VOLUME 8 ISSUE 2 2022

ISSN 2454-3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, No. 2, 34-41 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Nutritional Requirement of Nile Tilapia (*Oreochromis niloticus*) in a Commercial Farm: A Review

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Received: 6th June, 2022; **Accepted:** 7th July, 2022; **Published online:** 12th July, 2022

https://doi.org/10.33745/ijzi.2022.v08i02.006

Abstract: This article reviews the nutritional requirement of tilapia fish (nile tilapia – *Oreochromis niloticus)* in a commercial farm setting. Although the nutritional requirement of tilapia does not entirely depend on the habitat of the fish, in certain scenarios such as a commercial aquaculture farm, the requirements of the fish are often specific. These specific requirements are based on factors such as increased profits, economic feasibility, and commercial scalability. In this review, the above mentioned criteria serve as a guide to determine the nutritional characteristics of fish feed for a commercial tilapia fish farm.

Keywords: Feed, Tilapia, Digestibility, Feed formulation, Feed utilization, Energy, Amino acids, Minerals, Vitamins

Citation: Thirulogasundhar Balakamatchi, Muthu Thai Aparna S and Ramabhai V.: Nutritional requirement of Nile tilapia (*Oreochromis niloticus*) in a commercial farm: A review. Intern. J. Zool. Invest. 8(2): 34-41, 2022.
https://doi.org/10.33745/ijzi.2022.v08i02.006

Introduction

Tilapia rank 4th among fresh water fish in global farming by both value and quantity. Nile tilapia (*Oreochromis niloticus*) are the 8th most farmed species in terms of production value and 9th in production quantity. Due to its easy growth and relative disease stability, tilapia are increasingly farmed in many parts of the world for a total output of more than 4 million tons. Since capture fisheries have been saturated, currently, they are farmed in 78 countries and account for 3.69% of the world's total fish production. Given their stable market price as well as a global trend towards leaner healthier meats, aquaculture of tilapia is believed to have accelerated even more. As such, this review aims at understanding tilapia's feed requirements and factors to consider while formulating the feed in terms of nutrition typically at a commercial aquaculture farm. The following nutritional parameters have been taken into consideration and dealt with in great depth: amino acids requirement, vitamins and minerals requirement, lipid requirement and carbohydrate

requirement of Nile tilapia.

Amino Acids:

Amino acids are the building block of proteins, and the absorbability of proteins, as well as the quality of it is determined by the amino acid contents of the protein incorporated in the feed (Milward *et al.*, 2008). It is futile to have high contents of crude protein which are of poor absorbability or low nutritive value. It is crucial to include essential amino acids that cannot be produced by the fish. Lack of essential amino acids can cause disorders and hence affect the health and overall viability of the fish. The relative specific amino acid ratios are also important as exceeding these ratios can also inhibit growth and hinder the commercial value of the fish (Wilson *et al.*, 1986). Feeds are formulated so that protein content is optimized so as to not be used up for digestive energy, and be absorbed in the fish. Optimum digestible energy (DE) levels in tilapia diets with reasonable protein quality are 8.3 to 9.3 kcal DE/g of crude protein (Popma *et al.*, 1996). In case of feeds where the digestive energy is sourced by protein, tilapia store excess lipids in the visceral regions, and are not able to use it for improving energy efficiency; and additional lipid and protein did not significantly improve protein deposition or growth (Ng *et al.*, 2001). The amino acid requirement of Nile tilapia is given in Table 1.

