Chapter 22

Alternative Use of Plant-based Diet for Tilapia

Abubakar Burhan Nagi[1], Seemab Fatima[1], Muhammad Usman Hameed[1], Mariyum Basharat[1], Zobia Amin[1], Muhammad Bilal Zafar[2], Ayesha Batool[1] and Afaq Ahmad[3]

[1]Department of Zoology, Faculty of Science, University of Agriculture Faisalabad, Pakistan
[2]Department Agronomy, Faculty of Agriculture, University of Agriculture Faisalabad, Pakistan
[3]Faculty of Veterinary Sciences, University of Agriculture, Faisalabad, Pakistan
*Corresponding author: abubakarburhannagi@gmail.com

ABSTRACT

For growth and well-being, tilapia, an omnivore fish that is extensively farmed, needs proteins, fats, carbs, and vital minerals. While fats especially essential fatty acids are important for growth and health, the quality of proteins has a big influence on metabolic efficiency and growth. Because fish meal is becoming more and more expensive and has a negative environmental impact, aquaculture is looking into alternate protein sources. The nutritional profiles and palatability of plant-based alternatives such as soybean meal, insects, and animal proteins are gaining popularity. Insects are highlighted because of their high protein content and capacity to break down organic waste. Fish meal substitutes for Nile tilapia benefit from the vast research conducted on soybean meal because it is inexpensive and has a balanced amino acid profile. Plant-based diets have potential despite obstacles such as shortages in amino acids and antinutritional elements. Methods such as substituting soybean meal (SBM) can preserve tilapia development performance and enhance intestinal health. Subsequent investigations will focus on improving sustainability and effectiveness using better nutrient use and functional feed additives.

KEYWORDS
Tilapia, Alternatives, Proteins, Fats, Nutrition

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INTRODUCTION

The fastest-growing food industry in agriculture is aquaculture, which will eventually supply the majority of the world's food needs (Khieokhajonkhet et al., 2021). Aquaculture is the growing of aquatic organisms in regulated or semi-controlled conditions, such as freshwater or saltwater, including plants, invertebrates, and vertebrates. This technique provides a better way to grow selected aquatic species for use in food production (Stickney and Gatlin, 2022). Aquaculture has now become an important contributor to the seafood supply (Wu et al., 2021). Due to the decline in wild fish sources due to anthropogenic activities, aquaculture has become an essential means of fulfilling the increasing demand for seafood worldwide.

Aquatic farming nowadays is expanding at a faster rate than other traditional livestock industries, such as poultry, and this presents an encouraging development for food security. However as it develops, the effects on society and the environment must be carefully considered for better growth of fish industries (Little et al., 2016). The development of workable feeding plans to promise quicker and healthier fish growth is a growing area of interest for the fisheries industry (do Nascimento et al., 2020).

Ineffective policies related to fisheries and aquaculture are sometimes caused by the lack of knowledge about the complex problems these sectors face. Better administration requires acknowledging the real cause of the complexities faced by the fisheries sector so they can develop solutions appropriately (Jentoft and Chuenpagdee, 2013). The fish industry addresses concern about the environment, safety, and food security to enhance their habitat and to make sure the provision of seafood. Furthermore, it is noted that successful health care, breeding grounds and initiatives with proper feeding strategies would raise the world's fish production (Furuya et al., 2023).

Fisheries have grown at an exponential rate becoming a significant source of animal protein due to high polyunsaturated fats (PUFA) (Hua et al., 2019). Tilapia, an omnivorous versatile freshwater fish known for its fast growth and ability to thrive on plant-based diets, emerges as a key player in meeting the rising global demand for seafood (Prabu et al., 2019). They have been purposefully introduced all over the world (Makwinja and Geremew, 2020). Tilapia can

withstand stress better than the majority of other fish species (Lv et al., 2021).

