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Effect of feed processing during the nursery rearing of the Nile tilapia (*Oreochromis niloticus*).

Efeito do processamento das ração durante a alevinagem de tilápias do Nilo (*Oreochromis niloticus*).

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Abstract

This study aimed to compare 5 feed processing for *O. niloticus* fingerlings: ME1: micro-extruded 1 mm; ED03: extruded and disintegrated 0.3 mm; ED06: extruded and disintegrated 0.6 mm; BF03: bran 0.3 mm and BF06: bran 0.6 mm. Feed conversion was lower in ME1 and ED06. The protein retention coefficient was statistically higher in ME1. The fish proximate composition did not differ among treatments. Although superior in ME1 weight gain did not differ statistically from ED06. ME1 resulted in nitrogen and phosphorus in water statistically lower. ME1, ED06 and BF06 obtained the highest partial net revenues. Thus, ME1 presented the best zootechnical indices, economic performance and reduced impact on water quality.
Keywords: Rearing tilapias. Food management. Food strategy. Aquaculture.

Resumo

O estudo objetivou comparar 5 rações para alevinos de *O. niloticus*: ME1: microextrusada 1 mm; ED03: extrusada e desintegrada 0,3 mm; ED06: extrusada e desintegrada 0,6 mm; BF03: farelada 0,3 mm e BF06: farelada de 0,6 mm. A conversão alimentar foi menor em ME1 e ED06. O coeficiente de retenção proteica foi estatisticamente maior em ME1. A composição centesimal não diferiu entre tratamentos. Embora superior em ME1, o ganho de peso não diferiu estatisticamente de ED06. ME1 resultou em níveis de nitrogênio e fósforo na água estatisticamente inferiores. ME1, ED06 e BF06 obtiveram maiores receitas líquidas parciais. Assim, ME1 apresentou melhores índices zootécnicos, econômicos e menor impacto na qualidade da água.
Palavras-chave: Alevinos de tilápia. Manejo alimentar. Estratégia alimentar. Aquicultura.

Introduction

Nile tilapia (*Oreochromis niloticus*) is a fish species of African origin with omnivorous feeding habits, rustic and with fast growth in intensive production systems. Due to the expressive growth of Brazilian fish farming over the past few decades, fish production exceeded 561 thousand tons (IBGE, 2019), which was mostly due to tilapia farming that currently represents 55% of the total national production. For this reason, this species has been widely studied, with focus on improving the efficiency of modern production systems (JERÔNIMO et al., 2011; BRITO et al., 2017), and with special attention to nutrition (LEE et al., 2016).

Depending on the strategy used for feed processing, fish may face difficulties during feeding, leading to significant nutrient losses, and consequently, affecting the tanks water quality negatively (RODRIGUES, FERNANDES, 2006; BITTENCOURT et al., 2012). The identification of the ideal pellet size is one of the most important aspects regarding fish nutrition (TRAN-TU et al., 2017), especially during larviculture and nursery stages, given the small size of fish (BAILEY et al., 2003), and consequently its mouth opening.

Micro-extruded diets for nursery (<1 mm) are currently found on the market, which can be consumed by small fish, thus improving its digestibility (GAO et al., 2019). However, in order to obtain pellets of reduced size in this ration, feed factories have to increase the degree of fineness, which commonly precludes the extrusion of small diets or micro- extruded diets (<1 mm), due to increased costs. Hence, in general, fish farmers feed tilapia fingerlings with powder diets (brans) until the animals reach approximately 5 g of body weight, then switch to extruded diets, which are the most used feeds throughout growth and termination (RICHE, GARLING, 2003). Therefore, fish feed processing conditions is as important as the nutritional value of feeds (POTRICH et al., 2011; GAO et al., 2019) demonstrating the need to perform bioeconomic analyzes to assess the cost and benefit of refining this process.

In this sense, this study aimed to evaluate the effect of grain size and processing strategy of different diets for Nile tilapia fingerlings, regarding its zootechnical performance and in the quality of the rearing water.

Material e methods

The experiment was conducted at the Laboratory of Aquaculture of the Aquaculture Management Study Group - GEMAq, in University of West Paraná (UNIOESTE), Campus Toledo/PR, Brazil. This study was approved by a bioethics committee and was performed according to the technical standards of biosecurity and ethics on animal use (protocol number 26-19).

The treatments consisted of five forms of feed processing for tilapia fingerlings: ME1- micro-extruded with 1 mm diameter; ED03-extruded and disintegrated with 0.3 mm; ED06- extruded and disintegrated with 0.6 mm; BF03-bran feed with 0.3 mm; BF06-bran feed with 0.6 mm. Feeds were formulated in order to meet the nutritional demands of the species in this stage of development (Table 1), according to the Brazilian tables of tilapia nutrition (FURUYA, 2010). Each nutrient in the feed was expressed with the aid of the program SuperCracr 6.1 Master (TD, 2019).

