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Growth, feed efficiency and carcass yield of female yellow-spotted amazon river turtles (*Podocnemis unifilis*) subjected to different stocking densities

Crescimento, eficiência alimentar e rendimento de carcaça de tracajás (*Podocnemis unifilis*) fêmeas submetidas a diferentes densidades de estocagem

Crecimiento, rendimiento alimentario y rendimiento de la carcasa de tortugas terecay (*Podocnemis unifilis*) hembras sometidas a diferentes densidades de almacenamiento

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ABSTRACT
The yellow-spotted amazon river turtle, *Podocnemis unifilis,* is one of the most consumed species in the Amazon region. However, the basic zootechnical parameters of its production in captivity are not yet fully established to support a sustainable breeding system. Thus, the objective of this

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study was to investigate the effect of stocking density on the growth and feeding of *Podocnemis unifilis* in captivity. A total of 112 females of the species were used for 120 days, housed in 16 polyethylene water tanks with a capacity of 1000 L, containing 250 L of water, with 40% dry area and 60% flooded area. The animals were fed extruded commercial fish feed with 28% crude protein (CP), in the amount of 0.5% live weight, for five days per week. A randomized block experimental design was used, with four treatments (stocking densities of 16 animals/m³, 24 animals/m³, 32 animals/m³ and 40 animals/m³), and four replicates each, totaling 16 experimental units. divided into two blocks (accommodation). The growth of *Podocnemis unifilis* was not influenced by different stocking densities; however, there was an effect on the use of food by the animals and on fat accumulation. The study showed that the higher the density in the *P. unifilis* cultivation (up to 40 animals/m³) the greater the proportion of animal body fat.

Keywords: animal farming, wild animals, aquaculture, turtle farming, chelonian.

RESUMO

O tracajá, *Podocnemis unifilis*, é uma das espécies mais consumidas da região amazônica. Entretanto, os parâmetros zootécnicos básicos de sua produção em cativeiro ainda não estão totalmente estabelecidos para embasar um sistema de criação sustentável. Desta maneira objetivou-se investigar o efeito da densidade de estocagem sobre o crescimento e alimentação de *Podocnemis unifilis* em cativeiro. Utilizou-se 112 fêmeas da espécie, durante 120 dias, alojados em 16 caixas d'água de polietileno com capacidade de 1000L, contendo 250 L de água, com 40% de área seca e 60% de área alagada. Os animais foram alimentados com ração comercial extrusada para peixe com 28% proteína bruta (PB), na quantidade de 0,5% do peso vivo, durante cinco dias por semana. Foi utilizado delineamento experimental em blocos casualizado, com quatro tratamentos (densidades de estocagem 16 anim./m³, 24 anim./m³, 32 anim./m³ e 40 anim./m³), e quatro repetições cada, totalizando 16 unidades experimentais, divididas em dois blocos (alojamento). O crescimento de *Podocnemis unifilis* não foi influenciado por diferentes densidades de estocagem, entretanto houve influência no aproveitamento do alimento pelos animais e no acúmulo de gordura. O estudo demonstrou que quanto maior é a densidade no cultivo de *P. unifilis* (até 40 animais/m³) maior é a proporção de gordura corpórea do animal.

Palavras-chave: produção animal, animais silvestres, aquicultura, quelonicultura, quelônio.

RESUMEN

El terecay, *Podocnemis unifilis*, es una de las especies más consumidas de la región amazónica. Sin embargo, los parámetros zootécnicos básicos de su producción en cautividad aún no están totalmente establecidos para sustentar un sistema de cría sostenible. Por lo tanto, se objetivó investigar el efecto de la densidad de almacenamiento sobre el crecimiento y la alimentación de *Podocnemis unifilis* en cautividad. Se utilizaron 112 hembras de la especie durante 120 días, alojadas en 16 cajas de agua de polietileno con capacidad para 1000 litros, que contenían 250 litros de agua, con un 40 % de área seca y un 60 % de área inundada. Los animales fueron alimentados con pienso comercial extruido para peces con un 28 % de proteína bruta (PB), en una cantidad equivalente al 0,5 % de su peso vivo, durante cinco días a la semana. Se utilizó un diseño experimental en bloques aleatorios, con cuatro tratamientos (densidades de almacenamiento de 16 animales/m³, 24 animales/m³, 32 animales/m³ y 40 animales/m³), y cuatro repeticiones cada uno, lo que sumó un total de 16 unidades experimentales, divididas en dos bloques (alojamiento). El crecimiento de *Podocnemis unifilis* no se vio influido por las diferentes densidades de almacenamiento, sin embargo, sí hubo influencia en el aprovechamiento del alimento por parte de los animales y en la acumulación de grasa. El estudio demostró que cuanto mayor es la densidad en el cultivo de *P. unifilis* (hasta 40 animales/m³), mayor es la proporción de grasa corporal del animal.

