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Review Article

Potential Use of the Miracle Tree (*Moringa oleifera*) Leaves in Aquaculture: A Recent Update

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ABSTRACT

The superfood *Moringa oleifera* leaves are an alternative food source for human nutrition and animal feeds in different countries. This highly nutritious plant has several medicinal uses as well. Abundant vitamins and minerals make this plant a source of curiosity to underdeveloped and developing countries to meet the requirements of nutrients. Higher crude protein levels in moringa leaves have become popular as alternative feed sources for animals. Moreover, the leaf contains a rich amount of macro and micronutrients such as minerals and vitamins. It is also popular in some countries for its aphrodisiac use. Moringa leaves are used in the diet as a supplement to enhance growth and reproductive performance in animals, including fish. These leaves have been used in diets to replace fishmeal, soybean, and other plant-based meal sources. The antibacterial properties of the leaves are functional as a way of lessening the spread of diseases and as an immunity booster in aquaculture. According to the literature surveyed, moringa leaves can be utilized in the diet at 10-30% in omnivore and herbivore fish and 10-20% in carnivore fish without adverse effects. In this review, we discuss the utilization of supplemented moringa leaves and their effect on the growth and reproduction of fish. We also discuss how these leaves affect the hematological and physiological performance of fish.

Keywords: Fish, growth performance, supplement, reproductive performance, alternative feeds

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INTRODUCTION

Aquaculture industries are growing each day. Sustainable aquaculture depends on economically viable quality feed. The feed industries frequently use fishmeal and oil to maintain the high-quality feed. However, the natural fish stock is limited, which poses a big challenge for those working on getting available fishmeal at the desirable level for the industry. Therefore, scientists are working to find alternative feed sources to cope with the challenges. Much research has been done on plant-based alternative diet sources. Plant-based additives are also used as growth promoters and to boost reproductive performance in aquaculture. Researchers have tested plant-based supplements in aquaculture as an alternative to artificial chemicals. Improving the diet of cultured fish and enabling weight gain are two goals of using plant-based additives in aquaculture (Dada, 2015). It has been the usual practice to use plant-based resources in the feed industry for many years.

Moringa oleifera is called a drumstick plant in English and is known as *shajna* in India and Bangladesh. Due to its extremely high nutritional content, *Moringa oleifera* is a widespread vegetable plant in India, Bangladesh, Africa, and other regions. Leaves can be used in fresh, dried, or powdered form. Fish and animals can consume the bark, leaves, pods, seeds, and roots of the moringa plant (Kou et al., 2018). Its broad beans or pods are mainly used to pre-

pare different curries and soups. In addition, its leaves are also nutritious and full of vitamins and minerals. The pods and leaves of *Moringa oleifera* are an abundant source of minerals like magnesium, calcium, manganese, phosphorus, iron, zinc, copper, and others (Aslam et al., 2005). Moringa leaves have a common practice in ethnomedicine in different countries, especially in India and Africa. In addition to being a widespread plant in the Indian subcontinent, it may also be found in other regions. Even in dry conditions, *Moringa oleifera* may grow rapidly, and it serves as an excellent protein supplement for livestock (Oduro et al., 2008). According to Fuglie (1999), *Moringa oleifera* contains more vitamin A than oranges and carrots, more protein than yogurt, more calcium than milk, more potassium than bananas, and more iron than spinach. The National Institute of Health (USA) recognized it as the "Botanical of the Year 2007" (Gupta et al., 2018).

Moringa oleifera increases antioxidant enzyme levels and enhances detoxification (Hasan et al., 2019). Dry moringa leaves contain 25-30 % protein and a good amount of lipids. In moringa, the polyunsaturated fatty acid is higher than saturated fatty acids. More than 16-19 amino acids are found in moringa leaves, of which tens are essential amino acids (Moyo et al., 2011). Many studies utilize plant-based diets to replace fishmeal (Elumalai et al., 2020; Ahmadifar et al., 2019) as they are easily accessible, safe for the environment, affordable, sustainable, and eco-friendly (Hardy, 2010). Fish are influenced in a variety of ways by medicinal herbs and their extracts. When added to fish diets, these substances can influence growth performance and boost immune activities.

