steamed – shelled;

– those who fatten – cook their produce to sell after processing.

Those who only fatten snails are interested in obtaining a maximum number of adult animals, because non-adult animals are valued far less. A kilogram of live adult animals can be traded for between 25 and 35 francs, whereas non-adult animals sell for 5 to 15 francs per live kilogram. By contrast, to the breeder who processes his production himself, adult and non-adult animals are worth the same, and so his aim is simply to produce the greatest amount of biomass possible.

Besides overall production indicators (such as the total weight of adults obtained in a container, total biomass per container), we calculated gross margin in order to calculate optimal densities in economic terms.

Two hypotheses were proposed to easily calculate the gross margins in relation to the fattening period (separate from the rest). On the one hand, whereas many breeders buy newly-hatched 1 day old snails from other breeders and then take care of the beginning of growth themselves in the nursery, we worked on the assumption that the animals were bought at the juvenile stage ready to be fattened (i.e. aged 9 weeks, already having gone through the nursery period). On the other hand, we assigned a commercial value to the animals at the end of rearing regardless of their final purpose, including on-site processing, as if the breeder who fattens – cooks snails was selling his live animal production to himself.

Gross margin (GM) per container is defined as such:

GM = Pr – VC, where Pr is the produce obtained per container and VC the variable costs.

Pr is broken down as so: Pr = Sn*Wn + Sa*Wa, where Sn is the selling price of the non-adult animals, Sa is that of the adult animals, Wn is the total weight of the non-adult animals and Wa that of the adult animals.

VC is broken down as so: VC = Pf*Fc + Sj*Nj, where Pf is the price of a kilogram of feed, Fc the number of kilograms of feed consumed, Sj is the unit selling value of juveniles and Nj the number of them. As a reference situation, we chose the prices most commonly used in practice: Pf = 3 $FF \cdot kg^{-1}$ for the price of feed, Sj = 0.07 FF for the price of a snail ready to be fattened (estimated price), Sa = 30 $FF \cdot kg^{-1}$ for the selling price of adult animals and Sn = 10 $FF \cdot kg^{-1}$ for the price of non-adult animals. We then varied the prices according to these average prices so as to find out the effect of price evolution on the gross margin.

2.5. Statistical analyses

The normality of the variables was checked by calculating skewness and kurtosis. In order to approach normality, the percentage of dead snails was examined following logarithmic transformation.

In order to study the density effect, regression analysis (of the trait measured against density) was carried out for all the variables studied. In the case of the regression being non-significant, and in order to check that no significant non-linear relationship existed between the variable and the density, one-way variance analysis was carried out:

$$Y_{ij} = \mu + D_i + E_{ij}$$

where Y_{ij} is performance *j* at density *i*, μ is the overall mean, D_i is the density *i* effect and E_{ij}, the residual.

3. RESULTS

Elementary statistics are given in Table I. In total, 2 806 adult snails were produced. They reached a mean weight of 8.61 grams. Mortality per container (20.99%) over the whole period was average. The percentage of adults collected over the whole experiment was quite low (21.98%). The total

Table I. Elementary statistics.

	Number of data	Mean	Standard deviation	Minimum	Maximum
% of adults	18	21.98	11.2	4.11	46.40
% of dead snails	18	20.99	9.89	4.83	46.11
Adult weight (g)	2 806	8.61	1.25	4.52	14.45
Mean non-adult weight (g)	18	5.00	0.55	4.04	6.26
Total adult snail weight (g)	18	1 343	621	299	2401
Total non-adult snail weight (g)	18	2 084	526	1 215	2 849
Total biomass (adult and non-adult, g)	18	3 427	896	2 018	5 018
Individual intake (g per week)	162	0.61	0.19	0.24	1.16
Total intake (g)	18	3 481	719	2 289	4 759
Feed conversion intake	18	1.87	0.63	1.27	3.73

biomass produced in a container varied between 2 and 5 kilograms.

Regression analysis of the density effect against the traits measured is summed up in Table II. The relationship between mortality rate and density was not significantly linear. Nor did variance analysis show significant differences between the densities. With respect to growth performance, the regression of the percentage of adults against density was of borderline significance (P = 0.06), with the percentage of adults decreasing as the density increased. Thereby, the percentage of adults at a density of 500 was 42% lower than that at a density of 250. Variance analysis showed that the percentage of adults was significantly different at a density of 250 on the one hand and at a density of 400 or 450 on the other. Similarly, mean adult weight and individual intake decreased linearly (P = 0.0001) when density increased. By contrast, no linear relationship existed between mean individual non-adult weight and density. For this variable, one-way variance analysis showed that there was no significant difference between the densities ($P > 0.1$).

With respect to the overall production performances over the whole experiment (which directly determines the breeder's profits), it was observed that in spite of better growth performances at a density of 250 (more adults and fatter adults), total adult weight was not linearly related to density. One-way variance analysis did not show any significant difference between densities. However, the relationship between

Table II. Effect of density on the traits measured.

