FOOD CONVERSION RATE (FCR) IN *Caiman latirostris* RESULTED MORE EFFICIENT AT HIGHER TEMPERATURES

María V. Parachú Marcó, Carlos I. Piña and Alejandro Larriera

SUMMARY

The effects of temperature on the growth of Caiman latirostris *were investigated in order to evaluate the efficiency of food conversion at 29 and 33°C. Sixty-eight captive raised animals, two months old, taken from four nests, were used. All groups were maintained up to 70 or 72 days in similar environmental treatments except for temperature. Animals maintained at 33°C reached greater body mass (BM) and total length (TL) than those maintained at 29°C. A more efficient nutritional conversion rate was found in animals kept at 33°C. The increase of temperature could improve the amount of energy extracted from food, producing a more efficient FCR.*

LA TASA DE CONVERSIÓN ALIMENTICIA (FCR) DE *Caiman latirostris* RESULTA MÁS EFICIENTE A TEMPERATURAS ALTAS

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RESUMEN

El efecto de la temperatura sobre el crecimiento de Caiman latirostris *fue estudiado a fin de evaluar la eficacia de la conversión alimenticia en cautiverio a 29 y 33°C. Fueron utilizados 68 animales cautivos de dos meses de edad, provenientes de cuatro nidadas. Todos los grupos fueron mantenidos hasta por 70 o 72 días en tratamientos ambientales similares, a excepción de la temperatura. Los animales mantenidos a 33°C alcanzaron mayor peso y longitud total que aquellos mantenidos a 29°C. Una tasa de conversión alimenticia más eficiente fue encontrada en los animales criados a 33°C. El aumento de la temperatura podría mejorar la cantidad de energía extraída del alimento, produciendo un FCR más eficiente.*

A TAXA DE CONVERSÃO DO ALIMENTO (FCR) DO *Caiman latirostris* É MAIS EFICIENTE A TEMPERATURAS MAIS ELEVADAS

María V. Parachú Marcó, Carlos I. Piña e Alejandro Larriera

RESUMO

*Para avaliação de um método econômico na criação em cativeiro de Jacaré-de-Papo-Amarelo (*Caiman latirostris*) estudio-se o consumo de ração, a taxa de conversão e o efeito da temperatura de cria no crescimento da espécie. Para este estudo foram utilizados 68 jacarés de dois meses de idade, nascidos de quatro ninhos coletados na natureza e incubados artificialmente. Durante o experimento os animais foram mantidos a duas temperaturas: 29ºC e 33ºC até 70 ou 72 dias. Como esperado, os animais mantidos a 33ºC mostraram maior taxa de crecimento (comprimento total e peso), e maior consumo de ração que aqueles mantidos a 29ºC. A taxa de conversão de alimento também foi mais efetiva quando a temperatura de cria foi maior. Concluí-se que o aumento da temperatura poderia melhorar a quantidade de energia extraída da ração, produzindo uma taxa de conversão mais eficiente.*

Introduction

Temperature is an important factor influencing growth rates of reptiles, including *Caiman latirostris* (Larriera *et al*., 1990; Piña and Larriera, 2002). Crocodilians are ectothermic animals and rely upon external heat sources in their environment to attain and maintain preferred body temperatures (Diefenbach, 1975a, 1988; Lang, 1987; Coulson *et al*., 1996). Body temperature affects metabolic rate and the speed and duration of digestive processes in crocodilians (Diefenbach, 1975a, b, c; Coulson and Hernández, 1983). *Caiman latirostris* increased their food consumption and

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growth rates when exposed to a higher temperature (Larriera *et al*., 1990). A difference of 4°C resulted in growth rates differing by as much as 400% between treatments (Piña and Larriera, 2002). Lang (1987) reported that increased temperature resulted in augmented appetite, frequency and amplitude of gastric contractions, and peptic activity in *Alligator mississippiensis*, and he also mentions that presumably it would not increase the total amount of energy extracted from a meal.

Webb *et al*. (1983) proposed that temperatures could affect food conversion rate (FCR) in crocodiles. Vianna *et al*. (1995a, b) using two-month-old *C. latirostris* hatchlings during a 120 day experiment reported that growth and food consumption were greater for animals maintained at higher temperatures, while FCR was less efficient. It was assumed that this was due to the greater speed of food transit through the intestines at higher temperatures, resulting in a lower intake of nutrients.

Food typically accounts for a high proportion of costs for caiman farming operations, and the extent to which temperature affects FCR is considered an economically important rearing strategy on caiman farms. To shed light on this question, the FCR and resulting growth of *C. latirostris* maintained at 29 and 33°C for a period of 70-72 days was studied.

Materials and Methods

Sixty-eight *Caiman latirostris* specimens were used in this study. They were obtained from eggs collected from four different randomly selected wild nests in Santa Fe province, Argentina. Two nests (1 and 2) were harvested in the 1999/2000 nesting season, and two (3 and 4) in 2001/2002. Eggs were artificially incubated in Santa Fe City.

