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Water hyacinth as potential feed and compost in aquaculture: A review

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Abstract
Water hyacinth consists of high biomass, fibrous tissue, high energy and protein content that can be used for a variety of useful applications like waste water treatment, compost and fertilizer, animal feed etc. On one hand manure and fertilizers are getting costlier day by day and on the other hand we have resources like village ponds, lakes, rivers, reservoirs, wetlands, canals, drains etc. where the much needed nutrients in the form of aquatic weeds (which otherwise pollute the water and go waste) are lying free of cost in the form of protein rich water hyacinth and make them a more suitable water resource for aquaculture. Therefore, recovering these valuable nutrient resources and recycling into some productive system like feed and compost in aquaculture makes sense both ecologically and economically. This article discusses use of water hyacinth as fish feed and compost.

Keywords: Water hyacinth, aquatic weed, fish feed, compost, aquaculture

Introduction

Water hyacinth is listed as one of the most productive plants on earth and is considered one of the world's worst aquatic plants. It can double its size in 5 days and a mat of medium sized plants may contain 2 million plants per hectare that weigh 270 to 400 tons. These dense mats interfere with navigation, recreation, irrigation and power generation. The blockage of canals and rivers can even cause dangerous flooding. On the other hand, increased evapo-transpiration due to water hyacinth can have serious implications where water is already scarce. Water hyacinth also presents many problems for fisherman. Water hyacinth is blamed for the reduction of biodiversity as well. Water hyacinth has apparently become a problem in different states of India due to its uncontrolled and rapid growth.

Water hyacinth (*Eichornia crassipes*) is a wild freshwater fern belonging to the family Pontederiaceae. The family Pontederiaceae has nine genera including *Eichhornia*, which has eight species of freshwater aquatics including water hyacinth (*Eichhornia crassipes*) [1]. The name water hyacinth refers to its aquatic habitat and the similarity of the flower colour to that of the garden hyacinth [2]. Water hyacinth is an erect, free-floating, stoloniferous, perennial herb [3] and lives at the air-water interface forming two distinct canopies; leaf canopies comprising above-water structures and root canopies comprising below water structures [4]. This plant is native to South America, but has been naturalized in many tropical and subtropical regions of the world. It grows and reproduces (by seeds and by daughter plants) at very high rates, yielding up to 100–400 Mt/ha/year [5, 6, 7]. It is considered the world's worst aquatic plant. It forms dense mats that block navigation and interfere with irrigation, fishing, recreation and power generation [5]. These mats also prevent sunlight penetration and aeration of the water, leading to oxygen deficiency, competitively exclude submersed plants and reduce biological diversity. The mature water hyacinth consists of roots, rhizomes, stolons, leaves, inflorescences and fruit clusters [8]. Although water hyacinth is seen as weed responsible for many of the problems outlined above but there are other useful applications for the plant. Water hyacinth contains more than 95% water but due to its fibrous tissue and a high energy and protein content (on dry matter basis), it can be used for a variety of useful applications.

Chemical composition of water hyacinth

The composition of water hyacinth is characterized by low dry matter and high crude protein and ash contents. Light green leaves and petioles of the immature plant are softer and contain a higher proportion of protein than those of the mature plant [9]. The leaf protein content is higher than sweet potato leaf [10] while the protein content in whole plant is considerably higher than grasses such as elephant grass [11] and can be used as a protein supplement of low quality diets [12]. Protein in leaves contains most essential amino acids and is particularly rich in glutamine, asparagine and leucine [13]. Chemical composition of water hyacinth varies with season, habitat [14, 15] as well as with harvesting frequency [16]. Protein concentration is high in the immature forage but declines with advancing maturity [17]. Lignin, followed by silica and cutin, are the primary limiting factors of digestibility [18]. Lignin content of water hyacinth is in the range from 7 to 10% has been reported while silica has varied widely from 0.5 to 5% [19]. The leaves of water hyacinth grown in sewage wastewater were also found to contain about 33% of average crude protein (dry weight basis). As nutrient composition of water hyacinth is generally related to nutrient availability in the habitat where the plants are growing, water hyacinth grown in sewage has high protein and mineral contents [20]. Hence, the water hyacinth grown in enriched medium could potentially serve as a substantial dietary supplement or mineral source.