The oxidative stress brought on by many stressors during fish culture can be lessened using medicinal plants and their extracts (Ahmadifar et al., 2021). According to Siddhuraju et al. (2003), the natural antioxidants contained in moringa leaves have similar functions to popular synthetic antioxidants like butylated hydroxyanisole and butylated hydroxytoluene. As moringa leaves have some significant medicinal value, they can be utilized to treat several diseases in animals. They may perform a variety of roles, including that of bactericides and immunostimulants (Coppin et al., 2013). Research has also demonstrated that *Staphylococcus aureus, Bacillus subtilis*, and *Vibrio cholera* are susceptible to the crude leaf powder and extracts of *Moringa oleifera* (Jayawardana et al., 2015).

Studies have revealed that both fresh and post-thawed semen benefit from the herb or phytochemical extracts (Azimi et al., 2020; Ahmed et al., 2020). It has been shown in various species that utilizing plant additives with antioxidants in the feed improves in vitro fertilization by decreasing oxidative stress production in the medium (Azimi et al., 2020; Ahmed et al., 2019). However, plant-based compounds are also utilized to stimulate animal reproduction. A saponin called protodioscin is found in *Tribulus terrestris* and is assumed to be the compound responsible for improving testosterone levels (Ganzera, 2001). Moringa leaves also contain different saponins, tannins, flavonoids, terpenoids, and glycosides (Fahey, 2005; Singh et al., 2009), which might help to improve the reproductive performance and increase the testosterone level in fish. Additionally, moringa leaves have a good amount of selenium, zinc, calcium, and vital vitamins (Vit-A, Vit-B, and Vit-C).

In the last couple of years, the multipurpose plant moringa has been used in the diets of ruminates, rabbits, rats, chickens, and fish to evaluate its effect on growth and reproductive performance. Moringa leaves have been used as supplemented diet, aqueous extract, ethanol extract, and other forms of inclusions in the diet of cultured fish. This review aims to summarize the findings of published articles on the use of *Moringa oleifera* leaves in aquaculture species.

The Miracle tree - *Moringa oleifera*

Description of *Moringa oleifera*

Moringa oleifera originated from Southeast Asia, the Middle East, and Africa, however, it is now widely distributed throughout America, the Caribbean countries, several countries in Asia, the Philippines and Indonesia (Morton, 1991; Mughal et al., 1999; Seshadri & Nambiar, 2003). *Moringa oleifera* can survive droughts; thus, it grows well in hot regions. The *Moringa oleifera* tree thrives in sandy-loam soil that drains well and has a pH range of 5 to 9. *Moringa oleifera* can easily grow from seeds and cuttings (Hasan et al., 2019).

Moringa oleifera is a leafy plant of the family Moringaceae, commonly called a drumstick tree. The drumstick tree is typically 8–15 m tall. It is solid and has a soft woody stem (Figure 1a, 1b) and a tuberous root. When grown, its leaves are dark green (Figure 1c). The tree produces 30–50 cm long, broad pods (Figure 1d). Most people eat the fleshy part of the pods as vegetables (Seshadri & Nambiar, 2003). Moringa flowers and seeds are presented in Figures 1e and 1f.

Nutritional values of moringa leaves

Due to being rich in micro and macronutrients, *Moringa oleifera*, a well-known vegetable of the Indian subcontinent, is recognized as a miracle tree. In addition to being an abundant source of β-carotene, moringa also contains significant levels of other minerals, including iron, calcium, phosphorus, and zinc, as well as