Fish from the cichlid family, tilapia, are omnivores that are native to Africa. They have been inadvertently or purposefully introduced all over the world. Because of its special benefits, tilapia stands out among other commercially farmed fish as a possible contender for aquaculture in the future. Hardy freshwater fish native to Africa and the Middle East, tilapia develop quickly and reproduce prolifically. Because they can adapt to a wide range of meal sources and are herbivorous, tilapia can live at a lower trophic level than many carnivorous fish that must eat fish. This dietary characteristic makes tilapia production less detrimental to the environment, more significant, and less taxing on wild fish populations. In addition, tilapia are a commercially appealing aquaculture option due to their mildly flavored flesh and quick market size attainment (Yue et al., 2016) Tilapia can survive in unfavorable environmental conditions that other fish species would typically not be able to, such as low dissolved oxygen and high ammonia levels. *O.niloticus,* the Nile tilapia, is undoubtedly the most widely cultivated fish (Magbanua and Ragaza, 2024).

The heavily farmed Nile tilapia has achieved success, but now it must strike a balance between fish health and affordability. Although issues with growth and adaptability were addressed through selective breeding, increased demand is driving up feed prices. Fish meal is the ideal feed (Munir et al., 2023) due to its nutrient-rich nature, but it is not cheap and non-sustainable. An alternative that is more affordable and sustainable is plant-based protein (derived from plants), such as soybean meal and maize gluten. Therefore, employing the appropriate processing techniques and amino acid supplementation to create a cost-effective balance that increases fish health is the key to successful plant-based tilapia diets (Magbanua and Ragaza, 2024).

Nutritional Needs of Tilapia

With its superior nutritional profile and ease of use, fish meal has emerged as a viable alternative to all animal protein sources. Because fish meal is in short supply right now, the cost is rising daily. Given that the majority of commercial fish species are either omnivorous or carnivorous, it is therefore vital to identify an appropriate, affordable, and environmentally acceptable replacement protein source (Bera et al., 2022). A successful feed management strategy is essential for tilapia farming. Innovations in aquaculture make it possible to build feeds that are customized to meet certain requirements and even let farmers use locally available items to make feed. As a result, assessing these components is crucial to creating diets that are ideal for different aquaculture species and carrying out accurate nutritional studies (Gule and Geremew, 2022). The omnivorous fish tilapia may be fed a variety of plant-based foods (Yang et al., 2021).

Tilapia needs proteins, fats, carbohydrates, vitamins, and minerals for its normal growth. In the fish body, macro minerals like Ca, K, Mg, Na, and P and microminerals like Zn, Mn, Cu, Fe, Se, and I have distinct functions that include skeletal system development and homeostasis (El-Sayed et al., 2023). While trace elements such as copper, iron, chromium, zinc, iodine molybdenum, etc. are also essential for its health, excessive concentrations can be hazardous to fish (Makwinja and Geremew, 2020). Proteins, lipids (L), and carbohydrates (Gurunathan et al.) These are the main energy sources used in aquaculture-formulated meals. Fish require a greater amount of protein—the most expensive nutrient—than terrestrial animals do to maintain proper growth and health (Xie et al., 2017).

Proteins

The primary organic substance found in fish tissue is protein. An important portion of the fish's total body weight, around 65–75% dry weight, was made up of protein (Subandiyono and Hastuti, 2020). Dietary protein content has a major effect on fish growth and development. Although an increase or shortage of protein can retard growth, the effects are usually different. While high protein can result in inadequate nutritional absorption and increased ammonia excretion, which can have detrimental effects on fish health, growth, and the environment, low protein lowers digestive enzyme function retarding its growth (Yang et al., 2021).

The nutritional value of fish diets generated is known to be influenced by the quality of the protein source used in feed composition (Luthada-Raswiswi et al., 2021). Feed is the most significant expense for the productive growing of tilapia in closed aquaculture systems, particularly the feed's protein component. Numerous investigations on various feed additives that could complement the protein supply in fish feed have been conducted by different researchers (Nguyen et al., 2021).

