ALLIANCE™
(https://www.globalseafood.org)

Responsible Seafood ADVOCATE

Health & Welfare

How decomposition of organic matter impacts aquaculture ponds

8 May 2017
By Claude E. Boyd, Ph.D.

Bacteria are the primary organisms of decay in aquaculture systems

Bacteria – ubiquitous in terrestrial and aquatic habitats as spores, resting cells, or actively growing cells – are the primary organisms of decay in an aquaculture system, including its organic matter. Photo by Darryl Jory.

In aquaculture, organic matter is applied to ponds directly in manures (animal dung, grass and agricultural waste) and feed. It also is produced through photosynthesis by phytoplankton and other aquatic plants. These plants die and their remains become dead organic matter.

Organic matter is the food for many small animals in the water and sediment, and organic matter is decomposed by bacteria and fungi. A small portion of the organic matter is transformed into the bodies of the small animals, bacteria and fungi, but most of it is oxidized to inorganic compounds – mainly carbon dioxide and ammonia. Of the organic matter consumed by the culture animals and not expelled as feces, most is oxidized for energy with the release of carbon dioxide, ammonia and other inorganic substances. The remainder makes up the biomass of the culture animals.

Organic matter that enters the water is initially particulate and, if large enough, the particles settle to the bottom. Otherwise, they remain suspended in the water as particulate matter. Organic matter, whether it settles or remains suspended, is leached of soluble substances by the water. This results in soluble organic matter in the water column.

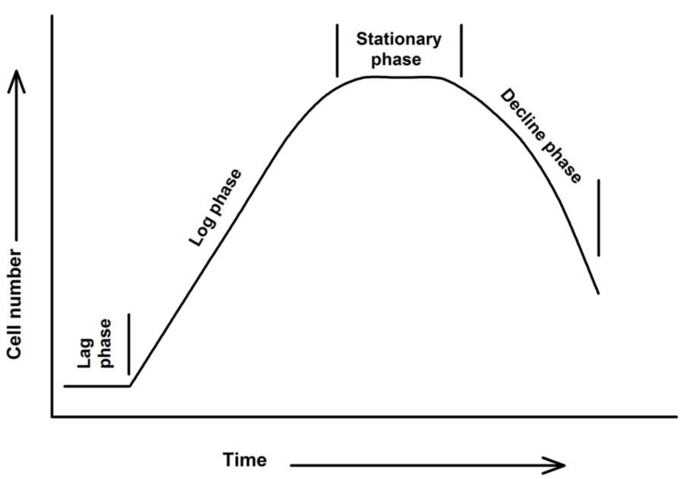
The particles are broken into smaller particles by mechanical action of water currents until they become small enough to be consumed by the small animals and microorganisms of decay. Bacteria grow on the surfaces of particles of organic matter in water and sediment. They also can release extracellular enzymes that break up particles of organic matter into smaller fragments that they can absorb. Bacteria and fungi also can absorb dissolved organic matter from the water.

Role of bacteria

Bacteria are the primary organisms of decay in aquaculture systems. They are ubiquitous in terrestrial and aquatic habitats as spores, resting cells, or actively growing cells. If fresh organic matter is applied to a habitat initially low in organic matter concentration and bacterial activity, bacteria will rapidly respond to this substrate (food) and increase in number as they decompose the substrate.

Bacteria reproduce by binary fission in which a cell simply divides into two cells, these two cells divide again, etc. The time between divisions may be only one or two hours, and cells multiply in an exponential fashion. They also use the substrate at an exponentially increasing rate. The easily decomposable fraction of the substrate will diminish in response to microbial decomposition – assuming no more is applied. Microbial growth will slow, and when the readily decomposable substrate is depleted, the bacterial population will decline to a low level.

Of course, if more substrate is added, the process described above will be repeated. The growth pattern of bacteria in a culture media is depicted in Fig. 1.



Several factors influence bacteria growth. These are as follows: adequate moisture; temperature (30 to 35 degrees-C is probably ideal); slightly alkaline conditions (pH 7.5-8.5 is usually optimum); a supply of molecular oxygen (for aerobic bacteria); sufficient, readily decomposable substrate.

Aquaculture ponds usually present an excellent environment for decomposition of organic matter. There is plenty of moisture. Most pond aquaculture is done in the tropic, subtropic, or temperate zones where water temperature is high enough for rapid microbial activity year around, or at least, during seven to eight months a year. If ponds are naturally acidic, they are limed to improve pH, and ponds are managed to assure plenty of dissolved oxygen in the water column and at the sediment-water interface.

Organic matter in pond bottoms

Organic matter added to aquaculture ponds usually is of good quality for microbial degradation. Feed is manufactured from high quality plant and animal meals with a low carbon:nitrogen ratio necessary for rapid microbial decomposition.

