Use of the Brazil nut in the juvenile silver catfish diet and its effect on zootechnical performance and body composition

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ABSTRACT

This work aimed to evaluate the effect of dietary Brazil nut (*Bertholletia excelsa*), on zootechnical performance of juveniles silver catfish (*Rhamdia quelen*). Fifty juveniles silver catfish (14.75 ± 1.42 g) were assigned to 5 treatments in a completely randomized design. The experimental treatments were different inclusion percentages of Brazil nut in the diet (T0, T3, T6, T9, T12) for 45 days. The variables final weight gain, average daily gain, protein efficiency rate, body protein deposition, body fat deposition, carcass yield and survival were evaluated. The data were submitted to analysis of variance, and the means compared by the Tukey test at 5 % significance. A lower final weight gain and a decrease in average daily gains were observed in the animals of the T3 group compared to T0. Protein efficiency rate, body protein and fat deposition, carcass yield and survival were not affected by the treatments evaluated. The inclusion of 3 % Brazil nut in the juveniles silver catfish diet, decreased the final weight gain and affected the average daily gain of the fish evaluated, without affecting the rest of the zootechnical variables studied.

Key words: fish feeding, aquaculture, inclusion, nutrition, *Bertholletia excelsa*, animal performance, carcass composition, *Rhamdia quelen.*

Uso de la nuez de Brasil en la dieta del bagre plateado juvenil y su efecto sobre el rendimiento zootécnico y la composición corporal

RESUMEN

Este trabajo tuvo como objetivo evaluar el efecto de la nuez de Brasil (*Bertholletia excelsa*) en la dieta, sobre el rendimiento zootécnico de juveniles de bagre plateado (*Rhamdia quelen*). Se asignaron cincuenta juveniles de bagre plateado (14,75 ± 1,42 g) a 5 tratamientos en un diseño completamente al azar. Los tratamientos experimentales fueron diferentes porcentajes de inclusión de nuez de Brasil en la dieta (T0, T3, T6, T9, T12) durante 45 días. Se evaluaron las variables ganancia de peso final, ganancia diaria promedio, tasa de eficiencia proteica, deposición de proteína corporal, deposición de grasa corporal, rendimiento de canal y supervivencia. Los datos se sometieron a análisis de varianza y las medias se compararon mediante la prueba de Tukey al 5 % de significancia. Se observó una menor ganancia de peso final y una disminución en las ganancias diarias promedio en los animales del grupo T3 en comparación con T0. La tasa de eficiencia proteica, la deposición de grasas y proteínas corporales, el rendimiento de la canal y la supervivencia no se vieron afectados por los tratamientos evaluados. La inclusión de nuez de Brasil al 3 % en la dieta de juveniles de bagre plateado, disminuyó la ganancia de peso final y afectó la ganancia diaria promedio de los peces evaluados, sin afectar el resto de las variables zootécnicas estudiadas.

Palabras clave: alimentación de peces, acuicultura, inclusión, nutrición, *Bertholletia excelsa*, desempeño animal, composición de la canal, *Rhamdia quelen.*

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INTRODUCTION

The silver catfish is one of the 11 species that make up the genus *Rhamdia*. Fortynine synonyms of silver catfish (*Rhamdia quelen*), have been reported (Silfvergrip 1996, Scaranto *et al*. 2018, Koerber and Reis 2020). It is a benthic animal that analyzes the substrate and feeds on crustaceans, vegetable remains, fish, as well as terrestrial and aquatic insects (Oyakawa *et al*. 2006, Gomiero *et al*. 2007, Olaya-Nieto *et al*. 2010, Barreto *et al*. 2020). According to Parra (2008), Tessaro (2012), Decarli *et al*. (2016) and Gomes *et al*. (2019), this fish has good acceptance in the consumer market, good productivity in tanks and has a high potential for commercialization, making it a great option for promoting fish farming. Due to the great commercial importance of this teleost, known as South American catfish, further studies related to its biological characteristics are still needed.

In fish farming, as in any animal breeding, food represents a high percentage of operating costs (40 to 60 %), and protein ingredients are responsible for most of this cost (Cheng *et al*. 2003, Borghesi *et al*. 2007, El-Sayed 2019). The search for alternative food sources for feed for aquaculture species is a worldwide trend, especially foods of plant origin, which are already used in the diet of fish (Alceste and Jory 2000, Yue and Zhou 2008, Yousif *et al*. 2019). Thus, Brandão (2009) and Brandão *et al*. (2018), ratifies this use in diets, as they are rich in vitamins and compounds with antioxidant capacities. However, factors such as seasonality, non-uniform distribution, absence of established production systems for most of these species, high harvest market price and the lack of knowledge about the nutritional efficiency of these ingredients, result in the low use of these products as ingredients in the formulation of diets (Guimarães and Storti Filho 2004, Rodrigues 2014).

Plant species that can provide alternative ingredients are available in large quantities and are endemic in certain regions, which facilitates obtaining them. The use of plant species with high biological value protein has been an alternative to partially replace animal protein sources (de Souza *et al*. 2004, dos Santos *et al*. 2009). The Brazil nut *Bertholletia excelsa* is originally from Latin America, being found in some states of the Amazon Basin and in Peru, Colombia, Bolivia, Venezuela and Ecuador (Müller *et al*. 1995, Damaceno 2017). The almond of the Brazil nut, contains polyunsaturated fatty acids, a lipid fraction of good quality and high food value, which present in the following proportions: 37.42 % oleic and 37.75 % linoleic, totaling 75.17 % of total fatty acids. It also contains 24.83 % of saturated acids such as palmitic, stearic and arachidonic, with 13.15 %; 10.36 % and 1.32 %, respectively (de Souza and de Menezes 2004, da Silva *et al*. 2010, Cardoso *et al*. 2017).

