

Application of Vermicompost Fertilizer in Aquaculture Nutrition: Review

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Abstract

Semi-intensive aquaculture using ponds is among the most common practices of fish production, whose output depends highly on the ponds' natural primary productivity. With the increased sustainability and health concerns with artificial fish feeds and chemical fertilizers, organic manure has been credited as a cheap, safe and sustainable alternative source of aquaculture nutrition. Apart from supplying nutrients to the phytoplankton, organic manures supply food directly to zooplankton and fish, provide substrate for microbes and improve water and pond sediment quality. Vermicompost fertilizer (excrete of earthworms) has been recognized as a potential pond fertilizer because it has superior nutritional quality (of up to five times), contains microbes, and is in ready-for-uptake form. Besides, the vermicompost contains humic acid, which has antibiotic properties, and promotes fish gut health, stress management, and immune systems. Nonetheless, the application of vermicompost fertilizer in aquaculture is still not a common practice. Therefore, this study reviews the concept of vermiculture *vis-à-vis* pond fertilization and the various utilizations of the vermicompost in fish farming. This is to enable fish farmers to make an informed decision on identifying and selecting proper biofertilizer, which can increase yields and cut costs of production, thus maximizing profits and improving resource utilization.

Keywords: vermiculture, primary production, vermicompost, pond fertilization

1. Introduction

Most of the aquaculture productions in developing countries are practiced in rural areas using semi-intensive fish pond culture systems. This rural aquaculture plays a major role in improving livelihoods, enhancing social equity, advancing gender equality, contributing to global food production (food and nutritional security), and promoting regional economies. Consequently, aquaculture helps curb the high rate of malnutrition occasioned by undernourishment in most rural setups (particularly in Africa) since the superior nutrition in fish improves health by providing food and supporting both mental and physical development and functioning [1]. Besides, unlike some animal protein sources, fish and fish by-products are widely accepted among various social, cultural, and religious backgrounds [2]. Moreover, in developing countries where people have the highest share of fish protein in their

diets, the aquaculture sector plays a vital role in maintaining reasonable livelihoods through food and nutrition provision as well as job creation.

Nevertheless, the significant role played by aquaculture and the increasing demand of aquatic organisms as well as the advancement in science and technology, fish farming in most developing countries is still at infancy stages, being practiced secondary and part-time to agriculture.

Fish feed challenge has been identified as one of the limitations to the commercialization of aquaculture, particularly in Africa. This is because farmers prefer and highly depend on fishmeal as the main protein source due to its superior nutritional properties, palatability, and biological value. Consequently, the majority of the farmers do not achieve their full potential due to the cost, scarcity, and ecological implications associated with obtaining the fishmeal.

The majority of rural fish farming is undertaken in semi-intensive culture systems using earthen (polythene lined or cemented) ponds with limited or no supplementary feeding. Therefore, pond fertilization is taken as a crucial step in pond management to promote phytoplankton production that is the key link to the fish food chain. Studies have considered this old age undertaking as a cost-cutting practice that has the potential of enhancing the fish yields up to 2.8 times [3]. Fertilization is undertaken to improve the growth and reproduction of natural food organisms, which include zooplanktons, phytoplanktons, bacteria, microscopic algae, and insects. These natural organisms in water are eaten directly or indirectly depending on the fish-eating behaviors. For example, the herbivorous fish (such as carps) feed on algae and bacteria biomass, the carnivores (such as catfish) consume zooplanktons and insects, while omnivorous fish (such as tilapia) feed on all.

Therefore, when a pond is fertilized for example using manure, some portion is assimilated or stored by the phytoplanktons, while another share is consumed directly by zooplanktons and fish. Another portion goes to pond bottom where it combines with organic matter to promote the development of the microbial community, which apart from being fed by fish, the bacteria and fungi play a crucial role in ponds of decomposing uneaten fish feeds and toxic wastes [3]. There is also another portion of the manure that is adsorbed by pond sediment whereby it improves bottom soil quality and its water retention properties, and in case of decreased nutrients in the pond, these manures are released slowly back to the water body to promote the plankton development.

The fertilizers used are either organic or inorganic. The large-scale fish ponds are disposed to using inorganic fertilizers thanks to their easy storage and distribution as well as consistent and high nutritional contents. However, their utilization is limited by their scarcity, high cost of obtaining them, and the risks of impairing soil fertility, causing environmental degradation through the pollution to receiving waters, CO₂ generation, and depletion of fossil fuels. Furthermore, chemical fertilizers if not used properly can cause fish toxicity by decreasing dissolved oxygen concentration and increasing total dissolved solutes, alkalinity, conductivity, and free carbon dioxide [4]. Besides, chemical fertilizer application beyond certain levels leads to decreased pond's natural productivity due to self-shielding of sunlight by the upper layer of dense crops of phytoplanktons.