Regarding diet preparation, the ingredients were ground in a hammer mill (Vieira, MCS 280, Tatuí - São Paulo, Brazil), using meshes screen of 0.3 or 0.6 mm, according to the treatment, and for ME1 it was milled at 0.3 mm before extrusion. For the diets extrusion, a machine Extec was used (EX Micro, Ribeirão Preto - São Paulo, Brazil). A bromatological characterization of the feeds was performed (Table 1), by assessing the contents of dry matter, crude protein, ether extract, ash, and crude energy, according to the methodology described by the AOAC (2016). All diets had the same composition, therefore only the processing type was different and was it that determined the categorical variables. In order to estimate the average price of bran feed, the industrialization costs were discount from the average price of disintegrated feed (which goes through standard extrusion processing), as the bran does not pass-through extrusion. The cost of industrialization considered was 26.02%, according to Sonoda et al. (2016).

Table 1 - Description of the ingredients and values (g. kg^{-1}) of diets composition offered for Nile tilapia (*Oreochromis niloticus*) fingerlings, formulated based on the Brazilian table of nutrition and bromatological composition (g. kg^{-1}).

Ingredient	Inclusion (g kg^{-1})	Ingredient	Inclusion (g kg^{-1})
Maize meal	257,5	Calcitic lime	5,6
Concentrated soybean prot	223,9	L-threonine	5,5
Rice grits	100,0	Salt	5,0
Poultry viscera meal	100,0	Dl-methionine	3,8
Feather meal	68,0	Vitamin C	2,0
Maize gluten	50,0	Choline chloride	1,5
Blood meal	50,0	Calcium propionate	1,0
Soy oil	33,3	Antioxidant (BHT)	0,2
Alcohol yeast	20,0	Total	1000
Dicalcium phosphate	17,7	Chemical composition (g kg^{-1})	
Fishmeal 55%	16,7	DM	935,20
Poultry hydrolysate protein	16,7	CP	390,30
Wheat gluten	10,0	CF	70,00
Premix	6,0	Ash	84,40
L-lysine HCL	5,8	CE (cal g^{-1})	4,293

*All ingredients were bought at local market. Diet formulated based on the Brazilian Nutrition and composition table (g kg^{-1}). DM: dry matter; CP: crude protein; CF: crude fat; CE: crude energy
Assurance levels per kilogram of product: Vit. A 1.750.000 UI; Vit. D3 375.000 UI; Vit. And 20.000 UI;
Vit. K3, 500 mg; Vit. B1, 2,000 mg; Vit. B2, 2.500 mg; Vit. B6, 2.500 mg; Vit. B12 5.000 mg; Folic acid 625 mg; Calcium pantothenate, 7.500 mg; Vit. C 37.500 mg; Biotin, 50 mg; Inositol 12.500 mg; Niacin, 8.750 mg; Coline, 100.000 mg; Co, 50 mg; Cu, 1.250 mg; Fe, 15.000 mg; I, 100 mg; Mn 3.750 mg; Se, 75 mg; Zn, 17.500 mg.

Five hundred Nile tilapia (*Oreochromis niloticus*) fingerlings belonging to GIFT strain (Genetic Improvement of Farmed Tilapia), were previously adapted for a week in 180-liter tanks with feeds that were used in the trial (5 times per day, each time with different processing so that everyone received all the rations). Everyone was weighed for average weight that was 0.975 g. Posteriorly, 250 of them were distributed in 25 (ten per tank) polyethylene tanks (90 L) with constant aeration. The experimental design consisted of five treatments with five replicates. The juveniles were acquired at a local commercial fish farm and transported to the laboratory in isothermal transport boxes with constant aeration.

During the execution of the study, individual tanks were siphoning with the removal and replacement of 30% of the water daily, 15% in the morning and 15% in the afternoon, with water of a temperature close to the tanks. There was no water recirculation between the experimental units to guarantee the independence of the experimental units and no interference in the chemical responses of water quality.

The feeding management of the juveniles throughout 40 days of the experiment consisted of offering the feed six times a day, from 8:00 to 18:00 with two hours intervals, until apparent satiety, weighing the ration before the start of the trial and at the end.

Every week the pH, dissolved oxygen ($mg.L^{-1}$), and electrical conductivity ($\mu S.cm^{-1}$) were measured, while temperature (°C) was assessed twice a day (Table 2). Water samples were collected at the end of the experiment from the experimental units, which were stored in dark polyethylene bottles and kept cold for posterior analysis of total nitrogen (NT) and total phosphorus (PT) by methodology of Adams (1990).

The animals were keep fasted 12 h before the end of the experiment when they were deadened with eugenol (100 $mL\ L^{-1}$ of alcohol), weighed and measured to calculate the zootechnical performance. The weight gain (WG), apparent feed conversion (AFC), protein retention coefficient (PRC) and specific growth rate (SGR) indexes were calculated as demonstrated by the following equations (Equation 1 to 4):

(1): $WG=FW-IW$ (2): $AFC=\frac{CF}{WG}$ (3): $PRC=\frac{BPC}{WG}x100$ (4): $SGR=\frac{lnFW-lnIW}{t}x100$

Where FW is the final weight, IW is the initial weight (g), CF is the consumed feed (g), WG is the weight gain, BPC is the body protein gain (g), lnFW and lnIW are the neperian logarithm of FW and IW, respectively. And *t* is the duration of the experiment in days.