Therefore, the present study aimed to evaluate the effect of the use of Brazil nut at different levels of inclusion in the diet of juvenile silver catfish, on the zootechnical performance and body composition of the animals.

MATERIALS AND METHODS

Study location and experimental design

The experiment was carried out at the Laboratory of Pisciculture and Aquaculture (LAPA) at the Federal University of Pampa, Dom Pedrito Campus, RS, Brazil (30°59'37.4"S; 54°40'02.8"W). The experiment was conducted for 45 days (May to June 2014).

Fifty juvenile *Rhamdia quelen* (initial weight 14.75 ± 1.42 g) (Figure 1), from Piscicultura Bela Vista, Restinga Seca, RS, Brazil (29°42'05.9"S; 53°31'36.8"W), were assigned to completely randomized design, with 5 treatments (T0, T3, T6, T9, T12) and 2 repetitions. The fish were raised in a closed water recirculation system, using 10 experimental units containing 5 animals each.

Figure 1. Juvenile silver catfish (Rhamdia quelen) used in the study.

The experimental units were arranged on a mobile galvanized iron bench, arranged on two floors with 8 units per bench, equipped with an individual water inlet and outlet system. The water circulation in the experimental units was maintained at a volume of 1.87 liters per minute, for 24 hours a day. The system had a capacity of 948.8 liters, with 500 liters of water in the fiber box and 448.8 liters in a total of 8 experimental units of 56.1 liters each, which are supplied through a submerged pump installed in the biofilter, forming thus, the closed circulation system.

The water quality was monitored daily through the following parameters and instruments: temperature and dissolved oxygen (MO-900 meter, Instrutherm®), pH (Mpa-210A meter, MS Tecnopon®), electrical conductivity (HMCDB-150 meter, Highmed), salinity (RHB0-90, AKSO), ammonia, nitrite and alkalinity (colorimetric kit, Alfakit®).

Experimental diets and feeding management

The experimental diet was prepared in LAPA; the dry ingredients were weighed and homogenized to 1 mm (Figure 2). For drying, the ration was placed in an oven with forced air circulation for 48 hours (55 °C), and then it was packed in plastic pots and conditioned in a refrigerator at a temperature of 4 °C. The treatments were T0, T3, T6, T9 and T12 with inclusion of 0 %, 3 %, 6 %, 9 % and 12 % of Brazil nut respectively. Brazil nut used can be seen in Figure 2.

Figure 2. Brazil nut Bertholletia excelsa grounded, used in the study.

Feeding was given twice a day (9 am and 4 pm), in the proportion of 5 % of the total biomass. The diets were isoproteic and had 3300 $Kcal^{-1}$ of calculated Digestible Energy. The composition of the experimental feed was described by Coldebella and Radünz Neto (2002). The diets were analyzed at the Laboratory of Bromatology and Animal Nutrition (UNIPAMPA), according to the methodology described by AOAC (1995). The diets are described in Table 1.

Table 1. Proximate and bromatological composition of diets containing different levels of inclusion of Brazil nut (*Bertholletia excelsa*), in dry matter.

	T0	T3	T6	T9	T12
Soybean meal	24.01	25.5	23.33	22.25	22.38
Wheat bran	7	7.5	10.02	10.39	8.89
Corn in Grain	19.21	15	11.62	10.19	9.98
Canola oil	13.03	12.25	12.28	11.42	10
Brazil nut	0	3	6	9	12
Meat Flour	35	35	35	35	35
Premix[2]	0.75	0.75	0.75	0.75	0.75
Salt[1]	1	1	1	1	1
Bromatological Composition (%) (*)					
DM	96.40	97.02	97.54	97.51	97.79
CP	40.61	40.67	40.33	40.47	40.78
EE	10.22	11.81	12.02	12.54	13.05
A	7.81	7.83	7.67	7.94	7.95
CF	2.69	2.36	2.97	2.85	2.68

[1]According to Luchini (1990);[2]Vitamin premix composition (per kg): Calcium 210 g, Phosphorus 52 g, Methionine 29.40 g, Vitamin A 140,000 IU, Vitamin D 30,000 IU, Vitamin E, 250 IU, Vitamin K3 30 mg, Vitamin B1 38 mg, Vitamin B2 100 mg, Vitamin B6 52 mg, Vitamin B12 200 mcg, Pantothenic acid 260 mg, Niacin 700 mg, Folic acid 16 mg, Choline 3,030 mg, Sodium 40.50 g, Manganese 1,870 mg, Zinc 1,750 mg, Iron 1,125 mg, Copper 200 mg, Iodine 18.75 mg, Selenium 7.50 mg, Phytase 1.500 mg, Salinomycin 1.650 mg, BHT 150 mg, Chlorohydroxyquinoline 750 mg. (*)DM = dry matter; CP = crude protein; EE = ether extract; A = ash; CF = crude fiber. Analyzed - Laboratory of Bromatology and Animal Nutrition - UNIPAMPA.

Variables studied

To assess the zootechnical performance, the parameters; Final Weight Gain (WG), Average Daily Gain (ADG), Protein Efficiency Rate (PER), Body Protein Deposition (BPD), Body Fat Deposition (BFD), Carcass Yield (CY) and Survival (S), were calculated according to Silva *et al.* (2018) and Bomfim *et al*. (2020), using initial and final body weight of fish, food consumed, analysis of body composition and diets, as follows:

$$WG = final\ weight - initial\ weight$$

$$ADG = \frac{(final\ weight - initial\ weight)}{trial\ period}$$

$$PER = \frac{weight\ gain}{protein\ ingested}$$

$$BPD = \frac{(fin.weight \times fin.carcass\ crude.prot) - (init.weight \times init.carcass\ crude.prot)}{100}$$

$$BFD = \frac{(fin.weight \times fin.carcass.fat) - (init.weight \times init.carcass.fat)}{100}$$

$$CY = total\ weight - viscera\ and\ gills$$

$$S = \left(\frac{fish\ survivors}{number\ of\ fish\ in\ each\ treatment}\right) \times 100$$

At the beginning and the end trial, 10 animals per treatment were euthanized for initial and final carcass composition determination. These were carried out using the methodology described by Melo *et al.* (2002) and Hilbig *et al*. (2017).

