Notas Científicas

Apparent digestibility of ingredients in diets for *Salminus brasiliensis*

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Abstract – The objective of this work was to determine the nutritional value of different protein sources for "dourado" (*Salminus brasiliensis*). Thirty juveniles per group (33.51±1.4 g) were hand fed on a reference diet (70%) added of tested ingredients (30%) and chromium oxide III (0.1%). Apparent digestibility coefficients of the gross energy (ADC_{GE}), crude protein (ADC_{CP}) and amino acids of the tested ingredients were evaluated. Corn gluten meal yielded the best results for ADC_{GE} and ADC_{CP} (95.7 and 96.9%, respectively) amongst plant ingredients. Spray-dried blood meal yielded the best values of ADC_{GE} and ADC_{CP} amongst animal ingredients (94.1 and 96.3%, respectively). Wheat bran yielded poorest ADCs coefficients (77 for ADC_{GE} and 88.2% for ADC_{CP}).

Index terms: aquaculture, biologic value, digestible energy, digestible protein, nutritive value.

Digestibilidade aparente de ingredientes em dietas para *Salminus brasiliensis*

Resumo – O objetivo deste trabalho foi determinar o valor nutricional de diferentes fontes protéicas para o Dourado (*Salminus brasiliensis*). Trinta juvenis por grupo (33,51±1,4 g) foram alimentados *ad libitum* com ração referência (70%) mais ingredientes-teste (30%) e marcador de óxido de cromo III (0,1%). Foram determinados os coeficientes de digestibilidade aparente da energia bruta (CDA_{EB}), proteína bruta (CDA_{PB}) e aminoácidos. Entre os ingredientes de origem vegetal, a glutenose apresentou os melhores resultados para CDA_{EB} e CDA_{PB} (95,7 e 96,9%, respectivamente). A farinha de sangue se destacou entre os ingredientes de origem animal (94,1 e 96,3%, respectivamente). O farelo de trigo apresentou menor digestibilidade entre todos, 77% para CDA_{EB} e 88,2% para CDA_{PB}.

Termos para indexação: aqüicultura, valor biológico, energia digestível, proteína digestível, valor nutritivo.

The growth of aquaculture industry, associated to the use of intensive production strategies, requires high-quality ingredients to allow the formulation of diets of high nutritional value, economically viable and environmentally correct, aiming at maximizing fish production and minimizing environmental impact. As for any animal production, food comprises 40–60% of the operational costs in fish farming (Cheng et al., 2003).

Some feedstuffs, considered excellent nutrients sources based on their chemical composition, can otherwise be of little biological value, hence they can not be well digested and absorbed by animals. Therefore, the determination of digestibility coefficients of feed ingredients provides a more precise evaluation of their value as energy and protein sources in the formulation of balanced fish feeds (Furuya et al., 2001).

Dietary protein sources differ regarding their nutritional and biological values. The biological value of a protein varies with its composition in amino acids and digestibility. Deficiency or low availability of a single essential amino acid in a given protein source limits its use in animal diets and reduces animals' growth (Anderson et al., 1995).

The "dourado", *Salminus brasiliensis*, a golden-yellow, carnivorous, diurnal, neotropical characiform species is the largest scale fish of the Plata Basin. Recent studies have been conducted on the species ecology (Esteves & Lôbo, 2001), reproduction and hatchery (Mai & Zaniboni Filho, 2005; Vega-Orellana et al., 2006), and farming (Fracalossi et al., 2004). However, little is known about the biological value of food sources and protein and amino acid requirements of "dourado".

The objective of this work was to determine apparent digestibility coefficients of energy, protein and amino acids of feedstuffs ordinarily used in the formulation of diets for the "dourado".

The experiment was conducted at Laboratório de Nutrição de Peixes, Departamento de Zootecnia, Escola Superior de Agricultura Luiz de Queiroz, Piracicaba, SP, Brazil (22°42'S; 47°38'W; altitude 546 m). Groups of "dourado" juveniles (33.51±1.4 g; n = 30) were randomly distributed in 60 L, cylindrical plastic cages, housed in circular fiberglass tanks (1,000 L) with continuous water supply (8 L min^{-1}) in closed, biological-filtered circulation system, with controlled temperature (25±2ºC) and photoperiod (12 light/dark hours). Water quality parameters – temperature (25±2ºC), dissolved oxygen (5.1 mg L^{-1}) and pH (6.7±0.3) – were monitored daily and remained within the recommended range for tropical fish (Neill & Bryan, 1991).

The experiment lasted 39 days. Fish were hand-fed to apparent satiety in four daily meals for seven days with the reference, fish meal-based diet (45.19% crude protein, 4,491 kcal kg^{-1} gross energy). After that, fish were fed to apparent satiety with test diets combining 70% of the reference diet (RD) and 30% of test different animal or plant ingredients, added of 0.1% chromium oxide III (Cr_2O_3) as inert marker. Three-day intervals were observed before changing the test ingredients.

