Wolffia globosa in Aquafeeds for Profitable and Eco-friendly Sustainable Aquaculture

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Abstract

Aquaculture is a fast-growing sector that produces high-quality fish. Finding reasonably priced feed is necessary for aquaculture operations to be sustainable and generate high marginal profits. Health and growth of cultured fish species are impacted by nutritious aquafeeds. Cost-effective feed must be available in order to make money. High digestibility, acceptable palatability, great amino acid content, and lack of non-nutritional components are just a few of the critical requirements that protein sources used in aquafeeds must satisfy. Wolffia globosa, which can boost fish profitability when added to diets in a well-processed state, is highlighted in this article. Aquaculture can be sustainably produced by wolffia by the conversion of ambient (CO_2) and nitrogen (N_2). In addition to crude protein, wolffia meal offers high concentrations of essential amino acids, vitamins, and minerals for the growth and development of many farmed fish. It can also lead to reduced feed costs and less environmental impact than traditional fishmeal production in aquaculture. The article emphasises that integrating well-processed wolffia meal to fish diets can boost profitability. Environmental benefits of wolffia in aquafeed has the ability to sustainably transform atmospheric carbon dioxide (CO_2) and nitrogen (N_2) into aquaculture. The significant quantities of crude protein, vital amino acids, vitamins, and minerals found in wolffia meal aid in the growth and development of several farmed fish. It can also minimise aquaculture feed costs and reduce the environmental effects of producing fishmeal the conventional way.

Keywords: *Wolffia globosa*, Aquafeeds, Farmed Fish, Sustainable Aquaculture

Introduction

High-quality animal protein is produced by the rapidly expanding aquaculture sector. However, the availability of inexpensive feed is a prerequisite for sustainability in aquaculture development with high marginal profit. Fish species raised in tanks benefit from nutritious aquafeeds in terms of growth and health. Fish species raised in tanks benefit from nutritious aquafeeds in terms of growth and health. Excellent amino acid content, high digestibility, acceptable palatability, and the lack of non-nutritional components are just a few of the critical requirements that protein sources used in aquafeeds must satisfy. The main protein source in aquafeeds has been fishmeal since it contains essential amino acids (EAAs), minerals, vitamins (B12, biotin, and choline), omega (n-3) fatty acids, and vitamins A, D, and E. But if fishmeal is the only protein source, wild fish populations are negatively impacted. Furthermore, one of the primary barriers to aquaculture's growth is the escalating cost of fishmeal. Generally speaking, feed costs account for half of all aquaculture operating costs, with protein sources making up the majority of these costs. Duckweed, a rare and valuable plant, thrives in well-controlled environments. Wolffia, the smallest duckweed, has reduced morphology and core pathways, making it a potential synthetic plant biology chassis. Its minimal gene set and relaxed time-of-day gating make it ideal for bottom-up and top-down genome engineering. Wolffia's aquatic nature allows for precise manipulation and speed for experiments, enabling detailed description of cellular function and synthetic plant construction.

Recently, there has been a lot of interest in plant-based proteins as potential substitutes for animal proteins. Future food issues and low protein intake can be addressed by using plant-based proteins, which are more environmentally friendly and more productive to manufacture than animal proteins. Aquafeed formulas are now using plant-based proteins including soybean meal, wheat gluten meal, and cottonseed meal in place of expensive and non-renewable fishmeal. Although aquatic weeds, like wolffia, can be used as ingredients in fish diets, they are often regarded as waste. Wolffia may be produced on a farm in a short amount of time and at a minimal cost in a controlled setting. In the process of photosynthesis, it can fix atmospheric nitrogen and carbon dioxide to produce

ammonia and carbohydrates. In order to reduce production costs and improve crop yield and quality, can be used in place of nitrogenous fertilisers. Wolffia reduces the rate of evaporation in irrigated rice fields and can be fed to ducks, chickens, pigs, cattle, buffalo, fish, prawns, snails and crabs.

Morphology

Wolffia globosa, also referred to as "water lentils," is a member of the Lemnaceae family's Wolffoideae subfamily. Its biological characteristics are similar to those of its Lemnoideae relatives in that it is the smallest flowering plant, grows at the fastest rate in the plant kingdom, and does not have a pseudo root system. It has become a viable option for sustainable food production because of its quick growth rate, high protein content, and nutritional value, especially in areas with difficult agricultural conditions. The tiniest higher plant is called Wolffia globosa, and it differs completely from other higher plants in terms of morphology. It just possesses a frond that is unrelated to any of the three main organs, instead of the conventional morphology of roots, stems, and leaves. The fastest growing plant on Earth is called Wolffia globosa, and it has no roots. In four months, if given unlimited access to CO_2 and nutrients, it might yield 1030 plants.

