**Peruvian Journal of Agronomy**
http://revistas.lamolina.edu.pe/index.php/jpagronomy/index

**RESEARCH ARTICLE**
https://doi.org/10.21704/pja.v7i3.2064

Received for publication: 11 October 2023
Accepted for publication: 30 November 2023
Published: 30 December 2023
ISSN: 2616-4477


# Digestible energy content and apparent digestibility coefficients of fish meal, soybean meal, corn, wheat middlings and soybean oil in paiche *Arapaima gigas*

## Contenido de energía digestible y coeficientes de digestibilidad aparente de la harina de pescado, torta de soya, maiz, harinilla de trigo y aceite de soya en paiche *Arapaima gigas*

Víctor Jesús Vergara-Rubín[1,2], Víctor Rodrigo Guevara-Carrasco[3]

[1] Laboratorio de Investigación en Nutrición y Alimentación en Peces y Crustáceos (LINAPC), Departamento de Nutrición, Universidad Nacional Agraria La Molina, La Molina, Lima, Perú.
[2] Programa de Investigación y Proyección Social en Alimentos (PIPSA), Departamento de Nutrición, Universidad Nacional Agraria La Molina, La Molina, Lima, Perú.
[3] Universidad Nacional Agraria La Molina, La Molina, Lima, Perú.

*Corresponding author: vjvergara@lamolina.edu.pe
https://orcid.org/0000-0002-1702-2789

## Abstract

A balanced feed will optimize the performance and nutrient utilization of the paiche according to its genetic potential. Information is required regarding the nutritive value of the ingredients and the bioavailability of the nutrients. For this reason, and given the limited information available, the objective of this research was to determine the apparent digestibility coefficients of nutrients and digestible energy of fish meal, soybean meal, corn, wheat middlings and soybean oil through the indirect method using chromic oxide as an inert marker. The apparent digestibility of dry matter ranged from 49 % -87 %, protein ranged from 68-90 %, lipids ranged from 73-93 % and energy ranged from 54-97 % for the different ingredients tested. The digestible energy of the fish meal was determined to be 4.34 Mcal.DE/kg. Soybean meal, corn, wheat middlings and soybean oil had values of 3.67 Mcal.DE/kg, 2.63 Mcal.DE/kg, 2.24 Mcal.DE/kg and 9.19 Mcal. DE/kg. Knowledge of the digestibility of nutrients will allow the development of feeds for the paiche with ingredients of greater digestibility, allowing to increase the productive performance of the paiche, the reduction of feeding costs resulting in the improvement of the profitability of fish farmers for a sustainable activity.

***Keywords:*** *Arapaima gigas, paiche, digestibility*

## Resumen

Un alimento balanceado permitirá optimizar la performance y la utilización de los nutrientes del paiche acorde a su potencial genético. Se requiere información en relación al valor nutritivo de los ingredientes y conocer la biodisponibilidad de los nutrientes. Por tal motivo y ante la limitada información disponible, la presente investigación tuvo como objetivo determinar el coeficiente de digestibilidad de los nutrientes y la energía digestible de la harina de pescado, torta de soya, maíz, harinilla de trigo y aceite de soya; a través del método indirecto utilizando óxido crómico como marcador inerte. La digestibilidad aparente de la materia seca varió de 49-87 %, la proteína varió entre 68-90 %, los lípidos entre 73-93 % y la energía entre 54-97 % en los

**How to cite this article:**
Vergara-Rubín, V., & Guevara-Carrasco, V. (2023). Digestible energy content and apparent digestibility coefficients of fish meal, soybean meal, corn, wheat middlings and soybean oil in paiche *Arapaima gigas*. *Peruvian Journal of Agronomy, 7*(3), 179-185. https://doi.org/10.21704/pja.v7i3.2064

diferentes ingredientes probados. Se determinó que la energía digestible de la harina de pescado fue de 4.34 Mcal. ED/kg, la torta de soya 3.67 Mcal. ED/kg, el maíz 2.63 Mcal. ED/kg, la harinilla de trigo 2.24 Mcal. ED/kg, y el aceite de soya 9.19 Mcal. ED/kg. El conocimiento de la digestibilidad de los nutrientes, permitirá el desarrollo de alimentos balanceados para el paiche con ingredientes de mayor digestibilidad, permitiendo aumentar el rendimiento productivo del paiche, la reducción de los costos de alimentación, mejorando la rentabilidad de los piscicultores para una actividad sostenible.