Statistical analysis

The averages were submitted to analysis of variance and F test (significance level of 5 %). The means were compared using the Tukey test. The statistical package used was SAS (2001).

RESULTS AND DISCUSSION

During the experimental period, the water quality parameters were: 5.68 ± 0.11 mg.L^{-1} (dissolved oxygen), 23.91 ± 0.25 °C (temperature), 7.45 ± 0.13 (pH), 4.16 ± 2.23 mS/Cma 25 °C (conductivity), 5.37 ± 2.06 ‰ (salinity), 55 ± 5.77 mg.L^{-1} $CaCO_3$ (alkalinity), 0.075 ± 0.05 mg.L^{-1} (total ammonia), 0.04 ± 0.01 mg.L^{-1} (nitrite). The results obtained are in accordance with Boyd *et al*. (1997) and Lopes *et al*. (2009) for the development of fish and by Piedras *et al*. (2004, 2005) for the species *R. quelen*. The results of the zootechnical performance evaluation are described in Table 2.

The final weight gain of the fish in T3 group was lower compared to T0 (P= 0.0455). There was no difference among T0 and the rest treatments. This variation between treatments could be caused by the appearance of antinutritional factors due to the dietary adjustment of soybean meal in the formulation of the T3 diet (being the item of greatest value in the proximate composition of T3 diet). Studies

Table 2. Zootechnical parameters of juvenile silver catfish (*Rhamdia quelen*) fed a diet containing different levels of inclusion of Brazil nut (*Bertholletia excelsa*), at 45 experimental days.

	T0	T3	T6	T9	T12	P
WG (g)	11.68 ± 6.61a	4.15 ± 2.22b	8.66 ± 5.13ab	6.49 ± 3.20ab	7.6 ± 4.30ab	0.0455
ADG (g/day)	0.95 ± 0.28a	0.67 ± 0.11b	0.82 ± 0.22ab	0.75 ± 0.16ab	0.8 ± 0.20ab	0.0487
PER (g)	0.28 ± 0.18	0.10 ± 0.07	0.21 ± 0.17	0.16 ± 0.10	0.18 ± 0.17	0.0955
BPD (g)	8.18 ± 4.96	3.29 ± 1.98	6.20 ± 4.59	4.59 ± 2.77	5.30 ± 4.42	0.0981
BFD (g)	2.16 ± 1.22	0.39 ± 0.39	1.44 ± 1.05	1.12 ± 0.65	1.28 ± 1.03	0,0975
CY (g)	82.13 ± 29.94	81.42 ± 14.63	82.46 ± 35.39	82.29 ± 19.05	86.54 ± 40	0.9955
S (%)	100	100	100	100	100	

Different letters in the lines show a significant difference by the Tukey test (P < 0.05). (*) WG = final weight gain; ADG = average daily gain; PER = protein efficiency rate; BPD = body protein deposition; BFD = body fat deposition; CY = carcass yield; S = percentage of survivors.

carried out by Stech *et al*. (2010) demonstrated the presence of antinutritional factors (tannins) in soybean meal, which can affect protease inhibition and consequently generates less weight gain. Less weight gain has been observed in *Oreochromis niloticus* fed with a diet containing 66 and 100 % of mango flour as a carbohydrate (de Lima *et al*. 2011). Likewise, Guimarães *et al*. (2009) observed a significant reduction in WG and feed intake in *O. niloticus*, when using mesquite pod bran partially replacing corn in the diet, particularly as the bran levels increased. In contrast, satisfactory results have been reported with the use of cottonseed meal for *O. niloticus* fingerlings, canola and cottonseed meal for *Leporinus macrocephalus* and fingerlings, canola and sunflower meal for juveniles *O. niloticus* (Furuya *et al*. 2000, Galdioli *et al*. 2001, de Souza and Hayashi 2003).

Average daily gain (ADG) was affected by treatments (P=0.0487). Greater gain in T0 was observed compared to T3 (Table 3), but not among T0 and the other treatments. Similar results were reported by Lui *et al*. (2012), who evaluated organic wheat to replace organic corn, in the juvenile *O. niloticus* diets. Opposite results were found by Jesus *et al*. (2011), in *O. niloticus* fed with diets supplemented with 20 % of *Prosopis juliflora* bran and *Manihot esculenta* leaf. In this experiment, the fish presented satisfactory results, without compromising ADG. Likewise, Azevedo *et al*. (2013) showed positive results in juvenile *O. niloticus*, fed with diets containing palm oil cake. It was observed better zootechnical performance, without altering body characteristics, energy retention and plasma cholesterol level.

Protein efficiency rate (PER) was unaffected by the evaluated treatments (P = 0.0955). Previous studies have reported that the body protein percentage does not differ between fish (*Ictalurus furcatus*) fed with protein sources of animal or vegetable origin (Webster *et al*. 1995). Similar results were observed in fingerlings *Prochilodus lineatus* V. and *Oreochromis niloticus* L. during the sexual reversion period, in trials that compared meat meal and soybean meal (Galdioli *et al*. 2000, de Souza *et al*. 2004). Similar to this study, no differences were observed in *Leporinus macrocephalus* fed with different levels of canola meal in replacement of soybean meal (Soares *et al*. 2000). On the other hand, studies carried out by Hevrøy *et al*. (2005) indicated that the protein efficiency rate of juvenile *Salmo salar* was affected by the consumption of 18 to 24 % fish hydrolyzed protein.