Techniques for Wolffia Culture

Wolffia may be grown in (i) pits, (ii) containers, or (iii) ponds, (iv) cement tanks however, the area and the size of an Azolla culture unit depends on the quantity to be harvested and the availability of space. Small, marginal, landless, and resource-poor farmers are able to use the culture technology due to its cheap investment requirements. The procedures for wolffia culture in pits and cement tanks are as follows:

The College of Fisheries at Central Agricultural University (Imphal), Lembucherra, Tripura, India, kept twenty-day-old *L. rohita* fry in six outdoor cement tanks of 20 m3 (4 m × 5 m × 1 m), with a stocking density of 30 fry/m^2. Three tanks were given a random application of prepared feed and live wolffia each. Before the tanks were filled with animals, a 6–8 cm soil layer was provided. The tanks were filled with ground water after being thoroughly cleaned, dried, and treated with lime (500 g of Ca $(OH)_2$ each tank) at a rate of 250 kg/ha. The tanks were also well-exposed to sunlight. Tanks were fertilised with slurry made from cow dung and mustard oil cake that had been steeped in water for 24 hours before application, following a week of water filling via pumping. Healthy plankton populations were developed before *L. rohita* were stocked. The formulated feed and live Wolffia were fed in two equal feedings at 9:00 and 16:00 hours each day, at a rate of 8%–10% (dry matter basis) of the daily feed ration. An equal amount of nitrogen was added to the formulated feed and live Wolffia.

Fig 1. Steps of Wolffia culture in cemented tank, Resource : COF, CAU, Tripura

Everyday, right before feeding, live wolffia was gathered from the farm. Wet feed was used for live wolffia, while dry feed was used for formulated feed. Consequently, taking into account 95% of the moisture content of live Wolffia, the amount of isonitrogenous live Wolffia needed for the prepared feed ration was computed. To track growth and modify the feed ration, fish samples were taken every two weeks.

Conditions of Wolffia Culture

In order to properly flourish, wolffia needs at least 13 centimetres of water and sunlight under conditions of partial shade. The optimal temperature range for wolffia growth is 25–35° C. It needs water with a pH between 5 and 7.3 and a relative humidity between 80 and 90%. Locations that receive sufficient but not direct sunlight should be chosen. Supplementing with nutrition is necessary, particularly with micronutrients.

Fig. 2 Feeding of fresh Wolffia in aquaculture pond

Fig. 3 Effects of Wolffia feed on cultured pengba fish (*Osteobrama belangeri*)

varied between 0.02% and 0.15% on a dry weight basis, respectively.

Application of wolffia in Aquaculture

The use of two macrophytes (Lemna and Wolffia) in their quality as a biofilter in RAS resulted in a significant increase in dissolved oxygen and decrease in total dissolved solids, ammonia, nitrite, orthophosphate, and total phosphorus in the water. Additionally increase in the growth of the fingerlings of cultivated carp.

Nutrient Profiling

The wolffia species, which are traditionally consumed by humans in Asian nations, have been studied as potential food sources. The genetic background and cultivation circumstances determined the amount of macro and micro components. There was a range of 20–30% total protein content, 10-15% starch and fat content, and 25% fibre content. There was a high content of essential amino acids and polyunsaturated fatty acids (over 60% of total fat). Wolffia microscopica's quick growth and large production make it a promising candidate for practical human nutrition. As a percentage of dry weight, the W. globosa has the following contents: 45.54% protein, 5.33% fat, 9.98% crude fibre, 20.43% ash, and 19.21% nitrogen free extract. Additionally, it contains 15.1% w/w of 15 different types of amino acids. Total phenolics, flavonoids, and chlorophylls were found to include 55.28 ± 1.35 (ig GAE/g dry weight), 159.84 ± 6.65 (ig catechin equivalent [QE]/g dry weight), and 22.91 ± 0.15 (mg/g dry weight), triacylglyceride level

