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The Role of Microorganisms in Aquaponics

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Abstract

When people think about aquaponics, the first thing that comes to their mind is fish and plants, as aquaponics is often defined as a combination of producing fish and growing plants in a single eco-friendly sustainable system. Bacteria, on the other hand, are a vital part of an aquaponics system. To maintain a successful aquaponics system, the three major components must be present: fish, plants, and microbes. Proper water quality parameters must be maintained to grow the selected bacteria group. Change in water quality makes other harmful bacteria group to grow which retards the growth of plants and animals in aquaponics. In this article, microbes and its maintenance in aquaponics system are discussed in details due to its irreplaceable role in converting the fish waste into valuable food products.

Introduction

Beneficial bacteria are required for the fish and plants to thrive in an aquaponics system. Bacteria decompose fish excrement, keeping the water clean for the fish, and converting the waste into nutrients for the plants. The plants absorb the nutrients from water, which helps to keep the water clean for the fish. Bacteria can be found on the bottom of the fish tank and in the growing media of the plant beds. Excess feed and fish waste are the key ammonia source in which microorganisms work to break down the waste. Aquaponic system benefit from nitrifying and mineralizing bacteria, however, some bacteria are also hazardous. They are sulphate reducing bacteria, denitrifying bacteria and pathogenic bacteria. These bacteria thrive in anaerobic (no oxygen) environments. Sulphate-reducing bacteria produce hydrogen sulphide (H_2S), which is a serious problem due to its poisonous effect on fish. It smells like rotten eggs and develops murky black sediment. Denitrifying bacteria turn nitrate back to atmospheric nitrogen makes unavailable for plants. On the other hand, pathogenic bacteria cause disease in plants, fish and humans. In general, adequate dissolved oxygen (DO), sanitation and common sense are the strongest defences against infections in aquaponics.

Nitrifying Bacteria and Nitrification

In the whole aquaponic process, nitrifying bacteria play a critical function. The nitrifying bacteria convert fish waste (ammonia) into nitrate, which is major macronutrient for plant growth. Nitrification is the oxidation of nitrogen compounds. Nitrification starts with ammonia-oxidizing bacteria (AOB) that convert ammonia to nitrite, which is the initial step. The genus name of the most prevalent group is Nitrosomonas, which is frequently referred to these types of bacteria. The nitrite-oxidizing bacteria (NOB) perform the second step of converting nitrite to nitrate. These kinds of bacteria are grouped by its genus name as Nitrobacter. As a result, a healthy bacterial colony is critical to the successful operation of an aquaponic system. The following equation represents the nitrification process in aquaponics.

$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ NO_2^- + 2\ H_2O + 4\ H^+$ (Nitrosomonas, Nitrosospira and Nitrosolobus)

$2\ NO_2^- + O_2 \rightarrow 2\ NO_3^-$ (Nitrobacter, Nitrospina and Nitrococcus)

Nitrifying bacteria takes several days or even weeks to multiply and build colonies. Farmers need patience until the full colonies get developed. Many aquaponic systems have failed due to the addition of too many fish before the bacteria colony had fully matured. Bacteria in general, require dark environment with high water quality and surface area, appropriate food, and oxygen to grow. Nitrifying bacteria have a peculiar odour (Not particularly nasty) and produce mild brownish mucous on the biofilter.

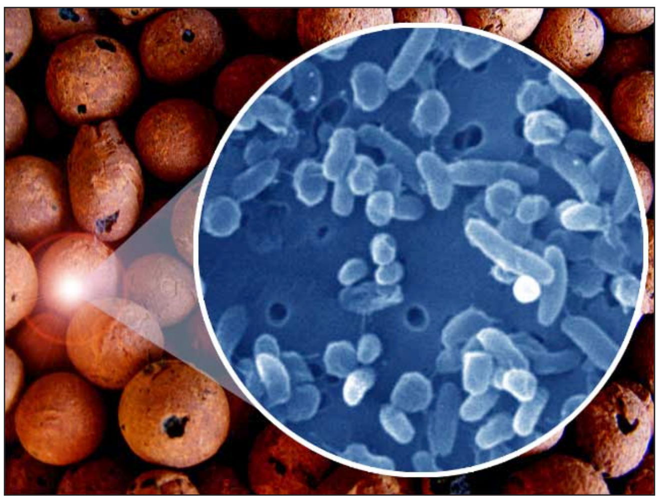

Figure 1: Beneficial bacteria in Lightweight expanded clay aggregate (LECA)

Heterotrophic Bacteria and Mineralization

In aquaponics, there might be another important bacterium group called as heterotrophic bacteria. These bacteria feed on organic carbon and are primarily responsible for the breakdown of solid fish and plant wastes. Most fishes retain only 30-40% of the food they consume, implying that 60-70% of what they consume is wasted. 50-70% of this waste is dissolved and discharged as ammonia. The residual waste, on the other hand, is an organic mixture of proteins, carbohydrates, lipids, vitamins, and minerals. These solid wastes are metabolized by heterotrophic bacteria and this process is known as mineralization. Mineralization is a process which makes important micronutrients available to aquaponic plants.

