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ORIGINAL ARTICLE

Apparent digestibility of Ora-pro-nobis (*Pereskia aculeata*) leaf meal by Nile tilapia (*Oreochromis niloticus*)

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Abstract - The objective of this study was to determine the apparent digestibility of ora-pro-nóbis leaf meal (OLM) in Nile tilapia diets, assessing the digestibility of crude protein (CP), amino acids (AA), gross energy (GE), ether extract (EE), and dry matter (DM). The indirect method with chromic oxide and feces collection by sedimentation was used. Two diets were formulated: a reference diet and a test diet, the latter containing 30.0 % OLM and 70.0 % of the reference diet. The apparent digestibility coefficients (ADC) of OLM were 30.01 % (DM), 40.60 % (GE), 76.86 % (EE), and 45.51 % (CP). Among the essential AA, tryptophan (98.00 %) and leucine (80.00 %) had the highest values, while threonine (25.00 %) and arginine (39.00 %) had the lowest. Despite its low protein and energy digestibility, OLM supplied significant amounts of essential amino acids that were absorbed by the fish. Thus, it can be used as a complementary ingredient in Nile tilapia diets, but not as the main protein or energy source.

Keywords: Alternative food. Fish nutrition. Tilapia farming. Unconventional food. Vegetable food.

Digestibilidade aparente da farinha de folhas da Ora-pro-nóbis (*Pereskia aculeata*) para tilápia-do-nilo (*Oreochromis niloticus*)

Resumo - O objetivo deste estudo foi determinar a digestibilidade aparente da farinha de folhas de ora-pro-nóbis (FFO) para tilápia-do-nilo, avaliando proteína bruta (PB), aminoácidos (AA), energia bruta (EB), extrato etéreo (EE) e matéria seca (MS). Utilizou-se o método indireto com óxido crômico e coleta de fezes por sedimentação. Foram preparados dois alimentos, um aplicado a uma dieta referência e outro a uma dieta teste, sendo esta última composta por 30,0 % de FFO e 70,0 % da dieta referência. Os coeficientes de digestibilidade aparente (CDA) da FFO foram 30,01 % (MS), 40,60 % (EB), 76,86 % (EE) e 45,51 % (PB). Entre os AA essenciais, o triptofano (98,00 %) e a leucina (80,00 %) tiveram os maiores valores, enquanto a treonina (25,00 %) e a arginina (39,00 %) apresentaram os menores. Apesar da baixa digestibilidade da proteína e energia, a FFO forneceu quantidades significativas de aminoácidos essenciais absorvidos pelos peixes. Assim, pode ser utilizada como ingrediente complementar em dietas para tilápia-do-nilo, mas não como principal fonte proteica ou energética.

Palavras-chave: Alimentação alternativa. Nutrição de peixes. Criação de tilápia. Alimentação não convencional. Alimentação vegetal.

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Introduction

Ora-pro-nobis (*Pereskia aculeata*) is an unconventional food plant widely distributed in Central and South America, including Brazil (Pinto *et al*., 2020). Its leaves contain high protein, iron, and carotenoid contents, therefore, serving as an incentive for local family farming and dietary inclusion (Simonetti; Fariña; Simonetti, 2021).

It is a perennial plant, that is, with a long cycle, with records lasting up to 10 years. Considered rustic, it adapts to different types of soil and climate, does not require high fertility, in addition to being drought tolerant and has a low incidence of pests and diseases (Panain *et al*., 2021). Madeira *et al*. (2022) observed an average of 2.43 tons of leaves per ha^{-1}/cut every 60 days, resulting in approximately 15 tons annually. In addition, its propagation is easy and low-cost, since it can be done asexually via cuttings, even employing family labor (Ribeiro Junior *et al*., 2021).

The leaves are wide, juicy, and have mucilage, a food additive widely used in the food industry as a thickening, stabilizing, and gel-forming agent (Panain *et al*., 2021). Considering that fish feeding occurs in an aquatic environment, this substance contributes to the formation of pellet, as it helps in the aggregation of ingredients and, consequently, reduces the leaching of nutrients from the diet.

From a nutritional point of view, ora-pro-nóbis is a plant rich in macronutrients, such as protein, and micronutrients, including minerals like calcium, magnesium, manganese, zinc, and iron, as well as vitamins such as vitamin A, vitamin C, and folic acid (Takeiti *et al*., 2009). Per 100 g of dried leaves, the plant contains approximately 20 g of crude protein (Almeida Filho; Cambraia, 1974). The amino acid profile is also a highlight: the leaves are great sources of essential amino acids such as tryptophan, phenylalanine, isoleucine, leucine, threonine and lysine (Botrel *et al*., 2019).