Palabras clave: producción animal, animales silvestres, acuicultura, quelonicultura, quelonio.

1 INTRODUCTION

The yellow-spotted amazon river turtle, *Podocnemis unifilis*, is a semiaquatic chelonian species that has a wide geographic distribution, inhabiting lakes, plains and along the main rivers of the Amazon basin, has high reproductive rates (Malvasio, 2005; Fantin *et al.*, 2008), and is one of the most consumed turtles in the Amazon (Ferrara *et al.*, 2016). Its production and commercialization are authorized by Brazilian law (Brasil, 2015).

Feeding on turtle meat in the Amazon goes beyond obtaining protein; it is a strong cultural and traditional habit of the communities (Pezzuti *et al.*, 2010). However, the decrease in natural stocks is evident, and fishing/hunting has been the most common form of exploitation of these resources, causing unknown losses, even with an incisive prohibitive legislation (Albuquerque *et al.*, 2009).

Chelon farming, the commercial production of chelonians in captivity, which includes *P. unifilis*, can be used as an alternative to reduce trafficking, source of income for communities, as well as to preserve their cultural identity, since consuming this species is part of the Amazon culture (Araújo *et al.*, 2024). However, for the activity to be sustainable, it is necessary to know the zootechnical parameters of this species. Knowledge of the pattern of growth and weight gain, as well as feed efficiency during each production phase, enables planning of the production system and product flow, facilitating management and reducing the possibilities of production failure (Araújo *et al.*, 2023).

A biological factor of high importance in commercial production is the stocking density, which acts on the survival and development of the organism, requiring its determination and the influence of its effects, for target species, in the different stages of production, seeking the highest productivity. and lower cost (Marques *et al.*, 2004). Several animals, including reptiles, are sensitive to stocking density when in captivity (Ortega *et al.*, 2023)

The basic zootechnical parameters for *P. unifilis* are not yet established to support a viable breeding system. The lack of preliminary information on captive management can interfere and compromise growth, reproduction and fattening (Araújo *et al.*, 2013), making captive breeding difficult, increasing feeding costs, and compromising the financial return for the producer.

Therefore, the present study aimed to investigate the effect of stocking density on feeding, growth and carcass yield of *Podocnemis unifilis* in captivity.

2 METHODOLOGY

2.1 ANIMALS AND ENVIRONMENT

A total of 112 females of the species *Podocnemis unifilis* (yellow-spotted amazon river turtle) belonging to the Embrapa Amapá herd were individually identified and weighed, with an average initial weight of 1215.79 g (± 50.76 g). The animals were housed in 16 polyethylene water tanks with a capacity of 1000 L, containing 250 L of water, with 40% dry area and 60% flooded area, divided into two groups.

The study was submitted to and approved by the Ethics Committee on Animal Use (Comissão de Ética no Uso de Animais - CEUA) of Embrapa Amapá, under protocol number 006-CEUA/CPAFAP.

2.2 EXPERIMENTAL DESIGN AND DURATION

The study was conducted for 120 days, preceded by a 10-day acclimatization period. A randomized block experimental design was used, with four treatments (stocking densities of 16 animals/m³, 24 animals/m³, 32 animals/m³ and 40 animals/m³), and four replicates each, totaling 16 experimental units, divided in two blocks, consisting of the experimental housing batteries.

Feed Management

The animals were fed extruded commercial fish feed with 28% crude protein (CP) once a day, for five days a week, based on 0.5% of the live weight of the animals. After one hour of feeding, the leftovers were removed and quantified.

2.3 BIOMETRICS

During the experimental period, biometric evaluations of all animals were performed to monitor weight gain and body development. For the analysis of the morphometric measurements of the animals, the following methodologies were used according to Araújo (2017): carapace length (CL), carapace width (CW), plastron length (PL), plastron width (LW) and height (H). In addition to the actual feed intake (AFI), feed conversion (FC) and feed efficiency index (FEI), following the formulas below:

AFI (g) = Food offered (g) – Food not consumed (g)

FC = CR (g) / WG (g)

FEI= WG (g) / AFI (g) (1)

2.4 CARCASS YIELD

At the end of the experimental period, four animals per treatment were euthanized, one from each replicate. Next, bleeding, bridge sawing, plastron removal, evisceration, skinning, trimming, removal of the carapace and separation of extramuscular fat from the carcass were performed.

