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Feeding rates for bullfrogs with automated feed management and high feeding frequency

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SUMMARY

Three feeding rates (3, 4 and 5% of body weight/day - BW/day) with automated feed management and high feeding frequency (24 meals/day) for bullfrogs (*Lithobates catesbeianus*) under wet systems were evaluated in this 60-day experiment. Bullfrogs with an average weight of 31.91±0.97 g, were distributed into twelve 20 m^2 wet pens at a density of 60 frogs/m^2. Commercial extruded feed for carnivorous fish was supplied directly onto water surface by automatic feeders. At 20 and 40 days of the experiment, the best growth was observed in frogs treated with a feeding rate of 5% BW/day. The frogs reached an average weight of 100.2 g at the end of the experiment but there was no difference among the feeding rates. At the end of the experiment, feeding rates of 3, 4 and 5% BW/day resulted in apparent feed conversion values of 1.08, 1.56 and 1.52, respectively, which are considered excellent for frog rearing. Bullfrogs reared at ideal temperature and with an average weight of 31.9 to 87.6 g can be fed at a high feeding rate (5% BW/day) for a greater growth. When temperature is lower than 25°C, feeding rate of 3% BW/day could be considered the most suitable for bullfrog weighing from 87.6 to 100.2 g, because the feed conversion ratio was numerically better and reduced feed leftovers.

Taxas de alimentação para rã-touro com manejo alimentar automático e alta frequência alimentar

Palavras-chave adicionais

Alimentação automática.
Lithobates catesbeianus.
Sistema inundado.

RESUMO

Três taxas de alimentação (3, 4 e 5% do peso vivo/dia – PV/dia) com manejo alimentar automatizado e alta frequência alimentar (24 refeições/dia) para rã-touro (*Lithobates catesbeianus*) em sistema inundado foram avaliadas em 60 dias de experimento. Rãs-touro, com peso médio de 31,91±0,97 g, foram distribuídas em 12 baias inundadas de 20 m^2 com densidade de 60 rãs/m^2. Ração comercial extrusada para peixes carnívoros foi fornecida diretamente sobre a superfície da água por meio de alimentadores automáticos. O melhor crescimento das rãs, aos 20 e 40 dias de experimento, foi observado com as rãs alimentadas com taxa alimentar de 5% PV/dia, e ao final do experimento as rãs atingiram peso médio de 100,2 g, entretanto não houve diferença entre as taxas de alimentação. As taxas alimentares de 3, 4 e 5% PV/dia proporcionaram ao final do experimento conversão alimentar aparente de 1.08, 1.56 e 1.52, respectivamente, considerados excelente na criação de rãs. Rãs-touro criadas em temperatura ideal, com peso médio de 31,9 a 87,6 g, podem ser alimentadas com alta taxa alimentar (5% PV/dia) para maior crescimento. Quando a temperatura é menor que 25°C, a taxa alimentar de 3% PV/dia pode ser considerada mais adequada para rãs-touro pesando 87,6 a 100,2 g, pois apresentou taxa de conversão alimentar numericamente melhor, diminuindo os desperdícios de ração.

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INTRODUCTION

Feeding rate is an important factor in feed management of aquatic organisms since excessive feed supplying negatively affects productive performance and feed conversion ratio, and pollutes the environment due to the deterioration of feed leftovers, besides increasing feeding costs. On the other hand, insufficient feed provision results in decreased weight of animals (Barbosa *et al.*, 2005; Fenerick Jr and De Stéfani, 2005).

Temperature is a major influencing factor of daily feeding rate for bullfrogs (Lima and Agostinho, 1988). The development of this species is directly related to temperature as it influences the animal's metabolic activities, interfering in feed intake and use (Braga and Lima, 2001). In addition to varying

with temperature, the feeding rate varies according to the animals' age and average weight. According to Lima *et al*. (2003), feeding rate can range from 5.2% of body weight for young frogs (8 to 19 g) to 1.2% of body weight for frogs close to ideal slaughter size (210 to 230 g).

One of the major advantages of the wet system in which frogs are reared in inundated pens and feed is supplied directly on the water surface, is the elimination of fly larvae feeding (Mello, 1998). However, alongside advances reached with feed supplying on the water, some challenges have come up mainly regarding water quality in rearing pens. In this rearing system, the daily feed amount is divided into a few meals; therefore, a large feed amount is supplied on the water surface at each meal and the feed excess sinks due to the frogs' movement in the water, making it inaccessible for intake, and compromising the water quality and frogs' productive performance (Castro *et al*., 2012). According to Borges *et al*. (2012), frog production effluent can accelerate the eutrophication process of receiving water bodies, because of the ammonia and phosphorus concentrations from the fecal decomposition and unconsumed feed. The use of good feeding management practices that result in frogs' greater growth and lower feed waste can solve this deficiency in frog farming and ensure the production success and sustainability (Castro *et al*., 2014a).

