Brazilian Species 28

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Introduction

Brazilian territory comprises several freshwater hydrographic basins which hold many native fish species with aquaculture potential. Four species have been selected for this review based on information available on nutritional requirements, feeding management practices, current production and market preferences. They are the omnivorous tambaqui (*Colossoma macropomum*) and pacu (*Piaractus mesopotamicus*, former *Colossoma mitrei*), both characins native to the Amazon (northern Brazil) and Prata (western-central Brazil) river basins, respectively, and the carnivores peacock bass (*Cichla* sp.) and pintado (*Pseudoplatystoma coruscans*). Peacock bass is a cichlid native to the Amazon basin and pintado is a silurid native to the Prata and São Francisco (north-eastern Brazil) river basins. Despite the increased interest in raising Brazilian freshwater native species in the past 20 years, the available information on their nutritional requirements and feeding practices is still scarce. A significant amount of information included in this chapter was retrieved from theses or dissertations, developed at Brazilian universities or freshwater fish research centres, thus having limited distribution. Most of the studies reviewed here were performed using practical-type diets, which can confound results due to uncontrollable variables and nutrient interactions. Additionally, the nutritional contribution of natural food in the pond studies was seldom accounted for. This could also lead to confounding results since some species, such as tambaqui, have numerous fine and long gill rakers, which enable them to efficiently consume food organisms besides the experimental diet.

Nutritional Requirements

Protein and energy

Pintado fingerlings, averaging 25.1 g, were fed practical-type diets containing 30, 36, 42 or 48% crude protein (CP) and two dietary digestible energy (DE) concentrations of 3500 and 4000 kcal kg^{-1} for 90 days. Highest weight gain and protein efficiency ratio (PER) were obtained for the fish fed the 30% CP with a DE of 4000 kcal kg^{-1} (Machado, 1999). However, at the lower dietary energy level (3500 kcal kg^{-1}), the optimum dietary CP concentration for best performance was 36%. Based on this information, good performance was obtained with diets containing a CP-to-DE ratio (CP/DE) of 75–102 mg $kcal^{-1}$. In a similar study, 10 g peacock-bass fingerlings were fed diets containing 30, 33, 37 or 41% CP and 3500 kcal DE kg^{-1} for 65 days. For this carnivorous species, highest weight gain and feed efficiency were observed when diets had a CP/DE between 105.7 and 117.1 mg $kcal^{-1}$ (Sampaio *et al.*, 2000).

Results of studies on the dietary protein and energy requirement for tambaqui are summarized in Table 28.1. The dietary CP-to-energy (DE or gross energy (GE)) ratios were not given, but they were calculated in an attempt to define a requirement range. The ratio that promoted the best performance for tambaqui was between 79 and 89 mg protein $kcal^{-1}$ of DE or GE. Optimum dietary protein and energy concentration varied from 24 to 50% and from 2700 to 4660 kcal kg^{-1}, respectively. However, Macedo (1979) reported a lower dietary protein requirement for tambaqui. She observed that 5 g fish had the highest weight gain when fed diets containing 22–26% CP, while there was no difference in weight gain among 18 g fish fed dietary protein levels of 18, 22 or 26%. However, Eckmann (1987) pointed out that the growth rate of fish in Macedo's study was far below the maximum growth rate of the species. Tambaqui showed that the highest growth rates when 100 or 75% of the dietary

Table 28.1. Dietary protein and energy requirements of different sizes of tambaqui.

Crude protein (%)	Energy* (kcal kg^{-1})	Fish initial weight (g)	Reference
18	3200 GE	18	Macedo (1979)
22	3200 GE	5	Macedo (1979)
24	3300 DE	30.2	Camargo *et al.* (1998)
25	3100 GE	37.5	Vidal *et al.* (1998)
30	2700 DE	30	Merola and Cantelmo (1987)
31	3800 DE	0.5	Hernández *et al.* (1995)
37	4660 GE	–	Eckmann (1987)
40	4613 GE	125	Van der Meer *et al.* (1995)
40	4493 GE	50	Van der Meer *et al.* (1995)
50	4589 GE	5	Van der Meer *et al.* (1995)

* DE = digestible energy (estimated or measured) or GE = gross energy.

protein originated from plant sources in a 30% CP diet (Werder and Saint-Paul, 1979).