The solid portion of the fish waste is decomposed by these heterotrophic bacteria and fungi. They accomplish it by releasing nutrients which are trapped in solid waste into the culture water. Plants cannot absorb nutrients in solid form, thus this mineralization process is necessary. For the roots of the plants to absorb, wastes must be broken down into simpler molecules. Heterotrophic bacteria feed on solid fish waste, uneaten fish feed, decayed plants, dying plant leaves, and even dead bacteria. In aquaponic systems, these bacteria have access to a variety of food sources. Heterotrophic bacteria require similar development conditions, especially in high amounts of DO like nitrifying bacteria. The heterotrophic bacteria populate in all parts of the unit, but they are denser where solid waste accumulates. Heterotrophic bacteria reproduce far more quickly than nitrifying bacteria, in hours rather than days. Wastes collected at the bottom of media beds, creating a constantly damp zone where many heterotrophic bacteria can be discovered. The main colonies are found on the filters and separators, as well as in the canals and in other systems. A colony of other species assists heterotrophic bacteria in the process of breaking down the solid wastes. In aquaponic systems creature's like earthworms, larvae, isopods, amphipods and other small animals collaborate with bacteria to digest solid waste, and having this community in the system helps to avoid solid waste accumulation.

Maintaining a Healthy Bacterial Colony

Adequate surface area and appropriate water conditions are two major factors that influence bacterial growth and it should be considered when maintaining an effective biofilteration.

High Surface Area

To grow large colonies of nitrifying bacteria, high specific surface area (SSA) in filtration media is needed. The surface area exposed from a given volume of medium is defined by the SSA ratio, which is stated in square meters per cubic meter (m^2/m^3). The bigger surface area and the smaller and more porous media particles are the essential factors of biofiltration. This porous medium establishes more bacteria to colonize easily. As a result, biofiltration will be more effective. One such is the volcanic ash which has a SSA of 300 m^2/m^3. It is employed in aquaponics as growing substrate and also for biofiltration. Other porous media like gravels, expanded clay, and biofilter balls which are made of commercial plastic, have a SSA of 600 m^2/m^3, which is sufficient for the bacterial growth. The capacity of the biofilter should be larger if the biofilter medium has a poor surface area to volume ratio. It would be inefficient to have too many biofilters, yet an extensive number of biofilters would not harm an aquaponic system. Many systems have been saved from collapse due to its capacity.

Water pH

A pH range of 6-8.5 is sufficient for nitrifying bacteria to function properly. In general, higher pH is preferable for these bacteria. Nitrosomonas and Nitrobacter groups require a pH in the range of 7.2-7.8 and 7.2-8.2 respectively. However, the ideal pH for aquaponics is 6-7, which represents a compromise among all creatures in this ecosystem (Within this range, nitrogen-fixing bacteria work normally). A lack of bacterial diversity is a major concern. At the same time more bacteria can counteract efficiency. Thus biofilters should be sized appropriately.

Water Temperature

The temperature of the water is critical for bacteria and aquaponics in general. Temperatures of 17-34 °C are good for bacterial growth and productivity. Bacterial productivity will decrease if the water temperature falls below 17 °C. If the temperature is below 10 °C, productivity loss of up to 50% is possible. The Nitrobacter group in particular, are less tolerant to low temperatures than the Nitrosomonas group. As a result, nitrite levels should be closely monitored throughout the colder months to avoid toxic accumulations.

Dissolved Oxygen

To maintain high levels of productivity, nitrifying bacteria require a constant supply of dissolved oxygen (DO) in the water. Nitrification is an oxidative reaction in which oxygen is utilized as a reagent; the reaction will halt if oxygen is not present. DO values of 4-8 mg/litre are ideal for nitrification and mineralization. If DO concentrations fall below 2.0 mg/litre, nitrification rate will be reduced. Furthermore, without enough DO, another sort of bacteria can thrive, one that converts the precious nitrates back into unusable molecular nitrogen in an anaerobic process called denitrification.

UV Light

Nitrifying bacteria are photosensitive, which means they are affected by ultraviolet (UV) light. The sun poses a threat to those kinds of microbes. This is especially true during the early stages of the bacterial organization. When a new aquaponic system is set up, bacteria colonies will grow. Once the bacteria have taken up residence (3-5 days), UV light does not pose a significant concern on a surface. There is a simple approach to get rid of this threat is to use UV-protective material to cover the fish tank and filtration components while ensuring that none of the water in the plant bed is exposed to the light, at least until the end of the initial stages colonization. Nitrifying bacteria will thrive on materials with a high surface area, be protected from the sun with UV protection material, and be submerged in suitable water conditions.

Monitoring Bacterial Activity

It is safe to presume that, the bacteria are present and working appropriately if all the above five parameters are maintained at the appropriate range. However, bacteria are so important in aquaponics, it's worth understanding how they're performing at any particular time. Bacteria, on the other hand, are impossible to observe without a microscope because they are so tiny. Testing of ammonia, nitrite, and nitrate is a straight forward way to monitor bacterial function that provides information on the health of bacterial colonies. Ammonia and nitrite are dangerous and should be avoided. In a well-functioning and balanced aquaponic system, its concentration should always be 0-1 mg/liter. If either can be detected, it means there is an issue with the nitrifying bacteria. One is the inadequate biofilter size for the available amount of fish waste and fish feed. To fix it, either increase the biofilter size or alter the fish feeding schedule and stocking density of fish. Second, even if the system is balanced, the bacteria themselves might not be work properly because of the improper maintenance of water quality and each of those symptoms could signal a different problem. The above mentioned parameter should be monitored and maintained. This is especially common during the winter season when the temperature drops below the normal and bacterial activity begins to slow down.

Conclusion

A bacterium plays significant role in aquaponics by converting fish faecal matter into valuable nutrients for plants which ultimately leads to sustainable food production. Absence of bacteria suffocates fishes and plants and causes an imbalance in the system. Bacteria are equally important as the fish and plants in an aquaponics system. Hence this article will provide necessary information to the stakeholders, to maintain a healthy bacterial colony to avoid major problems like nutrient deficiency for plants, fluctuations of ammonia, nitrite and nitrate and management of other water quality parameters for proper maintenance of aquaponics.

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