The following variables were measured for the carcass yield analyses:

a) Total weight of the animal;

b) Total weight after slaughter and bleeding;

c) Weight of the eviscerated animal;

d) Total carcass weight;

e) Bone-in carcass weight;

f) Extramuscular fat weight;

g) Carapace weight

h) Plastron weight;

i) Viscera weight.

Through the variables measured, yield parameters were calculated, namely:

a) Post-bleeding yield (PSY) = (weight after bleeding x 100)/Total weight;

b) Eviscerated whole animal yield (EWY)= (eviscerated animal weight x 100)/Total weight;

c) Fat yield (FY)= (fat weight x100)/Total weight

d) Shell yield (CR)= (carapace weight + plastron weight)*100)/Total weight

e) Loin yield (RL)= (loin weight x100)/ Total weight

f) Bone-in carcass yield (BCY)= (Carcass weight with bone x 100)/Total weight

2.5 STATISTICAL ANALYSIS

The data were subjected to the Shapiro-Wilk test to verify normality and the Bartlett test to verify homoscedasticity. When the normality and homoscedasticity of the data were verified, they were subjected to ANOVA and least significant difference test (LSD). In the case of the variables that showed abnormality and heteroscedasticity of the data, the Kruskal-Wallis test was applied, followed by the SNK test. A significance level of 5% was used for all tests.

The variables were also subjected to the Pearson correlation test ($p<0.05$) to verify the existence of a correlation between them.

3 RESULTS AND DISCUSSIONS

The mean maximum and minimum temperature in the city of Macapá during the experimental period was 33.22 ºC (±0.23) and 24.82 ºC (±0.39), respectively, and mean humidity of 73.95% (±10.16) (INMET, 2017).

The different stocking densities of *P. unifilis* had no effect on weight gain, actual feed intake and feed efficiency index. However, there was no difference between the amounts of food ingested by the animals at different densities. It was possible to observe that the stocking density influenced feed conversion, demonstrating that stocking density of 16 and 24 animals/m³ obtained better use of the ingested food (Table 1).

Table 1 . Mean values of feeding and performance parameters of *Podocnemis unifilis* grown under different stocking densities

Parameters	Densities					
	D16	D24	D32	D40	CV	P Value
PI (g)	1227,01	1200,93	1212,39	1222,87	-	-
PF (g)	1398,31	1380,62	1331,64	1345,54	-	-
WG (g)	171,30^{a}	188,94^{a}	119,25^{a}	122,67^{a}	27,95	0,093
AFI (g)	89,89^{a}	89,98^{a}	86,09^{a}	86,95^{a}	4,86	0,484
FC*	3,62^{a}	3,42^{a}	5,04^{b}	5,14^{b}	20,84	0,034

FEI	0,28^a	0,31^a	0,20^a	0,21^a	24,21	0,067
S (%)	100	95.83	100	100	-	

D16, 16 animals/m³; D24, 24 animals/m³; D32, 32 animals/m³; D40, 40 animals/m³. Initial weight (IP); Final weight (FW); Weight gain (WG); actual feed intake (AFI); feed conversion (FC), feed efficiency index (FEI) and survival (S). *Different superscript letters in the same row indicate statistically significant difference according to the LSD test (P<0.05).
Source: Authors

Studies conducted by Jing and Niu (2008) with the cultivation *of Pelodiscus sinensis* (stocked at high densities of 48 animals/m² and 96 animals/m²) and de (Mayeaux *et al.*, 1996) with *Chelydra serpentine* (stocked at 58 animals/m²), showed lower weight gain and higher feed intake with increasing stocking density. In the present study, it was possible to verify that there was no difference between the feed intake by the animals at the different stocking densities. However, there was a difference in feed utilization for body weight gain, as animals stocked at densities up to 24 animals/m ^{3} had lower feed conversion than animals stocked at densities of 32 and 40 animals/m ^{3}.

The length of the carapace and plastron are measurements used to evaluate the body development of the animal (Rodrigues *et al.*, 2005) and are important for the commercialization of turtles, since they are most often sold alive, taking into account the size or weight of the animal. The present study showed that the stocking density does not influence (p>0.05) the size of the animals up to the stocking density of 40 animals/m ^{3} (Table 2). However, it is possible that this influence occurs at higher densities because (Chen *et al.*, 2007) in the cultivation of *P. sinensis*, reported low growth and lower weight gain at high densities for this animal species (18.75 animals/m^2), considering that its size is larger than that of *P. unifilis* .