***Palabras clave:*** *Arapaima gigas, paiche, digestibilidad*

## Introduction

Paiche (*Arapaima gigas)* is considered the carnivorous species with the greatest potential for the development of Amazonian fish farming, due to its hardiness, adaptation to management, rapid growth, achieving weights of 10 to 12 kg in one year, high culture density, high tolerance to handling and its adaptation to balanced feed (Alcántara-Bocanegra et al., 2006). However, for Amazonian species, there is little information on the digestible values of nutrients and energy of most conventional ingredients, which is essential for feed formulation.

Feeds and feedstuffs contain nutrients and energy sources essential for fish growth, reproduction, and health. Energy intake is a basic nutritional requirement because maintenance of life processes takes priority over growth and other functions (National Research Council [NRC], 2011). Therefore, before formulating diets, it is necessary to know the bioavailability of feed energy to the fed animal. Only from rations with high digestibility coefficients, will be possible to obtain better feed conversion responses, maximize benefits, and, mainly, minimize the environmental impact that some of these ingredients can provide (Pezzato et al., 2002).

To generate information to optimize the formulation of paiche feed, which would reduce the cost of feed, and to generate a sustainable and profitable culture of a local species that provides a source of protein to the diet of the Amazonian community, apparent digestibility coefficients (ADC) of nutrients and digestible energy content are important.

Therefore, this research aimed to determine the ADC of nutrients and digestible energy content of fish meal, soybean meal, corn, wheat middlings, and soybean oil for paiche.

## Materials and Methods

The evaluations were carried out at the Laboratory of Nutrition and Feeding Research for Fish and Crustaceans (LINAPC), and the experimental diets were manufactured at the Animal Feed Plant of the Food Research and Extension Program at the Academic Department of Nutrition, Faculty of Animal Science, both located at Universidad Nacional Agraria La Molina.

The Laboratory of Nutrition and Feeding Research for Fish and Crustaceans (LINAPC) operates aquariums under a water recirculation system. The laboratory has two acclimatization aquariums of 120 liters each, 18 of 75 liters for growth trials, and nine of 55 liters of Guelph type for digestibility trials. Water was recirculated through mechanical and biological filters (inoculated with aerobic, anaerobic, and facultative bacteria), continuous aeration was provided (1 hp air blower), and temperature was maintained (heat pump 12000 BTU/h). Water parameters were kept according to the requirements of the species; temperature (27.03 T°) and dissolved oxygen (5.48 mg/L) were recorded daily, while pH (6.80), water hardness (152.81 ppm), total ammonia-nitrogen (0.21 mg/L) and nitrite (0.62 mg/L) were measured three times a week. Temperature, dissolved oxygen, and pH were measured with a Multi-parameter (HANNA HI9829), GH test kit was used to measure water hardness, and a colorimetric kit PRO AQUATES was used to measure total ammonia-nitrogen and nitrite.

### *Fish, feeding, experimental diets*

An in vivo digestibility test was performed to evaluate the apparent digestibility coefficients (ADC) of energy and nutrients in five ingredients. Fish were obtained from a commercial hatchery in Iquitos and transferred to LINAPC acclimatization aquariums, where they were kept for two weeks before starting the test to allow the fish to acclimatize to the laboratory conditions. During acclimation, fish were fed to satiation with the reference diet without chromic oxide.

The trial was conducted in the digestibility aquariums of LINAPC, where a total of 54 paiches were randomly allocated into five treatments with three replicates. The paiches had an average weight of 154.75 g and an average size of 25.09 cm. The reference composition of the reference diet is detailed in Table 1. For protein constituents, the experimental diets comprised 69.5 % of the reference diet, 30 % of the test ingredient, and 0.5 % of chromium oxide ($Cr_2O_3$). For energetic ingredients, 59.5 % of the reference diet was utilized in conjunction with 40 % of the test ingredient and 0.5 % chromium oxide ($Cr_2O_3$). For soybean oil, 9 % of the reference diet was utilized in conjunction with 0.5 % chromium oxide ($Cr_2O_3$). The test ingredients that were assessed individually comprised soybean oil, maize meal, soybean meal, and wheat middlings. The aquariums were allocated diets at random.