Fish need essential amino acids for the formation of proteins, as other animals do. The fish have to get these essential amino acids from their surroundings because they are not able to make them on their essential amino acids to get them from their diet. Fish health and growth are traditionally associated with 10 essential amino acids (EAAs), which include methionine, arginine, and lysine etc. Any of these EAA deficiencies can restrict the synthesis of proteins and have a detrimental effect on fish development and decreases its growth and health (Furuya et al., 2023). Plant-based protein diets like fish meal are inferior to those including maize gluten feed and cottonseed meal (Magbanua and Ragaza, 2024).

Fats

Lipids are just as important to aquatic species' diets as protein. Fish health depends on essential fatty acids (FAs), which have an impact on immunological response, development, and reproduction. They also influence the health and functionality of cell membranes through elements such as phospholipids (Nakharuthai et al., 2020). Lipids perform

essential and dynamic role in growth and health, neural and visual development (de Oliveira Coutinho et al., 2018).

Essential fatty acids and other important lipid groups are provided by these non-protein energy sources, supporting general health and development (Jia et al., 2020). Because high-fat diets (HFDs) are economical and help fish retain protein, they are widely used in contemporary aquaculture (Qian et al., 2021). Omega-3 and omega-6 PUFAs, among other important fatty acids, can be found in Tilapia i.e., The main n-3 PUFAs are α-linolenic acid (ALA), docosahexaenoic acids (DHA), eicosapentaenoic acid (Ravindran et al.) and docosapentaenoic (DPA) (Chepkirui et al., 2021).

Carbohydrates

Although carbohydrates are not considered necessary development products for fish, fish feed contains carbs since they are less expensive energy sources (de Oliveira Coutinho et al., 2018). A large amount of carbohydrates (30–70%, depending on age) can be used by Nile Tilapia in their diet. A recent study investigated the effects of different dietary carbohydrate amounts (0–50%) on adult Nile Tilapia metabolism (Oonanuntanasarn et al., 2018).The content of carbohydrates has a major impact on how easily carbohydrates can be digested and eliminated overall in the diet (Maas et al., 2020). Unsuitable or excessive carbs may spike glucose levels in fish might impair immunological response, development, and general health (Azaza et al., 2020).

Reduce tilapia's capacity for nutritional digestion, results in poor assimilation of nutrients which results in nutrients like protein ending up as metabolic waste (Bashar et al., 2021). Fish growth is highly dependent on how well they are able to convert food into nutrients that they can use known as FCR (Food Conversion Ration), especially in the early stages of development (Santo et al., 2020). It has been suggested that probiotic dietary supplements improve fish health and illness resistance. Additionally, research shows that dietary probiotics can improve aquatic animals and nutrient digestibility by activating their digestive enzymes which increases fish health and metabolism (Maas et al., 2021). Probiotics for aquaculture can be made from the intestinal microbes present in fish (Reda et al., 2018). Aquaculture is increasing day by day and hence there is a rise in the use of probiotics, which are live bacteria living in fish gut with health advantages. By improving digestion, eliminating dangerous germs, and strengthening the immune system, the dietary supplements can encourage fish growth, development and illness resistance (Liu et al., 2017).

Protein Alternative Sources

Animal

Animal protein sources have long been thought of as the best replacement protein sources for fish meal in fish diet formulation because of their higher protein and fat content, improved essential amino acid profile, and exceptional palatability which increases the digestion and results in better assimilation (Luthada-Raswiswi et al., 2021).

Fish meal substitutes are becoming more popular; because of their high nutrient content and palatability, animal protein sources are especially appealing. However, a possible obstacle to its long-term use in fish feed is the growing need for animal protein worldwide across all industries (Luthada-Raswiswi et al., 2021). The comparatively high levels of protein, fatty acids, energy, well-balanced amino acids, and minerals (sodium, iron, potassium, and zinc) found in insects have been linked to their sustainable use as feed (Wachira et al., 2021).

