Aquafeeds

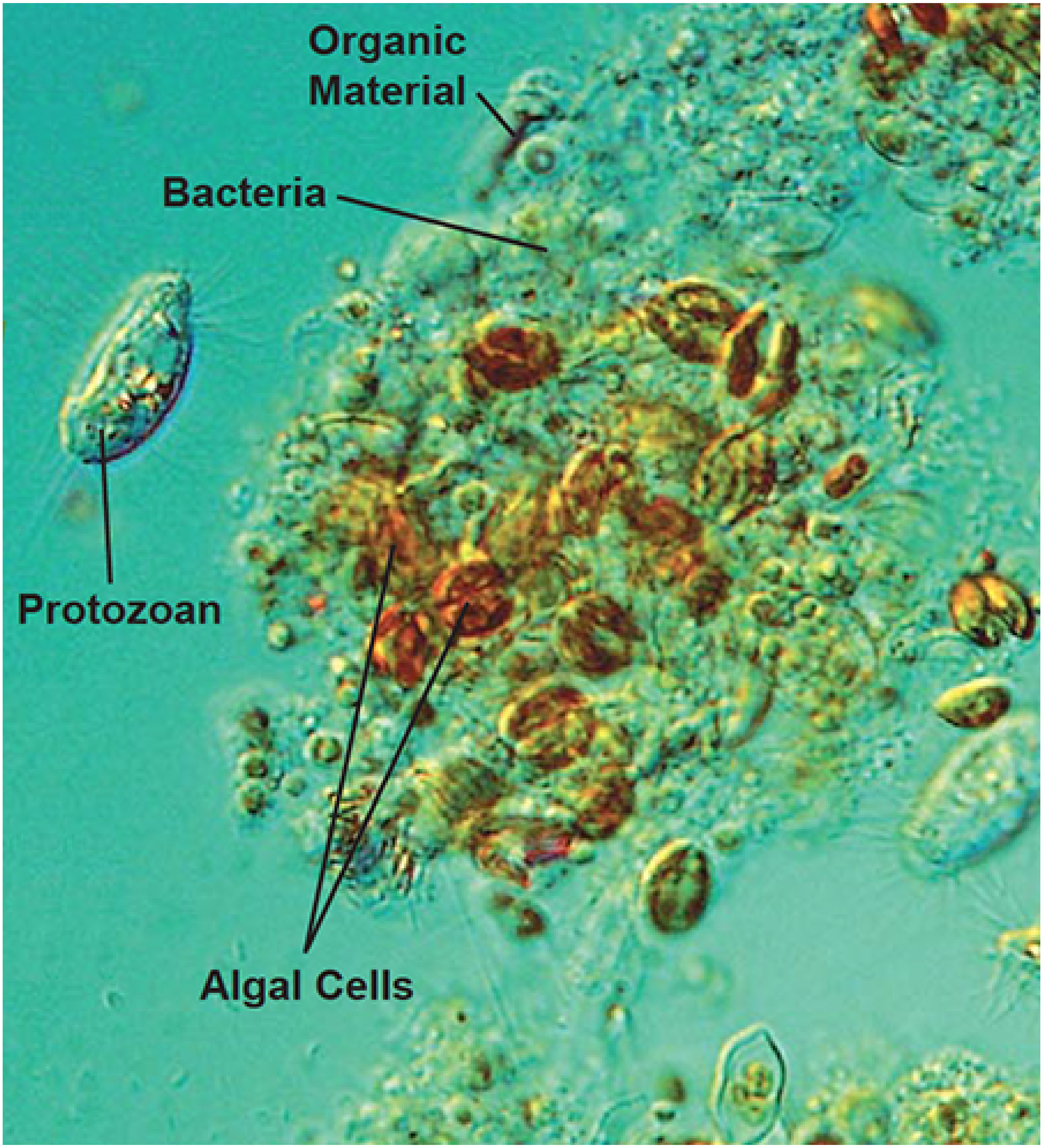
Advantages of aerated microbial reuse systems with balanced C:N, part 2

Friday, 1 June 2001

By George Chamberlain, Ph.D. , Yoram Avnimelech, Ph.D. , Robins P. McIntosh and Mario Velasco, Ph.D.

Composition and nutritional value of organic detritus

Aerated microbial reuse (AMR) systems utilize intense aeration and mixing to produce yields of 10- 30 metric tons (MT) per hectare per cycle with little or no water exchange. The first in this series of articles reviewed the mechanism of AMR systems, in which an active microbial community reprocesses wastes into detrital food. This second article reviews the nutritional value and composition of detrital material.