No significant differences were observed in BDP (P = 0.0981) between the treatments tested. Different results were shown by Pradhan *et al.* (2018) in indian major Carps, in which an increase of the fillet protein content was observed with increased feeding levels of feed plant-ingredient-based. Protein deposition determines growth. It is a highly complex and integrated process, which involves various interactions between the mechanisms involved, such as amino acid metabolism, amino acid flux between organs, protein turnover, and skeletal muscle growth (Silva 2013). The yield and performance of *R. quelen* have been reported to be unaffected by dietary lipids of different sources (canola oil, cod liver oil and swine fat; Melo *et al*. 2002). Previous studies carried out by

Table 3. Bromatological composition of the carcass of juvenile silver catfish (*Rhamdia quelen*) containing different levels of inclusion of Brazil nut (*Bertholletia excelsa*), in dry matter.

	Begin	T0	T3	T6	T9	T12
DM	97.55	97.79	97.34	97.41	97.11	96.83
CP	61.46	65.21	63.59	64.61	63.99	64.46
EE	13.70	15.67	13.45	15.26	15	14.89
A	11.35	9.81	11.73	10.34	10.13	10.65
CF	2.84	2.1	2.57	3.00	2.81	2.81

DM= dry matter; CP= crude protein; EE = ether extract; A = ash; CF = crude fiber. Analyzed - Laboratory of Bromatology and Animal Nutrition - UNIPAMPA.

El-Sayed and Teshima (1992) and later confirmed by El-Sayed (2019), indicate that protein deposition in *O. niloticus*, is not affected by the source of dietary lipids (soy oil, cod liver oil).

The BFD values did not show significant differences between the evaluated treatments (P = 0.0975). Similar results were found by Baoshan *et al*. (2019), using wheat germ oil in the juvenile hybrid grouper feed. The contents of crude lipid of whole fish were not affected by diet. Opposite results were reported by Pradhan *et al*. (2018) in *Catla catla* and *Labeo rohita*, in which an increase of the fillet lipid content was observed with increased feeding levels of feed plant-ingredient-based. Studies conducted by Bomfim *et al*. (2005) in *Prochilodus affins*, concluding that fish fed diets containing a higher energy level showed greater body fat gain than those fed with diets containing lower energy levels.

There was no significant difference in carcass performance among the treatments tested (P = 0.9955). Similar results were found by Pradhan *et al*. (2018), during carcass traits evaluation of indian major Carps fed plant-ingredient-based feed. Likewise, Li *et al.* (2017), did not observe differences in the carcass yield of the Pond-raised Hybrid Catfish, fed with vegetable protein sources. The inclusion of mango residue bran (0, 5, 10 and 15 %) in the juveniles *O. niloticus* diet, produced carcass yield values close to those obtained in this experiment (de Lima *et al*. 2011). Lower CY values (60.93 %) were found by Lanna *et al*. (2004) in the evaluation of sugarcane bagasse in the diet of *O. niloticus*.

Survival rates of all experimental groups were 100 %, and not affected by Brazil nut. Similar results have been observed in *L. macrocephalus* subjected to diets with different levels of triticale (Nagae *et al.* 2001). The same result was reported in groups of *Ctenopharyngodon idella* fed different levels of inclusion of cassava bran in replacement of corn (Lacerda *et al.* 2005). Responses lower than the values obtained in this study were reported in *O. niloticus* (88 %) fed with wheat (Signor *et al*. 2007).

Nogueira and Rodrigues (2007) reported that factors such as the imbalance of the carrying capacity and the concentration of animals in small volumes of water, has negative effect on the survival rate. Likewise, these authors indicate that up to a 10 % mortality rate is acceptable in production systems.

The bromatological composition of juveniles silver catfish included in the experiment, are described in Table 3. The chemical composition values are within the values quoted for the species (Contreras-Guzmán *et al*. 1994). Protein and lipid values of 68.2 % and 13.77 % respectively, have been reported in juveniles of silver catfish fed with different sources of lipids (Melo *et al*. 2002). Likewise, in other study evaluating the effect of feeding on the chemical composition of the *R. quelen* carcass, it reported similar values of 68.58 - 73.23 % CP, 1.80 - 13.54 % EE and 7.70 - 8.72 A (Melo *et al*. 2003). The A values ranged from 9.81 to 11.73 %, greater than those observed by Rocha *et al.* (2007), for *R. quelen* fingerlings (6.90 and 9.39 %). The values reported in this research are higher than those observed by Maia *et al.* (1999), in a study that evaluated the chemical composition of *Prochilodus cearensis*, in different months of the year (17.8 - 19.6 % protein, 2.5 - 5.2 % lipids, 1.1 - 1.7 % ash). Similarly, our results are higher than those observed in the *Prochilodus* genus, reported by Oliveira (1999), who showed crude protein and lipid contents between 18.0 - 20.5 % y 0.5 - 4 % respectively, for *P. scrofa*, *P. cearensis* and *P. nigricans*.

The results of the zootechnical performance evaluation obtained in T6, T9 and T12 groups indicate that the Brazil nut could be included in the juvenile *R. quelen* diet, without affecting growth performance. However, the values shown by the T3 group require careful evaluation.