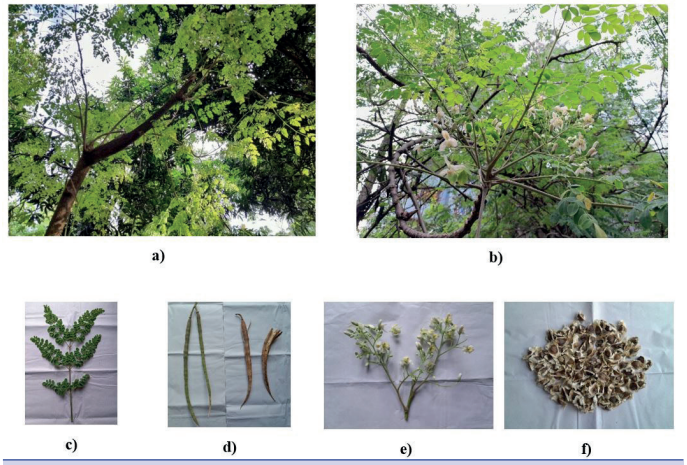

Figure 1. Different parts of *Moringa oleifera*. a) leaves and stem, b) leaves with flower, c) leaves, d) pods or beans (green and dry), e) flowers, f) seeds.

significant amounts of vitamins, including folic acid and ascorbic acid (Seshadri & Nambiar, 2003; Faboya, 1983). Almost every part of the moringa tree, including the leaves, pods, seeds, and flowers, is edible. Moringa leaves are well known for abundant protein, vitamin, and mineral content and also for natural antioxidants, i.e., carotenoids, flavonoids, and phenolic components (Dillard & German, 2000; Siddhuraju & Becker, 2003). The pods and leaves of *Moringa oleifera* are a rich source of minerals like magnesium, calcium, potassium, manganese, phosphorus, sodium, zinc, copper, iron, and others (Aslam et al., 2005). Parts of the moringa plant, such as the leaves, roots, beans, bark, and seeds, are extensively utilized in ethnomedicine in different countries (Stohs & Hartman, 2015). Moringa leaves are well known for having a high nutritional value. In their dried form, they possess 23-30% crude protein, 5.9% crude fiber, 7.6-12% ash, and 7.09% crude lipid (Su & Chen, 2020).

Drumstick leaves have 137.28 mg of vitamin C (ascorbic acid) / 100 g of fresh weight. Compared to spinach, the ascorbic acid concentration of drumstick leaves is 1.5 to 2 times higher (Seshadri & Nambiar, 2003). The highest concentration of β-carotene is found in moringa leaves (19210 µg/100 g fresh weight) (Nambiar & Seshadri, 1998). As a result, animals can consume moringa leaves as a natural supply of vitamin A. Nambiar and Seshadri (2001) worked on the albino rat to find the effect of moringa leaves as a Vit-A source and concluded that both fresh and dehydrated forms of moringa leaves enhance the growth performance more than the synthetic Vit-A.

Ethnomedicinal uses of *Moringa oleifera*

There are many therapeutic uses of *Moringa oleifera,* which have been found in different regions of the world. In addition to having antitumor and antimicrobial properties, *Moringa oleifera* is effective against infection, diabetes, typhoid, HIV, diarrhea, dysentery, ulcer, rheumatism, joint pain, arthritis, etc. (Fahey et al., 2005; Costa-Lotufo et al., 2005; Fuglie, 1999; Caceres et al., 1992; Faizi et al., 1998; Asres, 1995; Bharali et al., 2003).

Phytochemicals in moringa leaves

M. oleifera has high concentrations of several phytochemicals, including glucosinolates, isothiocyanates, kaempferol, caffeoylquinic acid, zeatin, quercetin, kaempferitrin, rhamnose, rhamnetin, and isoquercitrin (Fahey, 2005). Additionally, *M. oleifera* also contains chlorogenic acid, ferulic acid, ellagic acid, vanillin, and gallic acid in their aqueous extracts (Singh et al., 2009).

USE OF MORINGA LEAVES IN AQUACULTURE

Moringa oleifera leaves have been used in the feed of different omnivorous, herbivorous, and carnivorous fish to evaluate the effect on several physiological parameters, such as growth performance, reproductive performance, hematological parameters, enzyme activities, and disease resistant performance.