In general, insects are thought to be a good source of EAAs. The EAA concentration is frequently raised in insect species in comparison to soy protein (milligrams per gram of protein) (Hawkey et al., 2021). The adult crickets, mealworms, grasshoppers, and pupae of the black army fly have demonstrated superior outcomes among all insect larvae and pupae (Bera et al., 2022). Black soldier fly larvae (BSFL) have the highest potential being the most effective converter of organic waste into valuable biomass of high protein value (Magbanua and Ragaza, 2024). Insect meals have been identified as a potential feed element because they are high in protein (40–45%) and fat (26–35%), particularly in BSFL (Fawole et al., 2021).

Several aqua feeds have effectively exploited alternative insect protein to lessen dependency on the expensive and rare fish meal used in fish diets. The impact of insect-based feed on tilapia growth as a food source is also astonishing (Wachira et al., 2021). They can develop on relatively low-quality diets and ingest high-quality protein and a variety of other critical elements, insects have attracted a lot of attention due to their high levels of protein. Insects have different nutritional values according to their species, diet, and developmental stage. They provide a variety of easily obtainable vitamins and minerals, as well as high-quality protein, PUFA, and energy (Hawkey et al., 2021).

In order to create insect meals, the typical procedure is as follows:

1. First, we must confirm the availability of the specific insect abundance within that region
2. Next, decontamination is accomplished with the use of radiation or heat treatments.
3. The third phase involves using radiation or convection to dry the entire insect, pupae, or maggot.
4. Then, insects are ground into tiny fragments using a grinder. Some insects (like yellow-low mealworms) require the defattening process to obtain their fat during this period.
5. Next, using microorganisms to aid in the fermentation process, chitin needs to be extracted from the insect meal.

Insects require regulated environmental conditions for optimal growth during mass raising and breeding (Bera et al., 2022).

Periphyton

To increase the productivity of fish farming in ponds, waterbodies and cage systems, periphyton-based aquaculture

grows periphyton on artificial surfaces as a natural food source for fish. Periphyton is comprised of invertebrates such as zooplankton, bacteria, fungi, and algae. Naturally, periphyton grows on submerged substrates that are added to the water bodies. Moreover, because periphyton is largely composed of green microalgae, it has frequently been stated to be the primary producer in pond systems (Khieokhajonkhet et al., 2021).

Plants

Plant-based refers to a broader range of foods that are predominantly derived from plants, such as fruits, vegetables, nuts, oil, whole grains, and legumes (Alcorta et al., 2021). The production of fish that are appropriate for a plant-based diet has expanded, thanks to aquaculture. The nutrition of fish has been improved, which has reduced feed waste and, as a result, increased industrial profitability. The output, survivability, and quality of farmed fish have all increased with a diet high in beneficial components such as prebiotic compounds, antioxidants, and omega-3 fatty acids (Nagappan et al., 2021).

The more costly fish meals are replaced by many plant and single-cell protein sources (Luthada-Raswiswi et al., 2021). Single-cell proteins are isolated from the cells of microorganisms with a high protein ratio, such as fungi and bacteria (Aragão et al., 2022).

One of the significant ingredients that may be used in a variety of meal preparations is vegetable protein. They provide sustenance, but they also serve as sources of energy and amino acids, which control the chemical and physical characteristics (Etemadian et al., 2021). In the past, vegetable protein sources have been a convenient, affordable, and beneficial substitute for fish meal in aquafeed composition. Soybean meal (SBM) is the most widely utilised vegetable protein source in aquafeed formulation because of its high protein content, ideal amino acid profile, and digestibility. However, because of its high non-digestible carbohydrate content, SBM is known to have detrimental side effects on the intestinal health and fish welfare of some species of carnivorous fish (Randazzo et al., 2021).