CONCLUSION

The inclusion of 3 % Brazil nut (*Bertholletia excelsa*) in the juveniles silver catfish (*Rhamdia quelen*) diet, decreased the final weight gain and affected the average daily gain of the fish evaluated, without affecting the rest of the zootechnical variables studied. Further research is required to determine the adequate level of the Brazil nut in the *R. quelen* diet that allows to achieve an optimal zootechnical performance, as well as, to evaluate the effect of this ingredient on the antioxidant and immune response of this species.

CITED LITERATURE

Alceste, CC; Jory, DE. 2000. Tilápia – Alternative protein sources in tilapia feed formulation. Aquaculture Management 26(4):7-13.

AOAC (Association of Official Analytical Chemistry). 1995. Official methods of analysis. 16 ed. Arlington, USA, AOAC International. 1018 p.

Azevedo, RVD; Tonini, WCT; Braga, LGT. 2013. Palm oil and palm kernel cake in diets for juvenile Nile tilapia (on line). Pesquisa Agropecuária Brasileira 48(8) 1028-1034. Consulted 17 sep. 2020. Available in https://doi.org/fbm5

Baoshan, L; Jiying, W; Yu, H; Tiantian, H; Shixin, W; BingShan, H; Yongzhi, S. 2019. Effects of replacing fish oil with wheat germ oil on growth, fat deposition, serum biochemical indices and lipid metabolic enzyme of juvenile hybrid grouper (*Epinephelus fuscoguttatus* ♀ × *Epinephelus lanceolatus* ♂) (on line) Aquaculture 505 54-62. Consulted 20 sep. 2020. Available in https://doi.org/fbm5

Barreto, LS; Souza, ATC; Martins, CC; Araujo, SBL; Ribeiro, CAO. 2020. Urban effluents affect the early development stages of Brazilian fish species with implications for their population dynamics (on line). Ecotoxicology and Environmental Safety 188:109907. Consulted 14 sep. 2020. Available in https://doi.org/fbm6

Bomfim, MAD; Lanna, EAT; Serafini, MA; Ribeiro, FB; Pena, KS. 2005. Proteína bruta e energia digestível em dietas para alevinos de curimbatá (*Prochilodus affins*) (on line). Revista Brasileira de Zootecnia 34(6):1795-1806. Consulted 21 apr. 2020. Available in https://doi.org/cb674p

Bomfim, MAD; Marchão, RS; Ribeiro, FB; Siqueira, JCD; Silva, LR; Takishita, SS. 2020. Digestible tryptophan requirement for tambaqui (*Colossoma macropomum*) fingerlings (on line). Revista Ciência Agronômica 51(2):1-9. Consulted 14 sep. 2020. Available in https://doi.org/fbm8

Borghesi, R; de Arruda, LF; Oetterer, M. 2007. A silagem de pescado na alimentação de organismos aquáticos (on line). Boletim do Centro de Pesquisa de Processamento de alimentos 25(2):329-339. Consulted 21 apr. 2020. Available in https://bit.ly/3mYLecz

Boyd, C. 1997. Manejo do solo e da qualidade da água em viveiro para aquicultura. Coelho, S (trad.). Campinas, Brasil, Mogiana Alimentos S.A. 55 p.

Brandão, LV. 2009. Utilização de fitase em dietas para peixes (on line). Publicações em Medicina Veterinária e Zootecnia 3(5):1-10. Consulted 21 apr. 2020. Available in https://bit.ly/30ga8uF

Brandão, LV; Tenório, GLO; Brandão, VMD; Costa, LC; Pereira Junior, GP; Roubach, R. 2018. Influência da adição de fitase em dietas para tambaqui (on line). Boletim do Instituto de Pesca 41(4):1025-1032. Consulted 14 sep. 2020. Available in https://bit.ly/3l15OaB

Cardoso, BR; Duarte, GBS; Reis, BZ; Cozzolino, SM. 2017. Brazil nuts: Nutritional composition, health benefits and safety aspects (on line). Food Research International 100(2):9-18. Consulted 14 sep. 2020. Available in https://doi.org/gcggn4

Cheng, ZJ; Hardy, RW; Usry, JL. 2003. Effects of lysine supplementation in plant protein-based diets on the performance of rainbow trout (*Oncorhynchus mykiss*) and apparent digestibility coefficients of nutrients (on line). Aquaculture 215(1-4):255-265. Consulted 21 apr. 2020. Available in https://doi.org/bqzq6q

Coldebella, IJ; Radünz Neto, J. 2002. Farelo de soja na alimentação de alevinos de jundiá (*Rhamdia quelen*) (on line). Ciência Rural 32(3):499-503. Consulted 21 apr. 2020. Available in https://doi.org/dv32qz

Contreras-Guzmán, ES. 1994. Bioquímica de pescados e derivados. Jaboticabal, Brasil, FUNEP. 409 p.

Damaceno, JBD. 2017. Biocarvão e efeito residual de adubação fosfatada em mudas de Castanheira-do-Brasil (*Bertholletia excelsa* Bonpl.) em latossolo da Amazônia. Dissertação de Mestrado. Manaus, Brasil, Instituto Nacional de Pesquisas da Amazônia. 71 p.

