

CALCIUM AND PHOSPHORUS SOURCE AND AVAILABILITY IN THE DIET OF THE ARRAU SIDENECK TURTLE RAISED IN CAPTIVITY

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ABSTRACT

Apparent availability coefficient of the ash, calcium and phosphorus were studied in the Arrau sideneck (*Podocnemis expansa*). The sources of mineral material were meat and bone meal, poultry by-product meal, fish meal and dicalcium phosphate. The turtles used were 226 hatchlings with 5 months old and average weight of 38.32 g and 6.06 cm long shell from Projeto Quelônios da Amazônia, State of Mato Grosso. Experimental animals were raised in plastic containers, with continuous water flow and mean temperature kept at 29°C. Apparent availability coefficient was accessed by diets labeled with 0.1% of chromium oxide III (Cr_2O_3). The apparent availability coefficient of ash, calcium and phosphorus were, respectively, 69.32, 69.46 and 73.28% for meat and bone meal, 87.53, 92.48 and 92.19% for poultry by-product meal, 92.53, 95.83 and 94.93% for fish meal and 41.18, 81.01 and 54.46% for dicalcium phosphate.

Keywords: nutrition, *Podocnemis expansa*, minerals, chelonians, reptiles.

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FONTES E DISPONIBILIDADE DE CÁLCIO E FÓSFORO PARA A TARTARUGA-DA-AMAZÔNIA CRIADA EM CATIVEIRO

RESUMO

Foram estudados os coeficientes de disponibilidade aparente de matéria mineral, cálcio e fósforo da tartaruga-da-Amazônia (*Podocnemis expansa*). As fontes de matéria mineral foram a farinha de carne e ossos, farinha de vísceras de aves, farinha de peixe e fosfato bicálcico. Foram utilizados 226 filhotes com 5 meses de idade, peso médio de 38,32 g e comprimento médio de carapaça de 6,06 cm, provenientes do Projeto Quelônios da Amazônia, Estado de Mato Grosso. Os animais experimentais foram alojados em caixas plásticas, com fluxo contínuo de água e temperatura média mantida em 29°C. O coeficiente de disponibilidade aparente foi avaliado com dietas contendo 0,1% de óxido de cromo III (Cr_2O_3). Os coeficientes de disponibilidade aparente da matéria mineral, cálcio e fósforo foram, respectivamente: 69,32%, 69,46% e 73,28% para farinha de carne e ossos, 87,53%, 92,48% e 92,19% para farinha de vísceras de aves, 92,53%, 95,83% e 94,93% para farinha de peixe, e 41,18%, 81,01% e 54,46% para fosfato bicálcico.

Palavras-chave: nutrição, *Podocnemis expansa*, minerais, quelônios, répteis.

1. INTRODUCTION

The Arrau sideneck turtle *Podocnemis expansa* (Schweigger 1812) is the largest river chelonian in South America, with an average carapace measuring 80 cm long by 60 cm wide and reaches an average weight of 60 kg. Some individuals, however, reach carapace length of up to 1 m. It presents with a flattened carapace which broadens in the posterior and has a varying coloration of brown, gray and olive green. Young animals have yellow spots on their heads that fade during maturation, becoming a characteristic feature of adult females. In males these spots remain but are darker and faded (Luz; Reis, 1999).

While they are opportunistic omnivores, the Arrau sideneck turtle is predominantly herbivorous. Their broad diet includes fruits, flowers, seeds, stems, roots, arboreal and herbaceous leaves, insects, crustaceans, mollusks and fish (Luz, 2005). According to Molina and Rocha (1996), in nature they are predominantly herbivorous but will consume meat and fish in captivity.

The commercial breeding of this species has been permitted since 1992 in order to discourage trafficking in the animals and combat the illegal market sale of meat and by-products of the Arrau sideneck turtle. However, the commercial farming of this animal lacks necessary information, especially regarding feeding and nutrition requirements in captivity. In this context, calcium and phosphorus are vitally important nutrients for chelonians since 65% of their carapace is composed of minerals, with calcium being the most abundant (Huang; Lin; Wu, 2003).

This study seeks to investigate the digestibility of diets in the Arrau sideneck turtle and to evaluate the use of different mineral sources by determining the apparent availability coefficients of ash, calcium and phosphorus.

2. MATERIAL AND METHODS

The present research was carried out at the Universidade Estadual Paulista (UNESP), using 226 specimens of Arrau sideneck turtles from the city of Ribeirão Cascalheira in the Das Mortes river region of the state of Mato Grosso, within an area of operation of the Amazonian Chelonians Project (Projeto Quelônios da Amazônia) managed by ICMBio /RAN.