Dietary CP and energy concentration for pacu ranged from 26 to 36% and 2600 to 4200 kcal kg^{-1}, respectively (Table 28.2). The optimum range of the dietary protein-to-energy (DE or GE) ratio, calculated by the author (D.M. Fracalossi, unpublished), which promoted best performance of pacu was 72–109 mg $kcal^{-1}$. Lower protein-to-energy ratios were found in two studies (Carneiro *et al.*, 1992a; Fernandes, 1998). The reasons for such a discrepancy are not clear but could be linked to an underestimation of protein intake in at least one of the studies (Carneiro *et al.*, 1992a), since the experiment was carried out in outdoor ponds for 1 year and natural pond food could have contributed to the protein requirement of the fish. Apparent net protein utilization (ANPU) by pacu fingerlings was high when the dietary DE concentration was 3000 kcal kg^{-1} in a 26% CP diet, although the highest weight gain was obtained with a dietary DE concentration of 2600 kcal kg^{-1} (Cantelmo, 1993). Pacu showed a 15% weight-gain increase when fed diets containing a mixture of meat meal, fish-meal and soybean meal, compared with diets containing only soybean meal (Borguetti *et al.*, 1991).

Lipids and carbohydrates

Hernández *et al.* (1995) found that carbohydrates seemed to be as effective as lipids as dietary energy sources for 0.5 g tambaqui fingerlings. At dietary protein concentrations of 11–48%, feed efficiency and protein efficiency ratio (PER) were similar for carbohydrate and lipid energy sources. Similarly, Gunther (1996) concluded that tambaqui can efficiently use dietary carbohydrates and that best growth and protein utilization were obtained with a diet containing 38% carbohydrate and 11% lipid. Van der Meer *et al.* (1997a), however, found that growth and ANPU increased with increasing dietary lipid from 5 to 20% in either 20 or 40% protein diets. Tambaqui fingerlings (14 g average weight) showed

Table 28.2. Dietary protein and energy requirements of different sizes of pacu.

Crude protein (%)	Energy* (kcal kg^{-1})	Fish initial weight (g)	Reference
22	4200 GE	112.1	Fernandes (1998)
22	4000 GE	240	Carneiro *et al.* (1992b)
23	3200 DE	200	Carneiro (1983)
26	4200 GE	7.9	Fernandes (1998)
26	3000 DE	39	Carneiro (1983)
26	2600 DE	27	Cantelmo (1993)
30	3600 DE	28	Carneiro (1990)
35	3225 DE	44.5	Borghetti *et al.* (1991)
36	3300 DE	22.2	Brener (1988)

* DE = digestible energy (estimated or measured) or GE = gross energy.

the highest weight gain when fed 6% lipid diets containing either maize oil or a mixture containing high concentration (3% or more) of palm (*Elaies guineensis*) oil and deodorization distillates of soybean oil (a by-product of soybean-oil extraction) as the dietary lipid sources (Viegas and Guzman, 1998). Despite the wide variation of the saturated-to-unsaturated fatty acid ratio in the diets (0.27 to 0.62), fish maintained a fairly steady saturated-to-unsaturated fatty acid ratio both in the whole body and in the fillet (0.61 to 0.69) except with the maize-oil diet. This indicates that tambaqui can use dietary saturated-fat sources, such as palm oil, without affecting its fatty acid composition.