Percent composition and aminograms of the tested ingredients – fish meal (FM), meat and bone meal (MBM), spray-dried blood meal (S-DBM), poultry by-products meal (PBM), corn gluten meal (CGM), soybean meal (SBM), corn meal (CME) and wheat bran (WBR) – are presented in Table 1. Ingredient particles were homogenized to 0.5 mm before mixing to the reference diet. After additions of soybean oil and water (20%), the different, combined feeds were granulated in 3 mm die matrix and dried in forced-air circulation oven (55ºC) for 24 hours.

One hour after the last daily meal, fish were transferred to cylindrical-conical aquariums, aerated with partial water exchange in the upper portion (Portz & Cyrino, 2004). Three aquaria were used for each test diet, each containing 15 fish. At the end of each collection period, samples of feces were collected from each aquarium. Feces were collected overnight (6 pm to 6 am) by sedimentation in cooled containers (n = 3). Feces samples were combined for analysis.

Table 1. Percent composition and aminograms[1] of the test ingredients: fish meal (FM), meat and bone meal (MBM), spray-dried blood meal (S-DBM), poultry by-products meal (PBM), corn gluten meal (CGM), soybean meal (SBM), corn meal (CME) and wheat bran (WBR).

Contents	FM	MBM	S-DBM	PBM	CGM	SBM	CME	WBR
					(%)			
Dry matter	95.19	95.52	92.80	95.74	92.73	91.06	89.62	88.87
Crude protein	69.16	46.41	90.50	67.93	64.07	47.37	8.47	15.27
Lipids	5.85	11.10	0.42	13.63	3.79	1.38	3.46	3.37
Crude fiber	0.70	1.28	0.34	1.56	1.03	5.92	1.95	8.97
Ash	20.86	33.99	3.26	5.91	2.07	6.64	1.28	5.16
				Essential amino acids				
Arginine	4.395	3.561	3.969	4.781	1.996	3.709	0.519	1.132
Phenylalanine	2.411	1.567	7.002	2.460	4.031	2.592	0.461	0.688
Histidine	1.489	0.795	6.075	1.404	1.310	1.321	0.287	0.445
Isoleucine	2.456	1.248	0.735	2.464	2.588	2.337	0.32	0.529
Leucine	4.547	2.888	14.89	4.885	13.000	4.146	1.044	1.069
Lysine	4.747	2.590	10.62	4.563	0.951	3.240	0.356	0.727
Methionine	1.749	0.647	1.39	1.363	1.373	0.709	0.214	0.280
Methionine + Cystine	2.183	0.989	2.151	2.012	2.436	1.425	0.413	0.634
Threonine	2.784	1.540	5.266	2.619	2.171	2.026	0.362	0.585
Valine	3.121	2.069	9.503	3.077	3.011	2.424	0.443	0.756
				Non-essential amino acids				
Aspartic acid	6.135	3.603	10.93	5.736	3.994	6.137	0.680	1.200
Glutamic acid	8.754	5.719	8.906	9.195	14.81	9.469	1.625	3.332
Alanine	5.584	4.561	11.25	5.364	7.227	2.379	0.649	0.821
Cystine	0.435	0.342	0.761	0.649	1.063	0.716	0.199	0.353
Glycine	9.221	10.400	4.718	9.096	1.729	2.338	0.407	0.906
Serine	2.931	1.976	6.000	2.863	3.595	2.756	0.469	0.764
Tyrosine	1.961	1.038	2.960	2.016	3.188	1.753	0.329	0.465

[1]Dry matter basis.

Collected fecal material was stored in freezer (-10ºC) for chemical analyses, according to Association of Official Analytical Chemists (1995). Digestibility coefficients (%) of dietary dry matter of reference, test diets and ingredients were calculated according to Lovell (1998). Both RD and the test diet (TD) were consumed regularly by the fish all along the experimental period.

ADCs of energy of ingredients of animal origin were all higher than 90%, CGM stood out at 96%. ADC of energy of plant ingredients ranged between 77% (wheat bran) and 95% (corn gluten meal). Corn gluten meal yielded the highest absolute value of apparent digestible energy (ADE) (5,188 kcal kg^{-1}), and CME, the smallest (3,214 kcal kg^{-1}). ADC of protein of S-DBM (96%) and CGM (97%) stood above the mean ADC value concerning all protein sources (92%), contrasting with the MBM and WBR, which presented the lowest, and similar value of ADC of protein (88%) (Table 2).

ADC of protein reported by Portz & Cyrino (2004) for SBM (94.3%) and CGM (93.6%) relative to the largemouth bass *Micropterus salmoides* were similar to values of the present work; however, smaller ADCs were registered for FM (87.7%) and PBM (81.5%). ADCs of energy found for FM (78.3%), PBM (85.2%), SBM (75.4%), and CGM (76.5%) for largemouth bass were comparatively smaller than those of the "dourado".

The present work indicates that S-DBM and CGM are excellent protein sources for balanced carnivorous fish feeds. Still, restrictions regarding palatability – attractiveness of feeds – and possible alteration of flesh coloration of fillet also have to be considered to define maximum inclusion levels of these feedstuffs as substitutes for FM in commercial aquafeeds formulations.