The animals were randomly divided into groups of 15 and housed in plastic boxes measuring 0.60 x 0.39 x 0.21 m with water renewal, a constant temperature of 29°C was maintained via 80 w heaters connected to a thermostat with a total capacity of 800 w. The ambient room temperature was maintained by a 1000 w heater in the laboratory. The photoperiod was controlled by timer and consisted of 12 hours of light from 07h00 to 19h00 followed by 12 hours of darkness.

The animals were 5 months of age with an average weight of 38.32 g, average carapace length of 6.06 cm, average carapace width of 5.45 cm, average plastron length of 5.12 cm, average plastron width of 3.93 cm and an average shell height of 2.55 cm. In order to determine apparent availability coefficients (AAC) mixtures were composed with the maximum of diet tested, containing 0.1% of chromium oxide III (Cr_2O_3).

The apparent availability coefficients of ash, calcium and phosphorus of each studied source were calculated based on the content of chromium oxide III and dietary as well as fecal nutrient levels, according to the formula developed by Edin (1918) according to Maynard, Loosli and Hintz (1984):

$$\text{AAC}_n = 100 - \left[100 \left(\frac{\% \text{Cr}_2\text{O}_{3r}}{\% \text{Cr}_2\text{O}_{3f}} \right) \cdot \left(\frac{\% N_f}{\% N_r} \right) \right]$$

where:

AAC_n = apparent availability coefficient of diet;

$\% \text{Cr}_2\text{O}_{3r}$ = percentage of chromium oxide III in diet;

$\% \text{Cr}_2\text{O}_{3f}$ = percentage of chromium oxide III in feces;

$\% N_f$ = percentage of nutrients in feces;

$\% N_r$ = percentage of nutrients in diet.

The apparent availability coefficient of ash, calcium and phosphorus of dicalcium phosphate was calculated according to the formula presented by Cho e Slinger (1979):

$$AAC_{ing} = \frac{AAC_{rt} - b.AAC_{rb}}{a}$$

where:

AAC_{ing} = apparent availability coefficient of ingredient;

AAC_{rt} = apparent availability coefficient of ration with test ingredient;

AAC_{rb} = apparent availability coefficient of basal ration;

a = percentage of test ingredient;

b = percentage of basal ration.

The treatments used were numbered from 1 to 5 and tested:

- 1 – Meat and bone meal composing 89.9% of the test mixture, 10% wheat flour and 0.1% of the chromium oxide III marker;
- 2 – Poultry by-product meal composing 89.9% of the test mixture, 10% wheat flour and 0.1% of the chromium oxide III marker;
- 3 – Fish meal composing 89.9% of the test mixture, 10% wheat flour and 0.1% of the chromium oxide III marker;
- 4 – Dicalcium phosphate at a 5% level of diet, with the remainder of the mixture containing 89.9% fish meal, 10% wheat flour and 0.1% of the chromium oxide III marker;
- 5 – Dicalcium phosphate at a 10% level of diet, with the remainder of the mixture containing 89.9% fish meal, 10% wheat flour and 0.1% of the chromium oxide III marker;

The choice of fish meal as the base dietary component with dicalcium phosphate occurred after preliminary observation of the turtles indicated a preference for fish meal, followed by poultry by-product meal and meat and bone meal. The apparent availability coefficient of ash, calcium and phosphorus of dicalcium phosphate is represented as the averages of treatments 4 and 5.

The nutritional composition of the diets is presented in Table 1. In the preparation of the ration pellets, the ingredients were milled, weighed, mixed, infused with the marker, moistened, processed and dried in a forced air circulation dehydrator. The dry rations were then ground and sieved in mesh 7 with 2.8 mm openings at the Aquatic Organism Nutrition Laboratory – AquaNutri, at the Faculty of Veterinary Medicine and Animal Science, UNESP, Botucatu Campus.

Table 1. Nutritional composition of the experimental diets, as fed basis.

Composition	Treatment				
	MBM	PBM	FM	DP5	DP10
Dry matter (%)	93.42	93.50	92.87	94.39	94.35
Crude protein (%)	41.68	55.48	56.28	53.15	50.89
Ether extract (%)	9.60	10.52	10.16	10.00	8.10
Gross energy (kcal/kg)	3334	4141	4190	3938	3733
Ash (%)	33.37	19.00	20.14	22.55	25.38
Calcium (%)	9.44	7.94	5.44	6.83	7.79
Phosphorus (%)	6.07	3.66	3.04	3.42	4.59

MBM = meat and bone meal, PBM = poultry by-product meal, FM = fish meal, DP5 = dicalcium phosphate at the level of 5% of the feed, DP10 = dicalcium phosphate at the level of 10% of the feed

Feeding took place early in the morning and lasted one hour, after which the animals were transferred to different boxes of the same size in the same room. These boxes contained plastic screens with 1 cm gaps, with water both above and below the screen, so that the animals could submerge but not have access to feces. Monitoring and collection were constant and the feces were collected with Pasteur pipettes, then stored in dark plastic containers and stored in a freezer at - 20°C.

