Wolffia globosa (duckweed) in aquafeeds for profitability and eco-friendly sustainable aquaculture

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Aquaculture is growing fast and produces high-quality animal protein. But to stay profitable and sustainable, farmers need affordable fish feed. Fish in tanks grow better and stay healthier when fed nutritious aquafeeds.

Good fish feed needs to have several key qualities. It should have all essential amino acids, be easy to digest, taste acceptable to fish, and be free from harmful substances. Fishmeal has been the main protein source in aquafeeds. It is rich in essential amino acids, minerals, omega-3 fatty acids, and vitamins like B12, A, D, E, biotin, and choline.

However, using only fishmeal harms wild fish populations. Fishmeal is also becoming more expensive, which limits the growth of aquaculture. Feed makes up about 50% of total aquaculture costs, with protein being the biggest part of that cost.

Duckweed (*Wolffia*) is a plant that grows well in controlled environments. *Wolffia*, the smallest type of duckweed, has a simple structure and unique biology. It is useful for genetic research and synthetic plant biology. Its small genome and flexible biological clock make it easy to modify. Since *Wolffia* grows in water, it allows fast and precise experiments to study plant functions and design synthetic plants.

There is growing interest in using plant-based proteins instead of animal proteins. Plant proteins are more eco-friendly and cheaper to produce. They can help solve future food shortages and improve protein intake.

In aquaculture, feed makers are replacing costly and non-renewable fishmeal with plant proteins like soybean meal, wheat gluten meal, and cottonseed meal. Some aquatic plants, such as *Wolffia*, are also suitable for fish feed. But they are often seen as waste.

Wolffia can be farmed quickly and cheaply in a controlled environment. Through photosynthesis, it absorbs nitrogen from the air and carbon dioxide to produce ammonia and carbohydrates. This can reduce the need for chemical nitrogen fertilisers and help improve crop quality and yield.

Wolffia also lowers water evaporation in irrigated rice fields. It can be fed to many animals, including ducks, chickens, pigs, cattle, buffalo, fish, prawns, snails, and crabs.

Morphology

Wolffia globosa, also known as “water lentils,” belongs to the Wolffioideae subfamily of the Lemnaceae plant family. It shares many traits with other members of this group.

It is the smallest flowering plant in the world and grows faster than any other plant. Unlike most plants, it does not have roots. Because of its fast growth, high protein content, and good nutrition, it is useful for food production—especially in areas where farming is difficult.

Wolffia globosa is very different from other plants. It does not have roots, stems, or leaves. Instead, it has only a small, flat structure called a frond.

With enough carbon dioxide and nutrients, one plant can produce over 1,000 new plants in just four months.

Wolffia can be grown in different ways:

- Pits.
- Containers.
- Ponds.
- Cement tanks.

The size of the setup depends on how much *Wolffia* is needed and how much space is available. The method is low-cost, so small-scale and low-income farmers can use it easily.

At the College of Fisheries, Central Agricultural University (Imphal), Lembucherra, Tripura, India, a study was done using six outdoor cement tanks. Each tank was 20 cubic metres (4 m × 5 m × 1 m). They kept Labeo rohita fry that were 20 days old, with a stocking density of 30 fry per square metre.

Three tanks were fed with prepared feed. The other three received live *Wolffia*. Before adding the fish, each tank was prepared with a 6–8 cm layer of soil, cleaned, dried, and treated with 500 grams of calcium hydroxide $Ca(OH)_2$. This is equivalent to a rate of 250 kilograms per hectare. The tanks were filled with groundwater and left under sunlight.

Fertiliser was added using a mix of cow dung and mustard oil cake soaked in water for 24 hours. This was done a week after filling the tanks with water. Healthy plankton developed before the fish were added.

Fish were fed twice daily—at 9:00 and 16:00. They received either formulated feed or fresh *Wolffia*, at 8%–10% of their body weight (dry matter basis). Both feeds were adjusted to provide the same amount of nitrogen.