Vitamins:

Vitamins are organic compounds that are imperative for the proper functioning of fish. They control and play a vital role in a wide variety of pathways including respiration, breakdown of certain substances, mineral intake, blood clot, proper growth, nutrient deposits, anti-oxidation, and much more (Jauncey, 2000). While their roles are well understood, their dietary requirements in nile tilapia are poorly researched. It is hard to quantify due to the contribution of vitamins by microbes and organic matter in the water system and the natural vitamin content in feed formulation raw ingredients. Under culture conditions vitamin deficiencies are uncommon, however in aggressively cultivated tilapia vitamin C deficiency is seen, partially due to the stringent conditions required for its storage and also because it is quickly depleted in the fish under stressful conditions (Cai *et al.*, 2017). Other common supplements added to avoid depletion are: vitamin A, D, E, K, niacin, pantothenic acid and riboflavin (Popma *et al.*, 1996). Since water soluble vitamins are not stored in fish tissues like oil soluble vitamins, they commonly present deficiencies in addition to requiring regular intake to offset the short storage duration hence, their toxicity is rare; while care must be taken not to exceed recommended levels of oil soluble vitamins in feed as their toxicity is possible (Jauncey, 2000). The requirements for various vitamins for Nile tilapia is mentioned in Table 2.

Minerals:

Minerals are elemental micronutrients that play vital roles in metabolic functions, enzyme activity and other normal functions of the body. Studies have shown that incorporating minerals in the diet improves fish stability and performance (Dato-Cajegas *et al.*, 1996; Hassaan *et al.*, 2014). Supplementing calcium lactate or calcium propionate in small quantities in tilapia feed increases protein deposition in the body, improves growth and feed efficiency (Pierri *et al.*, 2020). It was also shown to increase hematocrit and hemoglobin content in the blood (Hassaan *et al.*, 2014). Li *et al.* (2009) reported that addition of citric acid in Nile tilapia feed released trace elements that may have increased protease activity. While formulating feed, specific degrees of absorbability of the nutrients should be taken into consideration; for example, while both phosphorous and calcium are available in the ambient environment, phosphorus from phytates is poorly absorbed by fish and hence has to be compensated whereas calcium which can be absorbed from lime in water through the skin (Dato-Cajegas *et al.*, 1996). Decreased bioavailability of minerals such as zinc due to dietary phytates as anti-nutritional factors (ANF) should also be taken into consideration (McClain *et al.*, 1988). Sodium and potassium are found in

Table 1: Amino Acid Requirement of Nile Tilapia

Amino Acid	Requirement in Nile Tilapia (in Total Feed)
Lysine	5.12%
Arginine	4.2%
Histidine	1.72%
Threonine	3.75%
Valine	2.8%
Leucine	3.39%
Isoleucine	3.11%
Methionine	2.68%
Methionine plus cystine1	3.21%
Phenylalanine	3.75%
Phenylalanine plus tyrosine2	5.54%
Tryptophan	1%

Table 2: Vitamins Requirement of Nile Tilapia

Vitamins		Vitamin Form	Requirement in Nile Tilapia (in Total feed)	Parameters
Water-soluble	Thiamine	Thiamine hydrochloride	3.5 mg/kg	†
	Riboflavin		5 mg/kg	†
	Vitamin B_6		3 mg/kg	†
	Vitamin B_{12}		-	†
	Vitamin B_3		26 mg/kg	†
	Biotin - Vitamin B_7		0.06 mg/kg	‡
	Folic Acid	Folic acid concentrate	0.5-1 mg/kg	‡
	Panthothenic Acid		10 mg/kg	‡
	Choline	Choline chloride	3000 mg/kg	‡
	Inosital	*myo*-inositol	100-400 mg/kg	‡
	Abscorbic Acid		420 mg/kg	‡
Lipid-soluble	Vitamin A		5000 IU/kg	‡
	Vitamin D		374.8 IU/kg	‡
	Vitamin E	Tocopherol-acetate	20-100 mg/kg	†
	Vitamin K		5.2 mg/kg	‡