Automatic feeding in frog farming contributes directly to the activity development because it enables feeding at predetermined feeding rates, contributes to a better control of the supplied feed amount, avoids waste, and also enables the use of high feeding frequency, which means smaller and more frequent feed amounts supplied throughout the day or night (Agostinho *et al*., 2010). These factors may influence feed utilization and animals' productive performance (Agostinho *et al*., 2011). Oliveira *et al*. (2009) evaluated the use of automatic feeders in bullfrogs' feeding management and observed that they are effective to stimulate feed intake by frogs, especially when the feed is released onto the water.

The use of high feeding frequency in bullfrog production improves growth and feed conversion ratio (Castro *et al*., 2012; Castro *et al*., 2014b). Moreover, it improves the animals' productive performance, reduces feed waste, and consequently causes less environmental pollution (Sousa *et al*., 2012). Some studies in fish production showed that it is possible to use higher feeding rates if the feed is distributed into more portions throughout the day (Silva *et al*., 2007; Trushenski *et al*., 2012; Oliveira *et al*., 2016). According to Silva *et al*. (2007), the feed amount at each meal is the main limiting growth factor, and the association of feeding rate with adequate feeding frequency has significant influence on the animals' productive performance. Thus, this study aimed to evaluate the effect of feeding rate using automated feeding management and high feeding frequency on bullfrogs' productive performance in wet system.

MATERIAL AND METHODS

Bullfrogs (*Lithobates catesbeianus*) with initial weight of 31.91±0.97 g were distributed in twelve 20-m^2 wet pens at a density of 60 frogs/m^2. The experiment had completely randomized design with evaluations of different feeding rates (3, 4 and 5% of BW/day) and four replications. The experiment was approved by the Ethics Committee on Animal Experimentation (CEEA – FMVZ/UNESP, registration No. 163/200).

The cleaning of the wet pens was done in the morning (8:00 to 11:30h) before feeding management started. After the cleaning, the wet pens were filled up with water until reaching the appropriate level according to the frogs' size and so that only the animals' heads were kept out of the water. The water temperature was monitored three times a day (8:00, 12:00 and 16:00h) during the experimental period.

The feeding management was carried out in the morning (12:00 to 18:00h), supplying the food directly onto the water surface. Thus, one automatic feeder (Agostinho *et al*., 2010), with a capacity of seven kilograms of feed, was positioned over the center of each wet pen. The automatic feeders enabled to control the functioning time and the feed amount to be supplied.

Commercial extruded feed for carnivorous fish was used to feed the frogs and, according to the manufacturer, it contained 40% crude protein, 10% lipid, 13% moisture, 4.5% crude fiber, 2.5% calcium and 1% phosphorus. Automatic feeders supplied feed at a frequency of 24 meals/day. The experiment lasted 60 days.

Biometrics was done every 20 days to monitor animals' growth. In each biometrics 100 frogs from each experimental unit were individually weighed. The productive performance was evaluated by the following parameters: average weight at 20, 40 and 60 days of experiment, weight gain, total weight gain, daily weight gain, apparent feed conversion ratio and survival.

The productive performance results were submitted to analysis of variance using the System of Statistical and Genetic Analysis - SAEG, and the averages were compared by Duncan's test ($p<0.05$).

RESULTS AND DISCUSSION

The ideal temperature for bullfrog rearing is between 25 and 30°C (Braga and Lima, 2001). In this study, the water temperature in the first experimental period (1 to 20 days) and second experimental period (21 to 40 days) was within the ideal range for bullfrog rearing (25.0 ± 5.4ºC); however, in the final experimental period (41 to 60 days), low temperatures were observed (22.5 ± 4.8ºC). According to Teodoro *et al*. (2005), bullfrogs decrease their feed intake at low temperatures.