For proximate composition, fish remaining from the other processes were pooled by tank and homogenized prior to the analysis. The proximate composition of fish was performed by analyzing the moisture content (pre-drying at 55 °C during 72 h, followed by drying at 105 °C during 6 h), crude protein (digestion and distillation of nitrogen by the Kjeldahl method), ether extract (Soxhlet extractor using ether as solvent), and ash content (calcination of the samples in a muffle oven at 550 °C during 6 h), all determined according to the AOAC (2016).

Partial economic analysis was also carried out, considering only the studied phase period (fry to juvenile). The costs considered in the economic evaluation were the fry and feed purchase. The profit percentage was based only on the sale price of juveniles in grams, the gross revenue was then calculated. The fry are usually sold in mille, so for the calculation, the average weight they are sold (10 g x 1000= 10000 g) was considered and divided by the average price per gram of fry. To calculate the partial net revenue (PNR), only the cost of fry and food were considered according to the following Equation 5:

$$PNR = GR - (FR + Fd)$$

Where GR is the gross revenue corresponding to the sale price of fishes according to their final weight, FR the cost of buying fry and Fd is the total feed cost.

Statistical analyses

It was initially verified whether the data variance reached the assumptions for performing one-way variance analysis (ANOVA), through the Shapiro-Wilk test (normality) and Levene (homogeneity), both being reached when the p-value was above 0.05 (5%). Posteriorly, the variables were submitted to ANOVA at a 5% significance level. In case of significant differences, means were compared by Tukey test. All statistical analyses were carried out in the statistical program R (R Core Team, 2019).

Principal components analysis - PCA

Several biological and chemical variables were measured during the study to evaluate the processing and, for this reason, a principal component analysis (PCA) was carried out in order to analyze the various variables in a more understandable way, since the PCA is multivariate and performs an exploration of the correlation structure between the variables, producing a group of components that reflect the original set (OLSEN et al., 2012). With this, it was possible to reduce the size of the data and to reject the components with the less variation. It was performed using R software (R Core Team, 2019) with multcomp packages (HOTHORN et al., 2008).

Results

No significant differences were observed among the treatments regarding the water quality parameters evaluated: temperature, dissolved oxygen, electrical conductivity, and pH (Table 2).

Table 2 - Mean ± standard deviation for water quality parameters in treatments: ME1, ED03, ED06, BF03 e BF06.

Variable	ME1	ED03	ED06	BF03	BF06
T (C)	25,71±0,24	25,69±0,23	25,87±0,24	25,50±0,23	25,53±0,23
DO (mg L^{-1})	7,16±0,07	7,18±0,08	7,14±0,06	7,11±0,05	7,18±0,07
EC (µS cm^{-2})	158,15±0,15	169,69±0,16	166,79±0,16	169,63±0,17	163,42±0,15
pH	7,50±0,05	7,51±0,05	7,49±0,04	7,50±0,05	7,50±0,05

T: temperature, OD: dissolved oxigen, CE: electrical conductivity, pH: hydrogen-ionic potential. *Means were not different according (P> 0,05).

Regarding the zootechnical performance, it was possible to observe that the animals fed with the ME1 diet displayed the highest WG, not statistically differing only from ED06 (p=0.09362), which in turn did not differ from meal diets BF03 and BF06 (p=0.48479 and p=0.94746, respectively). The lowest values were for the 3 mm rations (ED03 and BF03), that did not differ from each other by Tukey (p = 0.155761) (Table 3). Feed conversion was reduced in ME1, followed by ED06 (from which it did not differ, p = 0.23200), and ED06 also did not differ from BF06 (0.08733). As for SGR, treatment ME1 had the highest value, but its mean was not different from ED06 and BF06 by Tukey (p=0.16378 and p=0.07511, respectively).

Table 3 - Means ± standard deviation of weight gain (WG), feed conversion (FC), final weight (FW) and specific growth rate (SGR).

Variable	ME1	ED03	ED06	BF03	BF06
WG	9,26±0,95^{a}	5,19±0,53^{c}	7,65±0,78^{ab}	6,71±0,69^{bc}	7,24±0,74^{b}
FC	1,17±0,07^{a}	1,95±0,11^{c}	1,43±0,08^{ab}	1,92±0,12^{c}	1,75±0,10^{bc}
FW	10,23±0,92^{a}	6,16±0,56^{c}	8,63±0,78^{ab}	7,68±0,69^{bc}	8,22±0,74^{b}
SGR	5,22±0,22^{a}	4,09±0,18^{c}	4,84±0,21^{ab}	4,57±0,20^{bc}	4,73±0,20^{ab}

ME1: micro-extruded feed 1 mm; ED03: extruded and disintegrated feed 0.3 mm; ED06: extruded and disintegrated feed 0.6 mm; BF03: bran feed 0.3 mm; BF06: bran feed 0.6 mm. Means followed by different letters in the lines indicate statistical difference by Tukey's test.

