Turk J Zool
31 (2007) 265-270

Food Utilisation in a Laboratory Colony of the Giant African Land Snail, *Archachatina marginata* (Swainson) (Pulmonata: Achatinidae)

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Received: 28.03.2006

Abstract: This study investigates food consumption by juveniles and adults of the edible giant land snail *Archachatina marginata* under laboratory conditions. In one experiment, the snails were fed weekly from hatching for 13 months with weighed amounts of lettuce (*Lactuca sativa*), carrot (*Daucus carota*), potato (*Solanum tuberosum*), apple (*Malus pumila*), and calcium. Another group of 2-month-old *A. marginata* ovum was fed singly for 3 days on each of the test food items. The results show that, when given a choice, *A. marginata* can select from the 4 types of food and calcium. When given no choice, lettuce provided high digestibility and usability for the juvenile *A. marginata* but potato gave the best growth. The monthly consumption of calcium increased as the shell length was increasing rapidly until month 5, thereafter declining gradually, until from month 8 onwards the snails consumed very little calcium per month.

Key Words: Food utilisation, growth, laboratory colony, land snail, *Archachatina marginata*

Introduction

Ingestion and assimilation are essential phases of energy transport from one trophic level to another, and many terrestrial gastropods, being primary consumers, play an important role in the functioning of ecosystems (Staikou and Lazaridou-Dimitriadou, 1989). It is therefore important to perform a quantitative study of food consumption and assimilation in snails in order to assess their role in ecosystem dynamics (Mason, 1970; Charrier and Daguzan, 1980; Staikou and Lazaridou-Dimitriadou, 1989).

The food choices of terrestrial gastropods are influenced by the qualitative composition of the food and its quantitative availability as well as by the nutritional needs of the gastropods (Calow, 1970; Van der Steen et al., 1973). There is a positive correlation between food availability and its proportion in the gastropod diet (Speiser, 2001), and therefore the diet is likely to vary seasonally and may affect reproduction and growth (Van der Steen et al., 1973; Scheerboom, 1978). Diet specific to age has been observed in some terrestrial gastropods (Baur, 1992; Speiser, 2001); for example, in *Arianta arbustorum*, the hatchlings feed on the egg shell before they feed on plant materials for a few days after emergence from the shell (Baur, 1992). Juveniles of *Cantareus aspersus* feed on more green material than the adults (Iglesias and Castillejo, 1999), while in *Achatina achatina* it is only the adult that eats fruits (Hodasi, 1995).

Archachatina (*Calachatina*) *marginata* (Swainson, 1821), one of the giant African land snails, is endemic to tropical West Africa. It is restricted to an area from the Benin Republic in West Africa to Zaire in Central Africa (Bequaert, 1950; Mead, 1950) and attains an adult weight of about 700 g. *A. marginata* is economically important because the species is in high demand as a protein source in many West African countries including Nigeria (Ajayi et al., 1978), where the meat is a luxury food. Despite this, the species is not cultivated on a commercial level and, as a result of human-related impact (e.g., deforestation and collection for food (Ajayi et al., 1978) superimposed upon long pre-reproductive life and low fecundity (Egonmwan, 2004), the natural population in the wild is dwindling. However, in recent years the commercial potential of the species is being investigated by many amateur snail farmers and more attention is being paid to farming of the giant snail as opposed to exploitation of wild populations. In nature *A. marginata*

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feeds on both the leaves and fruits of agricultural and wild plants (Ajayi et al., 1978), and therefore there is an opportunity for a mixed diet. There was poor growth when *A. marginata* was fed on single diet of *Luffa officinalis*, a wild weed, or *Talinum triangulare*, water leaf (Ajayi et al. 1978), but snails fed on pawpaw fruit, maize, and cassava grew large. Artificial food developed for molluscs (Standsen, 1951; Wright, 1973), although promoting good growth rates, is expensive and spoils easily even at 4 °C (Parashar et al., 1986) and so it will not be suitable in West Africa, where temperatures are high and storage facilities are poor.

As the experiments were carried out for more than 12 months, this study presents a comprehensive report of food selection in *A. marginata* reared in the laboratory and the influence it has on the growth of the snails.

Materials and Methods

Biological material

Snails used in the experiment were the progeny, reared in the laboratory, of snails collected from the field. They were maintained in a temperature-controlled room at 25 °C with uniform illumination and a photoperiod of LD = 12:12 (the light phase began at 0700 hours).