† - *O. mossambicus* × *O. niloticus*; ‡ - *O. niloticus* × *O. aureus*

Above data based on reports of Kasper *et al.* (2000), Shiau and Lo (2000), Lim *et al.* (1993, 2011b), Soliman and Wilson (1992a, b), Shiau and Suen (1992), Ayyat *et al.* (2011), Shiau and Hsieh (1997), Shiau and Chin (1999), Shiau and Huang (2001), Barros *et al.* (*2009*), Shiau and Lung (1993), Soliman *et al.* (1994), Shiau and Hsu (1995, 1999), Peres *et al.* (2004), Shiau and Su (2005), Saleh *et al.* (1995), Hu *et al.* (2006), Guo *et al.* (2010), Shiau and Hwang (1993), Eleraky *et al.* (1995), Huang *et al.* (2003)

Table 3: Minerals Requirement of Nile Tilapia

Mineral	Requirement in Nile Tilapia (in Total Feed)
Calcium sulfate	7 mg/kg
Calcium lactate	3.5-4.3 mg/kg
Cr_2O_3	204 mg/kg
KCl	2-3 g/kg
Magnesium acetate (hydrous $4H_2O$)	0.59-0.77 mg/kg
MgSO4	5 g/kg
Ferric Citrate	150-160 mg/kg
Ferrous Sulfate	85 mg/kg
Monobasic Sodium Phosphate	5 g/kg
NaCl	2.375 g/kg
Zinc sulfate (hydrous $7H_2O$)	30 mg/kg
Zinc sulfate monohydrate	79.5 mg/kg

Above data based on reports of Shiau and Tseng (2007), Shiau and Sh, (1998), Pan *et al.* (2003), Shiau and Hsieh (2001), Dabrowska *et al.* (1989), Reigh *et al.* (1991), Shiau and Su (2003), Robinson *et al.* (1987), Shiau and Lu (2004), Cnaani *et al.* (2010), Eid and Ghonim (1994), do Carmo e Sa´ *et al.* (2004)

abundance in water needing no supplementation whereas the supplementation of other minerals like selenium and iodine are required (Van der Velden *et al.*, 1991a, b; Davis *et al.*, 1996). For Nile tilapia the requirements for minerals has been listed in Table 3.

Lipids:

Lipids or fatty acids in fish diet provide essential fatty acids other than providing energy. They also improve feed texture and palatability. It is a highly concentrated source of energy in the feed (Popma *et al.*, 1996). Lipids aid the absorption of oil soluble vitamins and also have a key role in cell membrane and hormonal activity. Warm water fish are generally known to be indifferent to n-3 fatty acid deficiencies; and it is observed that tilapia need higher amounts of n-6 fatty acids (e.g. linoleic acid) (De Silva *et al.* 1991; Chou and Shiau, 1996). Due to a lot of contradictory studies, the exact effect of n-3 and n-6 fatty acids on growth requires further scrutiny but generally 0.5% n-3 and 1% n-6 PUFA are incorporated in fish feed. Generally fish oil is used in fish feed but soy oil is also shown to be a good lipid source (Gaber *et al.*, 1996). Other effective supplements are menhaden oil and catfish oil, however, it has been found that lard increased the oxidative stress on the fish and tallow resulted in depressed growth (Stickney *et al.*, 1972; Ng *et al.*, 2013). While use of vegetable oils like soy or palm do not negatively affect growth, they show higher feed efficiency ratio than other vegetable oils like linseed oil (Ng and Wing-Keong, 2001). They decrease the omega-3 PUFA profile in fish fillet giving it potentially better oxidative stability. Low levels of PUFA decrease the fish's nutritional value for human consumption, as PUFA levels in the fillet are strongly influenced by PUFA in feed. It is suggested to use vegetable oil incorporated fish feed during growth and then switch to feeds incorporating omega-3 rich oils prior to harvest to increase their levels in the fish fillet by a "washout effect", alternatively a fish oil and vegetable oil blend of suitable ratios can be used (Karapanagiotidis *et al.*, 2006; Young, 2009). While designing feed, it is important to keep in mind the objective to decrease proteins involved in supplying digestive energy so that protein is spared for growth, and energy does not become "limiting" (Popma *et al.*, 1996). Hence, it is important to maintain lipid ratios, so as to not overshoot the lipid content which leads to protein catabolism and fatty fish. Regardless, tilapia show better results when lipids are included in their diet,

Table 4: Lipid Requirement of Nile Tilapia

Fatty Acid	Requirement in Nile Tilapia (in Total feed)	Remarks
18:2[n-6]	0.50%	Can be interchangeably used
20:4[n-6]	0.50%	
18:3[n-3]	0.50%	

which is suspected to be due to the high concentrated digestive energy lipids provide (Popma *et al.*, 1996). Table 4 depicts lipids requirement of Nile tilapia.