Wolffia sp. capacity for managing wastewater produced by climbing perch cultures. The outcomes demonstrated that Wolffia sp. biomass may be used to control pH and dissolved oxygen levels appropriate for freshwater fish culture, as well as efficiently lower wastewater's levels of ammonia, total suspended particles, total nitrogen, and total phosphorus. Duckweeds are known to extract all dissolved inorganic nitrogen (49–95%) from municipal wastewater, 43–55%) from swine wastewater as secondary effluent, and 46–62% from anaerobic digestion effluent. As a result, Wolffia sp. may yield useful nutrients for use in other sectors when utilised in wastewater treatment. It is noteworthy that duckweeds (Lemnaceae), such as wolffia globosa, are capable of effectively removing nitrogen, specifically NH4+, NO3-, and phosphorus from wastewater and aquaculture effluents and provide extremely valuable natural resources rich in starch, antioxidants, phenols, flavonoids, and carotenoids. Consequently, wolffia was used as a source of protein and carotenoid for ornamental fish and as an efficient live feed for Labeo rohita. Duckweeds are also

helpful in the production of animal feed, biofuel, bioethanol, bioplastics, medicinal and cosmetic products.

Effects of the wolffia in the Diet of Fish and livestock

In India, aquaculture is dominated by three giant carp species: *Labeo rohita*, *Catla catla*, and *Cirrhinus mrigala*. These species account for 87% of the country's freshwater productivity. Fish that are raised in clay ponds are fed low-nutrient sources. For seed growth and rearing, live wolffia globosa could be utilised in place of extra feed. Live wolffia globosa may entirely substitute other feed inputs, like silver barb (*Barbonymous gonionotus*), rohu, pengba (*Osteobrama belangeri*), and Amur common carp (*Cyprinus carpio*), in seed growing and carp growth. Frequently growing aquatic plants called duckweed are high in protein, low in fibre, and contain compounds that are bioactive. Wolffia, the tiniest blooming plant, grows well in polyculture systems and can be eaten raw. Carassius auratus, an experimental goldfish, was fed simulated meal including wolffia to boost its colour and nutritional content. It has been demonstrated that recirculating aquaculture systems with duckweeds (Lemna and Wolffia) boost common carp development while lowering ammonia, nitrite, total dissolved solids, and orthophosphate levels. Wolffia has been the subject of numerous investigations. Duckweed Wolffia (*Wolfia arrhiza*) was utilised as a substitute feed source for a range of fish, including Tilapia (*Oreochromis niloticus*) fry. *W. arrhiza* (L.) appears to improve the meat and organoleptic quality of several test fish species when grown in an intense polyculture system. Utilised as an alternative to soybean flour for grill chicken feed ingredients. Wolffia globosa have shown that it has potential for use as both a clean food source for humans and as a feed source for aquaculture and animal husbandry.

Fig. 4 Utilising wolffia in agriculture, livestock and fisheries

Wolffia used as human food

Duckweed is also consumed as food by people in a variety of countries. Wolffia globosa, for instance, is a rootless duckweed that is sold in traditional markets in Thailand under the names khai nam, kai-pum, or kai nhae, which mean "water eggs." Therefore, it can be concluded that Wolffia globosa protein is suitable to be counted as a nutritious alternative plant-based protein and to be used as a raw material for the production of novel functional ingredients.

Wolffia used as Bioactive compound

In particular, the nutritional value and bioactive components of incubating duckweed in various production methods such as different containers and light intensities have not been investigated when comparing it to commercial products. These results about the best aquaculture conditions to produce high nutritional value and bioactive chemicals like flavonoids, chlorophyll, and total phenolics would be helpful to the scientific community. In order to increase the nutritive value of the plant, this study looked at the best aquaculture conditions and drying parameters for duckweed while also considering its nutritional value and bioactive components. Duckweed is also useful in the manufacturing of biofuel, bioethanol, and animal feed, it is also useful in the creation of bioplastics, medications, and cosmetics.

Challenges for wolffia Use in Aquafeed

Plant cells contain high concentrations of carbohydrates and fibre. Carnivorous fish species usually cannot digest diets high in fibre because they do not have the enzymes to break down cell walls. Moreover, anti-nutritional factors (ANFs) such phenolic compounds, protease inhibitors, phytates, lectins, and oligosaccharides are present in large proportions in plant-based protein sources; these should be neutralised before adding them to aquafeed. Fish disease resistance may be adversely affected by the presence of ANFs in soybeans, for instance, which may stimulate cytosolic enzyme activity and an inflammatory response. Many plant-based materials can be utilised in aquaculture feed by lowering their ANFs, even if plant-based ANFs negatively impact farmed fish's nutritional metabolism and health.