In order to facilitate analysis, the feces were dehydrated at 55°C for 24 hours, ground and homogenized. Calcium was determined via atomic absorption spectrophotometry and phosphorus by colimetry of ammonium metavanadate, following the methodology of Malavolta, Vitti and Oliveira (1997), at the Fertilizer and Treatment Chemical Analysis Laboratory at the Faculty of Agronomic Sciences, UNESP, Botucatu Campus. Ash was determined by incineration of organic matter at 550°C, following AOAC (1995), and chromium

oxide III by the colorimetric method of s-diphenylcarbazide, because of its use as a biological marker, following Graner (1972) and Bremer Neto et al. (2005), at the Bromatology Laboratory of the Faculty of Veterinary Medicine and Animal Science, UNESP, Botucatu Campus.

Results were analyzed using variance analysis techniques and, when significant, via Tukey's multiple comparison test. All analyses were performed using the SAEG program (UFV, 1997) at a 5.0% level of significance.

3. RESULTS AND DISCUSSION

Fish and poultry by-product meals presented the largest apparent availability coefficients of ash and phosphorus, followed by meat and bone meal and dicalcium phosphate, which showed the lowest utilization. There was no significant difference between the utilization of calcium between the fish meal and the poultry by-product meal, nor between the utilization of calcium from poultry by-product meal and dicalcium phosphate. The results are presented in Table 2 and Table 3.

Table 2. Apparent availability ash, calcium and phosphorus coefficients of the feedstuffs used in diets for Arrau sideneck turtle.

Apparent availability coefficient (%)	Feedstuff			
	MBM	PBM	FM	DP
Ash	69.32 ^b	87.53 ^a	92.53 ^a	41.18 ^c
Calcium	69.46 ^c	92.48 ^{ab}	95.83 ^a	81.01 ^{bc}
Phosphorus	73.28 ^b	92.19 ^a	94.93 ^a	54.46 ^c

Averages in the same row followed by the same letter do not differ (Tukey, $P > 0.05$)

MBM = meat and bone meal, PBM = poultry by-product meal, FM = fish meal, DP = dicalcium phosphate

Table 3. Mean values of total and available ash, calcium and phosphorus of the feedstuffs used in diets for Arrau sideneck turtle.

Composition (%)	Feedstuff			
	MBM	PBM	FM	DP
Ash	35.49	21.56	20.76	83.74
Available ash	24.60	18.87	19.21	34.48
Calcium	11.41	6.87	6.22	20.04
Available calcium	7.92	6.35	5.96	16.23
Phosphorus	5.07	3.26	2.88	16.22
Available phosphorus	3.71	3.00	2.73	8.83

MBM = meat and bone meal, PBM = poultry by-product meal, FM = fish meal, DP = dicalcium phosphate

There is no information in the literature about turtles. The utilization of ash in fish meal by the Arrau sideneck turtle was superior to that found for the carnivorous fishes *Oncorhynchus mykiss* Walbaum, 1792 (Rainbow trout) and *Salminus brasiliensis* (Cuvier, 1816) (Dourado), for the omnivorous fish *Oreochromis niloticus* Linnaeus, 1758 (Nile tilapia) and for the carnivorous crustacean *Scylla serrata* (Forskål, 1775) (Mud crab). The availability of ash for poultry by-product meal was higher than that found for *O. mykiss* and *S. brasiliensis* and the meat and bone meal was higher than that found for *O. mykiss* and *S. serrata* (Sugiura et al., 2000; Hardy, 2002; Catacutan; Perla; Teshima, 2003; Köprücü and Özdemir, 2005; Borghesi; Dairiki; Cyrino, 2009) The ash, calcium and phosphorus availability levels of the species covered in present literature are presented in Table 4.