Due to its high protein content (40–51%), affordability, and widespread availability, soybeans are a popular choice for replacing fish meal. Raw soybeans, however, have anti-nutritional elements that may prevent fish from growing. These elements can be eliminated during processing by using techniques like solvent extraction or mechanical pressing, which results in soybean meal (SBM), a common ingredient in fish diets. Soybean protein concentrate (SPC), a different processed form, has an even better digestibility and protein content (65–67%) than soybean buttermilk (SBM) (Magbanua and Ragaza, 2024). The value of soybean meal for fish, especially Nile tilapia, when it comes to aquaculture diets where fish meal is substituted:

Using Fermented Soybean Meal (FSBM) in Place of Fish Meal

The study looks into using fermented soybean meal, or FSBM, in place of fish meal in tilapia diets.

Maintains Growth Performance

The growth performance of fish on a diet containing 7% FSBM was comparable to that of fish meal, suggesting that FSBM has the potential to be used in place of other feed.

Enhanced Plant-Based Diets

The addition of FSBM increased the tilapia's overall efficiency in using plant-based diets.

Enhances Gut Health

By raising the height of the intestinal villi and the quantity of goblet cells, higher FSBM inclusion levels (over 21%) enhanced gut health.

Overall, the results of this study indicate that fermented soybean meal may be a useful substitute for fish meal in tilapia (Picoli et al., 2022).

In the actual scenario of producing fish feed, the primary plant protein is soybean meal (SBM). This feedstock has a fairly well-balanced amino acid profile among the plant by-product meals, is produced in large quantities, is affordable, and has a moderate protein content (Wattanakul et al., 2021).

In aquaculture, soybean meal (SBM) is a viable source of protein that substitutes for fish meal for a number of reasons.

High Protein Content for Fish and Balanced Amino Acid Profile

Soybean plant have a greater amount of protein in it. SBM provides a better complete amino acid profile which result in better growth, development and results in a comparatively higher amount of usable protein for fish than other plant-based choices, both of which are critical for fish growth.

Stable Supply and Fair Price

SBM provides reliable availability at a lower cost than fish meal, which is subject to supply constraints and price swings.

Success with Particular Fish Species (Tilapia)

Research has shown that herbivorous fish species, such as Nile tilapia *Oreochromis niloticus,* can successfully substitute

fish meal in part or in full with SBM without sacrificing growth or health (Peng et al., 2022).

Diets denoted by D1, D2, D3, D4, and D5 contain 0, 25, 50, 75, and 100% of SBM, respectively, given gram/kg. According to this study, *O. niloticus* can grow well when up to 75% of its FM is replaced with SBM. When SBM was used in place of 100% FM (D5), it produced a decline in fish growth. Lower growth rates were the result of the higher SBM content. In the experiment of 180-day testing period, the fish group fed the diet (D4) containing 75% soybean meal (SBM) instead of fishmeal (FM) displayed increased length and weight hence better growth of the fish (Pervin et al., 2020).

The proper plant-based feed formulation in tilapia is due to the following reasons:

Relevance of Feed Management

The financial viability of tilapia farming depends on the effective use of plant-based feed ingredients which are economical and profitable as well.

Problems with Plant-Based Diets

Although plant-based diets provide a sustainable substitute for fish, they frequently include anti-nutrients that obstruct and hinders the assimilation and digestion resulting in improper growth of fish hence population growth declines.