Effect of moringa leaves on the growth performance of fish

Moringa leaves have been widely utilized in research to assess their impact on the growth performance of various fish species. Dietary fishmeal can be substituted up to 30% with solvent-extracted moringa leaves without adversely affecting growth parameters in *Oreochromis niloticus* (Afuang et al., 2003). In contrast, Richter et al. (2003) demonstrated that more than 10% inclusion of moringa leaves suppressed growth in Nile tilapia. Yuangsoi & Charoenwattanasak (2011) also suggested a 10% inclusion of moringa leaves in Nile tilapia diet. After eight weeks of the feeding trial, El-Kassas et al. (2020) reported that 5% moringa leaves in the feed significantly lowered the lipid profile and enhanced growth performance. The inclusion of moringa leaves up to 20-25% in the diet showed better growth efficiency in *O. niloticus* (Sherif et al., 2014). However, Kasiga et al. (2014) demonstrated that the replacement of soybean meal protein with moringa leaf meals is possible up to 30% without affecting growth in Nile Tilapia.

In *Labeo rohita,* body composition could be unaffected by the substitution of moringa leaves for soybean meal as a cost-effective source of high-quality plant protein (Masood et al., 2020). This statement has been supported by the findings of Arsalan et al. (2016), who demonstrated that fishmeal could be supplemented with moringa leaf meal up to 10% to boost the nutritional value of *L. rohita* fingerlings. Another study opposed the previous findings that fish growth is decreased when *Moringa oleifera* is added to the diet, which may be because some anti-nutrients have a detrimental impact (Mehdi et al., 2016). The contrary might be because the feed composition, size of the fingerlings, and duration of the experiment were different. In *Clarias gariepinus,* fishmeal can be replaced by up to 15% moringa leaf meal without any negative impact on growth parameters (Idowu et al., 2017). In addition, a 15% inclusion of moringa leaves in substitution of fishmeal showed the best performance in mean weight gain, specific growth rate (SGR), and feed conversion ratio (FCR). It is also possible to replace soybean meal at 20% with moringa leaves to get the highest performance of similar parameters in *Clarias gariepinus* (Ncha et al., 2015). According to Dienye and Olumuji (2014), 10% inclusion of moringa leaves showed no negative effect on blood parameters and enzymes level. In Asian seabass (*Lates calcarifer),* replacing 10% of fishmeal with moringa leaves was suggested to improve growth performance (Ganzon-Naret, 2014). The author also recommended that up to 30% of moringa leaves be used instead of fishmeal by adding Methionine to the diet, enhancing protein digestibility. In a 60-day feeding trial of *Pangasius bocourti,* Puycha et al. (2017) demonstrated that the inclusion of moringa leaves at 100 g could be utilized in the feed without negative effect on the growth performance, digestibility, and serum biochemistry.

An overview of the impact of moringa leaves on the growth performance, hematological indices, and other physiological parameters of omnivore, herbivore, and carnivore fish species is provided in Table 1, Table 2, and Table 3.

Effect of moringa leaves on reproductive performance of fish

To date, *Moringa oleifera* leaves have been used in research on several fish species to evaluate their biological and reproductive performance. However, the greater part of the research investigating the value of moringa leaves in fish feed has mainly focused on evaluating the effect on the growth performance, hematological parameters, and immune activities in several fish species, i.e., Tilapia, *Labeo rohita, Puntius altus, Lates calcarifer, Pangasius bocourti*, zebrafish, sea bream, rainbow trout, and

Table 1. Use of *Moringa oleifera* leaves in omnivorous fish culture.