Based on the frogs' average weight, the best growth ($p<0.05$) was observed for the highest feeding rate (5% BW/day) at 20 and 40 days of the experiment; and at 60 days there was no difference ($p>0.05$) among the treatments **(table I)**. For the feed conversion ratio, there was no difference ($p>0.05$) among the different feeding rates in all evaluated periods **(table I)**. The different

Table I. Average weight (AW) and apparent feed conversion ratio (FCR) of bullfrogs under wet systems fed for 60 days at different feeding rates (Peso médio (PM) e taxa de conversão alimentar aparente (CAA) de rãs-touro em sistema inundado alimentadas por 60 dias com diferentes taxas de alimentação).

Feeding rate (% of body weight/day)	1ª Biometry (20 day)		2ª Biometry (40 day)		3ª Biometry (60 day)	
	AW (g)	FCR	AW (g)	FCR	AW (g)	FCR
5	71.0[a]	0.64[a]	95.3[a]	1.12[a]	100.6[a]	1.52[a]
4	57.3[b]	1.03[a]	82.8[b]	1.23[a]	98.0[a]	1.56[a]
3	52.9[c]	1.10[a]	84.6[b]	0.80[a]	102.0[a]	1.08[a]
Average	60.4	0.92	87.6	1.05	100.2	1.39
CV (%)	38.53	53.41	30.75	26.92	27.83	26.41
p	0.00004	0.50652	0.00004	0.23735	0.13188	0.14804

*Averages values followed by different letters in the columns differ by Duncan test (p<0.05); CV= coefficient of variation; *p*, test value ANOVA single factor.

feeding rates did not affect (p>0.05) weight gain results (WG), daily weight gain (DWG), total weight gain (TWG) and survival (S) at the end of the experiment **(table II)**.

In the feeding table presented by Lima *et al*. (2003), the feeding rates of 3.2 and 2.5% BW/day are recommended for bullfrogs with average weight of 30 to 39 g and 40 to 109 g, respectively. In the present study, for frogs with average weight of 31.9 to 87.6 g, the best growth occurred at a higher feeding rate, 5% BW/day. It should be considered that the feeding management in this experiment was carried out at high feeding frequency (24 meals/day), which may have improved feed utilization, allowing the utilization of higher feeding rates. According to Oliveira *et al*. (2016), it is possible to increase feeding rate and obtain good results for feed conversion ratio with high frequency feed supplying.

When feeding is more frequent, that is, when feed is fractionated in small amounts and provided more times throughout the day, the animal can get better utilization (Sousa *et al*., 2012). According to Feder and Burggren (1992), the feeding pattern in amphibians may influence the time required for feed to pass through the whole digestive system (transit or passage time); frequent feeding probably stimulates the transport system more than infrequent feeding or a single meal. Wang *et al*. (1998) also points out that the greatest feed portioning throughout the day allows all animals the opportunity for feeding.

To calculate the feed amount to be offered daily, not only the animals' average weight must be considered, but also the feeding frequency and the temperature conditions. According to Figueiredo *et al*. (1999), temperature affects weight gain, growth, feed intake and feed conversion ratio in frogs. For average temperature of 25°C, Lima and Agostinho (1988) recommend feeding rate of 3 to 5% BW/day, and when the temperature varies from 18 to 25°C, the recommended feeding rate is from 2 to 3% BW/day. Therefore, until the 40th day of the experiment, the recorded temperatures were appropriate for frogs' growth and the feeding rate of 5% BW/day was enough to feed the animals; moreover, there were no great feed leftovers in the rearing pens. However, in the final period of the experiment, when the temperature decreased, the animals from all treatments reduced feed intake, and feed leftovers were found in several rearing pens. Therefore, in this period, feeding rates of 4 to 5% BW/day may have been excessive even with more frequent feed portions throughout the day, and the feeding rate of 3% BW/day was more appropriate.

If there had not been low temperatures in the final period of the experiment, it is likely that feeding rate of 5% BW/day supplied at high feeding frequency would have resulted in frogs' better productive performance throughout the experiment. According to Agostinho *et al*. (2011), the combination of the animals' weight and age with temperature variations makes automated feeding management more accurate. Therefore, further research is needed in bullfrog production to make feeding management more efficient, so that automatic feed supplying result in frogs' growth without generating feed waste. Therefore, feed provision should be done automatically according to temperature variations.