Manufacturing was performed using a Bühler pellet machine with a capacity of 500 kg/h. The process parameters were 4 bars of pressure, 70 degrees of temperature, and an intermediate process rate. The pellet size was 2 mm in diameter by 3 mm in length. The ingredients were mixed in a horizontal paddle mixer for 5 minutes after being ground to a particulate size of 300 microns. Representative samples of the diets were sent to the laboratory to determine the proximal nutrient content.

Fish were fed with the experimental diets twice a day, at 8:00 am and 5:00 pm, pellet by pellet to ensure total ingestion. After five days of adaptation to the experimental diets without

**Table 1. Reference diet composition for determination of apparent digestibility coefficients in paiche**

| INGREDIENTS | RD[1] % |
|---|---|
| Fish meal, 66 | 31.84 |
| Soybean meal, 47 | 19.90 |
| Poultry by-product | 14.93 |
| Wheat middlings | 28.26 |
| Soybean oil | 3.98 |
| Aquaculture premix[2] | 0.20 |
| Choline Chloride | 0.10 |
| Fungus Inhibitor | 0.10 |
| Growth promoter | 0.10 |
| Binder | 0.07 |
| Antioxidant | 0.03 |
| Chromic oxide | 0.50 |
| TOTAL | 100 |
| Dry matter, % | 90.89 |
| Protein, % | 43.56 |
| Crude fiber, % | 3.24 |
| Fat, % | 10.58 |
| Digestible energy, Mcal/Kg | 3.86 |
| Lysine, % | 2.84 |
| Methionine, % | 0.95 |
| Cystine, % | 0.65 |
| Arginine, % | 2.75 |
| Histidine, % | 0.99 |
| Isoleucine, % | 2 |
| Leucine, % | 3.24 |
| Phenylalanine, % | 1.68 |
| Tyrosine, % | 1.64 |
| Threonine, % | 1.79 |
| Tryptophan, % | 0.49 |
| Valine, % | 2.49 |
| Complied+Cis, % | 1.6 |
| Fen+Tyr, % | 3.4 |
| AG. Omega 3, % | 1.48 |
| AG. Omega-6, % | 1.85 |
| Total phosphorus, % | 1.52 |
| Calcium, % | 1.89 |
| Sodium, % | 0.5 |

[1]**RD:** Reference diet
[2] Composition of Aquaculture Premix: Iron 20-g, copper 1.5-g, iodine 1.5-g, Manganese 40.0-g, Zinc 20.0-g, Selenium 0.3-g, vitamin A 14,000-UI, vitamin D3 1,500-UI, vitamin E 50-mg, vitamin K 4-mg, vitamin B12 7-mg, vitamin B2 7-mg, Pantothenic acid 60-mg, nicotinic acid 120-mg, Choline chloride 600-mg, methionine 700-mg, Antioxidant 500-mg, Vehicle 1000-g.

feces collection, on the sixth day, one hour after the last feeding, fish aquariums were cleaned in order to eliminate food and feces residues from the system and start the collection at 8:00 am the following day. The sedimented feces were carefully extracted from the feces collection system and; passed through a 100 um mesh in order to place them in petri dishes. An oven at 65 ºC was used for 6 hours to reduce the humidity of the feces collected in the Petri dishes, then they were frozen and stored until laboratory analysis was performed. This procedure was repeated for 42 days to collect approximately 25 g of dry feces per aquarium.

### *Calculations*

Chemical analyses of test ingredients, diets, and feces were performed according to the Association of Official Agricultural Chemists (AOAC) for moisture (950.46), total protein (984.13), and ether extract (2003.05). Chromium oxide ($Cr_2O_3$) was determined by UV-visible spectrophotometry and gross energy by bomb calorimetry. The chemical composition of the ingredients is shown in Table 2.