On the other hand, small-scale farmers depend on organic fertilizers from agricultural wastes of crops and livestock animals such as cow dung and chicken droppings. Unlike chemical fertilizers, organic manures are cheap and locally available, contain organic matter, can be directly consumed by fish, and improve soil structure and water retention. In addition, the straw-like particles in organic manure provide an attachment substrate for microbes to flourish. In Israel, Schroeder [5, 6] demonstrated that organic manure application in fish culture yields three times more than inorganic fertilizer. Nonetheless, organic manure nutritional content is variable and

low and recently, they are becoming scarce and relatively expensive to obtain due to competition from crop and fuel production. In addition, cow manure increases biological oxygen demand (BOD) because of the high content of organic matter that consumes a lot of oxygen during their aerobic decomposition often leading to anoxic zones in pond bottoms. Further, livestock manure poses the risks of pathogen transfer to fish.

Therefore, there is a need to adopt economically and ecologically sustainable organic fertilizers such as vermicompost, which has no biosafety concerns. The vermicomposting biotechnology takes advantage of the voracious, polyphagous, fast-growing, and high reproduction nature of earthworms to consume large amounts of organic waste and excrete vermiwastes. The vermicomposting products are earthworm biomass and vermiwastes: vermicompost (solid waste) and vermiliquid (liquid waste). The earthworm biomass is either fed directly to aquatic organisms or used as the protein source in formulating fish diets [7–9]. Nonetheless, the earthworms biomass utilization in fish feed production is limited by processing challenges (handling, harvesting, and gut content evacuation) and the presence of anti-nutritional factors (coelom fluid and chitin), which inhibit uptake, digestion, and assimilation by aquatic organisms [8, 9]. The vermiwastes have also been used in formulating fish feeds; however, their utilization is equally limited by relatively low protein contents and processing impediments [10–12]. In addition, vermicompost utilization is still limited by its efficacy and undeveloped market when compared to compost and chemical fertilizers.

Therefore, this study reviews various applications of the vermiwastes in promoting aquaculture nutrition by improving pond primary production. This is to provide farmers with simple, easily available, and cost-effective fertilizer that can increase fish production and resource utilization without compromising water quality, health standards as well as environmental integrity.

2. Vermitechnology *Vis-à-Vis* aquaculture nutrition

Earthworms are ground-dwelling organisms, which belong to the phylum *Annelida* and class *Oligochaeta*. They are voracious omnivores that feed on dead and decaying organic matter. Consequently, the earthworms just like microorganisms serve the critical biological functioning of nature by ensuring nutrient flow from one system to another, thus reducing environmental degradation. For ages, earthworms have been utilized as agents of vermicomposting biotechnology to sustain soil fertility, reclaim wasteland, and treat organic wastes to a relatively less homogeneous and desirable esthetic compound. The vermicomposting biotechnology takes advantage of the voracious, fast-growing, and reproduction nature of earthworms to convert organic waste to highly nutritious compounds [7, 8].

In this biotechnology, the earthworms are made to consume large quantities of organic materials, which undergo a biochemical process in the worm's gut before being deposited as an excreta known as the vermicompost or vermicast or vermiwastes. This complex biological and ecological process of vermicomposting is enhanced by the presence of microorganisms, mucus, and enzymes in the gut of the earthworms to produce a stable and safe compost that contains and can hold more nutrients for over an extended period of time without affecting the environment. The excreta is rich in humus, which contains micro and macronutrients, antibiotics, vitamins, microbes, growth promoters, and fungal communities [13].

The commonly used omnivorous earthworm species in vermicomposting are *Eisenia fetida*, *Lumbricus rubellus*, and *Eisenia andrei*, which besides being voracious and fast-growing, they are epigeic (surface dwellers), hardy, and easy to culture.

The vermicomposting process is undertaken in simple structures using locally available organic wastes. It is desirable that the culture systems have a base (e.g., cemented or layered with polythene paper) that control the earthworms from burrowing, prevent leachates, and simplify harvesting. It is recommended to have the culture systems covered to prevent predators, rainfall, and direct sunlight, while the substrate is regularly sprinkled with water to conserve moisture and regulate the worm's body temperature.

