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ABSTRACT

Nile tilapia presents a very important characteristic for the commercial production, the use of vegetal ingredients. This opens a very wide range of possibilities in the formulation of rations, from the commercial to the artisan. Although there are a number of studies related to conventional ingredients, such as soybean meal, corn and fishmeal, few are with alternative ingredients as well as sparingly presented. The lack of standardization in the methodologies used for digestibility tests with Nile tilapia leads to divergence of information. The literature indicates that Nile tilapia has the capacity to use a wide range of alternative ingredients in its diet, however, the knowledge of the digestible fraction of the nutrients and energy of these is of utmost importance, since the variation of this in relation to the raw content. In this way, the Nile tilapia has the possibility of having in the composition of their rations the presence of alternative foods and present similar performance to rations formulated with conventional ingredients.

Keywords: Feeding; Protein sources; Nutrition; Fish farming, Replacement.

RESUMO

A tilápia do Nilo apresenta uma característica muito importante para a produção comercial, a utilização de ingredientes de origem vegetal. O que abre uma gama muito grande de possibilidades na formulação de rações, desde as comerciais até as artesanais. Apesar de se encontrar um bom número de estudos relacionados com ingredientes convencionais, como o farelo de soja, milho e farinha de peixe, poucos são com ingredientes alternativos, bem como estão apresentados de maneira esparsa. A falta de padronização nas metodologias utilizadas para os testes de digestibilidade com a tilápia do Nilo leva a divergência de informações. A literatura aponta que a tilápia do Nilo tem a capacidade da utilização de uma ampla gama de ingredientes alternativos na sua alimentação, entretanto, o conhecimento da fração digestível das nutrientes e energia destes é de suma importância, visto a variação desta em relação ao conteúdo bruto. Desta forma, a tilápia do Nilo tem a possibilidade de ter na composição das suas rações a presença de alimentos alternativos e apresentar desempenho semelhante a rações formuladas com ingredientes convencionais.

Palavras-Chave: Alimentação; Fontes proteicas; Nutrição.

1 INTRODUCTION

Brazil is one of the few countries that is able to meet the growing world demand for fishery products, mainly through aquaculture, which is an activity capable of transforming unproductive areas of small size or of low agricultural income into highly productive areas (Borghetti et al 2003).

Nile tilapia (Oreochromis niloticus), native to Africa, Israel and Jordan, spread globally (Zimmermann and Hasper 2004). Very versatile, it adapts to both extensive cultivation without any technology employed, and to the system of rearing in net tanks with high technology of production and complete rations (Meurer et al 2002).

Webster and Lim (2002) emphasize the importance of knowledge of the composition, digestibility and quantity of the protein source when formulating a diet. This species efficiently uses carbohydrates as a source of energy (Furuya 2010). Thus, they are among the tropical fish species most frequently used in the trials to determine the digestibility of alternative sources of plant origin (Santos et al 2009).

In economic exploitation, approximately 70% of the total cost of production refers to the feed factor (Kubitza 1997; Pezzato et al 2000). The formulation of fish feed is based mainly on corn, soybean meal and fishmeal, which often makes fish production economically unfeasible (Santos et al. 2009), with rations that present high levels of protein and high costs (Lanna et al 2004), hindering its commercialization.

The use of alternative source foods in rations provides a lower cost, with the substitution of certain products and by-products of agroindustry that are used as ingredients in fish diets, by substitute products, has been studied by several authors (Pezzato et al 2001).
However, in order for two rations formulated with distinct ingredients, such as one formulated with conventional ingredients and one with alternative ingredients, to provide fishes with similar growth, it is necessary that they have equivalent nutritional values. What can be achieved more easily with the use of nutrient and digestible energy values, since the digestion of the nutrients of an ingredient varies with respect to another.

Thus, the combination of nutrient and energy digestibility values of alternative ingredients, as well as their comparison with conventional ones, provides an important tool for the formulation of nutritionally adequate rations for Nile tilapia.