Dead aquatic plant material has a relatively small fibrous content, because water buoys these plants and they do not need a lot of cellular material (cellulose, hemi-cellulose, and lignin) for supporting structure. Phytoplankton in particular have a low carbon:nitrogen ratio. Manure is of much lower quality then feed or dead aquatic plants and its carbon:nitrogen ratio is higher than for the other forms of organic matter added to ponds.

Nevertheless, manure still has a substantial amount of readily decomposable organic matter. Also, in some ponds, nitrogen fertilizer is applied, and this nitrogen can be removed from the water by bacteria for facilitate organic matter decomposition.

Organic matter consists of readily decomposable carbohydrate, protein and fat, but it also has fiber and other components that are more resistant to decay. Readily decomposable organic matter (the labile fraction) is usually almost completely oxidized by bacteria during the crop period. When ponds are drained, considerable labile organic matter is swept from the bottom in outflowing water.

There is further decomposition of organic matter in bottom soil if ponds are left fallow for two to three weeks between crops. The remaining organic matter that decomposes more slowly is referred to as refractory organic matter. It seldom presents a problem in aquaculture ponds. The fresh, labile organic matter added during the crop is responsible for most of the oxygen demand and for many of the water quality problems in ponds.

Sediment depth in ponds where sediment is not removed increases over time, causing a gradual increase in the total amount of organic matter in pond bottoms even though the concentration of organic matter remains fairly constant. Photo by Darryl Jory.

Organic matter in pond bottoms tends to increase in concentration during the first few crops produced in a new pond, but it soon reaches an equilibrium – usually at a concentration of 2 to 3 percent organic carbon (about 4 to 6 percent organic matter). This results because the organic matter in the pond bottom reaches a concentration great enough that the annual decomposition of residual organic matter in sediment is equal to the annual input to the system. In ponds where sediment is not removed, sediment depth increases causing a gradual increase in the total amount of organic matter in pond bottoms even though the concentration of organic matter remains fairly constant.

Sediment interacts with pond water quality, but this interaction occurs only in the upper few centimeters. Also, dissolved oxygen penetrates only a few millimeters into the sediment, and while the surface layer is aerobic (oxygenated), underneath, the sediment is anaerobic (not oxygenated).

In anaerobic sediment, microbial activity continues, but it consists of fermentation that releases carbon dioxide, alcohols, aldehydes, organic acids and ketones. Fermentation does not completely oxidize organic carbon to carbon dioxide. However, there are other bacteria that can use oxygen from nitrate, iron and manganese oxides and hydroxides, sulfate, and carbon dioxide as an alternative to molecular oxygen in respiration. These bacteria completely oxidize organic carbon to carbon dioxide (or to methane in the case of organisms that can use oxygen from carbon dioxide).

The decomposition rate of labile organic matter occurs at roughly equal rates under aerobic and anaerobic conditions. Refractory organic matter decomposes slower and less completely than does labile organic matter. Toxic metabolites produced under anaerobic conditions usually do not enter the water column if the surface layer of the sediment is aerobic. Moreover, if the pond water has a dissolved oxygen concentration of 3-4 mg/L or more, it facilitates the oxidation of ammonia to nitrate by chemoautotrophic nitrifying bacteria. The presence of dissolved oxygen also favors oxidation of ferrous iron sulfide and other reduced substances from sediment.

Mechanical aeration is an important management measure to support adequate dissolved oxygen levels and promote organic matter decomposition. Photo by Darryl Jory.

Perspectives

Organic matter decomposition causes most of the water quality problems in aquaculture ponds by creating an oxygen demand and releasing ammonia, a potentially toxic metabolite, into the water. Efficient organic matter decomposition in aquaculture ponds requires, in particular, an acceptable pH (7.5-8.5) and plenty of dissolved oxygen.

In non-aerated ponds, organic matter inputs should not exceed the amount of oxygen available from natural sources. This can be verified by monitoring dissolved oxygen concentration; the concentration should not fall below 3-4 mg/L during the nighttime and especially near dawn. In ponds with aeration, the aeration rate should be in proportion to the feeding rate. Dissolved oxygen concentration usually can be maintained above 4 mg/L by applying about 1 hp of aeration for each 10 kg/ha increment in daily feeding rate. Another rule of thumb for aeration rate is 1 hp aeration for each 300-400 kg/ha increment of standing biomass.

Many fish and shrimp farmers delight in applying living bacterial cultures to ponds. There is no logical scientific reason why this practice would be effective. If bacteria are not already oxidizing organic matter and ammonia effectively, it is because natural environmental conditions, e.g., temperature or pH, are not adequate or the organic matter input exceeds the natural capacity or aeration capacity for supplying dissolved oxygen. There also is no experimental evidence that applying bacterial cultures improves water quality.

Author

CLAUDE E. BOYD, PH.D.

School of Fisheries, Aquaculture and Aquatic Sciences
Auburn University
Auburn, Alabama 36849 USA

boydce1@auburn.edu (mailto:boydce1@auburn.edu)