The culture substrates for earthworms comprises a wide range of organic materials that can promote the production of fungi, protozoa, and bacteria that are the highly preferred diets of the worms. Earthworms feed on different food materials, such as livestock manure wood, leave, crop and kitchen wastes, sewage sludge, and agro-industrial waste. The commonly used substrates are livestock manure and kitchen wastes. However, the kitchen wastes of onions and meat should be avoided because they kill fish by reducing pH and suffocation, respectively.

Depending on the culture substrate and worms species used, the vermicompost is usually ready within 2 to 4 months, but the vermiliquid can be harvested on daily basis. There are several techniques of separating the earthworms from the compost but the most convenient one is to, stop sprinkling the substrate with water, introduce light from the top side to prompt the worms to bury downwards, and then collect the upper vermicompost. Otherwise, one can starve the earthworm for few days then introduce a new feed substrate at the top prompting the worms to migrate upward then harvest the vermicompost at the base.

The harvested vermicompost has elevated nutrient levels, which are in ready-to-uptake form by plants (unlike compost that requires curing before use) because they are released relatively easily and faster, thus improving plankton and fish growth performance [14–18]. This is because the earthworms ingest large volumes of nitrogen-laden organic matter, mineralize it in their guts, and excretes it whereby it is stored in the vermicompost in form of nitrate that is more bioavailable to plants when compared to the ammonia form found in conventional compost [19, 20]. This mineralization of nitrates due to vermicomposting and the respiration by earthworms drops the C:N of fresh organic matter to the desired ratio of below 20:1 [12].

Apart from the vermicompost, the vermicomposting process produces vermiliquid, the leachate from the organic waste, and the vermicompost. The vermiliquid (also known as vermiwash or worm tea) just as the vermicompost is an equally nutritious fertilizer because it contains fecal excretion, organic materials, microorganisms, enzymes, earthworms secretions, mucus, and organic acids, and in addition, it contains soluble plant nutrients [21]. Vermiliquid has shown more potential to improve aquaculture nutrition because it further contains cocoons, body parts of worms, small and dead earthworms all that is edible to fish, and some zooplanktons and contributes to more nitrogen to the vermicompost [19, 22]. Besides, the vermiwash is known to contain bacterial biomass, hormones, antibiotics, free amino acids, vitamins (pro-vitamin B and D complex), metabolites suitable for fish growth, feed digestion, disease resistance, and immune boosters [16]. In addition, the vermiliquid has recommendable proteins contents with the potential of substituting basal ingredients in fish feed formulation [10, 11]. Musyoka et al. [12] demonstrated how a mixture of the three vermicomposting products (i.e. earthworms, vermicompost, and vermiliquid) also known as earthworm bedding has superior nutrition that is capable of economically replacing fishmeal in diets of Nile tilapia (*Oreochromis niloticus*) without compromising growth performance. Both the vermicompost and vermiwastes are highly recommended in organic farming whereby the use of fertilizers, growth regulators, hormones, feed additives, and pesticides are not encouraged.

When compared to the traditional compost and other farmyard manures such as cow dung, horse dung, and poultry droppings, vermicompost has been found to be more nutritious, containing relatively good amounts of carbon, nitrogen, phosphorus, calcium, and C:N ratio as shown in **Table 1**. Nonetheless, the quality of these vermiwastes can be enhanced by using nutritious substrates (preferably a mixture of different substrates) and different species of earthworms. For example Musyoka et al. [12] used mixed substrates of kitchen waste, coffee husks, barley waste, and livestock manure and produced vermicompost with superior nutrition when compared to farmyard manure as shown in **Table 1**. Similarly, when Marsh et al. [24] added shredded cardboard to aquaculture effluent they produced a vermicompost with superior nutrition when compared to Rahman et al. [25] who used cow dung substrate alone as shown in **Table 1**.