2 DIGESTIBILITY DETERMINATION

The digestibility, in theory, expresses the real use of the nutrient by the animal, through determination of the total of nutrient or energy ingested and excreted in the feces. Due to endogenous secretions such as: bile, enzymatic secretions and scaling of the epithelium, only a part of this nutrient found in feces comes from the food tested. Thus, the determination of the digestibility of a nutrient, without considering the endogenous losses, is called apparent digestibility (Young et al 1991).

According to Cho (1987), the determination of the digestibility of the nutrients and energy of a raw material, is the first caution when one intends to evaluate its potential of inclusion in a ration for fish. Total or dry matter digestibility of a food or diet shows how much of both was digested (De Silva and Anderson 1995).

Nose (1966) classified two methods for the determination of nutrient and energy digestibility in fish diets: the direct method, which involves total collection of feces and control of food consumption, using metabolic cages, and the indirect method, using Inherent reference substances as a marker, called internal, when they occur naturally in food and external when they are added to the diet (Young et al 1991, Kabir et al 1998).

However, for any component to be considered a marker in digestibility assays, it must satisfy the following prerequisites: it does not interfere with the animal's digestive metabolism or intestinal microflora; not be absorbed or metabolised; have the same rate of passage through the intestine as the experimental diet; be analyzed in diet and feces and be non-toxic (Kabir et al 1998).

The determination of the digestibility coefficients of the nutrients and energy of the feed used is based on measures taken by the animal feces collection, which may depend fundamentally on the conditions and methodologies applied in the realizations of the digestibility experiments (Portz 2001).

According to (Lanna and Bonfim 2004), the main factors that influence the digestibility coefficients are the methodology used for feces collection, fish species, fish age, feed composition, salinity, water temperature and type of processing of the diet. Among other benefits, the processing of the diet has the purpose of facilitating animal feed intake, increasing nutrient availability, reducing antinutritional factors, and reducing nutrient leaching (Rodrigues and Fernandes 2006).

There are several methods for collecting fish feces, which can be done directly from the digestive tract by manual extrusion, with light finger pressure in the ventral region of the fish, or carefully, from the bottom of the aquarium by means of a very thin net (Castagnolli 1979). Cho and Slinger (1979) have established a method of collecting feces through a system of constant siphoning the water of the aquarium that passes through a filter column that retains the feces for later determination of the undigested fraction of the nutrients.

External markers are the most used in fish digestibility studies, with chromium oxide or chromium III (Cr_2O_3) being the most accepted marker because it is completely indigestible and non-absorbable, has no pharmacological action on the digestive tract and passes uniformly through (Sullivan and Reigh 1995).

The determination of the percentage of Cr_2O_3 in the fish feces allows to estimate the total or partial digestibility coefficient of the metabolized nutrients, comparing it with the percentage of this oxide that is mixed with the feed (De La Noue and Choubert 1986).

All work on the digestibility of a given nutrient and energy for both fish and any other animal involves the determination of the nutrient content in the food and the estimation of how much of that nutrient was assimilated (Santos et al 2008). Using the chromic oxide, the apparent digestibility according to (Nose 1966), is estimated by the following equation:

$$\text{Digestibility (\%)} = 100 - \left(\frac{\text{\% of indicator in food}}{\text{\% of indicator in feces}} \times \frac{\text{\% of nutrientes in feces}}{\text{\% of nutrientes in food}} \times 100\right)$$

From the digestibility values of the nutrients and energy of an alternative ingredient it is important to determine the amount that it can be included in a feed or that it will replace a conventional ingredient (Meurer et al., 2002; Meurer et al. 2004, Boscolo et al 2005a, b Boscolo et al 2008, Meurer et al 2008).

3 CONVENTIONAL INGREDIENTS

Among protein sources, fishmeal is the most widely used ingredient in diets for aquatic organisms due to the essential and non-essential amino acid profile and the specific functions of each one (Teixeira et al 2006). In addition to the high concentration of crude protein, it is an excellent source of essential fatty acids, digestible energy, minerals and vitamins (Gonçalves Junior et al 2014). However, fish meal represents the most expensive source of protein in diets (Furuya et al 2001).