Choice of food by the snail

Forty hatchlings of *Archachatina marginata* were taken 2 days post-hatching and each was numbered with Indian ink. They were weighed individually and the shell length was measured with a calliper to the nearest 0.1 mm. The snails were reared singly in clear plastic containers with mesh tops lined with moist tissue paper.

Every week, the snails were provided with weighed amounts of lettuce (*Lactuca sativa* L.), carrot (*Daucus carota sativus* (Hoffm.) Archang.), potato (*Solanum tuberosum* L.), apple (*Malus pumila* Mill.), and natural chalk (calcium). The dry weight of the food given to the snail was obtained by multiplying the wet weight of each food by a factor of 0.055 for lettuce, 0.269 for potato, 0.126 for apple, and 0.096 for carrot, obtained by drying a weighed amount of each food in an oven at 60 °C until a constant weight was obtained.

At the end of each week, the uneaten food and faecal matter were removed and dried to a constant weight before weighing. The snails were weighed and measured weekly. The snails were then placed in clean lined boxes and fresh weighed food was provided. The experiment was terminated at 13 months, after the snails attained sexual maturity. The differences between the amounts of food ingested were statistically analysed using one-way analysis of variance (ANOVA) (Townend, 2002).

Another group of 17 two-month-old *A. marginata* (mean body weight 5.8 ± 0.3 g) were starved for 5 days to clear their guts, weighed, and then fed singly on each of the test food items in turn. Food was given to the snails randomly and after 3 days the uneaten food and faeces were removed and dried. The snails were starved again for another 5 days, and another type of food was provided, until all the 4 food types were used. The snails were weighed before each food was provided and after 3 days of the experiment for each food item being tested. The relationship between the amount of food eaten and body weight was statistically analysed.

The dry weights of the snails were calculated using a correction factor of 0.27 (obtained by drying a group of 17 snails to a constant weight in a 60 °C oven), that is, the water content of the snails is 73% of the wet weight.

Data analysis

The following were calculated for *A. marginata* following the methods described by Waldbauer et al. (1984) and Egonmwan (1992)

1. Approximate digestibility (AD)

$$= \frac{F-E}{F} \times 100$$

2. The efficiency of conversion of digested food to biomass (ECD)

$$= \frac{G}{F-E} \times 100$$

3. The efficiency of conversion of ingested food to biomass (ECI)

$$= \frac{G}{F} \times 100$$

The indices were calculated on a dry weight basis, where

E = dry weight of faecal matter

F = dry weight of food ingested

G = dry weight gained by snails

Results

Feeding and growth

Food intake increased during the first 5 months of life up to the first growth and feeding peaks (Figure 1). Food consumption dropped during months 6 to 7; this was followed by another feeding peak from month 8 until the end of observation at month 13. The rate of increase in body weight fluctuated from the beginning of the experiment until it was terminated at 13 months (Figure 1b). The monthly increase in shell length reached its peak by month 2 (Figure 1b), gradually declining thereafter (with an isolated trough at month 6) until it reached a very low level from month 11 to the end of the experiment. The development of an apricot-yellow columella indicated that the snails attained sexual maturity at month 8, although no eggs were laid during the period of the experiment.

Food selection

Potato made up the greatest percentage of food eaten by dry weight (44%), followed by apple (27%) and lettuce