	Density						Regression slope and significance
	250	300	350	400	450	500	
Percentage of adults	31.4	24.4	25.7	16.7	15.2	18.5	–0.03 0.06
Percentage of dead snails	14.5	19.3	17.3	24.6	28.3	21.8	– 0.14
Adult weight (g)	8.83	8.68	8.68	8.51	8.46	8.52	–0.0006 0.0001
Mean non-adult weight (g)	4.97	5.21	5.47	5.09	4.73	4.57	– 0.15
Total adult snail weight (g)	1 362	1 270	1 559	1 134	1 162	1 573	– 0.92
Total non–adult snail weight (g)	1 371	1 772	1 909	2 423	2 303	2 725	2.53 0.0001
Total biomass (adult and non-adult, g)	2 734	3 042	3 468	3 557	3 466	4 297	2.62 0.029
Individual intake (g per week)	0.71	0.68	0.60	0.62	0.53	0.52	–0.0004 0.0001
Total intake (g)	2 743	2 943	3 254	3 896	3 716	4 337	3.12 0.0002
Feed conversion index	1.65	1.67	1.6	2.39	1.75	2.12	– 0.26

increasing total non-adult weight and total biomass produced on the one hand, and density on the other, were significantly linear ($P = 0.0001$ and $P = 0.03$, respectively). The relationship between the increasing amount of feed intake throughout the whole experiment and density was significantly linear ($P = 0.0002$), whereas no significant linear relationship was observed between the densities in terms of feed conversion index. Variance analysis did not show any significant difference between the densities either.

The gross margins obtained at each density and for various price combinations are given in Figure 2. In most of the situations, the densities of 250, 300 and 350 had the higher gross margins that those of the other densities. Nonetheless, when the selling price of non-adults increased, the differences in gross margin between densities decreased. The grading of the densities was reversed: for a non-adult selling price of 15 FF·kg^{-1}, profitability at the density of 250 was triple that at the density of

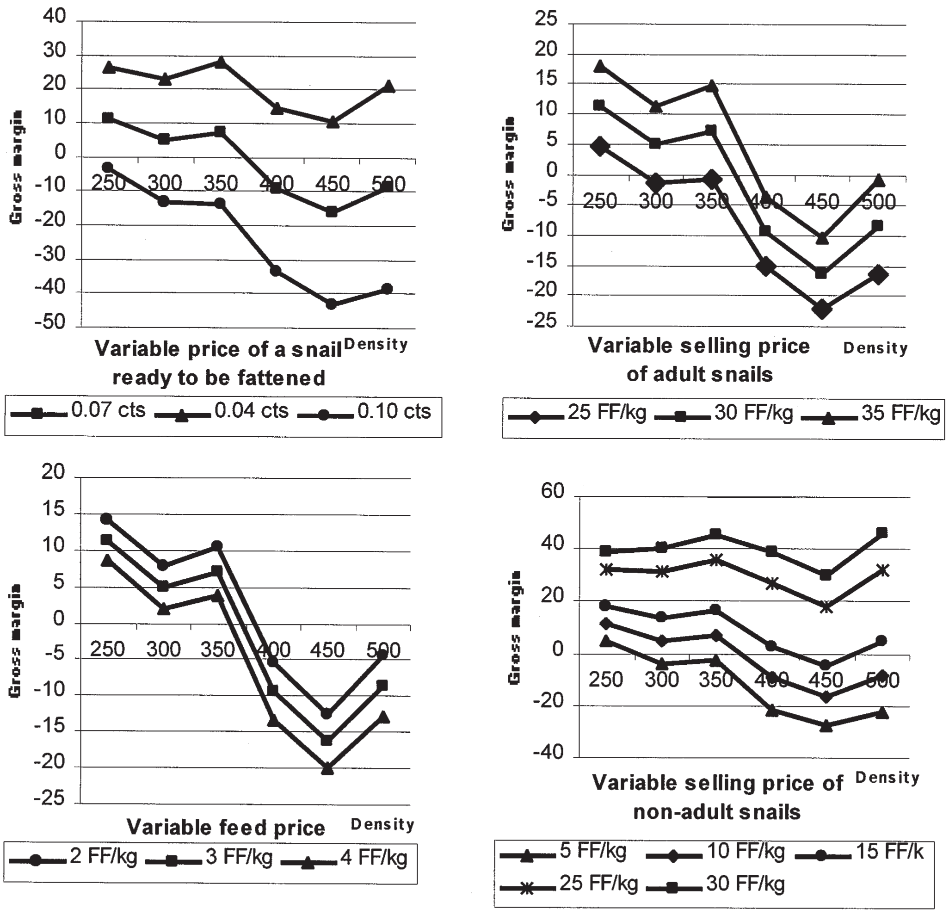

Figure 2. Gross margins. Variations with respect to the reference situation.
Reference situation: price of feed: 3 FF·kg^{-1}.
Price of a snail ready to be fattened: 0.07 FF, selling price of adults: 30 FF·kg^{-1}, selling price of non-adults: 10 FF·kg^{-1}.

500 (18 and 5 FF per container, respectively) whereas for a non-adult selling price of 30 FF·kg^{-1}, profitability at a density of 250 was slightly lower than that at a density of 500 (38 and 45 FF per container, respectively).