Apparent digestibility coefficients (ADC) for protein, ether extract, and gross energy of the reference and test diets were performed using the formulas found in NRC for fish and crustaceans (2011).

$$ADC_{(d)} = 100 - \left(100\left(\frac{\%Cr_2O_{3(d)}}{\%Cr_2O_{3(h)}}\right) x \left(\frac{\%Nut_{(h)}}{\%Nut_{(d)}}\right)\right)$$

Where: ADC (d) = apparent digestibility coefficient of the reference and test diet, $Cr_2O_3$(d) = % chromium oxide in the diets, $Cr_2O_3$(h) = % chromium oxide in the feces, Nut(d) = % of the nutrient in the diets and Nut(h) = % of the nutrient in the feces. Then the ADCs of the ingredients were determined with the following formula:

$$CDA_{(ing)} = CDA_{(dp)} + (CDA_{(dp)} - CDA_{(dr)}) * (\frac{b * N_{(dr)}}{a * N_{(i)}})$$

Where: CDA(ing) = apparent digestibility coefficient of the ingredient, CDA(dp) = apparent digestibility coefficient of the test diet, CDA(dr) = apparent digestibility coefficient of the reference diet, a = percentage of the test ingredient, b= percentage of the reference diet, N(dr) = percentage of nutrients or gross energy of the reference diet and N(i) = percentage of the ingredient or gross energy of the test ingredient. And finally, the digestible energy content was determined from the following formula:

$$ED_{(ing)} = CDA_{(ing)} \; x \; EB_{(ing)}$$

Where: ED(ing) = digestible energy of the test ingredient, CDA(ing) = apparent digestibility coefficient of the test ingredient and EB(ing) = gross energy of the ingredient.

## Results and discussion

The apparent digestibility coefficients (ADC) of nutrients and energy for each ingredient are shown in Table 3. Figure 1 shows the ADC of nutrients through a bar graph, it can be observed that wheat middlings show as lower ADC of nutrients than corn and soybean oil.

The ADC results of the nutrients of fishmeal obtained in the present study confirm the values found by Rivadeneyra (2019), for paiche juveniles, being slightly higher in the ADC for dry matter (87.90 % and 84.81 %) and ether extract (93.35 and 91.14 %), slightly lower for the ADC of crude protein (90.82 and 92.03 %) and gross energy (91.79 and 92.92 %). The results

**Table 2. Proximate chemical composition of the test ingredients**

| Nutrients % | FISH MEAL | SOYBEAN MEAL | CORN | WHEAT MIDDLINGS | SOYBEAN OIL |
|---|---|---|---|---|---|
| Dry Matter | 94.25 | 92.55 | 87.15 | 90.25 | 99.9 |
| Protein | 66 | 50.81 | 10.88 | 17.94 | 0 |
| Ether Extract | 7.79 | 1.51 | 4.05 | 3.8 | nd |
| GE Mcal/kg | 4.73 | 4.34 | 3.88 | 4.09 | 9.4 |

nd: not determined

**Table 3: Apparent Digestibility Coefficients (ADC) of Dry Matter, Crude Protein, Crude Fat, Gross Energy (GE) and Digestible Energy (DE) of the ingredients fed to "Paiche" (*Arapaima gigas*) on Dry Basis.**

| Nutrients % | FISH MEAL | SOYBEAN MEAL | CORN | WHEAT MIDDLINGS | SOYBEAN OIL |
|---|---|---|---|---|---|
| Dry Matter | 87.90 | 82.67 | 63.54 | 49.12 | 87.35 |
| Protein | 90.82 | 85.28 | 80.84 | 68.29 | nd |
| Ether Extract | 93.35 | 82.94 | 81.72 | 73.77 | nd |
| GE | 91.79 | 84.71 | 67.77 | 54.85 | 97.72 |
| DE Mcal/kg | 4.34 | 3.67 | 2.63 | 2.24 | 9.19 |