Experimental Fish	Feeding behavior	Doses used	Duration	Remarks	Recommended dose	Ref.
Nile tilapia (*Oreochromis niloticus*)	Omnivore	0, 5, 7, and 9 g/kg diet	60 days	Improvement in growth, maintenance of intestinal health, increase in antioxidant capacity, and boost of immunity in Nile tilapia.	5 g/kg	El-Son et al., 2022
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	Replacement of dietary protein at 0, 10, 20, and 30%	7 weeks	10% showed normal growth, others suppressed growth.	10%	Richter et al., 2003
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	Replacement of 0, and 30% dietary fishmeal	8 weeks	About 30% of the fishmeal could be replaced with solvent extracted moringa leaf meal.	30%	Afuang et al., 2003
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	0, 5, and 10%	8 weeks	Growth performance improved. Significantly lowered lipid profiles.	5%	El-Kassas et al., 2020
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	0, 5, 10, 15, 20 and 25%	6 weeks	Growth parameters were significantly higher in 20 and 25%.	15%	Sherif et al., 2014
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	0, 5, 10, and 15%	60 days	10% moringa leaf had no negative effects on fish health, growth, or protein digestion.	10%	Yuangsoi & Charoenwattanasak, 2011
Nile Tilapia (*Oreochromis niloticus*)	Omnivore	Replacement of soybean meal at 0, 15, and 30%	59 days	No effects on proximate composition, survival rate, FCR, weight gain, lysozyme activity, proteolytic enzyme activity.	30%	Kasiga et al., 2014
Mozambique tilapia (*Oreochromis mossambicus*)	Omnivore	0, 3, 6, 9, and 12%	45 days	Survival rate increased. Without affecting growth capacity, moringa can enhance fish health.	9, and 12%	Mbokane & Moyo, 2018
Fancy carp (*Cyprinus carpio*)	Omnivore	0, 200, & 500 g/kg replacement of soybean meal protein	6 weeks	No negative impact on growth and digestibility at 200 g /kg.	200 g/kg	Yuangsoi & Masumoto, 2012
Fancy carp (*Cyprinus carpio*)	Omnivore	0, 10, 20, 30, 40, and 50% of crude protein replacement	12 weeks	Growth parameters enhanced in 30%.	30%	Adeshina et al., 2018
Zebrafish (*Danio rerio*)	Omnivore	Control, M (only moringa), FM (supplemented moringa without vitamin & mineral), F_{vm} (feed without vitamin, mineral, and moringa)	12 weeks	Normal growth and reproduction in control group, No growth and no eggs in M group, reduced growth and reproductive performance in F_{vm}, recovery of growth and reproductive performance in FM.	Control	Paul et al., 2013

Table 1. Continue.

Experimental Fish	Feeding behavior	Doses used	Duration	Remarks	Recommended dose	Ref.
Bocourti's catfish (*Pangasius bocourti*)	Omnivore	0, 100, 150, and 200 g/kg of fish	60 days	No adverse impact on the growth, digestibility, feed utilization, and serum biochemistry at 100 g/kg.	100 g/kg	Puycha et al., 2017
Red-Tailed Tinfoil (*Puntius altus*)	Omnivore	0, 20, and 60 mg / g of fish feed	28 days	Fish health, growth performance, muscle protein profile improved significantly.	20 mg/g diet	Sirimongkolvorakul et al., 2015

FCR= Feed conversion ratio, FM= Fishmeal

Table 2. Use of *Moringa oleifera* leaves in herbivorous fish culture.

Experimental Fish	Feeding behavior	Doses used	Duration	Remarks	Recommended dose	Ref.
Milkfish *(Chanos chanos)*	Herbivore	Replacement of soybean meal at 0, 10, 25, 50, and 75%	60 days	No problem up to 50% replacement in terms of protein digestibility.	50%	Hamzah et al., 2021
Labeo rohita fingerlings	Herbivore	0, 10, 20, and 30%	2 months	Decrease in growth.	Control	Mehdi et al., 2016
Labeo rohita fingerlings	Herbivore	0, 10, 20, 30, and 40%	70 days	Fish carcass composition and hematological parameters are unaffected by the 10% inclusion of moringa leaves.	10%	Arsalan et al., 2016
Labeo rohita fingerlings	Herbivore	0, 10, 20, and 30%	90 days	Improved weight gain, FCR, SGR.	30%	Masood et al., 2020
Mrigal *(Cirrhinus mrigala)*	Herbivore	0, 1, 2, 3, 4 and 5% of acidified moringa seed meal by citric acid	90 days	Improved weight gain, SGR, and nutrient digestibility.	3%	Hussain et al., 2017
Cirrhinus mrigala	Herbivore	0, 10, 20, 30, 40, and 50% replacement of FM	90 days	10% showed best results, which leads to positive changes in hematological indices.	10%	Tabassum et al., 2021

FCR= Feed conversion ratio, FM= Fish meal, SGR= Specific growth rate.