In addition to direct human consumption, an increasing number of studies has verified the potential use of leaf meal (LM) obtained from various plants, such as pigeon pea (*Cajanus cajan*), mulberry (*Morus alba*), and river tamarind (*Leucaena leucocephala*), among others, as a feed ingredient for non-ruminants, including rabbits, broilers and fish (Babalola; Fakunmoju, 2020; Chen *et al*., 2019; Dias *et al*., 2022b; Matos *et al*., 2023; Saenthaweesuk, 2009). Cost reductions are the main reason for using LM in fish feed, as traditional sources such as fish meal and fish oil, the main animal origin ingredients, and soy bran, the main vegetable protein ingredient, have become increasingly expensive (Alfiko *et al*., 2022; Hlophe; Moyo, 2014).

Tilapia (*Oreochromis niloticus*) is the most cultivated fish species in Brazil and among the most cultivated globally, and is noteworthy for its hardiness and fast growth. According to data from the Brazilian Fish Association, this species comprised about 65.3 % of the entire Brazilian farmed fish production in 2023 (Associação Brasileira da Piscicultura, 2024). Although it is produced in commercial properties, it is hardy enough to adapt to subsistence crops and it mainly common in developing countries, where the species is generally fed artisanal feeds (Campos-Ramos *et al*., 2003).

Studies have reported that LM can partially replace conventional Nile tilapia dietary ingredients without impairing fish growth (Abo-State *et al.,* 2014; Chen *et al*., 2020; Dias *et al*., 2022b). However, due to the different chemical compositions of different food items, it becomes necessary to specifically determine LM digestibility values specifically for each farmed species, aiming at formulating feeds to be used according to specific nutritional requirements (Meurer;

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Hayashi; Boscolo, 2003b).

Thus, this study aims to evaluate the ability of Nile tilapia to utilize nutrients from ora-pro-nóbis leaf meal, with emphasis on the digestibility of protein, amino acids, and energy. To the best of our knowledge, no studies have assessed OLM digestibility in this species' diet. To address this gap, we assessed the apparent digestibility of crude protein (CP), amino acids (AA), gross energy (GE), ether extract (EE), and dry matter (DM) of OLM, using an indirect method with chromic oxide as an indicator and feces collection by sedimentation.

Materials and Methods

All experiments were carried out at the Aquaculture Technology Laboratory (LATAq) belonging to the Universidade Federal do Paraná (UFPR), at the Advanced Jandaia do Sul Campus, between March and April 2022. In were accordance with the Ethical Principles in Animal Experimentation adopted by the Brazilian National Council of Animal Experimentation Control (CONCEA) and approved by the Ethics Committee on the Use of Animals (CEUA/ Palotina - UFPR), under protocol N°18/2021.

Preparation of diets

The OLM was prepared from leaves taken from ora-pro-nobis plants harvested in the city of Palotina (PR), during the summer/autumn of 2020. The leaves were dried in a forced ventilation oven for 48 h at 55 °C, crushed using a 0.5 mm sieve and stored in plastic bags under refrigeration. The feeds listed in Table 1 were prepared by grinding each ingredient using a 0.5 mm sieve right after mixing and adding about 20% water at 60 ºC, followed by subsequent pelleting (Meurer; Hayashi; Boscolo, 2003b).

Table 1. Formulation of reference and test diets.

Ingredient	Reference diet (%)	Test diet (%)
Corn starch	44.18	30.93
Albumin	32.00	22.40
Gelatin	7.70	5.39
Ora-pro-nobis leaf meal	0.0	29.67
soybean oil	6.00	4.20
Cellulose	6.00	4.20
Dicalcium phosphate	3.00	2.10
Salt	0.50	0.50
Supplement (min + vit)[1]	0.50	0.50
Chromic oxide	0.10	0.10
Antioxidant (BHT)[2]	0.02	0.01

[1]Guarantee levels per kilogram of product (TECTRON): Vitamin A(min) 1,000,000 UI; vitamin D3 (min) 500,000 UI; vitamin E (min) 20,000 UI; vitamin K3 (min) 500 mg; vitamin B1 (min) 1,900 mg; vitamin B2 (min) 2,000 mg; vitamin B6 (min) 2,400 mg; vitamin B12 (min) 3,500 mg; vitamin C (min) 25 g; niacin (min) 5,000 mg; pantothenic acid (min) 4000 mg; folic acid (min) 200 mg; biotin (min) 40 mg; manganese (min) 7,500 mg; zinc (min) 25 g; iron (min) 12.5 g; copper (min) 2000 mg; iodine (min) 200 mg; selenium (min) 70 mg; BHT (min) 300 mg. [2]Butylhydroxytoluene.