The utilization of calcium from fish meal by the Arrau sideneck turtle was also superior to that found in the literature on *O. mykiss* and *O. niloticus*, as well as for the carnivorous fish *Oncorhynchus kisutch* (Walbaum, 1792) (Coho salmon), *Salmo salar* Linnaeus, 1758 (Atlantic salmon) and *Micropterus salmoides* (Lacepède, 1802) (Largemouth bass). The availability of calcium of poultry by-product meal was superior to that found for *O. mykiss*, *O. kisutch*, *M. salmoides* and swine, omnivorous mammals. The availability of calcium of meat and bone meal was superior to that found for *O. mykiss* and swine. The availability of calcium of dicalcium phosphate was lower than those found for *O. niloticus*, swine and broiler chickens, omnivorous birds (Storebakken; Shearer; Roem, 1998; Sugiura et al., 1998; Storebakken; Shearer; Roem, 2000; Sugiura et al., 2000; Furuya et al., 2001; Portz and Cyrino, 2004; Sá et al., 2004; Köprücü and Özdemir, 2005; Salguero et al., 2014; Bowzer et al., 2015).

The availability of phosphorus from fish meal was superior for the Arrau sideneck turtle in relation to *O. mykiss*, *O. kisutch*, *S. salar*, *M. salmoides*, *O. niloticus* and swine, in addition to the omnivorous fishes *Carassius gibelio* (Bloch, 1782) (Gibel carp), *Myxocyprinus asiaticus* (Bleeker, 1864) (Chinese sucker) and *Piaractus brachypomus* (Cuvier, 1818) (Cachama), carnivorous fishes *Dicentrarchus labrax* Linnaeus, 1758 (European sea bass), *Rachycentron canadum* (Linnaeus, 1766) (Cobia), *Lateolabrax japonicus* (Cuvier, 1828) (Japanese seabass) and *Channa argus* (Cantor, 1842) (Snakehead) and the carnivorous amphibian *Aquarana catesbeiana* (Shaw, 1802) (Bullfrog). The availability of phosphorus for poultry by-product meal was higher than those found for *O. mykiss*, *O. kisutch*, *R. canadum*, *L. japonicus*, *C. argus* and *A. catesbeiana* and lower than that found for *M. salmoides*. The availability of phosphorus for the meat and bone meal was higher than that of the species *O. mykiss*, *C. gibelio*, *R. canadum*, *L. japonicus*, *C. argus* and pigs and lower than the values found for *P. brachypomus* and *A. catesbeiana*. The utilization of phosphorus of dicalcium phosphate was superior to those found for the mollusk *Haliotis midae* Linnaeus 1758 (South African abalone) and for horses, both of which are herbivores. However, it was lower than that found for *O. niloticus*, *D. labrax*, the carnivorous fish *Paralichthys olivaceus* (Temminck and Schlegel, 1846) (Olive flounder) and swine (Storebakken; Shearer; Roem, 1998; Sugiura et al., 1998; Miranda et al., 2000; Storebakken; Shearer; Roem, 2000; Sugiura et al., 2000; Figueirêdo et al. 2001; Furuya et al., 2001; Cheng and Hardy, 2002; Lopes et al., 2003; Sales; Britz; Viljoen, 2003; Cheng; Hardy; Huige, 2004; Portz and Cyrino 2004; Zhou et al., 2004; Choi; Kim; Kang, 2005; Zhang et al., 2006; Pimentel-Rodrigues and Oliva-Teles, 2007; Bünzen et al., 2009; Yuan et al., 2010; Ramos-Páez and Vasquéz-Torres, 2012; Wang et al., 2012; Yu et al., 2013; Bowzer et al., 2015; Zhang et al., 2015).

Table 4. Comparison among the values of apparent availability coefficients (AAC) of ash, calcium and phosphorus of the tested feedstuffs and those reported by other authors.

Feedstuff	Specie	AAC (%)		
		Ash	Calcium	Phosphorus
Fish meal	Rainbow trout	66.2 a 76.6 ^a	1.9 a 29.3 ^{b c}	46.9 a 58.2 ^{a c}
	Coho salmon		12.1 a 18.8 ^b	40.4 a 57.3 ^b
	Atlantic salmon		5.4 ^d a 9.9 ^e	40.9 ^d a 44.8 ^e
	Largemouth bass		62.8 ^f	72.3 ^f
	Nile tilapia	38.1 ^g	17.1 ^g a 90.6 ^h	27.1 ⁱ a 49.8 ^h
	Gibel carp			38.8 ⁱ
	European seabass			49.2 a 63.3 ^j