By contrast, variation in the adult price (when the price of the non-adults remained at 10 FF·kg^{-1}) did not modify the grading of the gross margins at the different densities. Similarly, variation in the price of feed only had a slight influence on gross margin. Increasing the price of 9-week-old animals had a far greater effect and, moreover, increased the unfavourable effect of high rearing densities.

4. DISCUSSION

4.1. Rearing methods used

By using nursery boxes it is possible to provide more care for juvenile animals than with fattening containers, but obviously at the price of many more man hours. Particularly during cleaning, the animals can be gently put to one side so that the sprays of water do not damage them. When using fattening containers, it is not possible to pick up the animals each time the containers are cleaned without damaging the shells and harming the growth process, because of the size and shape of containers. Cleaning is therefore undertaken in the presence of the animals which suffer all the more from this treatment when they are young and small. Gomot and Deray [12] also recommended using small cells over a short period for the nursery of the juvenile snails, without which growth is much slower. According to these authors, the duration of this period should not exceed three weeks. Complementary studies ought to be carried out in order to determine the optimal duration of the nursery period or to test other animal early growth systems, as a function of production and economic profitability criteria.

4.2. Mean performances observed

The percentage of adults obtained appeared to be small. It was much lower than that which can be obtained in mixed production systems (80%), where fattening takes place in outdoor greenhouses. Lucarz and Gomot [14] showed that in an indoor production system, using self-cleaning plexiglas chambers, at a density of 4 individuals per m^2, 100% of the animals become adults, whereas at a density of 200 per m^2 only 5.7% become adults. Our rearing system appears to be better (31.4% of adults at 250 animals per m^2), but can undoubtedly be improved.

The mean individual adult weight was slightly lower than that obtained in mixed rearing systems which is 9.5 grams (Bonnet, data not published).

Mortality was quite high but this is often observed in snail farming. Indeed, no preventive or curative treatment is applied due to poor knowledge of snail pathology.

4.3. Density effect

Generally speaking, it would appear that the lower the density, the greater the feed intake of the animals, the bigger they are, and the higher the percentage of adult animals. This is consistent with previously published results for different snail species, different rearing systems, at low densities (less than 100 individuals per m^2 [2, 8, 13–15]) and very high densities (up to 6000 individuals per m^2 [7]) as well as at densities comparable to those studied here – in spite of often lower growth performances than ours [7, 8, 13, 14]. Only the study by Charrier and Daguzan [3] gives an optimal density: growth performance improved up to a density of 133 individuals per m^2 (group effect) and then decreased beyond this value (mass effect).

The studies by Cameron and Carter [2] and by Dan and Bailey [8], show that when density is increased, the activity and therefore the growth of the animals is inhibited. They suggest that inhibitor pheromones exist in the mucus. It is not known, however, whether hierarchical relationships exist between the individuals, i.e. whether the mucus of certain snails is more inhibiting (concentration or type of pheromones) or whether each snail is equally involved in inhibiting their age mates. Lastly, the presence of inhibitor pheromones in the mucus does not exclude the possibility of other causes of inhibition.

Analyses on adult animal weight, the percentage of adult animals and individual intake, lead to the conclusion that the density of 250 is the most efficient. Nevertheless, a study of general animal production parameters (biomass produced, gross margins) shows that the optimal density should be chosen depending on the value system of the chosen production. In particular, if the breeder processes his produce himself and has therefore the possibility of increasing the value of non-adult animals, the density of 500 may prove to be the most profitable. It should be noted that the gross margins calculated here do not give an accurate idea of the breeder's real income due to the simplifications made. Nonetheless, this calculation makes it possible to make comparisons between densities. In order to compare the potential profitability of indoor rearing with mixed rearing, it would be necessary to consider other economic elements so as to take into account fixed costs which are much greater in the case of entirely indoor rearing (depreciation and maintenance of buildings, heating, etc.).

5. CONCLUSION: INDOOR FATTENING AND SNAIL FARMING

The performances obtained, in particular the low percentage of adults, lead us to believe that indoor rearing must be improved much further before it can become competitive compared to mixed rearing. Certainly, the duration of rearing could be increased. This is however not necessarily desirable because, after 5 months of growth (9 weeks of nursery and 9 weeks of fattening), growth slows down and few snails become adults (Dupont-Nivet, unpublished data). This is all the more true since this restricts the number of rearable generations each year. Complementary experiments would be necessary to find out if it is more profitable to fatten the remaining animals for a longer amount of time or if it is better to discard them in order to produce more generations during the year.

Besides improving the rearing method itself, the diffusion of lines selected for their growth rate and weight would undoubtedly increase the interest in indoor rearing. The studies by Dupont-Nivet et al. [10] have in fact shown that adult weight and the age of animals when they become adult are highly heritable traits ($h^2 > 0.4$). A selection experiment on weight made it possible to gain a little more than 10% of the weight of adult animals per generation [11]. Indoor rearing would also probably benefit from advances made in research on snail pathology. In fact, the prevention, identification and eradication of disease would undoubtedly minimise mortality, and perhaps even reduce growth delay.

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