Barbosa *et al*. (2005) observed that very high feeding rates increase feed passage rate in the digestive tract, reducing digestion and assimilation, negatively influencing feed conversion ratio. Temperature also has great influence on the gastrointestinal transit time. In amphibians, as for most ectotherms, digestive rates increase with increasing temperature, whereas the time required for feed to pass through the gut decreases (Wells, 2007). Digestion is slower and more gradual at lower temperatures (Dias-Koberstein *et al*., 2005). Thus, in the final weeks of the experiment, the lowest feeding rate (3% BW/day) was more adequate, expressing a better value (numerically) for apparent feed conversion ratio when the temperature decreased **(table I)**. Therefore, it is suggested that automatic feeding management with high feeding frequency be carried out according to the temperature, especially for water temperature in the rearing pens, increasing feeding rates at increasing temperatures, and decreasing feeding rates when temperatures are lower in order not to provide feed in little amounts or in excess.

Table II. Average values of weight gain (WG), daily weight gain (DWG), total weight gain (TWG) and survival (S) of bullfrogs under wet systems fed for 60 days at different feeding rates (Valores médios de ganho de peso (GP), ganho de peso diário (GPD), ganho de peso total (GPT) e sobrevivência (S) de rãs-touro em sistema inundado alimentadas por 60 dias com diferentes taxas de alimentação).

Feeding rate (% of body weight/day)	WG (g)	DWG (g)	TWG (kg)	S (%)
5	59.10	1.05	62.80	90.0
4	56.40	1.06	63.70	92.3
3	63.40	1.08	64.90	87.0
Average	59.60	1.06	63.80	89.8
CV (%)	19.40	18.59	18.60	5.86
p	0.65638	0.93478	0.93427	0.37163

CV= coefficient of variation. p, test value ANOVA single factor.

In all periods (20, 40 and 60 days of experiment), the feed conversion results were excellent for bullfrog rearing, with average values of 1.52; 1.56 and 1.08 for feeding rates of 5, 4 and 3% BW/day at 60 day, respectively **(table I)**. According to Castro *et al*. (2014a), good results for feed conversion ratio imply in better feed use for animals with less wasted feed, reducing production costs and waste in the aquatic environment. Similar results were observed by Oliveira *et al*. (2009) in a study with bullfrogs with initial average weight of 32 g and providing the feed by automatic feeders directly onto the water, as in wet system. The authors observed average feed conversion ratio of 1.50 at end of 104 days of rearing, keeping water temperature at 27°C. In one of the first tests with frog rearing in wet system, Mello (2000) observed average feed conversion ratio of 1.50 for frogs with average initial weight of 24.75 g and rearing for 85 days at temperatures ranging from 18 to 30°C.

The average daily weight gain (DWG) at the end of the experiment was 1.06 g, considering all the treatments. The low temperatures recorded in the final experimental period probably influenced the animals' weight gain in all treatments due to lower food intake. In the growth phase, Braga and Lima (2001) evaluated the temperature effect on the productive performance of bullfrogs with an initial average weight of 35.7 g, and found a mean value of 0.93 g DWG at 20°C and 1.5 g at 25 and 30°C in pens similar to "amphifarm" system. Lima *et al*. (2003) monitored frog rearing in the growth phase of three commercial frog farms in "amphifarm" system, and they observed DWG values ranging from 0.4 to 2.2 g, and averages of 0.9 g, 1.2 and 1.4 g for the frog farms with average water temperatures of 20, 24 and 25°C, respectively.

The survival rate observed in the present study was satisfactory for frog rearing in a wet system. Regardless of the utilized feeding rate, the survival rate reached an average value of 89.8% **(table II)**. Castro *et al*. (2012) observed average survival rate of 90.3% for bullfrogs in wet system with automated feeding management and use of stocking density of 60 frogs/m^2, as in the present study, while water temperature ranged from 20.5 and 27.2°C. In a study with bullfrogs in a wet system, Mello (2000) observed survival rate of 62.6% for frogs in a wet system utilizing manual feeding management and high stocking density (initial 226 frogs/m^2 and final 116 frogs/m^2).

In this experiment, the use of automatic feeders was efficient for bullfrogs' feeding at high frequency and at different feeding rates. This result agrees with the ones by Oliveira *et al*. (2009), Sousa *et al*., (2010) and Castro *et al*. (2014b), who used automatic feeders in bullfrogs' feeding management at predetermined frequencies, periods and feeding rates, contributing to improve the frogs' productive performance.

CONCLUSION

Bullfrogs, with average weight of 31.9 to 87.6 g, in a wet system with automatic feeding at high feeding frequency (24 meals/day), under the conditions of this experiment, can be fed with high feeding rate (5% BW/day). Under ideal temperature conditions, there is greater growth with good results for feed conversion ratio. For the weight range of 87.6 to 100.2 g, at low temperatures, the feeding rate of 3% BW/day is the most appropriate as it provides better feed conversion ratio.

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