After hatching, the animals were raised in captivity for two months, before being used in the study. Individuals were identified by having two serially numbered Monel tags 1005-1 (Natl. Band and Tag CO., Newport, KY, USA) attached to each hind foot. The 1999/2000 hatchlings (32) were separated into four groups, each consisting of eight hatchlings. Each group had four hatchlings from nest 1 and four from nest 2. Two of the groups were maintained at 29°C, and two at 33°C. The 2001/2002 hatchlings (36) were separated into six groups each consisting of six hatchlings. Each group had three hatchlings from nest 3 and three from nest 4. Each group was randomly placed in an 80×45×30cm tank; three were maintained at 29°C and three at 33°C. Tanks contained water and one aquarium heater with an external thermostat. Each tank was covered with a plastic lid to reduce heat loss. Tank temperature was regulated using Hobo Temp data loggers (Onset Computer Corporation, Pocasset, MA, USA) that were monitored daily.

Animals were fed *ad libitum* three times per week with a mixture containing 60% chicken heads and 40% dry pellets. The pellets consisted of animal protein (50%), fat (14%), fiber (2.5%), vitamins and minerals. Food was placed in holding tanks during the morning. After 12h the remaining food was collected and dried to a constant weight in an oven at 60°C. All hatchlings were weighed and their total length (TL) measured (precision 0.5g and 0.5cm respectively) at the beginning and end of the experiment (70 days in 2000 and 72 days in 2002). Results are expressed as means ± standard error (SE).

The food conversion rate (FCR) was calculated for each group of animals by using dry weight of food consumed and total body mass (BM) increase for individuals in any particular group. Animals that lost weight were assumed to have not eaten, and therefore their body mass increase was zero.

Hatchling size was analyzed with an ANOVA where BM and TL were response variables; temperature and nest were grouping variables. Growth, determined by the difference between final and initial measurement values, was analyzed by an ANCOVA, using growth in BM and TL as response variables and temperature and nest as grouping variables; initial BM was the covariate. Food consumption and FCRs were analyzed by an ANOVA, where temperature and year were used as grouping variables.

TABLE I
MEAN TOTAL LENGTH AND BODY MASS AT THE BEGINNING (TLi, BMi) AND INCREASE (DIFF.) IN TOTAL LENGTH AND WEIGHT FOR EACH NEST IN BOTH YEARS

Nest	Temp (°C)	Total animals	Removed animals*	N	TLi (cm)	Diff. (cm)	BMi (g)	Diff. (g)
1	29	8	2 a	6	25.7 (0.48)	7.7	62.3 (2.09)	48.2
1	33	8	1 a	7	26.1 (0.25)	9	61.6 (2.26)	71.7
2	29	8	0	8	27.4 (0.80)	8.1	73.9 (6.22)	70
2	33	8	0	8	27.5 (0.73)	12.4	66.3 (5.47)	128.4
3	29	9	4 b, 2 c	3	29.7 (0.72)	3.3	78.3 (7.89)	16.5
3	33	9	0	9	32.9 (0.51)	5.8	109.3 (4.92)	37.6
4	29	9	1 b, 2 c	6	27.8 (0.49)	4.5	65.1 (4.18)	30.5
4	33	9	0	9	29.8 (0.35)	9.7	82.1 (3.14)	80.8

Nests 1 and 2 were collected in year 2000 and nests 3 and 4 in year 2002.
N: sample size on which means are based. SE given in brackets.
* a: dead animals, b: animals that lost weight, c: animals of discarded tray as FCR values were outliers.

Results

During year 2000, three animals died (two at 29°C, one at 33ºC after 30, 36 and 50 days, Table I). During year 2002, five animals kept at 29°C lost weight by the end of the experiment; four of them were from a single nest (nest 3). One tray (at 29°C, year 2002) was excluded from the results because food conversion rate value was an outlier. Mean (±SE) water temperature in the tanks was 28.96°C ±0.01 and 32.89ºC ±0.02 in 2000, and 28.69ºC ±0.01 and 32.81ºC ±0.01 in 2002.

The *Caiman latirostris* specimens maintained at 33°C for 70-72 days were longer and heavier than those maintained at 29°C ($P<0.0001$), with the largest differences recorded in 2002 (Table I). At 33°C the mean BM increase was twice that recorded at 29°C (79.6 ±13.2g at 33°C and 42.2 ±8.5g at 29°C; Figure 1a), and the mean increase in TL was 50% higher at 33ºC than at 29°C (9.2 ±1cm and 6 ±0.9cm; $P<0.0001$; Figure 1b). The four nests responded in the same way to ambient temperature (temperature by nest interaction; $P>0.209$), but mean increases in BM and TL varied between clutches at a particular temperature, and there was significant variation in individual growth rates among clutches ($P<0.0001$). Increases in BM or TL were not influenced by initial BM ($P>0.202$).

Average food consumption per animal at 33°C was greater than at 29°C, and

was different between years (P<0.0001; Table II). FCR was more efficient at 33°C than at 29°C (P=0.0010; Table II). A "temperature treatment by year" interaction (P= 0.0285; Table II) was also found. The interaction was caused because FCRs for animals at 33°C, in both years, were similar, but FCR at 29°C in 2000 was more efficient than in 2002.