Concerning nitrogen and phosphorus in the water, the 1 mm microextruded feed generated the lowest concentrations (Figure 1) in both parameters, being statistically different (P <0.00088) from the other treatments. On the other hand, bran diets of 0.3 and 0.6 mm in diameter were responsible for the highest concentrations of both nutrients.

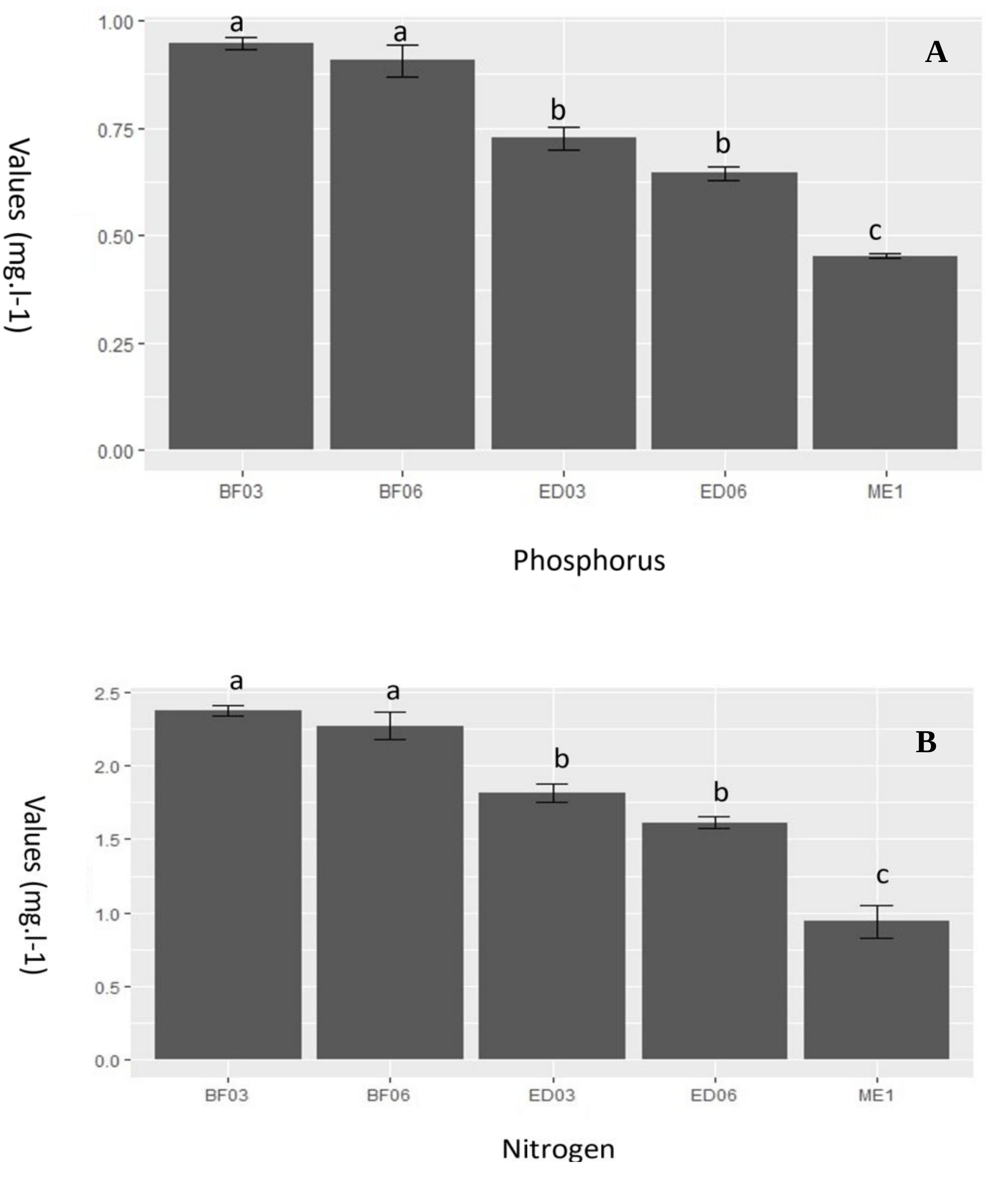

Figure 1 - Total nitrogen (A) and total phosphorus (B) in the rearing water throughout the experimental period with Nile tilapia (Oreochromis niloticus) fingerlings. ME1: micro-extruded feed 1 mm; ED03: extruded and disintegrated feed 0.3 mm; ED06: extruded and disintegrated 0.6 mm; BF03: bran feed 0.3 mm; BF06: bran feed 0.6 mm.