	Cobia			71.22 ^k
	Dourado	82.1 ^l		
	Chinese sucker			58.8 a 61.4 ^m
	Cachama			75.67 ⁿ
	Japanese seabass			53.51 ^o
	Snakehead			65.2 ^p
	Mud crab	76 ^q		
	Bullfrog			83.2 a 84.8 ^r
	Swines			85.54 ^s
Poultry by-product meal	Rainbow trout	74.1 a 79.6 ^a	31.8 ^b	34.5 ^t a 63.5 ^b
	Coho salmon		30.1 ^b	67.7 ^b
	Largemouth bass		86.7 ^f	93.9 ^f
	Cobia			62.7 ^k
	Dourado	84.5 ^l		
	Japanese seabass			59.52 ^o
	Snakehead			57.2 ^p
	Bullfrog			84 ^r
	Swines		73.59 ^u	
Meat and bone meal	Rainbow trout	22.4 ^v	9.5 ^v	26.9 ^v
	Gibel carp			17.6 ⁱ
	Cobia			62.4 ^k
	Cachama			76.69 ⁿ
	Japanese seabass			43.21 ^o
	Snakehead			39.5 ^p
	Mud crab	64.4 ^q		
	Bullfrog			81.3 ^r
	Swines		69.41 ^u	62.28 ^s
Dicalcium phosphate	Nile tilapia		81.3 ^h	61.1 ^h a 74.2 ^w
	European seabass			65.8 a 70.5 ^j
	Olive flounder			70 ^x
	South African abalone			27.9 ^y
	Swines		81.95 ^u	71.9 ^z
	Equines			32.4 ^{aa}
	Broilers		99.99 ^{ab}	

^aCheng and Hardy (2002), ^bSugiura et al. (1998), ^cBowzer et al. (2015), ^dStorebakken; Shearer; Roem (1998), ^e Storebakken; Shearer; Roem, (2000), ^fPortz and Cyrino (2004), ^gKöprücü and Özdemir (2005), ^hFuruya et al. (2001), ⁱZhang et al. (2006), ^jPimentel-Rodrigues and Oliva-Teles (2007), ^kZhou et al. (2004), ^lBorghesi; Dairiki; Cyrino (2009), ^mYuan et al. (2010), ⁿRamos-Páez and Vasquéz-Torres (2012), ^oWang et al. (2012), ^pYu et al. (2013), ^qCatacutan; Perla; Teshima (2003), ^rZhang et al. (2015), ^sBünzen et al. (2009), ^tCheng; Hardy; Huige (2004), ^uSalguero et al. (2014), ^vSugiura et al. (2000), ^wMiranda et al. (2000), ^xChoi; Kim; Kang (2005), ^ySales; Britz; Viljoen, (2003), ^zFigueirêdo et al. (2001), ^{aa}Lopes et al. (2003), ^{ab}Sá et al. (2004)

The potent utilization of ash, calcium and phosphorus by the Arrau sideneck turtle can be understood by the fact that 65% of its shell is mineral with calcium as the dominant element (Huang; Lin; Wu, 2003). According to Catacutan, Perla and Teshima (2003), the high ash

availability values of the mud crab *S. serrata* relative to other species may be due to the large quantity of minerals in the animal's skeleton.

The low availability for the Arrau sideneck turtle found for meat and bone meal in relation to other diets can be explained by the high content of ash, calcium and phosphorus, which decreases the absorption of calcium, phosphorus, iron, magnesium, molybdenum, manganese, copper, strontium and zinc through antagonistic reactions between minerals and the formation of primarily calcium phosphates in the intestinal lumen, which reduces absorption (Sugiura et al., 1998; Sugiura et al., 2000; Portz and Cyrino, 2004; Zhang et al., 2006). According to other authors, diets with lower phosphorus levels present greater availability (Cheng and Hardy, 2002; Cheng; Hardy; Huige, 2004; Zhou et al., 2004).

The results found for dicalcium phosphate may also have been influenced by the higher levels of ash, calcium and phosphorus in the diet. However, it is worth noting that the dietary inclusion of 5% and 10% levels of dicalcium phosphate were significantly higher than the levels tested in the species that presented better availability results.

4. CONCLUSION

The Arrau sideneck turtle showed good utilization of mineral matter, calcium, and phosphorus from the tested animal-based feeds, demonstrating the importance of these ingredients in chelonian diets. However, reducing feed costs is essential for the success of chelonian farming. Dicalcium phosphate proved to be an important mineral source due to its high content of available calcium and phosphorus. In addition, further studies need to be carried out with other feeds, such as those of plant origin.

5. REFERENCES

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTRY – AOAC. **Official methods of analysis**. 16. ed. Arlington: AOAC International, 1995.

BORGHESI, R.; DAIRIKI, J.K.; CYRINO, J.E.P. Apparent digestibility coefficients of selected feed ingredients for dourado *Salminus brasiliensis*. **Aquaculture Nutrition**, v. 15. n. 5, p. 453-458, 2009. Available at: <https://doi.org/10.1111/j.1365-2095.2008.00610.x>.