Table 3. Use of *Moringa oleifera* leaves in carnivorous fish culture.

Experimental Fish	Feeding behavior	Doses used	Duration	Remarks	Recommended dose	Ref.
Rainbow trout (*Oncorhynchus mykiss*)	Carnivore	0, 0.625, 1.25, 2.5, and 5%	8 weeks	5% untreated moringa leaves have no negative impact on fish performance.	5%	Stadtlander, & Tonn, 2015
Rainbow trout (*Oncorhynchus mykiss*)	Carnivore	10, 20, 30, and 40% replacement of fishmeal	90 days	20% showed best growth performance, improvement in immune response and antioxidant activities.	20%	Labh, 2020
Asian sea bass (*Lates calcarifer*)	Carnivore	0, 10, 20, and 30%	75 days	0% showed best result then 10, 20 and 30%.	10%	Ganzon-Naret, 2014

Table 3. Continue.

Experimental Fish	Feeding behavior	Doses used	Duration	Remarks	Recommended dose	Ref.
Gilthead Seabream (*Sparus aurata* L.)	Carnivore	0. 5, 10, and 15% supplementation	4 weeks	Adding Moringa to the diet increases the muscle's antioxidant activity, resulting in improved oxidative stability of the food.	15%	Jiménez-Monreal et al., 2021
Sea bream (*Sparus aurata*)	Carnivore	0, 5, 10, and 15%	4 weeks	5% inclusion showed best immune status, enhanced growth performance and acceptable immune surveillance found in 10%.	10%	Mansour et al., 2018
Sea bream (*Sparus aurata*)	Carnivore	0, 1, 2.5, and 5%	3 weeks	5% boosted the mucosal immune system. No adverse effect in cortisol and glucose level.	5%	Mansour et al., 2020
Heterobranchus longifilis	Carnivore	0, 5, 10, 15, and 20%	5 months	Improve growth parameters in 15% group.	15%	Eyo & Ivon, 2017
Heterobranchus longifilis	Carnivore	0, 5, 10, 15, and 20%	5 months	Final body weight and feed intake improved. No difference in FCR. Higher GSI in 15% group.	15%	Opeh et al., 2018
African catfish (*Clarias garipenus*)	Carnivore	0, 4.1, 8.2, 12.3 and 16.39 g inclusion of moringa leaves	12 weeks	Moringa enhance growth, and no adverse effect on fish health. FCR, AWG, SGR improved with moringa inclusion.	8.2 g	Ayoola et al., 2013
African catfish (*Clarias garipenus*)	Carnivore	0, 10, 20, 30, 40, and 50%	8 weeks	Blood serum and enzyme level had no negative effect at 10% inclusion. Mean weight gain, FCR are better in 10%.	10%	Dienye & Olumuji, 2014
African catfish (*Clarias garipenus*)	Carnivore	0, 20, 40, and 60% of soybean meal replacement	56 days	20% showed best performance in FCR, weight gain, SGR.	20%	Ncha et al., 2015
African catfish (*Clarias garipenus*)	Carnivore	0, 10, 15, 20, and 25%	8 weeks	Weight gain, FCR, SGR improved in 15%.	15%	Idowu et al., 2017

SGR= Specific growth rate, FCR= Feed conversion ratio, AWG= Average weight gain, GSI= Gonado-somatic index

fancy carp (Yuangsoi & Masumoto, 2012; Mehdi et al., 2016; Paul, 2013; Ganzon-Naret, 2014; Sirimongkolvorakul et al., 2015; Labh, 2020; Puycha et al, 2017; Mansour et al., 2018; El-Kassas et al, 2020). Limited studies were found on the reproductive performance of fish. Opeh et al. (2018) worked on African catfish (*Heterobranchus longifilis*) conducting feeding trials over a period of five months to check the effect of moringa leaves on the gonado-somatic index and fecundity at a rate of 0, 5, 10, 15, and 20%. In this study, 15% supplementation of moringa leaves improved gonadal development and increased fecundity significantly. Twelve weeks of feeding trials on zebrafish were conducted and designed with four groups: control diet, only moringa leaves (M), control diets without vitamins and minerals (F_{VM}), and moringa-supplemented diets without vitamins and minerals (FM). In this research, moringa-supplemented diets (FM) showed a greater increase in egg production than the F_{VM} group. In contrast, zebrafish fed with only moringa leaves without any additional nutrients did not produce eggs (Paul et al., 2013). The findings of this study imply that moringa leaves can be used as a suitable dietary supplement for macro- and micronutrients and may help allevi-