In Brazil, fishmeal is a scarce raw material, due to the reduced availability of fishes in the seas, so it ends up being made from the fish processing industry leavings (Teixeira et al 2006). Thus, depending on the raw material used, fish meal may show high variation in its composition, in terms of proteins, fats, ashes and amino acids (Gonçalves Junior et al 2014).

These variations will affect the digestibility and availability of these nutrients, resulting in fish performance impairment (Boscolo et al 2001).

The limited production of good quality fish meal together with its high price forced the search for alternative sources of protein. Satisfactory results were obtained with the partial or total reduction of fishmeal in the diet of cultured fish, with the most studied animal protein sources being chicken manure meal (Signor et al 2007), meat and bone meal (Pezzato et al. 2002), and blood meal (Barros et al 2004). In the case of regions farthest away from food producing centers, the use of alternative regional food is an interesting opportunity to reduce the price of feed (Tachibana 2007).

Among the sources of protein of plant origin, with great potential for the substitution of fish meal, we can highlight the soybean (Gonçalves Junior et al 2014). Soybean meal is an ingredient with high protein value and good availability of nutrients, (Silva et al 2006).
Corn is one of the main sources of energy for omnivorous and herbivorous fish, representing an item of quality and quantity in the process of ration elaboration, with the most used form being milled corn, since it is considered a nutritional food for nutritional purposes both for human and animal diets, due to its predominantly carbohydrate (starch) and lipid (oil) composition, but their inclusion content is given as a function of availability, economic viability, always analyzing their moisture content, presence of mycotoxins, pesticide residues and toxic seeds, however, among the main ingredients of a feed concentrate are energy-responsive corn and soybean meal for protein.

The study of alternative foods seeks to provide subsidies for the production of rations, in addition to being cheaper, of the same nutritional quality, providing productive performance equivalent to those formulated with conventional foods (Meurer et al 2000).

3.1 ALTERNATIVE INGREDIENTS

Millet (Pennisetum glaucum) is grown for the production of grains in the subtropical regions of Africa and the Indian subcontinent (Kumar, 1999).

The Lemnaceae family is represented by the smallest vascular plants in the world, often being confused with algae (Journey et al 1993). They are popularly known as "water lentils", "duckweeds" and "lemnas", although the latter is the name given to one of the genres (Mohedano 2014).

Journey et al. (1993) state that in lemnaceae cultivated in oligotrophic waters, the percentage of protein produced is low (15 to 25%) and the amount of fibrous matter is high

(15 to 30%). However, if grown in eutrophic environments, these plants may contain between 35 and 45% of proteins and 5 to 15% of fibers (Mohedano 2014).

In studies carried out by Islam (2002), it is observed that the proteins present in these vegetables are rich in all essential amino acids (except for methionine), and can be compared with sources of animal protein and soy. (Landesman et al., 2002) show the composition of Lemna gibba flour, where the crude protein reaches 41.7% and lipids do not exceed 4.4%. In this way it is deductible that animal feeding, constituted with lemna flour base, would require supplements riches in fat (Mohedano 2014).

Landolt and Kandeler (1987) reported the presence of 40 different minerals, vitamins A1, B1, B2, B6, C and E. (Khan et al., 2002) showed that the species of lemnaceae analyzed have a relatively high concentration of Ca, P, Na, K, Fe, Mn, Mg, Cu and Zn.

The use of Lemnaceae in fish feeding seems to be the most widespread way to use the biomass of this plant and may be offered fresh as an exclusive meal, or dehydrated food, in combination with other ingredients (Mohadano, 2014).

The cassava sweep flour is denominated in this way, because it is the flour that falls to the ground, and can not be consumed by humans and therefore is used for animal feed, having low cost and good energy concentration (Lacerda et al 2005). Cassava root or broken cassava flour is rich in starch, and this nutrient is efficiently used by Nile tilapia (Boscolo et al 2002). Crambe (Crambe abyssinica) is an oilseed of the cruciferous family, native to a temperate and warm region of Ethiopia, but domesticated and adapted to the dry and cold regions of the Mediterranean (Roscoe et al 2010). Crambe bran has a high protein content (28-38% of crude protein), contains 8-9% of mineral matter and 6-7% of fiber (Baker et al 1977). Pietro (2013) found crude protein levels of 82.37%, shown in table 1.