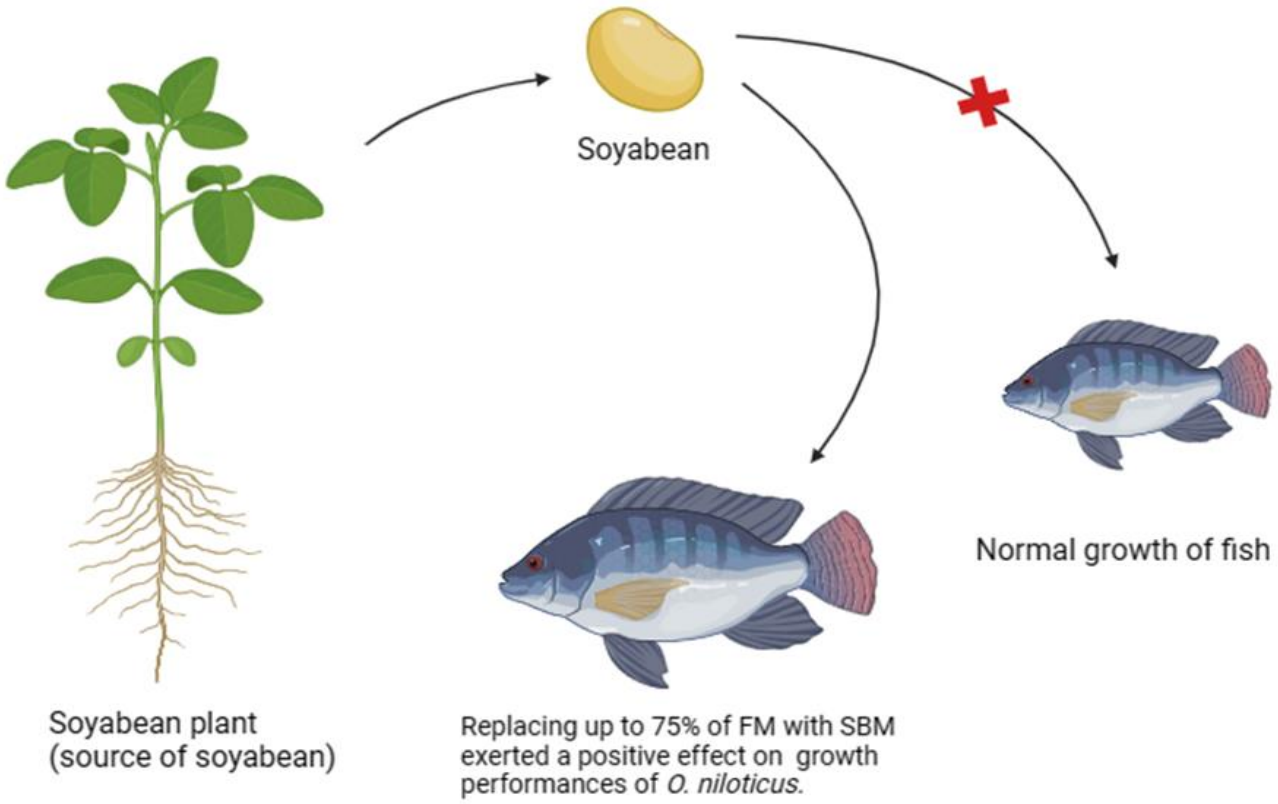

Fig. 1: Replacing upto 75% of Fish Meal with Soybean Meal exerted a positive effect on growth performances of Nile Tilapia. Created with biorender.com

Table 1: Formulation of Supplemental Diet with replacing Fish meal with Soybean meal.

Ingredients (I)	Diet 1 (D1)	Diet 2 (D2)	Diet 3 (D3)	Diet 4 (D4)	Diet 5 (D5)	References
Wheat Flour	100	100	100	100	100	(Pervin et al., 2020)
Wheat Bran	150	150	150	150	150	(Pervin et al., 2020)
Maize Meal	200	200	200	200	200	(Pervin et al., 2020)
Fish Meal	400	300	200	100	0	(Pervin et al., 2020)
Soybean Meal	0	100	200	300	400	(Pervin et al., 2020)
Vitamin B	5	5	5	5	5	(Pervin et al., 2020)
Cod Liver Oil	10	10	10	10	10	(Pervin et al., 2020)

Formulation procedures

To address and overcome these issues, the review examines a number of feed formulation procedures, including heat treatment, fermentation, and enzyme supplementation to maximize nutrient quality and availability for fish and to stop or minimize the procedures which reduces anti-nutritional effects.

Emphasis on Nutrient Utilization

The importance of further study to enhance the absorption and assimilation of nutrients from plant-based diets is essential for productive tilapia farming and enhanced growth and reproduction as well as normal metabolism. Nutrients are properly utilized by the body only when they are properly digested and assimilated efficiently.