In the proximate composition of whole fish, no statistical differences were found between treatments regarding moisture content (P=0.763), crude protein (p=0.3000), ether extract (0.801) and ash (0.606) (Table 4). PRC was higher in ME1, being statistically different (p<0.01714) when compared to other diets, followed by ED06, BF06 and ED03, with the lowest value found for BF03, which did not differ statistically from BF06 (p=0, 65190) and ED03 (p=0.93720) (Table 4).

Table 4 - Proximate composition values of Nile tilapia (*Oreochromis niloticus*) fingerlings, presented as mean ± standard deviation.

Variable	ME1	ED03	ED06	BF03	BF06
M	73,98±0,76	74,27±0,76	73,48±0,76	73,98±0,76	74,10±0,76
CP	16,44±0,71	16,61±0,71	16,16±0,69	15,46±0,66	15,81±0,68
CF	8,38±0,67	8,13±0,66	8,66±0,69	8,31±0,66	8,06±0,64
Ash	4,44±0,52	4,69±0,55	4,24±0,50	4,13±0,48	4,38±0,51
PRC (%)	36,47±3,13[a]	22,52±1,93[c]	29,62±2,54[b]	21,09±1,81[c]	23,69±2,03[c]

ME1: micro-extruded feed 1 mm; ED03: extruded and disintegrated feed of 0,3 mm; ED06: extruded and disintegrated feed of 0,6 mm; BF03: bran feed of 0,3 mm; BF06: bran feed of 0,6 mm. Means followed by different letters in the lines indicate statistical difference by Tukey's test.

The partial economic analysis showed that the ME1 treatment had the highest profitability, with a PNR of 5.91 USD, although it was the treatment with the highest processing costs. From this, the treatments ED06, BF03 and BF06 did not differ statistically (p=0.6408; p=0.1144; p=0.4232, respectively), (Table 5).

Table 5 - Gros revenue (GR), costs (C, USD) and partial net revenue (PNR) ± standard deviation in different processing feeds.

Variable	ME1	ED03	ED06	BF03	BF06
GR	7,19	4,67	6,53	5,81	6,23
C (USD)	1,28	0,63	0,67	0,58	0,58
PNR	5,91[a]±2,09	4,04[b]±1,43	5,86[a]±2,62	5,22[ab]±3,94	5,64[a]±2,75

ME1: micro-extruded feed 1 mm; ED03: extruded and disintegrated feed of 0,3 mm; ED06: extruded and disintegrated feed of 0,6 mm; BF03: bran feed of 0,3 mm; BF06: bran feed of 0,6 mm. USD: United States Dollar.

Principal component analysis - PCA

In PCA, the PC1 and PC2 axes explained 55.7 and 18.4% of the variation, totaling 74.1%. PC1 was positively associated with PRC, WG, FW, SGR and EE, and negatively with CA, N and P (Figure 2A). In this main gradient (PC1), the best results were observed in ME1, followed by ED06 (Figure 2A), in which the highest values of CRP, GP, PF, SGR and EE and the lowest values of FC, N and P were observed (Figure 2B).

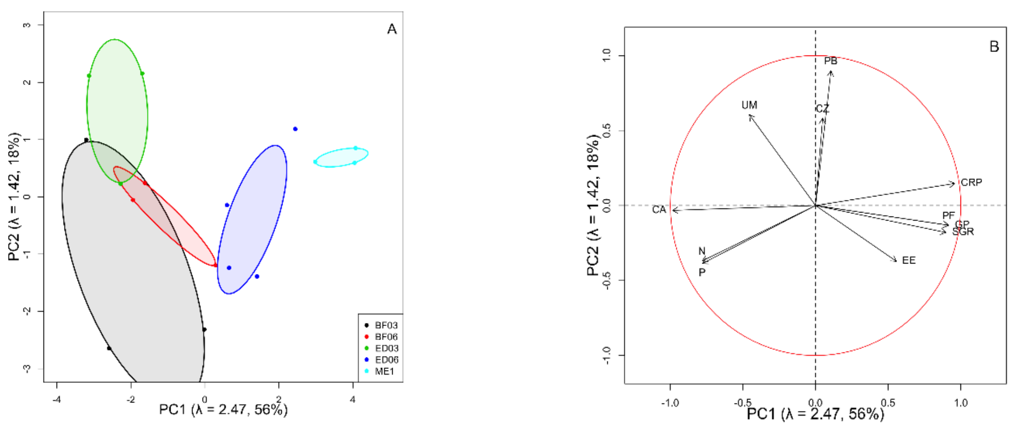

Figure 2 - A) Graph with the vectors of the variables used in the study and main components 1 and 2, PC1 and PC2, respectively. Ellipses represent the main trends of the described variables. B) Biplots of the first

and second main components, the arrows indicate the load of the parameters in the two axes. ME1: 1 mm microextruded feed; ED03: 0.3 mm extruded and disintegrated feed; ED06: extruded and crumbled 0.6 mm; BF03: mash feed 0.3 mm; BF06: mash feed 0.6 mm.