Table 2. Apparent digestibility coefficients (ADC) values of energy and protein and digestible energy (DE) and digestible protein (DP) values of tested ingredients (dry matter basis): fish meal (FM), meat and bone meal (MBM), spray-dried blood meal (S-DBM), poultry by-products meal (PBM), corn gluten meal (CGM), soybean meal (SBM), corn meal (CME) and wheat bran (WBR).

Ingredient[1]	ADC energy (%)	DE (kcal kg^{-1})	ADC protein	DP
			------------(%)----------	
FM	93.86	4,147	94.67	68.78
MBM	91.80	4,420	88.15	40.91
S-DBM	94.07	5,205	96.28	93.89
PBM	95.33	4,735	89.08	63.20
CGM	95.73	5,188	96.93	65.30
SBM	85.00	3,664	94.51	50.42
CME	80.84	3,214	89.65	8.47
WBR	77.02	3,351	88.24	15.16

Little variation was observed for mean value of amino acids ADC between ingredients of animal origin, with prominence for S-DBM, which reached mean digestibility of 97.9%, a value only 6% superior to the average ADC of MBM amino acids (92%) (Table 3). The mean ADC of amino acids was superior to 94%, that is, juvenile "dourado" presented a good digestive ability of amino acids. The highest values of amino acids ADC were registered for S-DBM (98.6%), except for isoleucin, which presented better ADC values (96.4%) when originated from PBM. In regard to plant ingredients, CGM presented the best amino acids ADC, 97.7% in average.

The smaller ADC was registered for WBR, 90.6% average. These data corroborate several reports, showing that WBR consistently present smaller ADCs of protein and energy in comparison to any other ordinarily used aquafeed ingredients. During the fecal collection period, aquaria in which fish received WBR, as tested ingredient, always presented greater volume of excrements in comparison to the other collecting structures. Similar observations were reported by Furuya et al. (2001), who worked with tilapia, and attributed to the high crude fiber and non-starch polysaccharides contents of WBR the higher amounts of fecal material observed for fish fed diets containing increasing levels of this feedstuff.

The smallest amino acids ADC among all tested ingredients was registered for cystine (91%). Alanine, cystine and glycine contents of FM (12.5; 6.5 and 42.9%, respectively) exceeded values ordinarily reported (Anderson et al., 1995). However, lysine and methionine mean contents, for instance, were 27 and 26% smaller, respectively. Except for glycine (ADC = 7.2%), ADC of FM amino acids varied in average 2% (1.6% for lysine, for instance). Therefore, it will remain difficult to top or equal FM as the best ingredient for formulating and processing aquafeeds which adequately meet fish nutritional requirements. Formulation of balanced aquafeeds for carnivorous, neotropical characins, thus, demands considering both species protein requirements and the amino acid profiles of feedstuffs.

The results of the ADCs of energy and protein of the ingredients tested suggest all can be useful in the

Table 3. Apparent digestibility coefficients values of the essential and non-essential amino acids (dry matter basis) on the ingredients: fish meal (FM), meat and bone meal (MBM), spray-dried blood meal (S-DBM), poultry by-products meal (PBM), corn gluten meal (CGM), soybean meal (SBM), corn meal (CME) and wheat bran (WBR).

Amino acid	FM	MBM	S-DBM	PBM	CGM	SBM	CME	WBR
				Essential amino acids				
Arginine	97.50	93.78	97.96	97.64	97.77	96.99	94.37	93.91
Phenylalanine	95.26	91.77	98.79	92.70	98.42	95.00	90.86	89.75
Histidine	96.53	93.35	99.38	97.11	97.72	95.84	92.98	92.14
Isoleucine	95.56	91.94	95.32	96.35	97.61	95.03	90.89	89.92
Leucine	96.11	93.04	99.20	96.97	99.58	95.48	92.53	91.04
Lysine	96.72	93.17	98.91	97.21	96.32	95.47	92.14	91.20
Methionine	96.27	92.55	97.28	96.93	97.72	94.31	92.14	90.82
Methionine + Cystine	95.06	90.54	96.77	96.05	97.45	93.58	90.09	89.07
Threonine	95.83	91.99	98.30	96.18	97.11	94.57	90.99	89.96
Valine	95.57	92.23	99.11	96.27	97.40	94.44	90.61	89.65
				Non-essential amino acids				
Aspartic acid	95.24	90.86	97.88	96.10	96.38	95.01	90.07	88.77
Glutamic acid	96.72	93.83	97.63	97.39	98.74	96.61	94.01	93.53
Alanine	96.46	92.33	98.89	96.80	98.42	94.11	91.46	90.32
Cystine	91.23	85.88	95.80	94.07	97.28	92.53	85.58	85.70
Glycine	97.49	93.12	97.56	97.58	96.94	95.26	93.61	92.96
Serine	96.22	92.70	98.43	96.77	98.00	95.62	92.37	91.45
Tyrosine	95.36	91.52	97.84	96.35	98.38	94.74	90.30	89.40

formulation of diets for “dourado”, with some restriction on corn meal and wheat bran, which presented lower coefficients. The use of specific amino acid digestibility coefficients might allow more accurate and economical feed formulation.

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