In general, the text emphasizes the need for appropriate formulation methods to fully realize the benefits of plant-based diets (Salavatian et al., 2022).

Although substitutes made of terrestrial plants are being investigated, fish health may be compromised by the anti-nutritional elements which are responsible for decreased growth and these anti nutritional elements are frequently present in them. While research on plant-based proteins is still ongoing, other novel ingredients such as insects and microalgae are receiving more attention because of their potential nutritional profiles and benefits for sustainability (Aragão et al., 2022).

Creating the ideal tilapia feed is crucial to ensure optimal nutrition and balanced diet particularly when using plant-based alternatives. This study shows how to combine chicken manure (dropping) with inexpensive, locally available plant components like bran. It's critical to examine the nutritional makeup and profile of these plant-based compounds which form diets for optimum growth of fishes. The section describes a typical technique for employing these substitutes, which frequently have a different protein composition than fish meal, to balance the protein levels in formulated feed. With plant-based diets, proper feed composition guarantees tilapia receive the nutrients they need for healthy growth, supporting a more economical and sustainable aquaculture industry (Hailu et al., 2019).

Strategies to Overcome Feed Challenges for Fish Health

Phytate is a challenge to tilapia's plant-based diets. When removed, this anti nutrient damages the ecosystem because it binds vital phosphorus, decreasing its availability which results in improper growth of fish and decreases its immune system. Since they were created for cold-water fish, current phytases—enzymes that break down phytate—might not be the best choice for tilapia due to their pH range. Furthermore, phytase efficacy is influenced by a number of circumstances (Manikandan et al., 2020).

This investigation of the use of herbal supplements (mint, basil, and lemongrass) in Nile tilapia fry feed revealed the advantages and disadvantages of plant-based diets. While fish development was improved by basil and lemongrass etc, mint had the opposite effect resulting in improper growth. The nutritional profile of the fish was similarly affected by plant preservatives. The results emphasize the necessity of choosing carefully which plants to use in tilapia aquaculture and which to not use. To find the best plant-based diet that support tilapia growth while maintaining their nutritional value and efficiency, more research is necessary (Ndour et al., 2020).

There were particular challenges even if total substitution with plant-based alternatives appeared promising. Some plant meals, such as soybean meal, were more successful and promising in promoting healthy growth than others, such as linseed meal. Furthermore, fish on plant-based diets often digested less efficiently results in less efficiency of the meal. Scientists recommend combining several plant sources to create a more balanced diet or adding vital amino acids to get over these restrictions. Another way to increase plant proteins' digestibility for tilapia is by fermentation. Through investigation of these approaches, scientists hope to create plant-based diets that support tilapia growth in a healthy manner and lessen reliance on fish meal (Gaber, 2006).

Impact of Plant based Diet on Tilapia

The increasing demand for tilapia aquaculture is due to population growth and declining fish stocks due to their high demand. It highlights the limitations of fish meal as a feed source and explores plant-based proteins as a substitute because feed sources have nutrition but fish meal also have drawbacks. The emphasis is on the need for cost-effective, locally available plant ingredients like rice polish to formulate tilapia feed and assess its impact on growth performance. Plant based diet is essential for plants due to high nutritional value and great impact on gut health and growth. (Rahman et al., 2023).

There is evidence which suggests that a plant based diet is good for fish health. In comparison to the control group, Nile tilapia that were fed particular plant extracts—namely, Asparagus racemosus and Basella alba—exhibited better growth performance.

Additionally, Plant based extracts showed immunostimulatory properties, which may have improved the fish's general health and growth. Increased immune system results in better adaptability and survivability of fish in harsh environments. These results imply that food supplements made of plants may help tilapia grow and stay healthy due to improved nutrition (Ghosal et al., 2021).

Research Findings Related to Plant-based Tilapia Diets

Fish meal and plant-based diets for Nile tilapia were examined in the study, they are compared to investigate the better feed for Tilapia. Fish fed the plant-based diet showed worse growth performance (weight gain, specific growth rate) and feed efficiency (feed conversion ratio) compared to fish meal-fed fish, even though the plant-based diet was more economical per kilogram of feed. Hence, not all plant based diets are essential for Tilapia (Jatta et al., 2022).