As shown in this microscopic view, detritus is a nutritious aggregate of amorphous organic material, bacteria, algal cells, and protozoans. Photo by Oliver Decamp.

Nutritional value of organic detritus

In 1988, Ken Leber and Gary Pruder published exciting research results from the Oceanic Institute in Hawaii, USA. They demonstrated that shrimp reared in microcosms receiving flow-through pond water and fed good-quality diets grew 50 percent faster than shrimp fed identical diets but maintained in clear well water from a seawater aquifer. In 1992, Shaun Moss and his colleagues at Oceanic Institute reported that suspended solids taken from an intensive shrimp pond stimulated the growth of fed shrimp reared in clear well water by 89 percent.

Using a progression of filters, Moss demonstrated that suspended solids in the 0.5 to 5.0 µm range increased growth rates by 53 percent, while solids greater than 5.0 µm increased growth by an additional 36 percent. The solids were characterized as microalgae and microbial-detrital aggregates. The growth-enhancing factor in the suspended solids was not identified, but bacteria were a strong candidate.

Single-cell protein

Over the years, a number of attempts have been made to commercially produce bacteria for sale as “single-cell protein” (SCP). A typical process was the Pruteen technology developed by Imperial Chemical Industries of Billingham, United Kingdom, which produced 6,000 MT per month of *Methylophilus methylotrophus* bacterium on methanol. However, the economic viability of the process was limited by the expense of concentrating and drying the product.

Single-cell protein performed well as a partial fishmeal replacement in trout diets. In studies with rainbow trout, Pruteen yielded a protein efficiency ratio of 1.62, a net protein utilization value of 0.38, a true digestibility value of 91.2, and a biological value of 0.41. Corresponding values for casein and fishmeal were protein efficiency ratio of 1.97 and 1.91, net protein ratio of 0.40 and 0.38, true digestibility of 98.7 and 91.2, and biological value of 0.41 and 0.41, respectively.

Advantages of aerated microbial reuse systems with balanced C:N, part 1

An alternative waste treatment is intense microbial processing of wastes to facilitate high yields with little or no water exchange.

Global Aquaculture Alliance

Economic viability

The economic viability of singlecell protein production was limited by the expense of concentrating, drying, and packaging. However, these steps are eliminated in aerated microbial reuse (AMR) systems, where the proteins are consumed in situ by the target animals, with no handling costs. Thus, AMR could represent the first commercially viable case of singlecell protein culture and utilization.

Composition of organic detritus

In the April 2000 *Global Aquaculture Advocate*, Robins McIntosh of Belize Aquaculture Ltd. analyzed suspended floc from commercial shrimp ponds managed as AMR systems in Belize. He found higher protein levels in suspended floc than in the feeds they were derived from (Table 1).

As reported in the April 2000 *Advocate*, Albert Tacon filtered suspended detrital floc from outdoor AMR tanks at Oceanic Institute in Hawaii at the end of a 56-day shrimp feeding trial. Chemical analyses of this material revealed a protein content similar to a 35 percent protein pelleted shrimp diet (Table 1).

Table 1. Composition of suspended detritus filtered from the water column of intensive zero-water-exchange shrimp ponds receiving 31.5% or 22.5% protein feed (McIntosh, 2000b).

Crude Protein Level of Feed (%)	31.5	22.5	Mean
Composition of Suspended Detritus			
Organic Matter (%)	78	66	72
Ash (%)	21	32	26
Protein (%)	51	35	43
Fat (%)	10	15	12.5
Arginine (%)	2.3	1.61	1.95
Methionine (%)	0.61	0.35	0.48
Lysine (%)	2.5	1.7	2.1

Table 2. Composition of microbial floc collected from outdoor shrimp-rearing tanks managed as intensive microbial reuse systems. Values are ranges and means (dry-matter basis) of 21 samples, except for amino acids, which are based on 12 samples (from Tacon 2000).