Fresh *Wolffia* was harvested daily before feeding. Since it contains about 95% moisture, the amount given was calculated to match the protein in dry feed.

Fish were sampled every two weeks to check growth and adjust the feed amounts.

Conditions for *Wolffia* culture

Wolffia grows best in shallow water—at least 13 centimetres deep. It needs sunlight but does well in partial shade.

The ideal temperature for growth is between 25°C and 35°C. The water should have a pH between 5.0 and 7.3. Humidity should be high, between 80% and 90%.

It is best to grow *Wolffia* in places with enough sunlight but not strong, direct exposure. Nutrient supplements are important, especially micronutrients, to support healthy growth.

Nutrient profiling

Wolffia species are traditionally eaten in some Asian countries. They are now being studied as possible food sources for people. The nutrient content depends on the plant's genetics and how it is grown.

Protein content ranges from 20% to 30% (dry weight). Starch and fat range from 10% to 15%, and fibre is about 25%. *Wolffia* is rich in essential amino acids and polyunsaturated fatty acids, which make up over 60% of its total fat.

Wolffia microscopica grows quickly and produces a large amount of biomass, making it suitable for human nutrition.

For *Wolffia globosa*, the dry weight composition is:

- Protein: 45.54%
- Fat: 5.33%
- Crude fibre: 9.98%
- Ash: 20.43%
- Nitrogen-free extract: 19.21%
- It also contains 15.1% (w/w) of 15 different amino acids.
- Other components per gram of dry weight include:
- Total phenolics: 55.28 ± 1.35 µg GAE
- Flavonoids: 159.84 ± 6.65 µg catechin equivalent (QE)
- Chlorophyll: 22.91 ± 0.15 mg
- Triacylglycerides: 0.02% to 0.15%

Application of *Wolffia* in aquaculture

Wolffia and *Lemna* are aquatic plants (macrophytes) that can improve water quality in recirculating aquaculture systems (RAS). They help increase dissolved oxygen and reduce harmful substances like ammonia, nitrite, orthophosphate, total phosphorus, and total dissolved solids. These improvements also support better growth in carp fingerlings.

Wolffia is also useful in managing wastewater from climbing perch (*Anabas testudineus)* cultures. It helps control pH and oxygen levels in water and reduces ammonia, total suspended solids, total nitrogen, and phosphorus.

Duckweeds, including *Wolffia*, are effective at removing dissolved inorganic nitrogen from wastewater. They can extract:

- 49–95% from municipal wastewater
- 43–55% from swine wastewater
- 46–62% from anaerobic digestion effluent

This makes *Wolffia* a valuable tool for wastewater treatment. At the same time, it produces nutrients that can be used in other sectors.

Wolffia globosa can remove nitrogen (NH_4^+, NO_3^-) and phosphorus from aquaculture wastewater. It also provides useful substances like starch, antioxidants, phenols, flavonoids, and carotenoids.

Because of this, *Wolffia* is used as a protein and carotenoid source for ornamental fish and as live feed for rohu. Duckweeds are also useful in making animal feed, biofuels, bioethanol, bioplastics, medicines, and cosmetic products.

Steps for Wolffia culture in cemented tank.

Effects of *Wolffia* in the diet of fish and livestock

In India, aquaculture mainly focuses on three carp species: Rohu (*Labeo rohita)*, catla (*Catla catla*), and mrigal (*Cirrhinus mrigala*). These species make up 87% of freshwater fish production.

Fish raised in clay ponds are usually fed low-nutrient food. For seed rearing, *Wolffia globosa* can be used as a complete replacement for extra feed. It has been successfully used to replace

feed for fish like silver barb (*Barbonymus gonionotus*), rohu, pengba (*Osteobrama belangeri*), and amur common carp (*Cyprinus carpio*).

Duckweeds like *Wolffia* grow quickly, are rich in protein, low in fibre, and contain useful bioactive compounds. As the smallest flowering plant, *Wolffia* thrives in polyculture systems and can be eaten raw.