Visceral lipid deposition of juvenile pacu increased with increasing dietary lipid concentrations from 8% to 24% of either lard or soybean oil (Pezzato, 1990). However, 8% of saturated fat (lard) in the diet promoted a higher visceral fat accumulation than the 24% soybean-oil diet. Additionally, it was demonstrated that young pacu can synthesize *de novo* medium-chain saturated and monoenoic fatty acids from their short-chain precursors. Alves (1999) reported that pacu fingerlings exhibited better weight gain, PER and ANPU when fed a 26% protein diet containing 7% lipid instead of 5 or 9% lipid. A dietary crude-fibre concentration of 16% promoted higher weight gain and feed conversion in 45 g pacu fingerlings than diets containing 4, 8 or 12% crude fibre among practical diets containing 30% CP and 3000 kcal DE (Zanoni, 1996). Feed consumption, PER and carcass composition, however, were not affected by crude-fibre concentrations.

Feeding Practices

Peacock bass fingerlings, conditioned to accept ground fish flesh (GF), were tentatively weaned from GF to dry pellets using gradual feed ingredient transition (GFIT) (Moura *et al.*, 2000). The fish, 0.5 g in weight, were fed a series of diets containing from 90% to 40% GF for 3 days. During that period, approximately 80% of the fish accepted the diet containing 40% GF. These fish were pooled and weaned to a 10% GF diet for the next 3 days with a series of diets containing from 30% to 10% GF combined with a fish-flavoured extruded commercial diet. In another study, 3.9 g pintado were initially trained to accept ground bovine heart, followed by a mixture of ground bovine heart and dry diet in different proportions until only dry diet was accepted (Machado *et al.*, 1998). After 84 days, fish showed a survival rate of 78.4%. Pintado larvae, 6.4 mm in length, were fed diets containing bovine heart, ground sardine and a mixture of bovine heart and ground sardine, four times a day (Oliveira *et al.*, 1998). All diets were supplemented with vitamin C, oxytetracycline and vitamin and mineral premixes; fish also received zooplankton twice a day. At the end of the 15-day weaning period, larval survival was 45%, 34% and 20% when fed the bovine heart, sardine and a mixture of the two, respectively. Hayashi *et al.* (1999) tested different fresh food items for weaning 0.18 g pintado fingerlings from fresh food to a 48% CP dry diet. Ground earthworm and ground bovine liver promoted higher weight gain than ground bovine heart and ground sardine, while survival rate

was not affected by diet, during a 12-day weaning period. Fernandes *et al.* (1998) reported that small pintado fingerlings averaging 0.67 g had better growth (1.49 g against 0.89 g) and survival (82.5% against 65%) when fed moist rather than dry diets.

Van der Meer *et al.* (1997b) reported that feed consumption of tambaqui fingerlings, 0.87 g average weight, was lower at 0700 than at 1900 h. The authors suggested that growth and diet uptake could be improved by extending the feeding period after 1900 h. The feeding frequencies tested ranged from one to five meals per day and intervals between meals from 3 h to 24 h. Higher growth rate and diet intake and lower feed utilization efficiency were observed with higher feeding frequencies.

The optimum diet particle sizes for pacu and tambaqui fingerlings were determined by Cantelmo and Ribeiro (1994) and are summarized in Table 28.3. Pacu fingerlings, 1.5 g initial weight, were stocked in outdoor ponds at a density of 0.7 fish m^{-2} and subjected to three feeding regimes: complete diet (26% CP at 5% body weight), supplemental diet (30% CP at 3% body weight) plus pig manure or supplemental diet (30% CP at 2.5% body weight) plus agricultural by-products (Barros *et al.*, 1994). Weight gain was not affected by dietary treatment after 10 months of feeding, suggesting that either pacu can efficiently utilize agricultural by-products and manure or that pacu can benefit indirectly from the addition of these ingredients into the pond through an increase in the production of natural foods. However, Bernardino and Ferrari (1986) reported that monthly bovine-manure or inorganic pond fertilization improved weight gain of tambaqui fingerlings (average weight 8.2 g) by 13.2% and 13.8%, respectively, when compared with feeding only a 30% protein diet, after 1 year of feeding. Juvenile pacu, 102 g average weight, were stocked in outdoor ponds at a density of 1 fish m^{-2} and were fed the same diet in three different forms, namely meal, pelleted or extruded, for 1 year (Carneiro *et al.*, 1992b). Fish showed higher weight gain and PER and lower feed conversion when fed the extruded diet during the warmer

Table 28.3. Recomended feed particle sizes for various stages of pacu and tambaqui (adapted from Cantelmo and Ribeiro, 1994).