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During the adaptation period, the fish remained in the feed box and were fed *ad libitum*, four times a day, at 8:00 am, 11:00 am, 2:30 pm and 5:30 pm. Samplings were conducted by distributing the cages in three cylindrical fiberglass 200 L-vats with conical bottoms (modified Guelph system) under constant artificial oxygenation through an air blower. The vats were used only during the feces collection period, with the cages inserted at 6:00 pm and removed at 7:00 am the next day. Chromic oxide (Cr_2O3) was used as an inert marker at a 0.1 % ratio, as recommended by the National Research Council (2011). Fish feces were collected daily, stored at 0 °C and subsequently dehydrated in a forced ventilation oven at 55 °C for 24 hours, sieved to remove scales and then ground.

Chemical-bromatological analysis

Chemical-bromatological feces, feed and food ingredient analyses regarding dry matter (method n° 930.15), crude protein (method n° 984.13), ether extract (method n° 920.39), mineral matter (MM) (n° 924.05), crude fiber (CF) (Method nº 978.10), acid detergent fiber (ADF) (method n° 973.18), were determined according to the AOAC International and Latimer Junior (2019). Neutral detergent fiber (NDF) according to methodology described by Van Soest, Robertson and Lewis (1991) and the amino acids were chemically analyzed, according to the Sindirações Compendium of Animal Nutrition (ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE RAÇÕES, 2017); (method nº 45). Chromium and other minerals were determined at the Soil Laboratory belonging to the State University of Maringá by atomic absorption spectrophotometry (Kimura; Miller, 1957). An adiabatic bomb calorimeter was used to determine the gross energy (GE) of the feces, feed and food ingredients.

Calculations

The apparent digestibility coefficients (ADC) for the nutrients and energy of the test and reference diets were calculated as follows (Cho; Slinger; Bayley, 1982).

$$ADC = 1- (F / D \times Di / Fi)$$

where: F=% nutrient (or kJ/g gross energy) of feces; D=% nutrient (or kJ /g gross energy) of diet; Di = % Indicator concentration (Cr_2O3) of diet; Fi=% Indicator concentration (Cr_2O3) of feces.

In addition, the suggestions proposed by Bureau (1999) were applied, where the digestibility of the reference diet and the test diet are taken into account.

$$AD_{\text{test ingredient}} (\%) = AD_{\text{test diet}} + [(AD_{\text{test diet}} - AD_{\text{reference diet}}) \times (0.7 \times D_{\text{reference diet}})/(0.3 \times D_{\text{ingredient}})],$$

where 0,3 = Proportion of test ingredient in test diet mash; 0,7 = Proportion of reference diet mash in test diet mash.

Water quality

The physicochemical water variables of the boxes and vats, dissolved oxygen and temperature, were monitored at 8:30 am and 4:30 pm, while pH, ammonia, nitrite, alkalinity and hardness were monitored weekly.

The water quality variables measured during the experimental adaptation period and feces collection period indicated suitable conditions for Nile tilapia farming, as follows: average water temperature in the morning of 24.9±1.0 °C and in the afternoon of 30.4±1.1 °C; average dissolved oxygen in the morning of 5.2±0.3 mg L^{-1} and in the afternoon of 7.0 ± 0.3 mg L^{-1}; mean pH of 7.69 ± 0.13; average ammonia values of 0.29 ± 0.07 mg L^{-1}, nitrite 0.85 ± 0.16 mg L^{-1}, alkalinity 95.75 ± 2.26 mg L^{-1} $CaCO_3$ and hardness 47.75 ± 1.55 mg L^{-1} $CaCO_3$.

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Results and Discussion

The chemicobromatological composition, as well as the ora-pro-nobis leaf meal apparent digestibility coefficients values for dry Matter, crude protein, ethereal extract, mineral matter, crude fiber, neutral detergent fiber, acid detergent fiber and gross Energy, are displayed in Tables 2 and 3, respectively.