BOWZER, J.; TRUSHENSKI, J.; RAWLES, S.; GAYLORD, T.G.; BARROWS, F.T. Apparent digestibility of Asian carp- and common carp-derived fish meals in feeds for hybrid striped bass *Morone saxatilis* ♀ × *M. chrysops* ♂ and rainbow trout *Oncorhynchus mykiss*.

Aquaculture Nutrition, v. 21, n. 1, p. 43-53, 2015. Available at:

<https://doi.org/10.1111/anu.12136>.

BREMER NETO, H.; GRANER, C.A.F.; PEZZATO, L.E.; PADOVANI, C.R.P. Determinação de rotina do crômio em fezes, como marcador biológico, pelo método espectrofotométrico ajustado da 1,5-difenilcarbazida. **Ciência Rural**, v. 35, n. 3, p. 691-697, 2005. Available at:

<https://doi.org/10.1590/S0103-84782005000300033>.

BÜNZEN, S.; ROSTAGNO, H.S.; LOPES, D.C.; GOMES, P.C.; HASHIMOTO, F.A.M.; APOLÔNIO, L.R.; BORSATTO, C.G. Digestibilidade aparente e verdadeira do fósforo de alimentos de origem animal para suínos. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 61, n. 4, p. 903-909, 2009. Available at: <https://doi.org/10.1590/S0102-09352009000400019>.

CATACUTAN, M.R.; PERLA, S.E.; TESHIMA, S.I. Apparent digestibility of selected feedstuffs by mud crab, *Scylla serrata*. **Aquaculture**, v. 216, p. 253-261, 2003. Available at:

[https://doi.org/10.1016/S0044-8486\(02\)00408-8](https://doi.org/10.1016/S0044-8486(02)00408-8).

CHENG, Z.J.; HARDY, R.W. Apparent digestibility coefficients of nutrients and nutritional value of poultry by-product meals for rainbow trout *Oncorhynchus mykiss* measured in vivo using settlement. **Journal of the World Aquaculture Society**, v. 33, n. 4, p. 458-465, 2002.

Available at: <https://doi.org/10.1111/j.1749-7345.2002.tb00025.x>.

CHENG, Z.J.; HARDY, R.W.; HUIGE, N.J. Apparent digestibility coefficients of nutrients in brewer's and rendered animal by-products for rainbow trout (*Oncorhynchus mykiss* (Walbaum)). **Aquaculture Research**, v. 35, n. 1, p. 1-9, 2004. Available at:

<https://doi.org/10.1111/j.1365-2109.2004.00941.x>.

CHO, C.Y.; SLINGER, S.J. 1979. Apparent digestibility measurement in feedstuffs for rainbow trout. In: World Symposium on Finfish Nutrition and Fishfeed Technology, Halver, J.E. & Tiews, K. ed., Berlin. **Annals...** Berlin, Heinemann, pp. 239-247.

CHOI, S.M.; KIM, K.W.; KANG, Y.J. Reevaluation of the phosphorus requirement of juvenile olive flounder *Paralichthys olivaceus* and the bioavailability of various inorganic phosphorus sources. **Journal of the World Aquaculture Society**, v. 36, n. 2, p. 217-222, 2005.

FIGUEIRÊDO, A.V.; VITTI, D.M.S.S.; LOPES, J.B.; BARBOSA, H.P. Disponibilidade biológica do fósforo de fontes fosfatadas determinadas por intermédio da técnica de diluição isotópica. II. Suínos em crescimento. **Revista Brasileira de Zootecnia**, v. 30, n. 5, p. 1514-1520, 2001.

Available at: <https://doi.org/10.1590/S1516-35982001000600019>.

FURUYA, W.M.; PEZZATO, L.E.; MIRANDA, E.C.; FURUYA, V.R.B.; BARROS, M.M., Coeficientes de digestibilidade aparente da energia e nutrientes de alguns ingredientes pela tilápia-do-Nilo (L.) (linhagem tailandesa). **Acta Scientiarum**, v. 23, n. 2, p. 465-469, 2001. Available at:

<https://periodicos.uem.br/ojs/index.php/ActaSciBiolSci/article/view/2701>

GRANER, C.A.F. 1972. **Determinação do crômio pelo método colorimétrico da s-difenilcarbazida**. Faculdade de Ciências Médicas e Biológicas / Universidade Estadual Paulista, Botucatu, São Paulo. 112 p.