da Silva, RF; Ascheri, JLR; de Souza, JML. 2010. Influência do processo de beneficiamento na qualidade de amêndoas de castanha-do-brasil. Ciência e Agrotecnologia 34(2):445-450. Consulted 21 apr. 2020. Available in https://doi.org/bx6d9d

de Lima, MR; Ludke, MCMM; Porto Neto, FF; Pinto, BWC; Torres, TR; de Souza, EJO. 2011. Farelo de resíduo de manga para tilápia do Nilo (on line). Acta Scientiarum Animal Sciences 33(1):65-71. Consulted 21 apr. 2020. Available in https://doi.org/d8w6qs

de Souza, JML; de Menezes, HC. 2004. Processamento de amêndoa de torta de castanha-do-Brasil e farinha de mandioca: parâmetros de qualidade (on line). Ciência Tecnologia de Alimentos 24(1):120-128. Consulted 21 apr. 2020. Available in https://doi.org/dv34hz

de Souza, SR; Hayashi, C. 2003. Avaliação do farelo de algodão na alimentação de alevinos de tilápia-do-nilo (*Oreochromis niloticus* L.) (on line). Revista Zootecnia Tropical 21(4):383-398. Consulted 21 apr. 2020. Available in https://bit.ly/3cCFtwt

de Souza, SR; Hayashi, C; Galdioli, EM; Soares, CM; Meurer, F. 2004. Diferentes fontes protéicas de origem vegetal para tilápia do Nilo (*Oreochromis niloticus* L.) durante a reversão sexual (on line). Acta Scientiarum Animal Sciences 26(1):21-28. Consulted 21 apr. 2020. Available in https://doi.org/ccrhmq

Decarli, JA; Bittarello, AC; Sividanes, VP; Sary, C; Feiden, A; Signor, A; Bittencourt, F. 2016. Farinha de minhoca para juvenis de jundiá *Rhamdia voulezi* criados em tanques-rede (on line). Agrarian 9(34):390-396. Consulted 14 sep. 2020. Available in https://bit.ly/33bbUz2

dos Santos, VG; Fernandes Junior, AC; Koch, JFA; Barros, MM; Guimaraes, IG; Pezzato, LE. 2009. Performance of Nile tilapia fed diets containing meal radish forage (on line). Boletim do Instituto de Pesca 35(3):451-459. Consulted 14 sep. 2020. Available in https://bit.ly/3cI9JWS

El-Sayed, AM. 2019. Tilapia culture. 2 ed. Academic Press. Amsterdam, Netherlands. 358 p.

El-Sayed, AM; Teshima, S. 1992. Protein and energy requirements of nile tilapia, *Oreochromis niloticus*, fry (on line). Aquaculture 103(1):55-63. Consulted 21 apr. 2020. Available in https://doi.org/cwqz99

Furuya, VRB; Furuya, WM; Hayashi, C; Soares, CM. 2000. Niveles de inclusión de harina de girasol en la alimentación de la tilapia del Nilo (*Oreochromis niloticus*), en etapa juvenil. Revista Zootecnia Tropical 18(1):91-106

Galdioli, EM; Hayashi, C; de Faria, ACEA; Soares, CM. 2001. Substituição parcial e total da proteína do farelo de soja pela proteína dos farelos de canola e algodão em dietas para alevinos de piavuçu, (*Leporinus macrocephalus*) (Garavello & Britski, 1988) (on line). Acta Scientiarum Animal Sciences 23(4):841-847. Consulted 21 apr. 2020. Available in https://doi.org/fbpf

Galdioli, EM; Hayashi, C; Soares, CM; Furuya, WM; Nagae, MY. 2000. Diferentes fontes protéicas na alimentação de alevinos de curimbá (*Prochilodus lineatus* V.) (on line). Acta Scientiarum Animal Sciences 22(2):471-477. Consulted 21 apr. 2020. Available in https://bit.ly/3icYnv4

Gomes, RLM; Moro, EB; Sosa, BS; Damasceno, DZ; Rodrigues, ML; Bittencourt, F. 2019. Sources of lipids in diets for silver catfish (*Rhamdia quelen*) juveniles (on line). Boletim do Instituto de Pesca 45(2):1-10. Consulted 14 sep. 2020. Available in https://doi.org/fbpn

Gomiero, LM; Souza, UP; Braga, FMS. 2007. Reprodução e alimentação de *Rhamdia quelen* (Quoy & Gaimard, 1824) em rios do Núcleo Santa Virgínia, Parque Estadual da Serra do Mar, São Paulo, SP (on line). Biota Neotropica 7(3):127-133. Consulted 21 apr. 2020. Available in https://doi.org/b33w8r

Guimarães, IG; Lima, CB; Ribeiro, VL; Miranda, EC. 2009. Farinha de algaroba em dietas para tilápia do Nilo (*Oreochromis niloticus*) (on line). Publicações em Medicina Veterinária e Zootecnia 3(3):491-496. Consulted 21 apr. 2020. Available in https://bit.ly/338RAy0

Guimarães, SF; Storti Filho, A. 2004. Produtos agrícolas e florestais como alimento suplementar de tambaqui em policultivo com jaraqui (on line). Pesquisa Agropecuária Brasileira 39(3):293-296. Consulted 21 apr. 2020. Available in https://doi.org/cv8cgv

Hevrøy, EM; Espe, M; Waagbø, R; Sandnes, K; Ruud, M; Hemre, G. 2005. Nutrient utilization in Atlantic

salmon (*Salmo salar* L.) fed increased levels of fish protein hydrolysate during a period of fast growth (on line). Aquaculture Nutrition 11:301–313. Consulted 21 apr. 2020. Available in https://doi.org/fs3rd3

Hilbig, CC; do Nascimento, NF; Granville, M; de Toledo, CR; Neumann, G; Bombardelli, RA; Nakaghi, LSO. 2017. Effect of broodstock age on reproductive parameters in silver catfish *Rhamdia quelen* (on line). Aquaculture Research 48(9):5150-5154. Consulted 21 apr. 2020. Available in https://doi.org/fbpv

Jesus, LSFD; Azevedo, RVD; Carvalho, JSO; Tavares Braga, LG. 2011. Farelos da vagem da algaroba e da folha da mandioca em rações para juvenis de tilápia do Nilo mantidos em água salobra (on line). Revista Brasileira de Saúde e Produção Animal 12(4):1116-1125. Consulted 17 sep. 2020. Available in https://bit.ly/30efkPs