Studies have shown vermicompost to contain up to seven times more nutritional and plant growth-promoting value thanks to the faster activation of humus when compared to conventional composting [26, 27]. Besides providing nutrition, the humic acid produced during vermicomposting has the ability to suppress the growth of harmful bacteria and fungi (particularly those responsible for mycotoxins production); thus when consumed by animals, it promotes gut health (for increased nutrient utilization), stress management, and immune systems and controls intestinal diseases [28]. Unlike the compost whereby nutrients such as nitrogen are denatured and microbes die due to high temperatures, vermicompost contain a rich microbial community (that remains unchanged even after drying the vermicompost), which has shown to be direct food to zooplanktons and fish as well as being beneficial in reducing pathogenic bacteria [29]. Kaur and Ansal et al. [30] recommended the development of biotechniques for isolating and harvesting of the beneficial microbial biomass present in vermicompost to be used as biocontrol. In addition, the presence of coelom fluid produced by earthworms (whenever they get agitated) makes vermicompost pathogen-free and goes a long way in protecting fish from diseases [29]. Moreover, the vermicomposting presents stable and mature organic matter rich in humic acids that reduce the harmful effects associated with toxic gases produced by undigested or semi-digested organic manure to fish. In addition, the earthworms reduce heavy metal concentrations on organic matter by baring them in their gut and skin whereby they are slowly broken down into non-toxic forms [31]. Further, the non-thermophilic vermicomposting produces fewer

Nutrients (%)	Vermicompost [23]	Vermicompost [12]	Vermicompost [24]	Vermicompost [25]	Farm yard manure [23]
Substrate used	—	Kitchen waste, coffee husks, barley waste, and livestock manure	Shredded cardboard and aquaculture effluents	Cow dung	
Nitrogen	1.6	1.06	2.7	2.65 ^a	0.5
Phosphorus	0.7	0.35	1.6	2.21 ^a	0.2
Potassium	0.8	0.66	2.7	—	0.5
Calcium	0.5	4.13	8	1.83 ^a	0.9
Carbon	—	12.9	40	8.76	—
C:N ratio	15.5	13.57	15.8	—	3.3

^amg 100 g⁻¹ manure.

Table 1.
 Comparison of the nutritional quality of vermicompost and farmyard manure.

greenhouse gases when compared to traditional composting [32]. Other advantages of vermicomposting over traditional composting are, being a friendly technology that is simple, cheap, relatively faster, can be done indoors using locally available organic materials and using less technical expertise. Correspondingly, studies have reported vermicompost to have great potential of replacing inorganic fertilizer. Sinha et al. [33] reported the vermicompost potential to enhance crop growth by up to 30–40% when compared to chemical fertilizers.

In addition, vermicomposting promotes waste treatment and resource utilization particularly in rural areas whereby cheap underutilized agro-industrial residues are in abundance. Importantly, these residues are not directly consumed by humans (unlike fishmeal), hence cheap and have less competition; however, their utilization in aquaculture nutrition is inhibited by unbalanced nutrition, unpalatability, high fiber, the presence of anti-nutritional factors, and have bio-safety, processing, and ethical issues. Various studies have demonstrated the potential of vermicomposting to vaporize these residues to nutritious earthworm biomass, vermicompost, vermiliquid, and earthworm bedding (mixture of the three) [7, 8, 34]. Besides, vermiremediation has been shown to reduce organic solid wastes by up to 75% faster, BOD and TDSS by over 95% and significantly removing chemicals, heavy metal contaminants, and undesirable gases such as H_2S , NH_3 [35, 36]. With the harvesting and processing challenges of earthworms as well as their bioaccumulation of toxic organic and heavy metals, the utilization of vermicompost in aquaculture has been seen as a suitable alternative [37]. Moreover, the utilization of vermitechnology has also been promoted by the preference to consume organically produced foods, the need to conserve energy, control organic waste pollution, and optimize economical resource utilization strategies.

3. Utilization of vermiwastes in fish ponds

The phytoplanktons, zooplanktons, benthos, microbes, and detritus are natural foods for aquatic organisms. These planktons are the key link to the food chain of aquatic ecosystems as they are the naturally preferred feeds by fish particularly the juveniles. Any artificial food in fish ponds is only required to supplement the deficiency of natural feeds in terms of quantity and quality. Just like most conventional artificial fish feed sources, the planktons have protein contents ranging between 40 and 60%, which is optimal for culturing fish [38]. Therefore, promoting the productions of planktons to adequate amounts can contribute to the overall development of fish in ponds and would mean less or none of the artificial feeds.