Discussion

Temperature, dissolved oxygen, electrical conductivity and pH values remained constant among treatments. These parameters had been within the ideal conditions for the development of the species from the stage of fry to juveniles, according to the classification described by Ridha & Cruz (2001). This shows that these parameters did not interfere with the other variables of the experimental units, even though there was an individual withdrawal of water from them.

The greatest weight gains were observed in the treatments ME1 and ED06, that have feed diameters of 1 and 0.6 mm, respectively, compared to the results of treatments ED03 and BF03 that have feed diameters of 0.3 mm. The increased adhesion in larger grains may explain the better results in treatments ME1 and ED06, possibly making them more stable and fluctuating, facilitating their consumption without the selection of ingredients, as previously demonstrated by Piedecausa et al. (2010). In addition, the extrusion process promotes starch gelatinization and improves the digestibility of diets (ROMANO, KUMAR, 2018), which also favors the two treatments mentioned, in other words, the degree of grinding and the way of processing interfered. Also, Rodrigues & Fernandes (2006) observed greater growth of *Pterophyllum scalare* fed with extruded diets compared to bran diets. They concluded that the separation and selection of ingredients by fish when fed bran diets led to these results, corroborating the results of the present study.

FC was statistically lower in treatments ME1 and ED06. Processing and grinding degrees interfered with the results. ED03 (0.3 mm) and BF03 (0.3 mm), both with the same grinding degree and different processing, obtained the worst FC results; Nor did ED06 (0.6 mm) and BF06 (0.6 mm) differ, both having intermediate values, inferring that, in this case, observing these two pairs of treatments mentioned, the pellet size was more important than the processing. Even so, the results suggest advantages to extruded diets in relation to mash ones, because, when observing feeds of the same diameter separately, it is noticed that the extruded ones had a lower FC (ED03<BF03 and ED06<BF06) (remembering that the smaller the FC, the better the result), although there was no statistical difference in this case.

Another factor that could change with particle size is the intestinal passage rate, as discussed by Sveier et al. (1999) who observed that in salmon species it was higher when the rations were more crushed, as the particles had more time for digestion and absorption of food. Tran-Tu et al. (2017) also observed greater digestibility in larger mills (1 mm compared to 0.8 mm).

This fact explains why the present results for different grinding grades and same processing show that the larger diameters (ED06 - 0.6 mm compared to ED03 - 0.3 mm, and BF06 - 0.6 mm compared to BF03 - 0.3 mm) obtained lower FC values. Also, the low stability of the smallest particle sizes in water was reported by Toyama et al. (2000) when observing the leaching and solubilization of nutrients. Such losses are mainly composed of water-soluble nutrients, such as vitamins and other low molecular weight components. A part of these vitamins (eg vitamin B1) is involved in energy and protein metabolism (CARVALHO GOMES et al., 2000). This can affect the digestibility of nutrients, especially with regard to proteins, which are offered in greater amounts during the first phases.

The results of PRC explain the information in the paragraph above, these results were higher in ME1 and ED06, inferring that in these treatments there was greater use of the ingested protein, which may be due to the lower proximity of vitamins involved in the metabolism of proteins in these diets. Also, as the protein is offered in larger quantities at this stage, its greater use confirmed by the PRC, leads to a reduction in FC, as a smaller amount of feed will be needed to meet the demand of the fingerlings.

The FC means were also reflected in the values of total nitrogen (N) and total phosphorus (P), corroborating the findings presented by Piedecausa et al. (2010) and Tran-Tu et al. (2017), who showed the relationship between feed processing and nutrient losses in water. They point out that when digestibility increases, lesser amounts of manure are produced. As N and P are the most limiting variables in the eutrophication process (JARVIE et al., 2018), the best use of feed can prevent the occurrence of problems related to eutrophication in water bodies. From this, it can be inferred that the microextrusion process with 1 mm in diameter improves feed conversion, while reducing the release of N and P in the water.

Therefore, the buoyancy in ME1, as well as the extrusion associated with a higher degree of grinding (0.6 mm), were more efficient in the use of the feed. As protein is made up of about 16% of nitrogen, the efficiency of PRC reduced N loads on ME1 and ED06, as reported in the paragraph above.

Although the ME1 feed was the most expensive, its PNR showed that its processing provided gains that outweighed the costs beyond those of the crumbled feed (ED03, BF03 and BF06), only ED06 was similar to ME1 in PNR, but this treatment had levels nitrogen and phosphorus in the water, which can represent an additional cost in production. From the results, it is possible to see that the extrusion was decisive in the profitability obtained.

Using PCA, the processes were classified with their biological (such as WG and FC) and chemical (such as N and P) variables, arriving at the approach that assessed the interrelation of this large number of parameters and explaining them in two dimensions, which is the objective of the PCA according to Gallo et al. (2013).