A fermented soybean meal (FSBM) as a fish meal replacement in tilapia diets. Replacing 7% of fish meal with FSBM maintained similar growth performance, while higher FSBM inclusions (over 21%) improved gut health in tilapia (Khan et

al., 2023). These findings suggest FSBM as a potential fish meal alternative for tilapia aquaculture increasing its growth and promoting better immune response (Picoli et al., 2022).

Recent research indicates potential, despite the fact that plant-based diets for tilapia were once thought to be inferior because of things like anti-nutritional components and amino acid profiles. Fish meal can be partially replaced with certain plant proteins (such as fermented Moringa oleifera leaves or dephytinized canola meal) to keep tilapia growing well and possibly even boost their immune systems (Magbanua and Ragaza, 2024).

Future Directions and Research Needs and Ongoing efforts and research on Tilapia Diet

Adding bile and cholesterol acids to tilapia diets that are plant-based. When compared to a plant-based diet alone, this combination can enhance the growth performance and liver health of tilapia. These nutrient additions maximize tilapia's plant-based diets (Jiang et al., 2024). Researchers are investigating the methods, including probiotics and enzymes, to enhance the metabolism and assimilation in these diets (Gule and Geremew, 2022).

To enhance nutrient utilization and overall fish production and growth, researchers are investigating the use of functional feed additives (such as probiotics and prebiotics) in plant-based tilapia diets. Probiotics are basically good bacteria and prebiotics non digestible plant fibres. This is in addition to initiatives to lower the price of these additives and look into their possible health benefits for fish growth (Neves et al., 2024).

There are trade-offs associated with plant-based diets for tilapia fish aquaculture, which is becoming more and more important. Future developments are probably going to center on two things:

1) Plant based diets are often affordable ones, hence finding more affordable and readily available plant-based foods for tilapia.

2) Making these diets more sustainable hence environmentally friendly, socially acceptable, and economically profitable. This indicates that more study should be done to create affordable plant-based ingredients and optimize their formulation for balanced nutrition and low environmental impact of food (Mitra, 2021).

The use of aquatic plants for tilapia as tilapia feed holds potential for sustainable aquaculture in the future. It offers two advantages:

1) Economical as it Lower costs by substituting cheap and plentiful aquatic plants for fish meal

2) Better environmental outcomes by limiting the spread of potentially harmful aquatic weeds, as food is readily available for tilapia in its own habitat. This implies that more investigation into the most economical methods of adding aquatic plants and weeds to tilapia diets that could be a major step towards sustainable aquaculture (Naseem et al., 2021).

A Two-pronged Strategy is Probably in Order for Sustainable Plant-based Tilapia Diets in the Future

Studies on FuFAs have shown promise in enhancing fish performance on plant-based diets by improving nutrient utilization, much like probiotics and enzymes do. Gaining an understanding of the mechanisms underlying FuFA additions will enable targeted enhancements through the application of biochemical and molecular approaches (Hossain et al., 2024).

Conclusion

To sum up all about alternative plant based diets, tilapia are ideally suited for sustainable aquaculture due to their innate capacity to flourish on plant-based diets. Although fish meal is still the best feed for fish, there are alternatives such as soybean meal, but the fish alternative diets must need to be investigated due to their drawbacks in terms of price, availability, accessibility, assimilation and environmental effect. Plant-based proteins are a viable alternative for fish diets, but formulation strategies for fish diets must address issues like non-assimilation and anti-nutritional factors which can be treated. One such strategy is fermented soybean meal. *O. niloticus* can grow well when up to 75% of its fish meal is replaced with SBM. To ensure a sustainable and productive aquaculture sector, future studies on functional feed additives, inexpensive plant sources, and improving nutrient absorption are essential to realizing the full potential of plant-based diets for tilapia.

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