Table 1: Apparent digestibility coefficients (ADC) of crambe meal.

Item:	**ADC (%)**
DM (%)	62.57
CP (%)	82.37
CE (Kcal/kg)	77.00

Tabela adaptada de Pietro, 2013.

The fodder turnip (Raphanus sativus var. Oleiferus), originating in East Asia and Europe, belongs to the Brassicaceae family, and presents an annual winter cycle. The byproduct of oil extraction to obtain biodiesel presents about 40.0% of crude protein, with probable potential to compose the protein fraction of the animal diet (Santos 2008). Comparatively, sunflower cultivars and hybrids have oil contents in the grain varying from 30.0 to 55.0% and crude protein contents in the meal by 50.3% (Camara and Heiffig 2001).

The mango residue meal (Mangifera indica L.) can be included in fish diets for both nutritional and therapeutic purposes (SAHU et al., 2007), the content of bromatological composition was 94.10% dry matter; 4.44% crude protein and 3724Kcal/ kg of crude energy (LIMA et al., 2011).

4 DIGESTIBILITY

Pezzato et al (2004) in studies with Nile tilapia determined the apparent digestibility of energy and nutrients of six energetic foods (Table 2): wet corn grain silage, integral oats, urucum, manioc rasp, alfalfa and algaroba hay and five proteins (Table 2): integral soybean, coconut meal, leucine, alcohol yeast and dehydrated milk whey. It was concluded that among the energy foods, cassava scrap and wet corn silage were the best apparent digestibility coefficients (ADC) for dry matter (DM), crude protein (CP) and digestible energy (DE), and among the protein foods, the ones with the best ADC for DM, CP and DE were whey, alcohol yeast and coconut meal, while leucaena and whole soybean presented the worst ADC for DM and CP and the lowest DE values.

Pezzato et al. (2004) studied the digestibility of cassava scrap for this same species and observed results of 59.66 ± 2.38%; 93.36 ± 2.91%; 2503 ± 21 kcal / kg, for DM, CP and DE, respectively. (Boscolo et al., 2002), evaluated the digestibility coefficients of cassava sweep flour and verified values of 91.11%; 97.52% and 3280.09 kcal / kg for DM, CP and DE. According to Santos et al. (2009), the cassava sweep flour had better digestibility indexes, allowing the use of this ingredient in future feed formulations.

Table 2: Apparent digestibility of energy and protein foods by Nile tilapia, values expressed as 100% of the dry matter.

Foods	Digestibility (%) DM	Digestibility (%) CP	Digestible energy (Kcal/Kg)
Energetic foods			
Moist coin silage	70.73	94.26	3023
Integral oatmeal	81.07	90.92	2636
Urucum	58.72	84.25	3063
Cassava scrap	78.14	90.22	3163
Alfafa hay	59.66	93.36	2503
Algaroba flour	55.99	81.92	3210
Proteic foods			
Integral soy	31.35	54.07	2500
Coconut bran	60.19	86.78	2990
Leucena	37.62	72.54	2700
Alcohol yeast	67.75	88.58	3620
Whey	86.87	91.66	3400

Table adapted from Pezzato et al 2004.

Sorghum grain (Sorghum bicolor) is an important source of energy in ruminant and monogastric aniamls diets, and can substitute cereals such as corn and wheat (Cabral Filho 2004). Comparatively, it presents 90 to 95% of the nutritive value of corn, being slightly lower in energy value (NRC 1994).

Furuya et al. (2004) also studied the apparent digestibility coefficient of crude energy and crude protein of low tannin sorghum silage and high tannin sorghum silage in Nile tilapia feed. The results indicated that crude energy and crude protein from sorghum silage can be efficiently used.