During the study, similarities were found between treatments by univariate analyses, mainly between ME1 and ED06, which revealed the superiority of the extrusion process and the larger size of the rations, however, in several parameters, this was not clear, and in most of them, there was no difference between ED06 and M1, although ME1 led to lower CA and GP. By PCA it was possible to reveal the different behavior of the feed extruded at 1 mm, separating it from the others in figure 2A.

Based on the results, the microextruded diet (1 mm) is the most suitable for the production of tilapia fingerlings among those tested, followed by ED06, since these treatments reduced feed conversion rates and minimized the environmental impact of the activity. Although microextruded food has the highest price, its FC values were the lowest. Thus, a lower amount of feed resulted in greater weight gain, offsetting the additional cost and achieving the highest profit (PNR) among the treatments tested. The ED06 treatment reached an PNR close to that obtained by ME1. However, N and P loads released into the water were higher than in ME1. This results in additional costs for water treatment, requiring greater water renewal over several cycles in cropping systems. Furthermore, it can be more aggressive to the environment due to its higher pollutant load.

Conclusion

The results indicate that the use of microextruded feed (1 mm) for Nile tilapia in the hatchery phase results in improvement of zootechnical parameters and water quality in relation to residual phosphorus and nitrogen. It also proved to be the best option over other forms of feed processing in terms of economic analysis.

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References

ADAMS, V. D. **Water and Wastewater Examination Manual**. 1st Ed. Routledge, 1990, 264p.

AOAC PUBLISHER. **Official Methods of Analysis of AOAC International**. 19th Ed. Maryland, The scientific Association dedicated to analytical excellence, 2016, 3390p.

BAILEY, J.; ALANÄRÄ, A.; CRAMPTON, V. Do delivery rate and pellet size affect growth rate in atlantic salmon (*Salmo salar* L.) raised under semi-commercial farming conditions? **Aquaculture**, v. 224, n. 1-4, p. 79-88, 2003. https://www.sciencedirect.com/science/article/abs/pii/S0044848603002084

BITTENCOURT, F.; SIGNOR, A. A.; BOSCOLO, W. R.; LUI, T. A.; BOSCOLO, R. J.; FEIDEN, A. Dietas farelada, peletizada ou pastosa para larvas de surubim do Iguaçu (*Steindachneridion melanodermatum*). **Acta Iguazu**, v. 1, n. 3, p. 1-7, 2012. http://e-revista.unioeste.br/index.php/actaiguazu/article/view/7083

BRITO, J. M; PONTES, T. C; TSUJII, K. M.; ARAUJO, F. E.; RICTHER, B. L. Automação na tilapicultura: revisão de literatura, desempenho, piscicultura, tecnologias, tilápias. **Nutritime**, v. 14 , n. 3, p. 5053-5062, 2017. http://www.nutritime.com.br/arquivos_internos/artigos/Artigo_422.pdf

CARVALHO GOMES, D. L.; GOLOMBIESKI, J. I.; GOMES, A. R. C.; BALDISSEROTTO, B. Biologia do jundiá *Rhamdia quelen* (Teleostei, Pimelodidae). **Ciência Rural**, v. 30, n. 1, p. 179-185, 2000. https://www.scielo.br/j/cr/a/G7CwJzyyzGncm6JxsS7bBLL/abstract/?lang=pt

FURUYA, W. M. **Tabelas brasileiras para a nutrição de tilápias**. 1ª Ed. Toledo: GFM, 2010, 100p.

GALLO, A.; MOSCHINI, M.; CERIOLI, C.; MASOERO, F. Use of principal component analysis to classify forages and predict their calculated energy content. **Animal**, v. 7, n. 6, p. 930-939, 2013. https://www.sciencedirect.com/science/article/pii/S1751731112002467

GAO, S.; JIN, J.; LIU, H.; HAN, D.; ZHU, X.; YANG, Y.; XIE, S. Effects of pelleted and extruded feed of different ingredients particle sizes on feed quality and growth performance of gibel carp (*Carassius gibelio* var. CAS V). **Aquaculture**, v. 511, p. 1-11, 2019. https://www.sciencedirect.com/science/article/abs/pii/S0044848619303448

HOTHORN, T.; BRETZ, F.; WESTFALL, P. Simultaneous inference in general parametric models. **Biometrical Journal**, v. 50, n. 3, p. 346-363, 2008. https://pubmed.ncbi.nlm.nih.gov/18481363/

IBGE. Instituto Brasileiro de Geografia e Estatística. **Pesquisa Pecuária Municipal (2019)**. https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?view=detalhes&id=784

JARVIE, H. P.; SMITH, D. R.; NORTON, L. R.; EDWARDS, F. K.; BOWES, M. J.; KING, S. M.; SCARLETT, P.; DAVIES, S.; DILS, R. M.; BACHILLER-JARENO, N. Phosphorus and nitrogen limitation and impairment of headwater streams relative to rivers in Great Britain: A national perspective on eutrophication. **Science of The Total Environment**, v. 621, p. 849-862, 2018. https://www.sciencedirect.com/science/article/pii/S004896971733187X