Table 2 . Mean carapace and plastron growth of females *Podocnemis unifilis* kept in captivity at different rearing densities during the 120-day period

Densities	Parameters				
	Δ CL (mm)	Δ CW (mm)	Δ PL (mm)	Δ PW (mm)	Δ H (mm)
D16	8,06^a	8,84^a	7,82^a	5,63^a	3,71^a
D24	7,08^a	6,92^a	7,99^a	5,30^a	3,06^a
D32	5,17^a	6,83^a	5,77^a	4,48^a	3,02^a
D40	5,27^a	6,95^a	5,66^a	4,20^a	3,78^a
CV	27,89	32,38	26,80	14,92	34,74
P Value	0,111	0,593	0,184	0,057	0,928

D16, 16 animals/m³; D24, 24 animals/m³; D32, 32 animals/m³; D40, 40 animals/m³. (Δ) Increase in carapace length (CL), carapace width (LC), plastron length (PL), plastron width (LP) and height (A). *Different superscript letters in the same column indicate that there is a statistical difference between treatments, according to the LSD test (P<0.05).
Source: Authors

Regarding the carcass yield variables, the influence ($p<0.05$) of stocking density on fat yield was observed (Table 3). There was a positive correlation (0.66) between the different densities and the fat yield of the animals ($p<0.05$).

In addition, it was observed that there is a positive correlation between density and fat yield. That is, the higher the density, the greater the amount of fat in the animal. Bezerra *et al.* (2023) observed changes in meat color in turtles housed at different densities. In a study conducted by Araújo *et al.* (2024), the authors obtained a yield of 6.45% and 2.27% of fat yield after 30 and 50 days of experiment, and the result obtained is in agreement with results obtained for animals in captivity.

According to Leme (2008), chelonian fat can be used in several ways, including medicinal and gastronomic. Becoming a product with high added value.

Table 3. Mean values of slaughter yield parameters of *Podocnemis unifilis* grown under different stocking densities

Densities	Parameters					
	PBY (%)	EWY(%)	FY*(%)	BCY (%)	SR (%)	LY (%)
D16	98,98^{a}	82,87^{a}	4,87^{b}	33,63^{a}	40,89^{a}	4,36^{a}
D24	98,82^{a}	82,53^{a}	4,91^{b}	33,32^{a}	40,85^{a}	3,82^{a}
D32	97,17^{a}	82,62^{a}	7,17^{ab}	34,00^{a}	41,06^{a}	4,36^{a}
D40	97,83^{a}	82,35^{a}	8,12^{a}	32,51^{a}	41,01^{a}	3,84^{a}
CV	1,10	2,51	26,47	8,19	4,33	13,75
P Value	0,109	0,987	0,037	0,885	0,998	0,351

D16, 16 animals/m³; D24, 24 animals/m³; D32, 32 animals/m³; D40, 40 animals/m³. Post-bleeding yield (PSY); eviscerated whole animal yield (EWY); fat yield (FY); bone-in carcass yield (BCY); shell yield (SR); loin yield (LY). *Different superscript letters in the same column indicate that there is a statistical difference between treatments, according to the LSD test ($P<0.05$).

Source: Authors

The variables post-bleeding yield, eviscerated whole animal yield, carcass yield with bone, hoof yield and loin yield showed no significant difference ($p>0.05$) in animals subjected to different stocking densities.

In observations made during the cultivation period, high activities were reported among individuals, such as swimming and agonistic interactions, especially at high densities. This fact would explain the high feed conversion in treatments with density above 24 animals/m³, as higher metabolic expenditure with these movements, redirecting energy that would be invested in body development, corroborating the results obtained by Jing and Niu (2008).

During the experiment, aggressive behavior was observed in the animals housed at densities of 40 animals/m³, with lesions on the legs and neck, in general, these conflicts result in aggressive activities that may be due to stress, when several animals compete for the same space, and by the formation of hierarchical groups within the treatments. In observations made in Atlantic salmon farming, inadequate densities may influence the emergence of hierarchical groups (Calabrese *et al.*, 2017). In this context, the dominant animals monopolize the food and ingest it first (Maclean; Metcalfe, 2001), as well as the formation of feeding points, which will be defended by the dominant animals, preventing the subordinates from feeding, contributing to heterogeneity within the same treatment (Huntigford; De Leaniz, 1997).

However, the breakdown of dominance is possible at adequate densities (Alanärä; Brännäs, 1996) assisting in the composition of less heterogeneous lots (Trzebiatowski *et al.*, 1981), increasing productivity (Hengsawat *et al.*, 1997) minimizing aggressiveness and cannibalism among organisms (Lahti; Lower, 2000).

4 CONCLUSION

Although the growth of *P. unifilis* was not influenced by different stocking densities, there was an effect on the use of food by the animals. It was also observed that the increase in density favors the accumulation of body fat by the animal. Thus, the producer must adjust the cultivation density to its commercialization purpose and customer demand, always taking into account animal welfare.

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