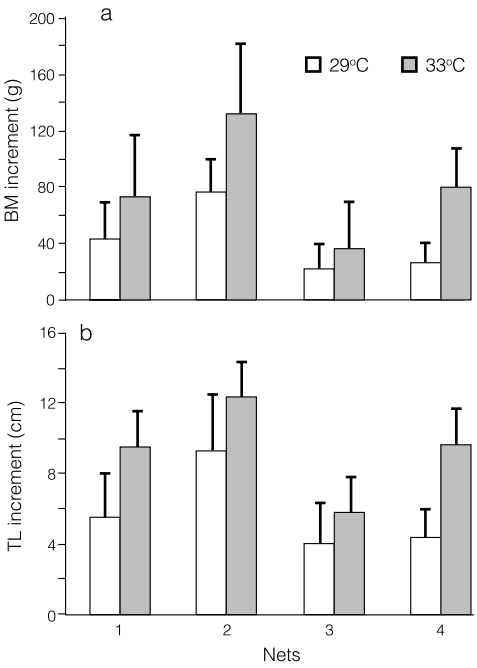

Figure 1. Increments (±SD) in body mass (a) and in total length (b) for the 4 nests used in the experiment, at growing temperatures of 29 and 33°C, up to 70 days. Nests 1 and 2 were collected in year 2000 and nests 3 and 4 in year 2002.

Discussion

Caiman latirostris maintained at 33°C over a period of 70-72 days grew faster than those maintained at 29°C. Animals maintained at 33°C increased 80% in BM and 50% in TL over animals kept at 29°C. Increased environmental temperatures have been previously reported to increase *C. latirostris* growth (Vianna *et al*., 1995a; Piña and Larriera, 2002) and also in other crocodilian species (Joanen and McNease, 1987; Coulson *et al*., 1996; Grigg and Seebacher, 2000). Larriera *et al*. (1990) reported that temperature had a significant effect on BM and increased real food consumption but not nutritional efficiency (weight increase/ real consumption). They concluded that a temperature increase, when rearing *C. latirostris*, would produce a greater BM in a shorter period of time. Lang (1987) also reported better growth in crocodilians maintained at temperatures that induce increased food ingestion (Schulte and Chabreck, 1990).

FCRs in our study were more efficient at 33°C than at 29°C. The FCR found at 33°C was contrary to expectations. Temperature was expected to affect the metabolism of ectothermic caimans, in a similar way to that demonstrated by Coulson *et al*. (1996), where the metabolic costs to maintain the animals at higher temperatures was greater and, thus, resulted in a reduced effective FCR. However, Vianna *et al*. (1995a) found that at higher temperature, the FCR was more efficient for up to 60 days, which agrees with the present findings; when the experiment was extended to 120 days, it resulted in a less efficient FCR at the higher temperatures. The difference found by the latter authors between 60 and 120 days was possibly related to the negative relationship between body size and the efficiency in FCR (Joanen *et al*., 1987; Coulson *et al*., 1996).

More food was consistently required to increase the BM of the study groups at 29°C when compared to those maintained at 33°C. In fact, when the groups kept at 33°C in both years are compared with those at 29°C, the amount of dry food necessary for 1g increase in BM was found to be larger (2.3× in 2002 and 1.5× in 2000) than that needed for groups maintained at 29°C. As found by Coulson *et al*. (1996), the difference between years in the present study may relate to the fact that initial average BM of the animals used in 2002 was greater (88.3 ±4.34g) than those used in 2000 (66.9 ±3.13g).

Lang (1987) proposed that an increase in temperature would reduce the time required for an animal to process food, but according to the present study, the increased temperature (33°C) for 70 days also produced a more efficient FCR. An explanation for these results could be that temperature clearly has major effects on the dynamics of digestion and assimilation (Coulson *et al*., 1978; Coulson and Hernández, 1983), because increased body temperatures following feeding would augment stomach acid production (Lang, 1987), accelerating the digestion and allowing the animals to return to feed again, resulting in greater growth. Also, the increase of temperature could improve the amount of energy extracted from food, producing a more efficient FCR. However, extracted energy was not measured in the present experiment.

TABLE II
DRY FOOD CONSUMED (FC) BY TRAY, AND FOOD CONVERSION RATE (FCR) ACCORDING TO TEMPERATURE IN THE TWO YEARS OF THE STUDY, FOR TWO-MONTH-OLD *C. latirostris*

Variable	Raising temperature	2000	2002
FC	29°C	1673 (76.1; 2)	627.9 (70.4; 2*)
	33°C	1983.5 (14.7; 2)	815.5 (52.1; 3)
FCR	29°C	3.9 (0)	5.4 (0.35)
	33°C	2.6 (0.15)	2.3 (0.30)

FCR: dry food consumed/body mass increase by tray, during 70 in 2000 and 72 days in 2002.
Numbers in brackets for FC SD and sample sizes on which means are based, and for FCR indicate SE.
* excluding the highest FCR value (7.00) of one tray, the mean value is 5.45 ±0.35 (2 observations). This tray was removed in all the calculations.

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