nd: not determined

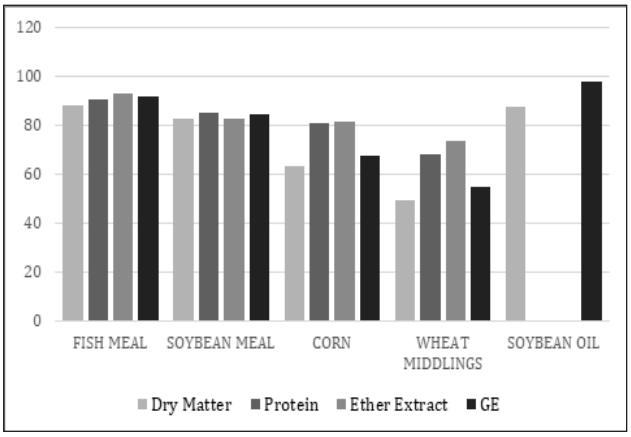


**Figure 1. Apparent Digestibility Coefficients of nutrients in paiche**

are compatible with the values obtained by Dos Santos (2016) for the ADC of dry matter (89.20 %), crude protein (97.6 %) and gross energy (89.10 %). In addition, similar results were found in another carnivorous species, such as trout, reported by Sorensen et al. (2002) for protein (90.60 %) and gross energy (89 %). Comparing with the results obtained in investigations carried out with carnivorous fish cultured in sea waters such as the pink snapper (*Luctanus guttatus*), Hernández et al. (2015), indicate that there is similarity in the ADC of gross energy (89 %), but lower in the ADC of dry matter (80.4 %) and crude protein (84.3 %). The differences in the results may be attributed to the raw material used for fishmeal production and the processing technology.

The ADC of the nutrients for soybean meal compared with the data presented by Barbarán (2019), are higher in dry matter (83 and 61 %), crude protein (85 and 81 %), and gross energy (84 and 71 %, respectively), but lower for ether extract (83 and 94 %, respectively). The variation in the acquired values is predominantly attributable to the heat treatment employed to eliminate the trypsin inhibitors that were present in the soybean bean. This heat treatment may have an impact on the nutrient digestibility.

In comparison to the findings reported by Ochoa (2019), the present study's ADC of corn nutrients for paiche yields numerically smaller values for crude protein (80.84 and 89.12 %), dry matter (63.54 and 71 %), and ether extract (81.72 and 93.78 %). Dos Santos et al. (2015), reported higher ADC values for dry matter and protein (76.37 and 93.44 %, respectively).

The CDA found in wheat middlings for paiche compared to the results presented by Benito (2022) are higher for dry matter (49 and 43 %) and gross energy (55 and 50 %), and lower for crude protein (68 and 86 %) and ethereal extract (74 and 86 %, respectively). The values obtained would be related to the level of fiber. ADC data found for wheat bran are higher than reported by Dos Santos et al. (2015) for dry matter (75.91 and 45.13 %) and crude protein (79.97 and 68.50 %).

DE of the ingredients is shown in Table 3. The highest values correspond to the protein ingredients, explained by the higher lipid content in relation to the energetic ingredients. The highest concentration of digestible energy corresponds to soybean oil and fishmeal, followed by soybean meal, corn, and finally wheat middlings.

The results obtained for the digestible energy content of paiche in the different ingredients differ from published values and are related to the digestibility coefficients; thus, data published by Barbarán (2019), and Benito (2022), are

higher for soybean meal (3.67 and 3.37 Mcal. DE/kg) and wheat meal (2.24 and 2.11 Mcal. DE/kg), respectively. However, the results of DE for fishmeal are lower than the results reported by Rivadeneyra (2019), 4.53 Mcal.DE/kg). Likewise, Ochoa (2019) presents a higher value for DE of corn (3.43 Mcal.DE/kg).

## Conclusions

According to the conditions of this research and the results obtained, it was concluded that the highest values of nutrient digestibility correspond to fishmeal, soybean meal, and soybean oil, followed by corn, and wheat middlings. The digestible energy content (dry basis) of energy ingredients for paiche, determined by a biological assay are: fishmeal 4.34 Mcal.DE/kg, soybean meal 3.67 Mcal.DE/kg, corn 2.63 Mcal.DE/kg, wheat middlings 2.24 Mcal.DE/kg, and soybean oil 9.19 Mcal.DE/kg. Knowledge of the potential utilization of nutrients will improve the quality of feeds for paiche. Information on digestibility coefficients of feed ingredients is very useful to enable formulation of diets that maximize the growth of paiche by providing appropriate amounts of available nutrient. Also, using ADC when formulating feeds can reduce food waste and improve the water quality.