Potential utilization of water hyacinth in aquaculture

Water hyacinth as fish feed

Cyprinus carpio fry were fed with a control (0% water hyacinth) and three different experiment diets, containing 15%, 30% and 45% of water hyacinth in place of fish meal as a protein source at 5% of the body weight for 120 days under laboratory condition and reported decrease in the growth performance indices of common carp as the percentage of water hyacinth increases [21]. They concluded that 15% *Eichhornia* feed would be optimum for the maximum growth of *Cyprinus carpio* and aquatic weed based feed are cheaper as compared to the conventional feed. In another experiment, Nile tilapia recorded higher growth rate (110% of control) at 20% inclusion of water hyacinth meal in the diet than control animals fed on a chicken diet. However, inclusion of water hyacinth in feed formulations at 30% and above significantly inhibited growth [22]. Hasan *et al*. [23] studied the use of water hyacinth for Indian major carp *Labeo rohita* at 20 and 40% of total dietary protein and compared to control with fish meal as the sole source of protein. The specific growth rates obtained were 79 and 68% of control. The results also showed that apparent digestibility decreased with increase in level of water hyacinth meal. A 63 day trial with three species of Indian major carps fed on diets containing 25-35% water hyacinth also showed encouraging results, both in the laboratory and under field conditions [24]. However, trials conducted to evaluate the suitability of leaf meal as a partial substitute for dietary fish- meal protein could not promote growth of Indian major carp fingerlings at 25-50% inclusion levels. Addition of molasses in the diet did not improve growth rate although feed conversion and protein utilization improved [25]. Patra [26] evaluated the nutritional value and possibilities of utilization of five aquatic weeds *Eichhornia sp., Pistia sp., Azolla sp., Nymphoides sp. and Hydrilla sp*. as feed for young *Labeo rohita*. Ray and Das [27] designed experiment to elucidate the digestibility pattern of nutrients from six aquatic macrophytes – *Lemna polyrhiza, Eichhornia crassipes, Pistia stratiotes, Salvinia cuculata, Hydrilla verticillata* and *Nymphoides cristatum* in *Labeo rohita* fingerlings. Bairagi *et al*. [28] used fermented duckweed (*Lemna polyrhiza*) leaf meal for feeding *Labeo rohita* fingerlings. Protein digestibility was highest (94.0%) from *Eichhornia crassipes*, followed by *Lemna polyrhiza*and *Nymphoides cristatum*. Digestibility of lipid from *Nymphoides cristatum* and *Lemna polyrhiza* was higher, whereas, digestibility of carbohydrates was found to be highest in *Eichhornia crassipes*. Though Hasan and Roy [25] observed less acceptability of water hyacinth incorporated diet by rohu fry, Keshavanath *et al*. [29] reported better body weight gains in rohu, grass carp and common carp fed diets incorporating the leaf meal powder at 50% level. Kumar *et al*. [30] also reported positive utility of water hyacinth for carp spawn. Mohapatra [31] studied the possibilities of substituting plant protein ingredients for fish meal in compound artificial diets in rearing of common carp fry, *Cyprinus carpio* L. Inclusion of water hyacinth, *Eichhornia* at different levels (0%, 10%, 20%, 30% and 40%) in place of fish meal were prepared to feed the fry. The acceptable nutritional value of water hyacinth as an ingredient in diets for fry was experimented under aquarium culture system at 5% of the body weight twice daily morning and evening for 70 days. The different inclusion levels of water hyacinth supported the growth of *Cyprinus carpio* fry but growth performance decreases as the level of water hyacinth increases. It was observed that weight gain growth rate was favoured by low inclusion of water hyacinth meal. There was no significant difference ($P \leq 0.05$) between the weights gains recorded for the fish fed all the experimental diets. Although fishmeal is non replaceable but can be supplemented with water hyacinth up to an optimum level to produce cost effective feed for the growth performance of *Cyprinus carpio*. The results showed that a diet consisting of up to 40% content could be used as a replacement for fish meal in diet formulation for common carp fry.

Saha and Ray [32] concluded from the study that *Eichhornia* leaf meal fermented with fish gut bacteria exhibiting extracellular enzyme activity can be recommended as a dietary ingredient in diets of *Labeo rohita* fingerlings up to 40% incorporation level replacing fish meal without any adverse effect on growth of the fish to produce cost effective formulated fish feed. Konyeme [33] revealed that 40% inclusion levels of water hyacinth as fish meal supplements is recommended in a practical diet of *Clarias gariepinus* for good yield and profitability and a decrease in the growth performance indices as the level of water hyacinth increases. Edwards *et al*. [34] observed better growth and feed utilization efficiency in tilapia, *Oreochromis niloticus* fed pelleted diets formulated with 75% composted water hyacinth. Whereas, Jafer Sadique *et al*. [35] worked on the effect of molasses-fermented water hyacinth feed on growth and body composition of *Cyprinus carpio* and reported that Molasses fermented water hyacinth can be replaced with rice bran up to 40% (of rice bran) in the diets for common carp fingerlings. Water hyacinth form an abundant alternative natural un-utilized resource for less expensive fish feed and higher fish yield to enhance farmer's income.