Table 2. Chemical-bromatological composition of ora-pro-nobis leaf meal by Nile tilapia (dry matter basis).

	Chemical-bromatological composition							
	DM %	CP %	EE %	MM %	CF %	NDF %	ADF %	GE (MJ kg^{-1})
Ora-pro-nobis leaf meal	95.56	24.36	4.54	20.6	18.96	42.28	8.91	15.54

DM – Dry Matter, CP – Crude Protein, EE – Ethereal Extract, MM – Mineral Matter, CF – Crude Fiber, NDF – Neutral Detergent Fiber, ADF – Acid Detergent Fiber, GE – Gross Energy

Table 3. Mean values of apparent digestibility coefficients (ADC) of nutrients and energy of ora-pro-nobis leaf meal by Nile tilapia (dry matter basis).

	Dry matter	Crude Protein	Ethereal Extract	Gross Energy (MJ kg^{-1})
ADC (%)	33.01	45.51	76.86	40.60
Digestible values (%)	31.55	11.09	3.49	6.31

Regarding OLM composition, DM values were similar to those reported by Sommer, Ribeiro and Kaminski (2022), and not far from those reported by Takeiti *et al*. (2009) and Almeida *et al*. (2014), of 95.28 %, 89.5 % and 87.54 % respectively. The crude protein (CP) content of the OLM was within the average range described in the literature, varying from the lowest value of 16.14 %, reported by Sommer, Ribeiro and Kaminski (2022), to the highest, 28.99 %, recorded by Almeida *et al*. (2014). The levels observed in this study were also close to those indicated by Almeida Filho and Cambraia (1974) and Mercê *et al*. (2001), who reported values of 25.4 % and 25.5 %, respectively.

The EE values were similar to other literature reports, of 4.1 % (Takeiti *et al*., 2009), 5.07 % (Almeida *et al.*, 2014) and 6.8 % (Almeida Filho; Cambraia, 1974). The MM contents were above those reporyed by Sommer, Ribeiro and Kaminski (2022), Almeida *et al*. (2014) and Takeiti *et al.* (2009), of 14.59 %, 14.81 % and 16.1 %, respectively and similar to the value reported by Almeida Filho and Cambraia (1974) of 20.1 %.

The only OLM CF data available in the literature are those reported by Almeida *et al*. (2014) and Takeiti *et al.* (2009), of 9.1 % and 9.8 %, both consistent and representing approximately half of those observed herein, while NDF and FDA values have not yet been reported in the literature. OLM GE contents have also not been well studied to date, with only one assessment found, reporting a value of 6.31 MJ kg^{-1} (Sommer; Ribeiro; Kaminski, 2022), lower than that determined in the present study.

The percentage of the determined OLM

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minerals, namely calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), phosphorus (P) and zinc (Zn), are presented in Table 4, as well as literature data comparisons. The OLM ADC values for AA are depicted in Table 5.

The minerals Ca, Mg and Zn in OLM were determined as within the range described in the literature, while K and P were lower, but still close to the concentrations described by Oliveira *et al*. (2013) and Takeiti *et al.* (2009), respectively. The determined Fe and Mn concentrations, on the other hand, were above the average values described in the literature, although the average Mn value corresponds to a single study.

Literature DM values are more consistent compared to CP, CF, MM and GE, which have been reported as more variable. Several factors can interfere with the levels of these nutrients. Mazia and Sartor (2012) argue that different soil nutrient concentrations directly influence the protein content metabolized by ora-pro-nobis and that clayey soils rich in organic matter are more suitable for crops compared to sandy soils. Genetic variability must also be considered, as Botrel *et al*. (2019) cultivated plants from different clones under the same conditions, followed by similar leaf sampling at the same development stage, and reported different CP contents. Other factors comprise physiological plant age, agronomic management, and botanical origin (Sousa *et al*., 2014).

Digestible protein refers to the fraction of protein effectively utilized by the fish. In the present study, bromatological analysis indicated a crude protein content of 24.36 %. However, considering the apparent digestibility coefficient (ADC) of protein, which was 45.51 %, only 11.09 % of this protein was assimilated by the tilapia.

Similarly, digestible energy represents the fraction of energy actually utilized by the fish. Although OLM has high energy content (Table 2), the energy digestibility data (Table 3) indicate that Nile tilapia utilized less than half of this amount, as the ADC of gross energy was 40.60 %, similar to that observed for crude protein.