JERÔNIMO, G. T.; LAFFITTE, L. V.; SPECK, G. M.; MARTINS, M. L. Seasonal influence on the hematological parameters in cultured Nile tilapia from southern Brazil. **Brazilian Journal of Biology**, v. 3, n. 71, p. 719-725, 2011. https://www.scielo.br/j/bjb/a/sL5RLPnYw6SfwdgkdgM7HKk/abstract/?lang=en

LEE, S.; NAMBI, R. W.; WON, S.; KATYA, K.; BAI, S. C. Dietary selenium requirement and toxicity levels in juvenile Nile tilapia, *Oreochromis niloticus*. **Aquaculture**, v. 464, p. 153-158, 2016. https://www.sciencedirect.com/science/article/abs/pii/S0044848616303313

OLSEN, R. L.; CHAPPELL, R.W.; LOFTIS, J. C. Water quality sample collection, data treatment and results presentation for principal components analysis - literature review and Illinois river watershed case study. **Water Research**, v. 46, n. 9, p. 3110-3122, 2012. https://pubmed.ncbi.nlm.nih.gov/22487543/

PIEDECAUSA, M. A.; AGUADO-GIMÉNEZ, F.; GARCIA-GARCIA, B.; TELFER, T. C. Total ammonia nitrogen leaching from feed pellets used in salmon aquaculture. **Journal of Applied Ichthyology**, v. 26, n. 1, p. 16-20, 2010. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1439-0426.2009.01352.x

POTRICH, F. R.; SIGNOR, A. A.; DIETERICH, T. G.; NEU, D. H.; FEIDEN, A.; BOSCOLO, W. R. Estabilidade e lixiviação de nutrientes com rações de diferentes níveis proteicos. **Revista Cultivando o Saber**, v. 4, n. 3, p. 77-87, 2011. https://cultivandosaber.fag.edu.br/index.php/cultivando/article/view/359

R CORE TEAM. **R: A Language and Environment for Statistical Computing**. R Foundation for Statistical Computing Vienna, Austria, 2019. https://www.r-project.org/

RICHE, M.; GARLING, D. Feeding tilapia in intensive recirculating systems. **NCRAC Extension Fact Sheets**, v. 6, p. 1-4, 2003. https://www.ncrac.org/files/biblio/ncrac114.pdf

RIDHA, M. T.; CRUZ, E. M. Effect of biofilter media on water quality and biological performance of the Nile tilapia *Oreochromis niloticus* reared in a simple recirculating system. **Aquacultural Engineering**, v. 24, n. 2, p. 157-166, 2001. https://www.sciencedirect.com/science/article/abs/pii/S0144860901000607

RODRIGUES, L. A.; FERNANDES, J. B. K. Influência do processamento da dieta no desempenho produtivo do acará bandeira (*Pterophyllum scalare*). **Acta Scientiarum Animal Sciences**, v. 28, n. 1, p. 113-119, 2006. https://periodicos.uem.br/ojs/index.php/ActaSciAnimSci/article/view/847/418

ROMANO, N.; KUMAR, V. Starch gelatinization on the physical characteristics of aquafeeds and subsequent implications to the productivity in farmed aquatic animals. **Reviews in Aquaculture**, v. 11, n. 4, p. 1271-1284, 2018. https://onlinelibrary.wiley.com/doi/abs/10.1111/raq.12291

SONODA, D. Y.; FRANÇA, E. D.; CYRINO, J. E. P. Modelo de preço de ração para peixe no período de 2001 a 2015. **Revista IPecege**, v. 2, n. 3, p. 57-71, 2016. https://revista.ipecege.com/Revista/article/view/79

SVEIER, H.; WATHNE, E.; LIED, E. Growth, feed and nutrient utilization and gastrointestinal evacuation time in atlantic salmon (*Salmo salar* L.): the effect of dietary fish meal particle size and protein concentration. **Aquaculture**, v. 180, n. 3-4, p. 265-282, 1999. https://www.sciencedirect.com/science/article/abs/pii/S0044848699001969

TD. **Software SuperCrac 6.1 Premium**, 2019. https://www.agropecuaria.inf.br/produtos/supercrac

TOYAMA, G. N.; CORRENTE, J. E.; CYRINO, J. E. P. Suplementação de vitamina C em rações para reversão sexual da tilápia do Nilo. **Scientia Agricola**, v. 57, n. 2, p. 221-228, 2000. https://www.scielo.br/j/sa/a/XZgyFcLysxtSW355p6FKjbw/?lang=pt

TRAN-TU, L.; HIEN, T.; BOSMA, R.; HEINSBROEK, L.; VERRETH, J.; SCHRAMA, J. Effect of ingredient particle sizes and dietary viscosity on digestion and faecal waste of striped catfish (*Pangasianodon hypophthalmus*). **Aquaculture Nutrition**, v. 24, n. 3, p. 961-969, 2017. https://onlinelibrary.wiley.com/doi/abs/10.1111/anu.12632

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