ate the effects of nutritional shortages in zebrafish. Gad et al. (2019) investigated the effect of moringa seeds on the reproductive performance of Nile tilapia. This study used ethanol extract moringa seed (EEM) and petroleum ether extract moringa seed (PEEM) at 0.5 g and 1.0 g. The control group had the lowest ovarian weight, whereas the 0.5 g PEEM group had the highest ovary weight compared to the 1.0 g EEM group. Moreover, in female fish, the gonadosomatic index and estradiol level were higher in moringa-treated groups than in the control group. In male fish, the gonadosomatic index, testosterone level, and cortisol level were higher in moringa-treated groups than in the control group. In a recent study, 14 weeks of feeding experiments were conducted in which moringa leaf was included at 0, 4, 8, and 16% into the diet to assess the impact on the reproductive performance of male rainbow trout (*Oncorhynchus mykiss*) (Momin & Memiş, 2022). The study results suggested that the 8% inclusion of moringa leaf boosts sperm quality parameters and improves reproductive performance. However, in male broodstock rainbow trout, 16% of moringa leaf can be fed without adverse effects (Momin & Memiş, 2022).

Effect of moringa leaves on other physiological parameters of fish

The hematological indicators of *Clarias garipenus*, ssuch as red blood cell count (RBC), packed cell volume (PCV), hemoglobin (Hb), and white blood cell count (WBC), etc., increased significantly when moringa leaves were added to the diets (Ezekiel et al., 2016; Ayoola et al., 2013). According to Sherif et al. (2014), feeding Nile tilapia with *M. oleifera* leaves significantly raised their hematological indices and serum alanine transaminase (ALT) and aspartate transaminase (AST) levels. In addition, Nile tilapia showed a significant drop in blood uric acid, urea, and creatinine when fed 1.5% moringa leaves compared to the control (Salama et al., 2016). Blood parameters such as RBC, WBC, Hb, and PCV increased with a greater inclusion of moringa leaves in the diet of *Cyprinus carpio* (Adeshina et al., 2018). Moringa supplementation at 15% in the diet of *Oreochromis niloticus* showed no significant differences in RBCs, Hb, PCV, mean corpuscular hemoglobin (MCH), and mean corpuscular volume (MCV), but WBC increased (Bbole et al., 2016). Mansour et al. (2020) suggested 5% moringa leaves inclusion in the diet of seabream to enhance skin-mucosal immune activities. In addition, four weeks of feeding trials in gilthead seabream (*Sparus aurata*) revealed that a 15% supplementation of moringa leaves in the diet increased the antioxidant activities of the muscles (Jiménez-Monreal et al., 2021). Arsalan et al. (2016) demonstrated that a 10% replacement of fishmeal with moringa leaves found the highest RBC count and Hb value in *Labeo rohita*. According to research on catfish (*C. gariepinus*), no negative impact was determined in the hematological indices or serum enzymes with 10% supplementation of moringa leaf in the diet (Dienye & Olumuji, 2014).

CONCLUSIONS

Moringa oleifera leaves are a potential alternative feed for fish in aquaculture industries because they contain high levels of nutrients such as proteins, minerals, and vitamins that can boost growth and reproductive performance. Studies have shown that supplementing a fish diet with 10-20% moringa leaves for carnivore fish and 10-30% for herbivore and omnivore fish does not have adverse effects. However, more research is needed to determine the appropriate dose for maximum benefit and to study the effect of moringa leaves on the reproductive performance of fish.

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