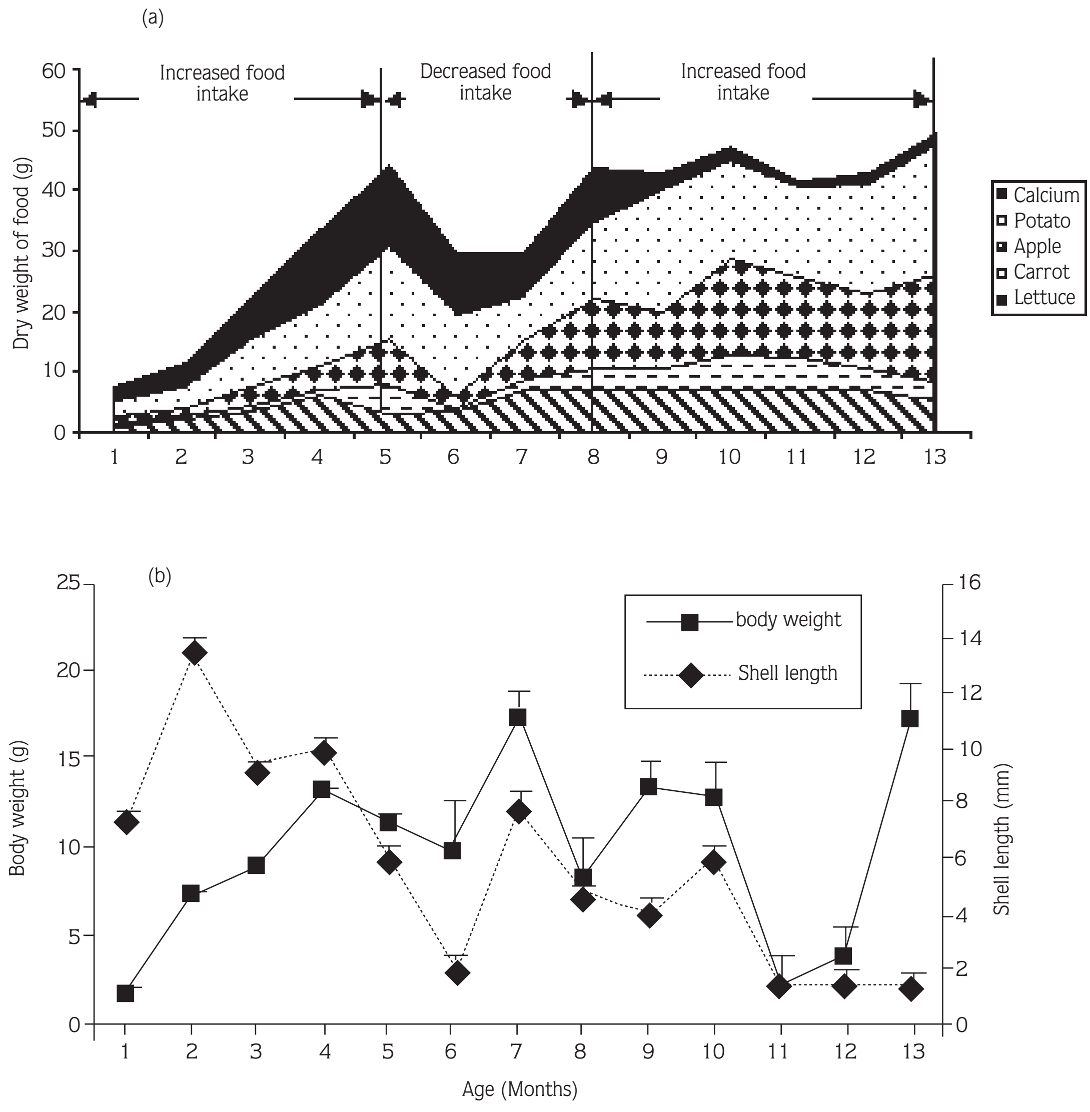

Figure 1. a. The total amount of dry food (lettuce, carrot, apple and potato) ingested by *A. marginata ovum*. The observations started when the snails hatched. Values are the monthly means.

b. The mean (± SE) monthly increase in body weight and shell length of *A.marginata ovum* fed on a mixed diet as above.

(21%), with carrot the least preferred (8%) (Figure 1a). There was a shift in the relative amounts of the different food eaten, but this shift occurred from month 7 onwards, starting before the attainment of sexual maturity at month 8. During months 1-6 the diet was made up of potato (49%), lettuce (24%), apple (21%), and carrot (7%), but for months 7-12 there was a reduction in the percentage of potato to 41% and lettuce to 19%, while the percentage of apple increased to 31% and that of carrot was little changed at 9%. Significant differences in the amounts of food ingested by the snails were detected (one-way ANOVA, $F_{4, 60} = 9.80$, $P < 0.0001$).

The monthly consumption of calcium increased from 2 g in month 1, as the shell length was increasing rapidly (peak 13 g at month 5), thereafter declining gradually, until from month 8 onwards the snails only consumed between 3.0 and 2.0 g of calcium per month (Figure 1a).

The assimilation efficiency (Figure 2) of the food provided fluctuated; the value for ECD was 2%-10.2% (Figure 2a); ECI was 1.2%-7.2% (Figure 2b) and AD was 53%-81% (Figure 2c). In month 7, when the snails experienced the best growth (weight gained, 17.5 ± 1.5 g, shell length gained, 8.0 ± 0.6 mm) but ate relatively little (29.5 g), the assimilation efficiencies were high: the digestibility of the food (AD) was 81 ± 2%, assimilation of the digested food (ECD) was 9 ± 2.2%, and overall utilisation of food (ECI) was 7.2 ± 1.4 (Figure 2). There was a peak in ECD and ECI at month 9, which was not accompanied by growth.