With the intensification of aquaculture, the abundance and diversity of planktons are augmented by fertilizer application. Intense fertilization has been shown to yield between 15 and 32 kg/ha/day with no additional supplemental feed in semi-intensive fish farming, translating to 100% replacement of conventional feed [6]. The vermicompost manure has been credited as potential pond fertilizer because it is nutritious enough to supply nutrients to the planktons [17, 30]. In vermicompost manured ponds, Kumar et al. [39] noticed a correlation between improved phytoplankton biomass and zooplankton abundance and diversity, with 68.38, 19.77, and 11.38% occurrence of rotifers, cladocerans, and copepods, respectively. These authors recommended a vermicompost application rate of 5000 kg/ha/year for optimum water qualities. Consequently, the vermicompost has been recommended as suitable manure for nursery pond management to provide zooplanktons that are the preferred feed diets by fingerlings. Habibnia and Bahram [40] observed improved growth and survival of *Rutilus kutum* (*Caspian kutum*) fry as a result of improved plankton abundance after vermicompost fertilization at an application

rate of 10,000 kg/yeah/ha. Similarly, Godara et al. [29] recorded the highest content of phytoplankton and zooplankton at vermicompost fertilization at the same application rate of 10,000 kg/ha/year. Correspondingly, Deolalikar and Mitra [41] recorded increased net productivity of 220.83 C/m/h from 32.03 C/m/h when they fertilized *Labeo rohita* pond with vermicompost still with the application rate of 10,000 kg/ha/year.

On average, the majority of the studies have recommended a vermicompost manure application rate of 10,000 kg/ha/year for optimal water quality parameters, and maximum plankton and fish performance as shown in **Table 2**.

Further, the vermicompost provides food directly to zooplanktons and fish [39]. Though the vermicompost alone might contain low protein value for feeding fish directly, the microbes adhering to organic manures improve their nutrition to contents suitable for the majority of aquatic organisms. Rahman et al. [25] fertilized monosex *Oreochromis niloticus* ponds with vermicompost and observed decreased use of supplementary food (from the traditional feeding rate of 5% body weight to 2%), with increased zooplankton genera and abundance, thus subsequently cutting feeding cost by up to 40%. The authors recorded the highest abundance of planktons and net economic returns of 1889 USD ha/15 weeks in vermicompost-manured ponds (at a fertilization rate of 24,000 kg/ha/year) when compared to control, which had 916 USD ha/15 weeks.

Importantly, vermicompost has been shown to improve aquatic organisms' survival and growth performance without compromising water quality [30, 41, 46]. Kaur and Gupta [45] indicated that vermicompost fertilizer did not alter the physicochemical properties of pond water and improved the growth performance of both planktons and fish. Likewise, Ansal et al. [47] and Kaur and Ansal [30] reported significantly increased dissolved oxygen concentration in fish ponds fertilized with vermicompost when compared to those fertilized with other organic fertilizers.

With the improved plankton biomass, water quality, the vermicompost manure subsequently produces significantly high fish growth performance. After fertilizing ponds with vermicompost, Godara et al. [29] observed significant high growth of catla (*Catla catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus mrigala*) at fish ponds that received application rates of 10,000 kg/ha and least performance in those manured with cow dung. In the same way, Kumar and Godara [44] observed two times more growth of Indian major carps in ponds fertilized with vermicompost (at an application rate of 10,000 kg/ha/yr) as compared to the control of pig, poultry, and cow manure. On the other side, Kaur and Ansal [30] produced the maximum weight gain, yields, and specific growth rate of *C. carpio* after manuring the fish ponds for 120 days with vermicompost at an application rate of 15,000 kg/ha/year and a 2% supplementary diet.

Just like most organic manures, vermicompost is recommended over inorganic fertilizers. Chakrabarty et al. [15] observed significantly high production of plankton diversity and *Cyprinus carpio* fish in vermicompost fertilized ponds when compared to those manured with diammonium phosphate. Also when compared to a mixture of SSP and urea in the ratio of 1:1, vermicompost-manured ponds had superior growth performance of both *Oreochromis niloticus* and plankton biomass [16]. In addition, Ghosh [43] noted that vermicompost-manured ponds had increased water retention capacity than inorganic fertilized ponds in monoculture fish farming. Besides, vermicompost-manured fish ponds have almost double soil moisture retention rate when compared to chemically fertilized culture systems [43]. On the other hand, Chakrabarty et al. [17] found vermicompost-manured ponds to have significantly high phytoplankton production of 3034/L (with increased abundance of *Myxophyceae*, *Chlorophyceae*, *Cyanophyceae*, and