HUANG, C.H.; LIN, W.Y.; WU, S.M. Effect of dietary calcium and phosphorus supplementation in fish meal-based diets on the growth of soft-shelled turtle *Pelodiscus sinensis* (Wiegmann). **Aquaculture Research**, v. 34, n. 10, p. 843-848, 2003. Available at: <https://doi.org/10.1046/j.1365-2109.2003.00891.x>.

KÖPRÜCU, K.; ÖZDEMİR, Y. Apparent digestibility of selected feed ingredients for Nile tilapia (*Oreochromis niloticus*). **Aquaculture**, v. 250, n. 1-2, p. 308-316, 2005. Available at: <https://doi.org/10.1016/j.aquaculture.2004.12.003>.

LOPES, J.B.; FURTADO, C.E.; VITTI, D.M.S.S.; ABDALLA, A.L.; TOSI, H.; HADDAD, M.L. Metabolismo do fósforo em equinos. 1. Avaliação dietética de diferentes fontes de fósforo. **Revista Brasileira de Zootecnia**, v. 32, n. 6, p. 1339-1347, 2003. Available at: <https://doi.org/10.1590/S1516-35982003000600008>.

LUZ, V.L.F. **Criação comercial de tartaruga e tracajá – Manual técnico**. Cuiabá: SEBRAE, 2005.

LUZ, V.L.F.; REIS, I.J. **Conservação e criação comercial de quelônios**. Goiânia: CENAQUA, 1999.

MALAVOLTA, E.; VITTI, G.C.; OLIVEIRA, S.A. **Avaliação do estado nutricional das plantas – Princípios e aplicações**. 2. ed. Piracicaba: POTAFOS, 1997.

MAYNARD, L.A.; LOOSLI, J.K.; HINTZ, H.F. **Nutrição animal**. 3. ed. New York: McGraw-Hill, 1984.

MIRANDA, E.C.; PEZZATO, A.C.; PEZZATO, L.E.; FURUYA, W.M. Disponibilidade aparente de fósforo em ingredientes pela tilápia-do-Nilo (*Oreochromis niloticus*). **Acta Scientiarum**, v. 22, n. 3, p. 669-675, 2000. Available at: <https://periodicos.uem.br/ojs/index.php/ActaSciAnimSci/article/view/2910/2192>.

MOLINA, F.B.; ROCHA, M.B. **Identificação, caracterização e distribuição dos quelônios da Amazônia brasileira**. Goiânia: CENAQUA, 1996.

PIMENTEL-RODRIGUES, A.; OLIVA-TELES, A. Phosphorus availability of inorganic phosphates and fish meals in European sea bass (*Dicentrarchus labrax* L.) juveniles. **Aquaculture**, v. 267, n. 1-4, p. 300-307, 2007. Available at: <https://doi.org/10.1016/j.aquaculture.2007.01.018>.
PORTZ, L.; CYRINO, J.E.P. Digestibility of nutrients and amino acids of different protein sources in practical diets by largemouth bass *Micropterus salmoides* (Lacepède, 1802). **Aquaculture Research**, v. 35, n. 4, p. 312-320, 2004. Available at: <https://doi.org/10.1111/j.1365-2109.2004.00984.x>.

RAMOS-PÁEZ, R.M., Vasquez-Torres, W. Digestibilidad del fósforo en ingredientes de origen animal utilizados en dietas para cachama (*Piaractus brachypomus*). **Orinoquia**, v. 16, supl. 1, p. 155-161, 2012. Available at: <http://www.scielo.org.co/pdf/rori/v16s1/v16s1a02>.

SÁ, L.M.; GOMES, P.C.; ALBINO, L.F.T.; ROSTAGNO, H.S.; D'AGOSTINI, P. Exigência nutricional de cálcio e sua biodisponibilidade em alguns alimentos para frangos de corte, no período de 1 a 21 dias de idade. **Revista Brasileira de Zootecnia**, v. 33, n. 1, p. 157-168, 2004. Available at: <https://doi.org/10.1590/S1516-35982004000100020>.

SALES, J.; BRITZ, P.J.; VILJOEN, J. Dietary phosphorus leaching and apparent phosphorus digestibility from different inorganic phosphorus sources for South African abalone (*Haliotis midae* L.). **Aquaculture Nutrition**, v. 9, n. 3, p. 169-174, 2003. Available at: <https://doi.org/10.1046/j.1365-2095.2003.00238.x>.

SALGUERO, S.C.; ROSTAGNO, H.S.; HANNAS, M.I.; CARVALHO, T.A.; MAIA, R.C.; PESSOA, G.B.S. Digestibilidade do cálcio de ingredientes para suínos, avaliada por meio de dois métodos. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 66, n. 5, p. 1539-1546, 2014. Available at: <https://doi.org/10.1590/1678-6950>.