	Fish		Particle size (mm)	
Species	Standard length (cm)	Mouth size (mm)	Min.	Max.
Pacu	1.6	1.92	0.35	0.42
	2.1	2.52	0.50	0.71
	3.1	3.72	0.71	1.00
	4.1	4.92	1.00	1.41
	4.5	5.40	1.00	1.41
Tambaqui	1.00	1.2	–	0.25
	1.34	1.6	–	0.25
	1.93	2.31	0.35	0.42
	2.85	3.42	1.00	1.41

season. During the cooler season, however, fish showed better performance when fed the pelleted (sinking) diet.

Borguetti and Canzi (1993) tested three feeding rates for juvenile pacu, average weight 95 g. Fish were stocked in cages at a density of 1.4 kg m^{-3} and fed the same diet (35% CP and 3225 kcal energy kg^{-1}) for approximately 8 months. Optimum feeding rate varied depending on water temperature: 1% body weight day^{-1} was sufficient for growth at a water temperature of 19–20°C, while 3% and 5% body weight day^{-1} were better at 24°C and 27–30°C, respectively.

References

Alves, J.M.C. (1999) Níveis de lipídios em dietas para o crescimento inicial do pacu, *Piaractus mesopotamicus* (Holmberg, 1887). MSc thesis, Universidade Estadual Paulista, Jaboticabal, Brazil.

Barros, M.M., Pezzato, L.E., del Carratore, C.R., Oliveira, M.C.B. and Salaro, A.L. (1994) Alevinos de pacu (*Piaractus mesopotamicus*) submetidos a diferentes manejos nutricionais. In: *Resumos do VIII Simpósio da Associação Brasileira de Aquicultura*. Associação Brasileira de Aquicultura, Piracicaba, p. 42.

Bernardino, G. and Ferrari, V.A. (1986) Efeitos da fertilização na produção de pacu *Colossoma mitrei* alimentado com ração. In: *Síntese dos Trabalhos Realizados com Espécies do Gênero* Colossoma. Centro de Pesquisa e Treinamento em Aquicultura, Pirassununga, p. 18.

Borghetti, J.R. and Canzi, C. (1993) The effect of water temperature and feeding rate on the growth rate of pacu (*Piaractus mesopotamicus*) raised in cages. *Aquaculture* 114, 93–101.

Borghetti, J.R., de Lepeleire, R.E.M. and Fernandez, D.R. (1991) Efeitos da origem da proteína no crescimento do pacu. *Revista Brasileira de Biologia* 51, 689–694.

Brener, M. (1988) Determinação da exigência de proteína do pacu (*Colossoma mitrei*, Berg, 1895). MSc thesis, Universidade Federal de Viçosa, Viçosa, Brazil.

Camargo, A.C.da S., Vidal, M.V. Jr, Donzele, J.L., de Andrade, D.R. and dos Santos, L.C. (1998) Níveis de energia metabolizável para tambaqui (*Colossoma macropomum*) dos 30 aos 180 gramas de peso vivo. 1. Composição das carcaças. *Revista da Sociedade Brasileira de Zootecnia* 27, 409–415.

Cantelmo, O.A. (1993) Níveis de proteína e energia em dietas para o crescimento do pacu *Piaractus mesopotamicus* (Holmberg, 1887). MSc thesis, Universidade Federal de Santa Catarina, Florianópolis, Brazil.