Vermicomposting substrate used	Parameters tested	Fish tested	Recommended application rate	Author (s)
Cow dung	Water quality, fish growth performance, and plankton biomass	<i>Catla catla</i> , <i>Labeo rohita</i> , and <i>Cirrhinus mrigala</i>	10,000 kg/ha/year	[42]
Cow dung and poultry manure	Water quality, zooplankton production, and growth performance	<i>Cyprinus carpio</i>	15,000 kg/ha/year	[30]
Cow dung	Growth performance	<i>Labeo rohita</i>	10,000 kg/ha/yr	[41]
Water hyacinth (<i>Eichornia crassipes</i>)	Water quality, plankton production, and fish growth performance	<i>Cyprinus carpio</i>	3970.56 kg/ha/90 days	[15]
Water hyacinth (<i>Eichornia crassipes</i>)	Plankton abundance and diversity and fish growth performance	<i>Cyprinus carpio</i>	3970.56 kg/ha/90 day	[16]
Cow dung	Growth performance of fish, water quality, and plankton production	<i>Oreochromis mossambicus</i>	4000.00 kg/ha/90 days	[17]
Solid municipal waste	Water quality, soil retention, and fish growth performance	Cat fish, <i>Clarias batrachus</i>	15,000 kg/ha/year	[43]
Livestock manure	Water quality parameters and plankton biomass	<i>Catla catla</i> , <i>L.o rohita</i> and <i>Cirrhinus mrigala</i>	10,000 kg/ha/year	[29]
Cow dung	Water quality, plankton production, and fish growth performance	<i>Oreochromis niloticus</i>	5550 kg/ha/105 days	[25]
Cow dung, pig manure, and poultry manure	Growth performance of fish	<i>Catla catla</i> , <i>Labeo rohita</i> and <i>Cirrhinus mrigala</i>	10,000 kg/ha/yr	[44]
Cow dung	Growth performance	<i>Cyprinus carpio</i>	10,000 kg/ha/year	[18]
Cow manure	Plankton abundance, growth indices, and survival	<i>Caspian kutum fry</i>	10,000 kg/ha/year	[40]
Cow dung	Fish growth performance and plankton biomass	<i>Catla catla</i>	10,000 kg/ha/yr.	[45]

Table 2.
Utilization of vermicompost in fish ponds.

Bacillariophyceae species) when compared to 2100/L found in chemical fertilizer. The authors noted this increased phytoplankton production translated to the improved growth performance of the test fish, *Oreochromis mossambicus* signifying the natural feeds alone contain the essential nutrients required for fish growth.

On the other hand, the vermiliquid has equally shown the prospects of directly improving plankton productivity, particularly zooplanktons such as *Artemia*, whose mass production is often limited by lack of nutritious feeds, costly and laborious tasks. Vahdat et al. [36] demonstrated the potential of vermiliquid powder to promote the survival, growth, body composition, total carotenoids, and reproduction performance of *Artemia franciscana* in small-scale laboratory cultures.

It is interesting to note that a symbiotic system is developed when vermiculture is integrated with aquaculture; the pond wastes provide feed substrates to earthworms, and in return, the earthworms consume and excrete them as biofertilizers for improving fish pond natural productivity. Studies have recommended vermicomposting biotechnology as a suitable bioremediation technic to treat and vaporize aquaculture wastes to stable and safe organic fertilizers and earthworm biomass, that can be reused for increasing pond primary productions and fish feed production, respectively [24, 48]. Aquaculture waste (principally from intensive recirculating systems) is known to be rich in organic matter due to the elevated nutrients in uneaten feeds and the waste products of the fish. The untreated wastes cause pollution, siltation and its use as fertilizer are problematic because they are susceptible to putrefaction and contains disease-causing agents [48]. Therefore, integrating vermiculture into fish farming is fundamental to not only provide nutrition but also help in the recycling of organic wastes including that of aquaculture itself.

4. Conclusion

Vermicomposting has been recognized as a natural and cheap biotechnique of treating and bio-transforming organic wastes to safe and steady biofertilizers with the potential to promote aquaculture nutrition. This is because vermicompost contains elevated nutrients, organic matter, microbial biomass, humic acid, and exchangeable cations suitable for supplying nutrients for phytoplanktons, providing food directly to zooplanktons and fish as well as improving immunity, disease resistance, and physiochemical properties of water and pond sediment quality. Besides, the biotechnology is highly considered over the traditional composting because it regulates, improves, enhances, and promotes itself, and it conserves nutrients and microbial communities, involves low or no energy, forms little or no sludge, releases minimal greenhouse gases, and is performed on-site using simple structures requiring minimal expertise. This is particularly significant in developing nations, whereby fish farmers are struggling to break-even (even with many underutilized resources) and have less technical know-how, and their purchasing power of chemical fertilizer and commercial fish feeds is very low. Therefore, integrating vermicomposting into fish-cum agricultural activities can not only improve fish yields but also improve water and resource management, thus promoting sustainable aquaculture, and improving food security and ecological balance.

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