No-choice Experiment

The assimilation efficiencies of juveniles provided with a single diet over a 3-day period are shown in the Table. Lettuce provided high digestibility (AD = 77.9 ± 2.4) and usability (ECD = 32.4 ± 8.0%; ECI = 22.5 ± 5.2). Apple had a high assimilation (AD = 80.1 ± 2.6%) but very low ECD (proportion of digested food turned into body tissue) (9.0 ± 2.7%) and hence ECI (overall utilisation efficiency) (6.7 ± 1.8%). The digestibility of carrot was only a little less than that of apple and lettuce (AD = 69.4 ± 4.2), while ECD (51.8 ± 7.1%) and ECI (36.9 ± 5.3%) for carrot were the highest of the 4 foods. Potato was assimilated least well; the proportion of digested food turned into growth (ECD) was 21.8% but overall utilisation (ECI) was low at 11% yet the snails grew better on potato (Table); there was a positive correlation between the amount of potato eaten and body weight ($r^2 = 0.519$, $P < 0.005$).

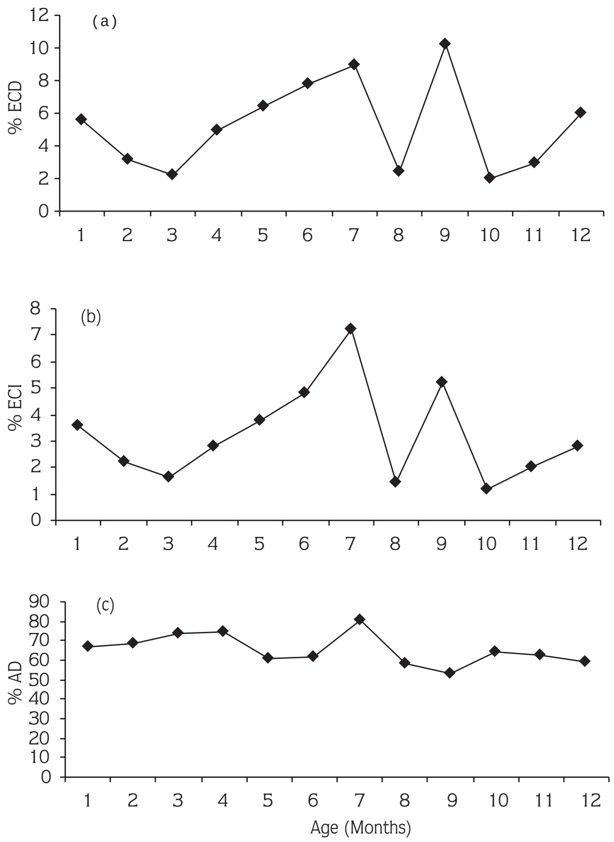

Figure 2. Monthly variation in the utilisation parameters for A. marginata ovum fed on a mixed diet of lettuce, carrot, apple, potato, and calcium from hatching.

a. Efficiency of conversion of digested food to biomass (ECD).
b. Efficiency of conversion of ingested food into biomass (ECI).
c. Approximate digestibility (AD).

Discussion and Conclusion

The present study indicates that *A. marginata* is able to select when given a choice of food just as the rock-dwelling gastropods, which, when given a choice, selected the species of lichen on which they grew best (Baur et al., 1994). Nisbet (1974) observed that *Archachatina marginata ovum* refused to eat cabbage, similar to the observations made by this author during a preliminary study. In field conditions, Ajayi et al. (1978) reported various plant foods on which *Archachatina marginata* feed in the wild, but did not show which of the foods the snails preferred in terms of their nutritional requirements; however, there is a broad correlation between availability of food and its proportion in the gastropod diet (Speiser, Table. Mean weight gained and utilization parameters of 2-month-old *A. marginata ovum* fed a single food. The values are the means of 17 replicates.