During the biodiesel production process there is production of glycerol (Knothe 2006). Crude glycerol is a potential source of energy for fish farming since, for Nile tilapia, it has an apparent digestible energy content of 3124 kcal / kg, with an apparent digestibility of 89% (Meurer et al 2012).

Beans (Phaseolus vulgaris L.) and peanuts (Arachis hypogaea) are grains belonging to the Fabaceae family of South American origin (Suassuna et al 2006). In studies for the chemical and nutritional evaluation of beans, it was found that raw grains have 20 to 35% protein, depending on the cultural treatments and the cultivar (Toledo and Canniatti-Brazaca 2008). According to Boateng et al (2007), the beans have high protein and mineral value.

Paul (2010) found only a decrease in the apparent digestibility of the dry matter and the proteins with the increased inclusion of bean flour, concluding that this flour can be incorporated in up to 24% in the diet for juveniles of Nile tilapia, corresponding to 20% soybean meal reduction. Peanut, on the other hand, is poor in lysine (Marques et al 2007), but is an excellent source of energy due to its high fat content (Suassuna et al 2006).

According to Paul (2010) it was also found a significant increase in the digestibility of dry matter, energy and protein with the increased participation of roasted peanuts in the mixture of test ingredients, but the fat digestibility was lower. When the bran comes from peeled and defoliated peanuts, it has its nutritive value very close to soybean meal and superior to the cotton meal (Teixeira 1998).

Santos (2008), studying apparent digestibility coefficients, showed that forage turnip occurs as a likely substitute for soybean meal in Nile tilapia diets, and can substitute up to 25% of the protein, without impairing productive performance and chemical composition of fillet. The results obtained for the apparent digestibility coefficient of crambe were similar to those presented by (Boscolo et al 2002), who found for soybean meal values for DM, CP and BE of 65.49%, 89.28% and 71, 38%, respectively, working with Nile tilapia. Pietro (2013) concluded that crambe meal presents good digestibility for protein and amino acids and can replace soybean protein up to 6% (4.44% inclusion).

5 INCLUSION / SUBSTITUTION

Cottonseed meal, a protein food of vegetable origin, is one of the byproducts of cotton processing (Gossypium hirsutum) (Botelho 2012). El-Sayed (1990) replaced fishmeal protein by cottonseed protein and demonstrated that it can be used as the exclusive protein source for Nile tilapia, and lysine supplementation did not improve performance. Discordantly, Viola & ou and Zohar (1984) reported that only 50% of soybean meal protein can be replaced with cottonseed protein without impairing productive performance.

Canola grown from rapeseed enhancement (Brassica campestris and Brassica napus) (Gonçalves Junior et al. 2014). Viegas et al. (2008) demonstrated that canola meal can be used as an alternative protein source in animal diets, in addition, it improves palatability. However, the response of fish to the inclusion of canola meal in the diet has been positive, with some restrictions on inclusion levels (Gonçalves Junior et al 2014).

Furuya et al. (2003) evaluated corn substitution by sorghum silage as an energy source for Nile tilapia juveniles, isocaloric and isoprotein experimental diets were formulated, corn meal was substituted for sorghum silage with low (LCSS) (0.44%) and high (HCSS) (1.14%) tannin content. The weight gain of fish fed LCSS was significantly higher than those fed diets containing corn and HCSS. The results indicated that the inclusion of 44% of sorghum silage in the diets can support normal growth in juveniles of this genus.

Yue and Zhou (2008) determined that 60% of soybean meal can be replaced with cottonseed meal supplemented with lysine, but total replacement reduced the nutritional value of the diet. (Mbahinzireki et al., 2001) replaced fishmeal protein in tilapia diets with cotton bran protein, noticing that the growth rate did not differ until 50% replacement.

Fasakin et al. (1999) tested 5 levels of inclusion (5, 10, 20, 30 and 100%) of Spirodela polyrhisa flour in isoprotein diets for tilapia fingerlings, with the best weight gain result being obtained with 30% inclusion in the diet. Bairagi et al. (2002) obtained the same result (30% inclusion) with fermented lemna leaves in diets for tilapia.