In goldfish (*Carassius auratus*), simulated diets with *Wolffia* improved both colour and nutrition. In recirculating systems, *Lemna* and *Wolffia* increased the growth of common carp while reducing ammonia, nitrite, total dissolved solids, and orthophosphate.

Studies show *Wolffia arrhiza* is a good alternative feed for various fish, including tilapia fry. It also improves the taste and quality of fish meat in intensive polyculture systems.

Wolffia globosa has been tested as a substitute for soybean flour in broiler chicken diets. It shows strong potential as a clean food source for both humans and as feed for fish and livestock.

Wolffia as human food

Duckweed is eaten by people in several countries. *Wolffia globosa*, a rootless duckweed, is sold in traditional markets in Thailand. It is known as khai nam, kai-pum, or kai nhae, which all mean “water eggs.”

Because of its high protein content, *Wolffia globosa* is a good plant-based protein. It can be used as a nutritious food and as an ingredient for making functional food products.

Wolffia as a source of bioactive compounds

The nutritional value and bioactive content of duckweed can change depending on how it is grown—such as the type of container or light intensity used. These factors have not been fully compared to commercial standards.

Understanding the best growing and drying conditions can help increase the amount of useful bioactive compounds in duckweed, such as flavonoids, chlorophyll, and total phenolics. This information is useful for scientists and food technologists.

Duckweed is also used in making biofuel, bioethanol, and animal feed. In addition, it is a resource for producing bioplastics, medicines, and cosmetics.

Challenges for *Wolffia* use in aquafeed

Plant cells have high amounts of carbohydrates and fibre. Carnivorous fish cannot digest high-fibre diets well because they lack the enzymes needed to break down plant cell walls.

Plant-based protein sources, including *Wolffia*, often contain anti-nutritional factors (ANFs). These include phenolic compounds, protease inhibitors, phytates, lectins, and oligosaccharides. ANFs must be removed or reduced before using these plants in aquafeeds.

For example, soybeans contain ANFs that can reduce fish disease resistance by triggering enzyme activity and inflammation in the body.

Even though ANFs can harm fish health and nutrition, many plant ingredients—including Wolffia—can still be used in feed if their ANFs are properly treated and reduced.

ANF reduction techniques for *Wolffia*

There are two main ways to reduce anti-nutritional factors (ANFs) in plant-based feeds: thermal processing and chemical processing.

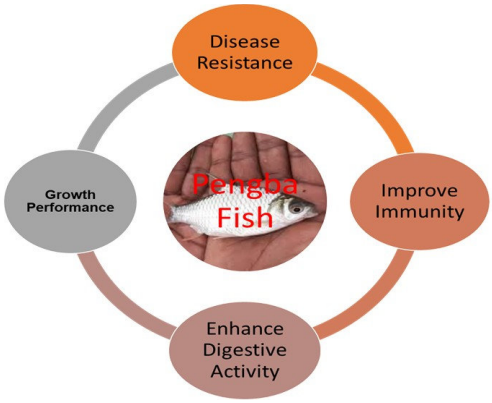
Thermal methods, such as baking, toasting, steaming, and extrusion, change the structure of the feed. This makes nutrients easier to digest and reduces harmful compounds. For example:

- Boiling reduces trypsin inhibitors, which block protein digestion.
- Extrusion destroys lectins, which interfere with carbohydrate absorption.
- Chemical treatments can also remove ANFs. For instance, the enzyme phytase breaks down phytates, which are otherwise indigestible.

Feeds with *Wolffia* can lower harmful ANF levels in the body, making it safer and more effective for aquaculture use.

Environmental benefit of *Wolffia* in aquafeed

Wolffia can naturally absorb carbon dioxide and nitrogen from the air, making aquaculture more sustainable. It is rich in essential amino acids, vitamins, minerals, and crude protein, supporting fish growth and health.