Table 4. Comparison of the mineral values of ora-pro-nobis leaf meal observed in this work with those reported by others authors.

	Minerals (%)						
	Ca	**Fe**	**K**	**Mg**	**Mn**	**P**	**Zn**
Author data	3.57	0.0545	0.39	1.29	0.0336	0.02	0.0072
Takeiti *et al.* (2009)	3.42	0.0142	1.63	1.90	-	0.16	0.0267
Oliveira *et al.* (2013)	2.16	0.0094	0.45	0.68	0.0028	0.45	0.0059
Almeida *et al.* (2014)	1.34	0.0205	3.91	0.58	-	0.32	0.0073
Souza *et al.* (2016)	4.65	0.0174	3.64	0.71	-	0.47	0.0037
Average values in the literature	2.89	0.0153	2.41	0.97	0.0028	0.35	0.0109

Ca – Calcium, Fe – Iron, K – Potassium, Mg – Magnesium, P – Phosphorus and Zn – Zinc.

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Table 5. Chemical composition, available values and apparent digestibility coefficients (ADC) of amino acids in ora-pro-nóbis leaf meal by Nile tilapia (dry matter basis) compared to the chemical composition and available values of common vegetable ingredients in the fish diets.

Aminoacids	Chemical composition (%)				Available values (%)				ADC (%)
	Ora-pro-nobis	Wheat bran*	Ground corn*	Soybean meal*	Ora-pro-nóbis	Wheat bran*	Ground corn*	Soybean meal*	Ora-pro-nóbis
Leu	1.74	0.54	0.88	3.42	1.38	0.44	0.81	3.11	80.00
Arg	1.31	0.92	0.38	3.75	0.51	0.77	0.35	3.61	39.00
Fhe	1.14	0.35	0.33	1.86	0.90	0.24	0.29	1.74	79.00
Lys	1.11	0.58	0.23	2.64	0.84	0.46	0.21	2.4	76.00
Ile	1.02	0.55	0.27	1.9	0.80	0.45	0.22	1.66	79.00
Thr	0.89	0.38	0.32	1.53	0.22	0.28	0.28	1.38	25.00
Trp	0.56	0.21	0.08	0.56	0.55	0.18	0.07	0.52	98.00
His	0.50	0.38	0.29	1.09	0.38	0.26	0.25	1,01	76.00
Met	0.21	0.27	0,16	0.55	0.14	0.20	0.14	0.31	64.00
Val	1.21	0.44	0.39	1.95	0.95	0.31	0.35	1.74	79.00
Glu	2.32	2.34	1.45	7.86	1.91	1.88	1.30	7.54	82.00
Asp	1.72	1.04	0.39	4.64	1.35	0.84	0.35	4.36	78.00
Ala	1.21	0.71	0.61	1.76	0.97	0.59	0.53	1.53	80,00
Gly	1.18	0.79	0.21	1.7	0.87	0.65	0.18	1.48	74.00
Pro	1.00	0.96	0.72	2.43	0.85	0.63	0.64	2.12	85.00
Tyr	0.87	0.36	0.43	1.08	0.61	0.28	0.36	0.96	70.00
Ser	0.80	0.74	0.30	1.86	0.64	0.63	0.26	1.8	79.00
Cys	0.17	0.18	0.17	0.55	0.13	0.13	0.15	0.52	74.00

Leu – Leucine; Arg-Arginine; Fhe-Phenylalanine; Lys-Lysine; Ile-Isoleucine; Thr-Threonine; Trp-Tryptophan; His-Histidine; Met-Methionine; Val-Valine; Glu- Glutamic Acid; Asp- Aspartic Acid; Ala-Alanine; Gly-Glycine; Pro-Proline; Tyr-Tyrosine; Ser-Serine; Cys- Cystine. * Values described by Furuya et al. (2001).

The low ADCs of DM, CP and GE noted herein suggests that the fibrous fraction (CF, NDF and ADF) of the investigated OLM contributed to lower nutrients and energy use. According to Meurer, Hayashi and Boscolo (2003a), crude fiber decreases Nile tilapia food bolus retention and, consequently, food gastrointestinal transit times, affecting the time that food is exposed to the digestive and absorptive processes, negatively interfering in absorption efficiency (Biudes; Pezzato; Camargo, 2009). Crude fiber can also interact with the surface of the intestinal wall, acting as an obstacle between nutrients and digestive enzymes (Jha; Berrocoso, 2015; Potty, 1996).