STOREBAKKEN, T.; SHEARER, K.D.; ROEM, A.J. Availability of protein, phosphorus and other elements in fish meal, soy-protein concentrate and phytasetreated soy-protein-concentrate-based diets to Atlantic salmon, *Salmo salar*. **Aquaculture**, v. 161, n. 1-4, p. 365-379, 1998. Available at: [https://doi.org/10.1016/S0044-8486\(97\)00284-6](https://doi.org/10.1016/S0044-8486(97)00284-6).

STOREBAKKEN, T.; SHEARER, K.D.; ROEM, A.J. Growth, uptake and retention of nitrogen and phosphorus, and absorption of the other minerals in Atlantic salmon *Salmo salar* fed diets with fish meal and soy-protein concentrate as the main sources of protein. **Aquaculture Nutrition**, v. 6, p. 103-108, 2000. Available at: <https://doi.org/10.1046/j.1365-2095.2000.00135.x>.

SUGIURA, S.H.; BABBITT, J.K.; DONG, F.M.; HARDY, R.W. Utilization of fish and animal by-product meals in low-pollution feeds for rainbow trout *Oncorhynchus mykiss* (Walbaum). **Aquaculture Research**, v. 31, n. 7, p. 585-593, 2000. Available at: <https://doi.org/10.1046/j.1365-2109.2000.00476.x>.

SUGIURA, S.H.; DONG, F.M.; RATHBONE, C.K.; HARDY, R.W. Apparent protein digestibility and mineral availabilities in various feed ingredients for salmonid feeds. **Aquaculture**, v. 159, n. 3-4, p. 177-202, 1998. Available at: [https://doi.org/10.1016/S0044-8486\(97\)00177-4](https://doi.org/10.1016/S0044-8486(97)00177-4).

UNIVERSIDADE FEDERAL DE VIÇOSA – UFV. **SAEG - Sistema de Análise Estatística e Genética**. Viçosa: UFV, 1997.

WANG, J.; YUN, B.; XUE, M.; WU, X.; ZHENG, Y.; LI, P. Apparent digestibility coefficients of several protein sources, and replacement of fishmeal by porcine meal in diets of Japanese seabass, *Lateolabrax japonicus*, are affected by dietary protein levels. **Aquaculture Research**, v. 43, n. 1, p. 117-127, 2012. Available at: <https://doi.org/10.1111/j.1365-2109.2011.02810.x>.

YU, H.R.; ZHANG, Q.; CAO, H.; WANG, X.Z.; HUANG, G.Q.; ZHANG, B.R.; FAN, J.J.; LIU, S.W.; LI, W.; CUI, Y. Apparent digestibility coefficients of selected feed ingredients for juvenile snakehead, *Ophiocephalus argus*. **Aquaculture Nutrition**, v. 19, n. 2, p. 139-147, 2013. Available at: <https://doi.org/10.1111/j.1365-2095.2012.00947.x>

YUAN, Y.C.; GONG, S.I.; YANG, H.J.; LIN, Y.C.; YU, D.H.; LUO, Z. Apparent digestibility of selected feed ingredients for Chinese sucker, *Myxocyprinus asiaticus*. **Aquaculture**, v. 306, n. 1-4, p. 238-243, 2010. Available at: <https://doi.org/10.1016/j.aquaculture.2010.05.017>.

ZHANG, C.X.; HUANG, K.K.; WANG, L.; SONG, K.; ZHANG, L.; LI, P. Apparent digestibility coefficients and amino acid availability of common protein ingredients in the diets of bullfrog, *Rana (Lithobates) catesbeiana*. **Aquaculture**, v. 437, p. 38-45, 2015. Available at: <https://doi.org/10.1016/j.aquaculture.2014.11.015>.

ZHANG, S.; XIE, S.; ZHU, X.; LEI, W.; YANG, Y.; ZHAO, M. Meat and bone meal replacement in diets for juvenile gibel carp (*Carassius auratus gibelio*): effects on growth performance, phosphorus and nitrogen loading. **Aquaculture Nutrition**, v. 12, p. 353-362, 2006. Available at: <https://doi.org/10.1111/j.1365-2095.2006.00431.x>.

ZHOU, Q.C.; TAN, B.P.; MAI, K.S.; LIU, Y.J. Apparent digestibility of selected feed ingredients for juvenile cobia *Rachycentron canadum*. **Aquaculture**, v. 241, n. 1-4, p. 441-451, 2004. Available at: <https://doi.org/10.1016/j.aquaculture.2004.08.044>.