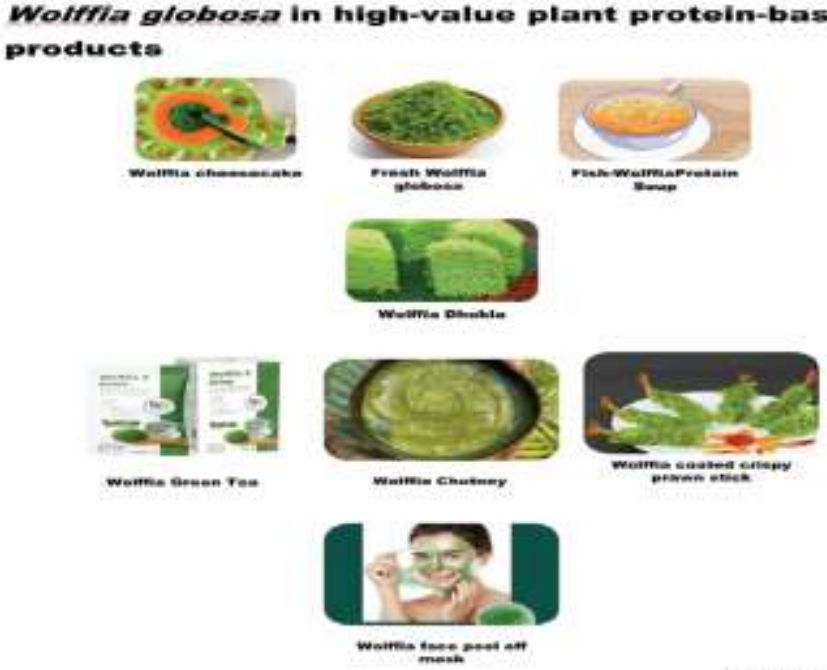

Fig. 5 Utilising wolffia in high- value plant protein – based products

ANF Reduction Techniques for wolffia

Two distinct approaches exist for reducing the amino acid content of plant-based feed ingredients: thermal processing and chemical processing. Thermal treatments improve the availability of nutrients and the digestion of fish by changing the chemical structure of the meal. These dangerous materials become inert when heated processes including baking, toasting, steaming, and extrusion are used. For example, boiling can reduce the amount of trypsin inhibitors, which prevent soybean proteins from being digested, and extrusion can denature lectins, which restrict the absorption of carbs. ANFs are also rendered inactive by specific chemical treatments. For example, phytotase can hydrolyse indigestible phytate. Meals high in wolffia have the potential to lower the body's levels of dangerous ANFs.

Environmental Benefit of wolffia in Aquafeed

In a sustainable manner, wolffia can transform atmospheric CO_2 and nitrogen (N_2) into aquaculture. A high concentration of vital amino acids, vitamins, minerals, and crude protein may be found in wolffia meal, which helps many farmed fish thrive and flourish. Wolffia globosa can be used as a phytoremediator to remove cadmium levels. It can help minimise feed costs in aquaculture and lessen the environmental effects of producing fishmeal the conventional way. Organic carbon and nitrogen into the soil during their breakdown, these substances have the ability to improve its chemical composition. The application of wolffia in biofertilizer, animal feed, pharmaceuticals, water purification, biogas generation, mosquito control, potential for reducing the carbon footprint and ammonia reduction can significantly mitigate the effects of global warming.

Conclusion

Duckweed, or Wolffia globosa consequently be a rich source of protein as an alternative natural feed for aquaculture, animal husbandry, or humans. Wolffia globosa, the duckweed, grows well both indoors and outdoors. In comparison to indoor settings, the ability to grow (specific growth rate, daily growth rate, and daily productivity) was higher outside. The potential of wolffia meal to boost aquaculture profitability in a sustainable manner is highlighted in this article. The large amounts of crude protein, vital amino acids, vitamins, and minerals found in wolffia meal aid in the growth and development of several farmed fish. It can also minimise aquaculture feed costs and lessen the environmental effects of producing fishmeal the conventional way. To attain good growth performance and survival in aquaculture, wolffia meal must first minimise ANFs. Moreover, it has a high percentage of unsaturated fatty acids (FAs), which are thought to be healthier than saturated FAs and have antioxidant qualities. It possesses greater concentrations of total phenolics and flavonoids than conventional crops, which could make it a rich source of antioxidants. Ultimately, Wolffia globosa low amounts of antinutritional factors were readily absorbed. These findings imply that nutrients are readily absorbed by the body and point to a possible food supply.