Koerber, S; Reis, RE. 2020. Evidence for the true type-locality of *Rhamdia quelen* (Siluriformes: Heptapteridae), and the geographical origin and invalid neotype designation of four of its synonyms (on line). Neotropical Ichthyology 18(1):1-12. Consulted 14 sep. 2020. Available in https://doi.org/fbp2

Lacerda, CHF; Hayashi, C; Soares, CM; Boscolo, WR; Kavata, LCB. 2005. Farelo de mandioca *Manihot esculenta* Crants em substituição ao milho *Zea mays* L. em rações para alevinos de carpa-capim *Ctenopharyngodon idella* (on line). Acta Scientiarum Animal Sciences 27(2):241-245. Consulted 21 apr. 2020. Available in https://doi.org/bjqnbc

Lanna, EAT; Pezzato, LE; Furuya, WM; Vicentini, A; Cecon, PR; Barros, MM. 2004. Fibra bruta e óleo em dietas em dietas práticas para tilápia do Nilo (*Oreochromis niloticus*) (on line). Revista Brasileira de Zootecnia 33(6 supl. 3):2177-2185. Consulted 21 apr. 2020. Available in https://doi.org/cttwpk

Li, M; Bosworth, B; Lucas, P. 2017. Replacing Soybean Meal with Alternative Protein Sources in Diets for Pond-raised Hybrid Catfish, ♀ *Ictalurus punctatus* × ♂ *Ictalurus furcatus* (on line). Journal of the world aquaculture society. Consulted 14 September 2020. Available in https://doi.org/gd3ftn

Lopes, PRS; Pouey, JLOF; Enke, DBS; Mallmann, CA; Kich, HA; Soquetta, MB. 2009. Use of adsorbent in diets containing aflatoxin for silver catfish fingerlings (on line). Revista Brasileira de Zootecnia 38(4):589-595. Consulted 14 sep. 2020. Available in https://doi.org/bs4b9v

Luchini, L. 1990. Manual para el cultivo del bagre sudamericano (*Rhamdia sapo*). Buenos Aires, Argentina, INIDEP. 63 p.

Lui, TA; Neu, DH; Boscolo, WR; Bittencourt, F; de Freitas, JMA; Feiden, A. 2012. Uso de trigo orgânico na alimentação de juvenis de tilápia do Nilo (*Oreochromis niloticus*) (on line). Pesquisa Agropecuária Tropical 42(4):383-389. Consulted 21 apr. 2020. Available in https://doi.org/fbp3

Maia, EL; de Oliveira, CCS; Santiago, AP; Cunha, FE; Holanda, FC; Sousa, JÁ. 1999. Composição química e classes de lipídios em peixe de água doce curimatã comum, *Prochilodus cearensis* (on line). Ciência e Tecnologia de Alimentos 19(3):433-437. Consulted 21 apr. 2020. Available in https://doi.org/b8h3xw

Melo, JFB; Boijink, CL; Radünz Neto, J. 2003. Efeito da alimentação na composição química da carcaça do jundiá *Rhamdia quelen* (on line). Revista Biodiversidade Pampeana 1(1):12-23. Consulted 21 apr. 2020. Available in https://bit.ly/3ibXD9t

Melo, JFB; Neto, JR; Silva, JHS; Trombetta, CG. 2002. Desenvolvimento e composição corporal de alevinos de jundiá (*Rhamdia quelen*) alimentados com dietas contendo diferentes fontes dSASe lipídios (on line). Ciência Rural 32(2):323-327. Consulted 21 apr. 2020. Available in https://doi.org/dk637s

Müller, CH; Figueiredo, FJ; Kato, AK; de Carvalho, JEU; Stein, R; Silva, A. 1995. A cultura da castanha-do-Brasil. Coleção plantar 23. Brasilia, Brasil, EMBRAPA SPI. 65 p. (Série Vermelha Fruteiras). Consulted 21 April 2020. Available in https://bit.ly/33aKhWH

Nagae, MY; Hayashi, C; Galdioli, EM. 2001. Inclusão do triticale em rações para alevinos de piavuçu, *Leporinus macrocephalus* (Garavello & Britski,

1988) (on line). Acta Scientiarum 23(4):849-853. Consulted 21 apr. 2020. Available in https://doi.org/fbp5

Nogueira, AC; Rodrigues, T. 2007. Criação de tilápias em tanques-rede. Salvador, Brasil, Sebrae. 23 p.

Oliveira, SLCL. 1999. Estudo dos constituintes lipídicos em peixes do Ceará. Dissertação de Mestrado. Fortaleza, Brasil, Universidade Federal do Ceará. 118 p.

Olaya-Nieto, CW; Hernández, DF; Ayarza, E. 2010. Biología reproductiva del liso *Rhamdia quelen* (Pisces: Heptapteridae) en el río Sinú, Colombia (on line). Acta Biológica Colombiana 15(3):61-74. Consulted 14 sep. 2020. Available in https://bit.ly/3j7ab3b

Oyakawa, OT; Akama, A; Mautari, KC; Nolasco, JC. 2006. Peixes de riachos da Mata Atlântica. São Paulo, Brasil. Neotrópica. 201 p.