Food type	Weight gained (g)	AD	ECD	ECI
Lettuce	129.2 ± 14.5	77.9 ± 2.4	32.4 ± 8.0	22.5 ± 5.2
Potato	201.5 ± 25.5	45.4 ± 3.7	21.8 ± 3.7	11.0 ± 0.9
Carrot	112.8 ± 16.1	69.4 ± 4.2	51.8 ± 7.1	36.9 ± 5.3
Apple	51.8 ± 13.4	80.1 ± 2.6	9.0 ± 2.7	6.7 ± 1.8

2001). The present study has shown that *A. marginata* in the laboratory can select between 4 foods in a mixed diet and choose to feed predominantly on those which gave maximum growth. Of the total organic food ingested by *A. marginata*, potato made up the greatest percentage by dry weight of food eaten (44%), followed by apple (27%) and lettuce (21%), with carrot the least preferred (8%). The water content of fresh lettuce (94.5 ± 0.2%) is much higher than that of potato (73.1 ± 1.3%), apple (87.4 ± 0.7%), and carrot (90.4 ± 0.4%); therefore, by wet weight, lettuce made up the highest amount ingested, followed by apple, potato, and carrot. In addition, there was a shift in the relative amounts of the different foods eaten, but this shift occurred from month 7 onwards, before the attainment of sexual maturity at 8 months.

The highest amount of potato was eaten in months 1-6, followed by lettuce, apple, and carrot. There was a slight reduction in the amount of potato and lettuce eaten in months 7-12, a slight increase in amount of carrot, and the amount of carrot was little changed. The peak observed in months 7-12 may be related to the fact that this is the period of attainment of sexual maturity when the snails start to prepare for their first egg laying, and indeed the development of an apricot yellow columella (Mead, 1950) at 8 months indicated that the snails had attained sexual maturity but they did not lay any eggs because they were isolated from each other during the entire period of the experiment. *A. marginata*, although a simultaneous hermaphroditic snail, cannot self-fertilise (Mead, 1950; Egonmwan, 2004); it is a reciprocally mating species, as has been reported for *Achatina fulica* (Tomiyama, 1994).

The fluctuation in the assimilation efficiency cannot be related to egg-laying as this species did not lay eggs within the 13 months of the experiment. The values for ECI (1.2%-7.2%) and ECD (2.0%-10.2%) were low when compared to those for insects (40%-50%) (Waldbauer, 1968), but high for a herbivorous animal (Dimitriadis, 2001). In this study the digestibility (AD) was 53%-81%. In *Arion ater* fed on lettuce for its entire life, 70% of the ingested food was utilised (Stern, 1970) and stylommatophorans generally exhibit higher assimilation efficiencies when provided with food from the natural environment (Dimitriadis, 2001). The palatability of any given food as well as the nutritional needs of gastropod species may be subject to seasonal changes (Speiser, 2001), and self-selection of food in insects results in an intake of nutrients that is better balanced than that gained by eating only one food alone (Waldbauer, 1968).

In the second experiment, when given no choice, the assimilation efficiencies in the juveniles were very high compared to the values when they were allowed to choose food. High values of daily consumption rate and daily assimilation rate in newly hatched snails may be due their high metabolic rate in relation to older snails (Staikou and Lazaridou-Dimitriadou, 1989) as in *Helix lucorum*, in which assimilation is higher in the hatchlings than in the adults. The AD of juveniles was 45%-80%, ECD was 9%-51%, and ECI was 7%-36.5%. Although apple and carrot had the highest digestibility (80.1 ± 2.6 and 69. 4 ± 4.2, respectively), growth was poor, while lettuce had a high digestibility (77.9 ± 2.4%) and also gave good growth. Potato had the lowest digestibility (AD = 45.4 ± 3.7%) but gave the best growth. Single presentation of food in a terrestrial gastropod shows whether a food is palatable, whereas simultaneous choices, which better simulates the conditions in the natural habitat, indicate food preference (Speiser, 2001).

The amount of calcium ingested by *A. marginata* fluctuated with growth contrary to the report by Greenaway (1971) that there was uniformity with age in the efficiency of calcium absorption in *Lymnaea stagnalis*. In *A. marginata*, monthly calcium consumption increased while the shell length was increasing rapidly (peaked at month 5), thereafter declining gradually until, from month 8 onwards, the snail only consumed very little. There is a positive correlation between snail abundance and amount of calcium (Johannessen and Solhøy, 2001) in terrestrial snails as starvation and dormancy restrict the capacity for calcium uptake (Fournié and Chétail, 1984).

The amount of calcium provided by the food is significantly less than the snail's requirement and the snails will benefit markedly from an external calcium source, particularly in the early stages. Snails need calcium for many purposes, one of these being the building of their protective shell, consisting of calcium carbonate.

Acknowledgements

I thank Dr H. Erhie (University of Lagos) for advice on statistical analyses and the anonymous reviewer for useful comments.

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