The algae Schizochytrium sp. is a type of microalgae (LEIPE et al., 1994) with high nutritional value (Barclay 1994). This algae can be applied in several aquaculture sectors (Atienza et al 2012). Evaluating inclusion levels of Schizochytrium sp. (0, 2.5, 5.0 and 7.5%) in diets for Nile tilapia, Saivasaeng et al. (2014) concluded that up to the 7.5% level of this alga, has improved the average daily rate of growth and feed conversion.

Cassava leaves provide a food rich in proteins, vitamins and minerals at low cost, however, they are most often wasted in all Brazilian regions (Madruga & Câmara 2000).
Lima et al., (2011) points out that the mango residue meal in the diets can be included up to the level of 15%, because when increasing the inclusion of the residue there was a decrease in the crude protein and dry matter parameters.

Table 3 represents data on the inclusion levels of alternative foods of plant origin in the diet for Nile tilapia, showing a diversity of ingredients, thus enhancing the use in the market.

Table 3. Inclusion levels of alternative dietary ingredients for Nile tilapia

Ingredients	Average Weight (g)	Diet Inclusion (%)	DM (%)	CP (%)	CE (%)	Reference
Millet	37.61	30	77.96	94.91	89.12	Boscolo et al 2002
Triticale	37.61	30	68.51	94.78	80.55	Boscolo et al 2002
Cassava sweep flour	37.61	30	91.11	97.52	91.40	Boscolo et al 2002
Whole wheat	37.61	30	86.51	96.30	87.07	Boscolo et al 2002
Rice bran	100	64,85	59.29	94.86	91.30	Pezzato et al 2002
Canola meal	100	56,82	66.38	87.00	74.59	Pezzato et al 2002
Cottonseed meal	100	44,25	53.11	74.87	51.00	Pezzato et al 2002
Sorghum	100	66,07	23.44	67.83	70.53	Pezzato et al 2002
Low sorghum silage Tannin	53.26	40	_	84,94	70.17	Furuya et al 2004 Furuya et al 2004
High tannin sorghum silage	53.26	40	_	82.40	68.37	Furuya et al 2004
Low tannin sorghum	100	40	50.68	87,87	70,06	Freire et al 2005
High tannin sorghum	100	40	32.86	75,12	63,15	Freire et al 2005
Leucena Hay	30 a 60	30	23.58	44,09	19,69	França Segundo 2008
Cassava rama hay	30 a 60	30	29.15	68,58	30,69	França Segundo 2008
Cunha hay	30 a 60	30	25.75	84,30	29,00	França Segundo 2008
Rice grits	150.57	40	96.45	63,01	95,34	Guimarães et al 2008
Rice bran	150.57	40	55.59	66.88	57.58	Guimarães et al 2008
Sorghum	150.57	40	87.29	56.77	82.37	Guimarães et al 2008
Biomass emerged flour (leaf lamina and petiole)	125.5	30	57.80	72.30	62.00	Biudes et al 2009
Biomass flour submerged (root and Rhizome)	125.5	30	38.30	50.80	32.00	Biudes et al 2009
Farinha da biomassa total (emersa + submersa)	125.5	30	45.70	57.30	42.30	Biudes et al 2009
Cottonseed meal	250	29,90	78.10	87.10	62.09	Gonçalves et. al, 2009
Rice grits	250	29,90	81.91	95.88	75.48	Gonçalves et. al, 2009

6 FINAL CONSIDERATIONS

Nutrition is expanding in fish farming, the elaboration of economically sustainable and environmentally correct rations are primordial to leverage production, to generate income for fish farmers. Despite the fact that a large number of studies related to alternative ingredients as a source of Nile tilapia feed are found, standardization of analysis methodologies is necessary to reach a consensus on the nutritional quality of these ingredients in the different stages of Nile tilapia cultivation.

The lack of standardization in the methodologies used for the digestibility tests with Nile tilapia causes divergence of information about alternative ingredients that have low cost and the nutritional quality required by the species. However, research indicates that the use of alternative sources in the substitution of soybean meal and corn, guarantee the desired performance and at a lower cost.

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