Water hyacinth as manure in aquaculture

Water hyacinth is considered the least desired species among the aquatic macrophytes to be utilized by herbivorous fishes directly. But attempt have been made to use vegetative parts of water hyacinth. Edwards *et al*. [34] reported enhancement of growth and feed utlilization of O*reochromis niloticus* fed with diets containing 25-75% composted water hyacinth with no significant change in physiological functions compared to the control diet of higher protein and energy levels. However, diets with 75% and 100% dried water hyacinth significantly inhibited growth compared to diets containing composted water hyacinth. A comparison of the proximate composition of the composted and dried water hyacinth meals indicated that while crude proteins were more or less similar, crude fiber and crude fat levels were approximately doubled by the composting process. The poor growth of fish feed consumption due to lesser palatability as well as higher crude fiber content in these diets.

Tavares and Braga [36] worked on the feeding activity of *Colossoma macropomum* larvae (tambaqui) in fish ponds with water hyacinth fertilizer. The fertilized pond evidenced more plankton abundance during the entire production period when compared with the control pond ($P < 0.001$). The phytoplankton community in the pond was not significantly different than in gut contents ($P > 0.05$) in both ponds (with and without organic fertilizer). Fish larvae failed to show any preference or selectivity in relation to the different algae ($P > 0.01$) in the pond, but exhibited high ingestion selectivity for zooplankton ($P<0.05$). Application of fertilizer increased ($P<0.05$) the abundance of phytoplankton and zooplankton in the treatment pond. Chakrabarty *et al*. [37] reported wide variation of *Cyprinus carpio* yield in a trial arranged in concrete cisterns (100 L) receiving water hyacinth compost (1952kg/ha), diammonium phosphate (3080 kg/ha), and vermicompost (3970 kg/ha) as direct application fertilizer and manure for 90 days and reported highest production of fish with vermicompost followed by diammonium phosphate and water hyacinth compost. Sahu *et al*. [38] studied the use of water hyacinth compost (8000 kg/ha) as manure (Group A), inorganic fertilizer-urea @ 60 kg/ha (Group B) and no treatment (Group C) in nursery ponds for larval rearing of Indian major carp, *Labeo rohita* for 60 days and recorded better performance with regard to growth and survivability of the *Labeo rohita* larvae in the ponds treated with water hyacinth compost than Group B and C. The use of water hyacinth compost as manure in nursery ponds for larval rearing of Indian major carp, *Labeo rohita* was studied. Better performance with regard to growth and survivability of the larvae was recorded in the ponds treated with water hyacinth compost (Group A) than in either the ponds treated with inorganic fertilizers (Group B) or the ponds where no treatment was applied (Group C). The average percentages of survival in Groups A, B and C were 14.3, 11.2 and 5.0, respectively. Thus about 186% increase in the survivability was recorded in the ponds treated with water hyacinth compost ($P < 0:01$), whereas the increase was about 124% in the ponds treated with only inorganic fertilizers, when compared with the ponds which were without any treatment. Saeed and Al Nagaawy [39] studied the impact of water hyacinth (*Eichhornia crassipes*) on physico-chemical properties of water, phytoplankton biomass and *Nile tilapia* production in earthen ponds and concluded that the presence of 5 and 10% water hyacinth cover did not significantly affect phytoplankton abundance and composition as well as fish production. Whereas, Kumari and Pandey [40] worked on the utilization of water hyacinth compost as manure for rearing of *Labeo rohita* and reported that *L. rohita* fry can be cultured well in tanks receiving water hyacinth compost without supplementary feeding.

Conclusions

According to chemical analysis, water hyacinth is rich in nutrition, with organic matter accounting for 80.1% of dry biomass, and in particular, the crude protein content is 12.4%, which includes many amino acids such as lysine and methionine and also different kinds of vitamin (Lindsey, 1999). Moreover, Water hyacinth consists of high biomass, fibrous tissue, high energy and protein content that can be used for a variety of useful applications like waste water treatment, compost and fertilizer, animal feed etc.

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