Unlike GE, the ADC of EE was higher than 70 %, with reported digestible values for Nile tilapia exceeding 1.15 % (Araújo *et al.*, 2012), 1.25 % (Dias *et al.*, 2022a), 1.54 % (Araújo *et al.*, 2012), and 2.9 % (Madalla; Agbo; Jauncey, 2013), which were obtained for leaf meals of maniçoba (*Manihot caerulescens*), mulberry (*Morus alba*), river tamarind (*Leucaena leucocephala*), and moringa (*Moringa oleifera*), respectively.

Methionine displayed the lowest OLM availability. Available values of this essential amino acid are directly associated to the amounts present in feed. in the present study, methionine was present at the lowest levels among all essential amino acids, similarly to that reported by Almeida Filho and Cambraia (1974), Takeiti *et al*. (2009) and Botrel *et al*. (2019), the latter reporting an average value determined from the analysis of five clones. These authors also reported that leucine was present at the highest amounts, except for Takeiti *et al*. (2009), who indicated that tryptophan levels exceeded leucine, which was, in turn, the second most representative amino acid.

The studied OLM presented higher available values for 15 of the 18 analyzed amino acids when compared to wheat bran and ground corn, both traditional commercial fish feed ingredients (Table 5). Such values, however, are below those available in soybean meal, as expected, due to the different protein levels of these ingredients.

Concerning both essential and non-essential amino acids, only three, namely arginine, threonine and methionine, presented availability coefficients lower than 70%, demonstrating a good use of OLM AA by Nile tilapia. Considering that the AA percentages in OLM were lower than those reported by Almeida Filho and Cambraia (1974), Takeiti *et al*. (2009) and Botrel *et al*. (2019), probably due to the various aforementioned factors that can influence nutrient levels, the values available to Nile tilapia may be even higher.

It is important to emphasize that the objective of this study is not to recommend the use of ora-pro-nóbis leaf meal as the sole or primary protein and/or energy source in diets for Nile tilapia. Even if the ADCs of crude protein and gross energy reached values above 80%, which are considered excellent (Rodrigues; Bergamin; Santos, 2013), the digestible nutrients would still be insufficient to meet the nutritional requirements of Nile tilapia at different growth stages. Moreover, feeding fish with a single ingredient is inefficient, as it is unlikely that a single feedstuff will provide all the necessary nutrients in adequate proportions. The formulation of diets by combining different ingredients aims to balance nutritional components to meet the specific needs of farmed animals, as described by the Food and Agriculture Organization of the United Nations (New, 1987).

Although ora-pro-nóbis leaf meal contains more than 20% crude protein, classifying it as a protein ingredient (Rodrigues; Bergamin; Santos, 2013), its digestible levels are closer to those of energy ingredients, such as corn and wheat. Thus, it can be incorporated into Nile tilapia diets as a complementary component but not as the primary protein source.

Therefore, further evaluations of the digestibility of ora-pro-nóbis leaf meal for Nile tilapia are recommended throughout different seasons of the year, considering variations in soil composition, phenological stage, and fertilization. Additionally, studies that include this ingredient in formulated diets for the species are essential to determine the optimal inclusion levels.

Given that this ingredient is rich in phenolic compounds and antioxidants (Rodrigues; Bergamin; Santos, 2013), it is also crucial to investigate its impact on fish health, exploring its potential both as an ingredient and as a feed additive.

Conclusion

Ora-pro-nóbis leaf meal exhibits low apparent

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digestibility coefficients for energy and protein in Nile tilapia, at 40.60 % and 45.51 %, respectively. Ether extract was an exception, with a digestibility of 76.86 %. Despite the low protein and energy utilization, OLM provided a significant amount of essential amino acids absorbed by the fish. Thus, it can be incorporated into Nile tilapia diets as a complementary ingredient but not as the primary source of protein or energy.

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Conflict of Interests

The authors declare that the research was conducted in the absence of any potential conflicts of interest.

Ethical Statements

The authors confirm that the ethical guidelines adopted by the journal were followed by this work, and all authors agree with the submission, content and transfer of the publication rights of the article to the journal. They also declare that the work has not been previously published nor is it being considered for publication in another journal.

The study was conducted in accordance with the Ethical Principles in Animal Experimentation adopted by the National Council for the Control of Animal Experimentation (CONCEA) and approved by the Ethics Committee on the Use of Animals (CEUA-UFPR) under protocol nº. 18/2021-CEUA.

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