Cantelmo, O.A. and Ribeiro, M.A.R. (1994) Determinação do tamanho de partícula alimentar para o pacu *Piaractus mesopotamicus* Holmberg 1887 e tambaqui *Colossoma macropomum* Cuvier, 1818, no estágio de alevino. *Boletim Técnico do CEPTA* 7, 9–17.

Carneiro, D.J. (1983) Níveis de proteína e energia na alimentação do pacu, *Colossoma mitrei* (Berg, 1895). MSc thesis, Universidade Estadual Paulista, Jaboticabal, Brazil.

Carneiro, D.J. (1990) Efeito da temperatura na exigência de proteína e energia em dietas para alevinos de pacu, *Piaractus mesopotamicus* (Holmberg, 1887). PhD dissertation, Universidade Federal de São Carlos, São Carlos, Brazil.

Carneiro, D.J., Chaim, S.H.S. and Dias, T.C.R. (1992a) Efeito do processamento das dietas comerciais sobre o desenvolvimento produtivo de pacu, *Piaractus mesopotamicus*,

(Holmberg, 1887). In: *Anais do VII Simpósio da Associação Brasileira de Aquicultura*. Associação Brasileira de Aquicultura, Peruíbe, pp. 44–51.

Carneiro, D.J., Wagner, P.M. and Dias, T.C.R. (1992b) Efeito da densidade de estocagem e do nível de proteína bruta dietário no desempenho de produção do pacu (*Piaractus mesopotamicus*). In: *Anais do VII Simpósio da Associação Brasileira de Aquicultura*. Associação Brasileira de Aquicultura, Peruíbe, pp. 52–61.

Eckmann, R. (1987) Growth and body composition of juvenile *Colossoma macropomum* Cuvier 1818 (Characoidei) feeding on artificial diets. *Aquaculture* 64, 293–303.

Fernandes, E.B., Oliveira, C.Z.C., Oliveira, M.C.P., Carrazza, L.R., Senhorini, J.A. and Cecarelli, P.S. (1998) Desenvolvimento de alevinos de pintado, *Pseudoplatystoma coruscans*, (Agassiz, 1829), mediante alimentação artificial. In: *Book of Abstracts of the Aquicultura Brasil '98*. Associação Brasileira de Aquicultura/World Aquaculture Society, Recife, p. 59.

Fernandes, J.B.K. (1998) Fontes e níveis de proteína bruta em dietas para alevinos e juvenis de pacu, *Piaractus mesopotamicus* (Holmberg, 1887). PhD dissertation, Universidade Estadual Paulista, Jaboticabal, Brazil.

Gunther, J. (1996) Growth of tambaqui (*Colossoma macropomum*) juveniles at different carbohydrate–lipid ratios. *Journal of Aquaculture in the Tropics* 11, 105–112.

Hayashi, C., Gonçalves, G.S., Furuya, V.R.B., Nagae, M.Y. and Soares, C.M. (1999) Utilização de diferentes alimentos durante o treinamento alimentar de alevinos de pintado (*Pseudoplatystoma corruscans*) (Agassiz, 1829). In: *Proceedings of the Acuicultura '99*. Sociedade Venezolana de Acuicultura/World Aquaculture Society, Puerto La Cruz, pp. 258–267.

Hernández, M., Takeuchi, T. and Watanabe, T. (1995) Effect of dietary energy sources on the utilization of protein by *Colossoma macropomum* fingerlings. *Fisheries Science* 61, 507–511.

Macedo, E.M. (1979) Nível proteico ideal na nutrição do tambaqui, *Colossoma macropomum* Cuvier 1818 (Pisces, Characidae). MSc thesis, Universidade Estadual Paulista, Jaboticabal, Brazil.

Machado, J.H. (1999) Desempenho produtivo de juvenis de pintado (*Pseudoplatystoma coruscans*), arraçoados com diferentes níveis de proteína e energia. MSc thesis, Universidade Estadual Paulista, Ilha Solteira, Brazil.