Effects of Wolffia feed on cultured fish.

Wolffia globosa also acts as a phytoremediator—it can remove heavy metals like cadmium from water. This helps clean the environment and reduces the need for chemical treatments.

Using *Wolffia* in fish feed can cut feed costs and reduce the environmental impact of fishmeal production. When it breaks down, *Wolffia* adds organic carbon and nitrogen to soil, improving soil quality.

It also has potential uses in biofertiliser, livestock feed, medicine, water purification, biogas, and even mosquito control. These applications help lower ammonia emissions and carbon footprint, contributing to efforts against global warming.

Conclusion

Wolffia globosa, or duckweed, is a rich natural source of protein. It can be used as feed for fish, livestock, and even humans.

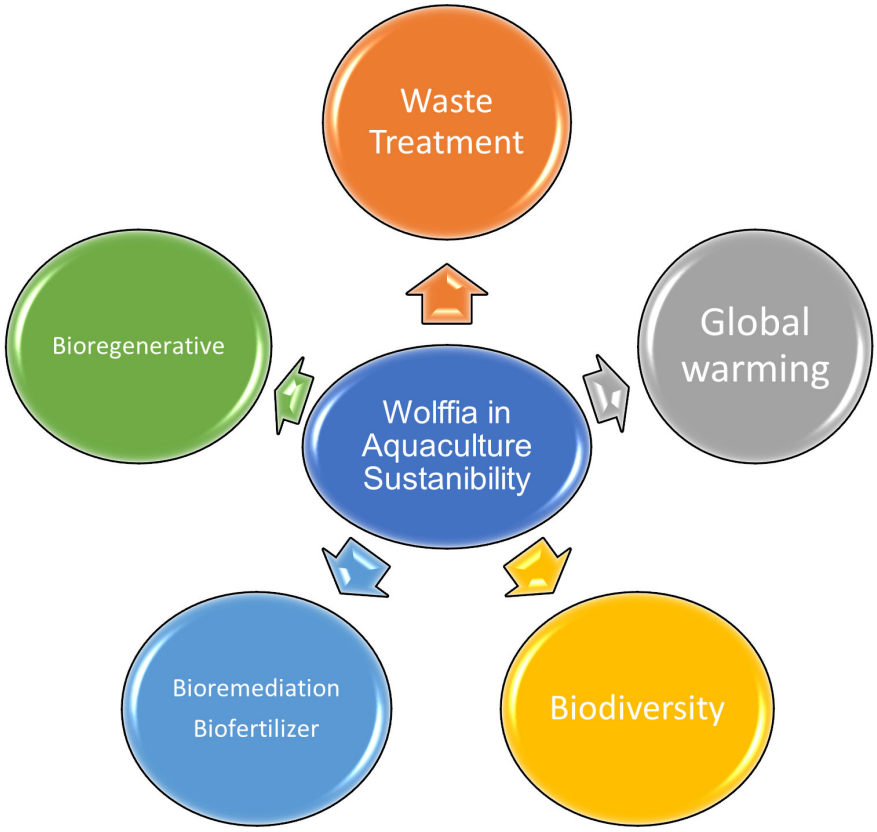
This plant grows well in both indoor and outdoor environments, but outdoor conditions support faster and more productive growth.

Wolffia meal contains high levels of crude protein, essential amino acids, vitamins, and minerals. These support the growth and health of farmed fish, while helping to reduce feed costs and the environmental impact of traditional fishmeal production.

To use *Wolffia* effectively in aquafeed, anti-nutritional factors (ANFs) must first be reduced. Once treated, the meal is easily digested.

Wolffia also has a high level of healthy unsaturated fatty acids, as well as strong antioxidant compounds like phenolics and flavonoids—more than many common crops.

Its low ANF content and good digestibility suggest that *Wolffia* globosa could be a valuable and sustainable food and feed source.



Performance of Wolffia towards aquaculture sustainability.