Parra, JEG; Radünz Neto, J; Veiverberg, CA; Lazzari, R; Bergamin, GT; Pedron, FA; Rossato, S; Sutili, F. 2008. Alimentação de fêmeas de jundiá com fontes lipídicase sua relação com o desenvolvimento embrionário e larval (on line). Ciência Rural 38(7):2011-2017. Consulted 21 apr. 2020. Available in https://doi.org/csc8dt

Piedras, SRN; Moraes, PRR; Isoldi, LA; Pouey, JLOF; Rutz, F. 2005. Comparação entre o selênio orgânico e o inorgânico empregados na dieta de alevinos de jundiá (*Rhamdia quelen*). Boletim do Instituto de Pesca 31(2) 171-174. Consulted 14 September 2020. Available in: https://bit.ly/2S940zC

Piedras, S; Moraes, P; Pouey, J. 2004. Crescimento de juvenis de jundiá (*Rhamdia quelen*), de acordo com a temperatura da água (on line). Boletim do Instituto de Pesca 30(2):177-182. Consulted 21 apr. 2020. Available in https://bit.ly/3ifg5xQ

Pradhan, C; Narassimmalu, R; Mohanty, S. 2018. Effect of Different Feeding Levels of Plant-ingredient-based Feed on Fillet Fatty Acid Profile, Carcass Trait, and Sensory Characteristics of Indian Major Carps in Earthen Pond Polyculture (on line). Journal of the world aquaculture society. Consulted 14 September 2020. Available in https://doi.org/fbp6

Rocha, CB; Pouey, JLOF; Enke, DBS; Xavier, EG; Almeida, DB. 2007. Suplementação de fitase microbiana na dieta de alevinos de jundiá: efeito sobre o desempenho produtivo e as características de carcaça (on line). Ciência Rural 37(6):1772-1778. Consulted 21 apr. 2020. Available in https://doi.org/fgr443

Rodrigues, APO. 2014. Nutrição e alimentação do tambaqui (*Colossoma macropomum*) (on line). Boletim do Instituto de Pesca 40(1):135-145. Consulted 21 apr. 2020. Available in https://bit.ly/3i5xetW

SAS. 2001. The SAS system for Windows. Version 8e. SAS Institute Inc. Cary, NC. 1 CD-ROM

Scaranto, BMS; Ribolli, J; Zaniboni-Filho, E. 2018. DNA barcoding reveals blend of silver catfish *Rhamdia* species from fish farms in Southern Brazil (on line). Aquaculture Research 49(5):1907-1913. Consulted 14 sep. 2020. Available in https://doi.org/gdcqwj

Signor, AA; Boscolo, WR; Feiden, A; Signor, A; Reidel, A. 2007. Triguilho na Alimentação da Tilápia do Nilo (*Oreochromis niloticus* L.): Digestibilidade e Desempenho (on line). Ciência Rural 37(4):1116-1121. Consulted 21 apr. 2020. Available in https://doi.org/c7j6k3

Silfvergrip, AMC. 1996. A sistematic revision of the neotropical catfish genus *Rhamdia* (Teleostei, Pimelodidae). Doctoral dissertation. Stockholm, Sweden, Stockholm University. 156 p.

Silva, JC; Bomfim, MAD; Lanna, EAT; Ribeiro, FB; de Siqueira, JC; de Sousa, TJR; Marchão, RS; do Nascimento, DCN. 2018. Lysine requirement for tambaqui juveniles (on line). Semina: Ciências Agrárias, 39(5):2157-2168. Consulted 14 sep. 2020. Available in https://doi.org/fbp7

Silva, TSC. 2013. Exigências em proteína e energia e avaliação de fontes proteicas alternativas na alimentação do cachara *Pseudoplatystoma fasciatum*. Tese de Doutorado. Piracicaba, Brasil, Universidade do Estado de São Paulo (UNESP). 44 p.

Soares, CM; Hayashi, C; Rossetto, V; Furuya, VRB; Furuya, WM; Galdioli, EM. 2000. Substituição parcial e total da proteína do farelo de soja pela

do farelo de canola na alimentação de alevinos de piavuçu (*Leporinus macrocephalus*, L.) (on line). Revista Brasileira de Zootecnia 29(1):15-22. Consulted 21 apr. 2020. Available in https://doi.org/fmdf5b

Stech, MR; Carneiro, DJ; de Carvalho, MRB. 2010. Fatores antinutricionais e coeficientes de digestibilidade aparente da proteína de produtos de soja para o pacu (*Piaractus mesopotamicus*). Acta Scientiarum Animal Sciences 32(3) 255-262. Consulted 21 sep. 2020. Available in https://doi.org/cqpk5b

Tessaro, L; Toledo, CPR; Neumann, G; Krause, RA; Meurer, F; Natali, MRM; Bombardelli, RA. 2012. Growth and reproductive characteristics of *Rhamdia quelen* males fed on different digestible energy levels in the reproductive phase (on line). Aquaculture 326-329:74-80. Consulted 21 apr. 2020. Available in https://doi.org/c374xc

Webster, CD; Tidwell, JH; Tiu, LS; Yancey, DH. 1995. Use of soybean meal as partial or total substitute of fish meal in diets for blue catfish (*Ictalurus furcatus*) (on line). Aquatic Living Resources 8(4):379-384. Consulted 21 apr. 2020. Available in https://doi.org/dwgkgq

Yousif, RA; Abdullah, OJ; Ahmed, AM; Adam, MI; Ahmed, FAM; Idam, OA. 2019. Effect of replacing fishmeal with water spinach (*Ipomoea aquatica*) on growth, feed conversion and carcass composition for Nile Tilapia fry (*Oreochromis niloticus*) (on line). Journal of Aquatic Science and Marine Biology 2(4):13-20. Consulted 14 sep. 2020. Available in https://bit.ly/3kYsdp0

Yue, YR; Zhou, QC. 2008. Effect of replacing soybean meal with cottonseed meal on growth, feed utilization, and hematological indexes for juvenile hybrid tilapia, *Oreochromis niloticus* × *O. aureus* (on line). Aquaculture 284(1-4):185-189. Consulted 14 sep. 2020. Available in https://doi.org/c454x8