Machado, J.H., del Carratore, C.R., Garossino, A.P.R., Mazeto, M.D. and Grechi, F.C.S. (1998) Treinamento alimentar para a aceitação de rações artificiais em alevinos de pintado (*Pseudoplatystoma coruscans*). In: *Proceedings of the Aquicultura Brasil '98*. Vol. 2. Associação Brasileira de Aquicultura/World Aquaculture Society, Recife, pp. 101–108.

Merola, N. and Cantelmo, O.A. (1987) Growth, feed conversion and mortality of cage-reared tambaqui, *Colossoma macropomum*, fed various dietary feeding regimes and protein levels. *Aquaculture* 66, 223–233.

Moura, M.A.M., Lovshin, L.L., Kubitza, F. and Cyrino, J.E.P. (2000) Feed training of peacock bass *Cichla* sp. *Revista Brasileira de Biologia* 60(4), 645–654.

Oliveira, M.C.P., Oliveira, C.Z.C., Fernandes, E.B., Carrazza, L.R., Senhorini, J.A. and Cecarelli, P.S. (1998) Efeito de diferentes fontes de alimento no desenvolvimento larval de pintado, *Pseudoplatystoma coruscans*, (Agassiz, 1829). In: *Book of Abstracts of the Aquicultura Brasil '98*. Vol. 2. Associação Brasileira de Aquicultura/World Aquaculture Society, Recife, p. 5.

Pezzato, L.E. (1990) Efeito de diferentes níveis de gordura de origem animal e vegetal sobre o desempenho e deposição de ácidos graxos em pacu (*Piaractus mesopotamicus*). PhD dissertation, Universidade Estadual Paulista, Jaboticabal, Brazil.

Sampaio, A.M.B. de M., Kubitza, F. and Cyrino, J.E.P. (2000) Relação proteína : energia na nutrição do tucunaré *Cichla* sp. *Scientia Agricola* 57(2), 213–219.

Van der Meer, M.B., Machiels, M.A.M. and Verdegem, M.C.J. (1995) The effect of dietary protein level on growth, protein utilization and body composition of *Colossoma macropomum* (Cuvier). *Aquaculture Research* 26, 901–909.

Van der Meer, M.B., Zamora, J.E. and Verdegem, M.C.J. (1997a) Effect of dietary lipid level on protein utilizaton and the size and proximate composition of body compartments of *Colossoma macropomum* (Cuvier). *Aquaculture Research* 28, 405–417.

Van der Meer, M.B., Van Herwaarden, H. and Verdegem, M.C.J. (1997b) Effect of number of meals and frequency of feeding on voluntary feed intake of *Colossoma macropomum* (Cuvier). *Aquaculture Research* 28, 419–432.

Vidal, M.V., Donzele, J.L., Camargo, A.C.da S., de Andrade, D.R. and dos Santos, L.C. (1998) Níveis de proteína bruta para tambaqui (*Colossoma macropomum*), na fase de 30 a 250 gramas. 1. Desempenho dos tambaquis. *Revista da Sociedade Brasileira de Zootecnia* 27, 421–426.

Viegas, E.M.M. and Guzman, E.C. (1998) Effect of sources and levels of dietary lipids on growth, body composition, and fatty acids of the tambaqui (*Colossoma macropomum*). *World Aquaculture* 29, 66–70.

Werder, U. and Saint-Paul, U. (1979) Experiência de alimentação com tambaqui (*Colossoma macropomum*), pacu (*Mylossoma* sp.), jaraqui (*Semaprochilodus theraponura*) e matrinchã (*Brycon melanopterus*). *Acta Amazonica* 9, 617–619.

Zanoni, M.A. (1996) Níveis de fibra bruta em dietas de crescimento do pacu (*Piaractus mesopotamicus*) Holmberg, 1887. MSc thesis, Universidade Federal de Santa Catarina, Florianópolis, Brazil.