Nutrient	Low	High	Mean
Suspended microbial floc, mg/l	31.7	340.1	156.5
Crude protein (N x 6.25), %	24.64	40.6	33.45
Crude lipid, %	0.46	0.83	0.61
Ash, %	22.91	38.54	30.21
Gross energy, cal/g	2656	3207	3014
Carotenoid, mg/kg	60	163	122.7
Phosphorus, %	0.38	2.29	1.44
Potassium, %	0.14	0.95	0.68
Calcium, %	0.45	3.06	1.81
Magnesium, %	0.13	0.48	0.28
Sodium, %	0.43	4.59	2.94
Manganese, mg/kg	9.58	49.64	30.47
Iron, mg/kg	182.42	394.04	342.82
Copper, mg/kg	4.12	95.53	24.5
Zinc, mg/kg	83.58	618.34	365.81
Boron, mg/kg	9.46	48.53	29.19
Amino acid (g/100g protein)			
Isoleucine	1.99	5.69	3.75
Leucine	2.43	8.57	6.87
Methionine	0.89	4.78	3.18

Phenylalanine	1.24	9.05	6.09
Histidine	1.2	1.65	1.4
Threonine	3.98	6.21	4.94
Lysine	2.98	5.32	3.93
Valine	2.76	10.14	6.07
Arginine	5.62	7.5	6.45
Tryptophan	N.A.	N.A.	N.A.

Lipids

Analysis of the snow-like particles of suspended detritus in AMR systems reveals material rich in protein, energy and minerals.

Lipid analyses of floc by McIntosh and Tacon revealed dissimilar results. McIntosh found high lipid levels (mean = 12.5 percent), while Tacon found low levels (mean = 0.61 percent). According to Litchfield (1990), the composition of microbial cells in suspended flocs varies widely depending on specific organisms and the conditions under which they are grown.

Substrate carbon:nitrogen ratios of 10:1 or less favor bacteria with high protein contents, while higher C:N ratios favor the accumulation of lipids in algae, yeasts and molds, and poly- β-hydroxybutyrate in bacteria. This implies that microbial feed composition can be manipulated to some extent to maximize nutritional value.

Amino acids

McIntosh reported floc amino acid levels that were adequate in lysine and arginine content, but somewhat deficient in methionine to meet shrimp nutritional requirements (Table 1). However, Tacon reported adequate levels of arginine and methionine and deficient levels of lysine (Table 2). In general, microbial proteins tend to be deficient in sulfur amino acids, although bacterial proteins are less deficient than algae, yeast, molds, or higher fungi.

Ash

Both McIntosh and Tacon measured high levels of ash (mean of 26.0 and 30.2, respectively) in suspended flocs. Analysis of minerals indicates that microbial floc is rich in phosphorus as well as a wide range source of other minerals (Table 2). Much of this mineral composition can be bound to bacteria in a bioavailable organic form.

Phosphorus

Velasco et al. (1998) tested three levels of dietary phosphorus – 0.4, 0.8 and 1.2 percent – for postlarval shrimp reared in indoor AMR tanks. The accumulation of total reactive phosphate in the water increased significantly with increasing dietary phosphorus level. This suggests that dietary phosphorus levels can be reduced in these systems, due to recycling.

Vitamins

Tacon reported that supplemental vitamins in shrimp feed can be completely dispensed in an AMR microcosm system used for feeding trials. This also was observed by Velasco and Lawrence (2000) in initial evaluations of vitamin requirements in indoor AMR tanks.

Conclusion

Although bacterial floc can be an important growth promoter and nutritional supplement, it is not ideal as a sole source of nutrition. Microbial cells contain higher levels of nucleic acid nitrogen and non-protein nitrogen than higher organisms. Typically, nucleic acid levels, mainly ribonucleic acid, range 8 to 25 grams per 100 g protein (dry-weight basis). The ratio of Kjeldahl nitrogen to true protein in microbial cells is in the range of 5.6 to 5.8, as opposed to the typical ratio of 6.25 for plants and animals (Litchfield, 1990).

Feeding trials with a variety of species have demonstrated growth suppression when microbial cells are used as the sole source of protein in the diet. Consequently, microbial proteins are considered only a supplemental feed in AMR systems.

(Editor's Note: This article was originally published in the June 2001 print edition of the Global Aquaculture Advocate.*)*

Authors

GEORGE CHAMBERLAIN, PH.D.

Global Aquaculture Alliance
St. Louis, Missouri, USA

george.chamberlain@aquaculturealliance.org
(mailto:george.chamberlain@aquaculturealliance.org)

YORAM AVNIMELECH, PH.D.

Faculty of Agricultural Engineering Technion
Israel Institute of Technology
Haifa, Israel

ROBINS P. MCINTOSH

Belize Aquaculture, Ltd.
Belize City, Belize

MARIO VELASCO, PH.D.

Empacadora Nacional C.A.
Guayaquil, Ecuador