Carbohydrates:

They are cheapest source of energy and thus of great economic importance in feed formulation. They can be divided into starch and non-starch polysaccharides (NSP). Dietary carbohydrates are not shown to have any specific requirement in fish (Wilson *et al.*, 1994), they are used as a concentrated energy source that prevent use of other nutrients like lipids and protein to be used up for metabolic energy (Burnell *et al.*, 2009). Carbohydrate in feed is generally included in the form of starch (wheat, soy, maize, etc.). In general, warm water and omnivorous fish like tilapia, can digest starch better than cold water fishes and/or carnivorous fish. Average total carbohydrate digestibility for tilapia was calculated to be 67% by Maas *et al.* (2020). NSP digestibility in tilapia studied in detail by them showed that it is poorly digested and increases ANF. Thus, it is best to keep the fish feed low in NSP content and high in starch. Increase in the level of gelatinization of starch is also shown to increase the growth in tilapia while also improving the nutritive value of diet (Adhikari *et al.*, 2015; Kanmani *et al.*, 2018). Starch can act as a binder and improve water stability and water-protein solubility. The optimal level for starch has been identified to be 46% by Wang *et al.* (2005). The mean apparent digestibility coefficient (ADC) of starch was found to be 94.5% based on of the findings of Amirkolaie *et al.* (2006), Leenhouwers *et al*. (2007) and Haidar *et al*. (2016).

Conclusion

The ideal nutrient levels of feed for nile tilapia were reviewed. It is seen that the feed must be formulated with the protein levels as base – whose content should be kept in optimum quantities so as to not be used up for catabolic energy, and in ratio with lipids and carbohydrates for effective absorption. Care must be taken to include n-6 rich lipid sources. Carbohydrates can be added as the bulk of the feed as it is shown to aid protein intake for deposition in the body, and it is also a cheap source of energy that adds stability to the feed. Water soluble vitamin supplements can be added in slight excess to avoid deficiencies while some micronutrients like sodium are found sufficiently in the water and hence does not need supplementation. Hence, an overview of the basic requirements for a feed for nile tilapia is constructed for maximum yield and profit. Vigorous research is needed regarding the specific vitamin levels of tilapia. Recirculating aquaculture systems (RAS) and bio-flocks tend to have a rich supply of ammonification bacteria and micro flora, fauna which significantly add quality to the nutrient profiles. The role of microbes in nutrient utilization and availability especially in such settings need to be further studied and understood, thus optimizing supplements of vitamins and minerals provided by microbes, which can reduce costs. Experimenting with locally available plant varieties of starch and lipid

oils can also lead to a better understanding of their utilization and better efficiency at a cheaper cost. With use of fish oils, the "washout method" requires more research and optimization so as to be an effective method of producing high quality fish with PUFA levels comparable to mixed vegetable and fish oil fed fish. If a recirculation system is used, lesser amounts of lipids can be used. Supplementation with enzymes that break down ANFs or aid digestion can also be used to aid absorbability as seen in the case of phosphorus absorption after addition of phytases.

Acknowledgement

The authors express their gratitude to the Management of AMET University for providing research facilities to carry out this work. The authors are thankful to the Dr. Swarnakala, Department of Botany, Central University of Punjab and Dr. R. Vijayaraj, Department of Marine Biotechnology, AMET University, Chennai for their support to successfully complete this work.

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