## Acknowledgments

The authors gratefully acknowledge the support of Fund for Innovation, Science and Technology (FINCYT) and the National Innovation Program for Competitiveness and Productivity (INNOVATE PERU).

## Conflict of interest

The authors have no conflict of interest to declare and note that the sponsors of the issue had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## Funding declaration

Funding was provided by Fund for Innovation, Science and Technology (FINCYT) and the National Innovation Program for Competitiveness and Productivity (INNOVATE PERU).

## Authors contribution

All authors have made substantial contributions to prepare this article.

The idea for this study and the experimental design was conceived by VV and VG.

The experiment was performed and the data was analyzed by VV.

The article was written by VV and VG.

All authors revised and approved the final version of the manuscript.

## ID ORCID and e-mails

Vergara-Rubín, V. vjvergara@lamolina.edu.pe
https://orcid.org/0000-0002-1702-2789

Guevara-Carrasco, V. vguevara@lamolina.edu.pe
https://orcid.org/0000-0002-3261-5160

## References

Alcántara-Bocanegra, F., Wust, W. H., TelloMartín, S., Rebaza-Alfaro, M., & Castillo-Torres, D. (2006). *Paiche el Gigante del Amazonas*. Instituto de Investigaciones de la Amazonía Peruana (Kaushik). Iquitos. Perú. 70 p.

Association Of Official Analytical Chemist. (1990). *Official methods of analysis: agricultural chemicals, contaminants and drogs*. 15.ed. Washington: Association of Official Analytical Chemists, 1990. v.1, 684 p.

Barbarán, R. E. (2019). *Digestibilidad de nutrients y energía digestible de la torta de soya (Glycine max) en Juveniles de Paiche*

(*Arapaima gigas*). [Thesis, Universidad Nacional Agraria La Molina].

Benito, C. E. (2022). *Digestibilidad y energía digestible de harinilla de trigo y polvillo de arroz en el paiche* (*Arapaima gigas*). [Thesis, Universidad Nacional Agraria La Molina].

Dos Santos, F., Santos De Lima., K., Bevitorio-Passinato, E., Mota De Jesus, R., Oliveira, F. Teles-Tonini, W.C., & Tabares-Braga, L.G. (2015). Apparent digestibility of energetic ingredients by pirarucú juveniles (*Arapaima gigas*). *Lat. Am. J. Aquat. Res.*, *43*(4), 786–791.

Dos Santos, F. (2016). Digestibility of animal and vegetable protein increments by pirarucú juveniles (*Arapaima gigas*). *Revista Brasileña de Zootecnia*, *45*(10), 581–586.

Hernández, R. W., Hardy., D. G., Marquez-Martine, Z., Rodríguez, P. V., & Gonzales-Rodríguez, B. (2015). Evaluation of apparent digestibility coefficients of individual feed ingredients in spotted rose snapper (*Lutjanus guttatus*). *Aquaculture Nutrition* 2015.

National Research Council. (2011)**.** *Nutrient Requirements of Fish and Shrimp*. The National Academies Press. Washington, D.C. 376 p.

Ochoa, D. T. (2019). *Digestibilidad de nutrientes y energía digestible del maíz (Zea mays) en juveniles de paiche* (*Arapaima gigas*). [Thesis, Universidad Nacional Agraria La Molina].

Pezzato, L. E., Miranda, E. C., Barros, M. M., Pinto, L. G. Q., Furuya, W. M., & Pezzato, A. C. (2002). Digestibilidade aparente de Ingredientes pela Tilápia do Nilo (*Oreochromis niloticus*). *Rev Bras Zootec, 31*, 1595–1604.

Rivadeneyra, J. L. (2019). *Determinación de la digestibilidad de nutrientes y energía digestible de la harina de pescado prime en juveniles de paiche (Arapaima gigas*). [Thesis, Universidad Nacional Agraria La Molina].

Sorensen, M. L. K. S. T., Ljøkjel, K., Storebakken, T., Shearer, K. D., & Skrede, A. (2002). Apparent digestibility of protein, amino acids and energy in rainbow trout (*Oncorhynchus mykiss*) fed a fish meal based diet extruded at different temperatures. *Aquaculture, 211*(1-4), 215–225.