International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

Review Article

Algae in Aquaculture

Priyadarshani I.[1], Sahu D.[1], Rath B.[2*]

[2]Reader and Head;
[1]Department of Biotechnlogy, North Orissa University, Sriram Chandra Vihar, Takatpur, Baripada-757003, Odisha.

[*]Correspondence Email: brath_2000@yahoo.com

Received: 25/11//2011 *Revised: 30/12/2011* *Accepted: 5/01/2012*

ABSTRACT

Algae are the first link in the chain of live food manufacturer and nutrition. It is the culture diet for rotifers and provides a direct nutrition for larvae. Algae are utilized diversely in aquaculture, but their main applications are related to nutrition. They are used in toto, as a sole component or as a food additive to supply basic nutrients, color the flesh of salmonids or for other biological activities. The need for nutritional sources safer than traditional animal products has renewed interest in plants in general and algae in particular. This report deals principally with the different role of algae in aquaculture. The larvae of molluscs, echinoderms and crustaceans as well as the live prey of some fish larvae feed on algae. Though attempts have been made to substitute inert particles for these micro-organisms which are difficult to produce, concentrate and store, only shrimp and live prey for fish will accept inert food, and only shrimp accept it fully. Several studies have confirmed that a live, multi-specific, low-bacteria algal biomass remains essential for shellfish hatcheries. Major advances are expected from new production system designs and operations, from batch-run open tanks to more sophisticated continuously run and closed loop reactors

Key Words: Aquatic, coastal, commercial, environment, fish, microalgae

INTRODUCTION

Since ancient times, coastal populations have used marine plants as food complement, as soil fertilizer, as fuel, as fodder for animals. Traces of algae found in ashes of prehistoric fire places allow us to think that algae were used in very early times as food stuff. Algae are photosynthetic organisms (contain chlorophyll) and obtain their energy from the sun and their carbon from carbon dioxide. Their size ranges from one micron to many meters. All organisms that use carbon dioxide for their carbon requirement are called autotrophs. Algae are generally beneficial in aquaculture by supplying oxygen and a natural food base for the cultured animals, such as dinoflagellates that cause the red tides. Algal production for feeds is divided into intensive monoculture for larval stages of bivalves, shrimp, and certain fish species, and extensive culture for grow out of bivalves, carp, and shrimp. Favoured genera of microalgae for larval feeds include *Chaetoceros*, *Thalassiosira*, *Tetraselmis*, *Isochrysis*, and *Nannochloropsis*. These organisms are fed directly and/or indirectly to the cultured larval organism. Indirect means of providing the algae are through artemia, rotifers, and daphnia, which are, in turn, fed to the target larval organisms. Microalgae are an essential food source in the rearing of all stages of marine bivalve molluscs (clams, oysters, scallops), the larval stages of some marine gastropods (abalone, conch), larvae of several marine fish species and penaeid shrimp, and zooplankton. Marine microalgae are known to be the basic source of important nutrients essential for larval development for almost all marine invertebrates, allowing growth and transformation through the juvenile and adult stages to proceed. Diatoms *Chaetocerus gracilis* and *Navicula ramoissima* are currently cultured for feed for aquaculture commodities in Samoa, namely for sea urchin *Tripneustes gratilla*. Microalgae (single celled algae or phytoplankton) represent the largest, but most poorly understood, kingdom of microorganisms on the earth. As plants are to terrestrial animals, microalgae represent the natural nutritional base and primary source of all the phytonutrients in the aquatic food chain. As the primary producers in the aquatic food chain, microalgae are the source of many phytonutrients, including docosahexaenoic acid (DHA) and arachidonic acid (ARA) precursors for the valuable nutritional component widely promoted as Omega 3 Fatty Acids. Microalgae also represent a vast genetic resource, comprising in excess of 80,000 different species. Mass- cultured unicellular algae are used as a sole food source in the intensive seed culture of bivalves. Due to the high production cost and the unpredictability of algae culturing, the development of a performing artificial diet is highly desirable. Microalgae such as *Dunaliella salina*, *Haematococcus pluvialis* and *Spirulina* are also used as a source of natural pigments for the culture of prawns, salmonid fish and ornamental fish. Over the last four decades, several hundred microalgae species have been tested as food, but probably less than twenty have gained widespread use in aquaculture. Microalgae must possess a number of key attributes to be useful aquaculture species. They must be of an appropriate size for ingestion, e.g. from 1 to 15 μm for filter feeders; 10 to 100 μm for grazers. [(1-3)] Algaculture is a form of aquaculture involving the farming of species of algae. Microalgae play a crucial nutritional role for marine animals in open ocean and consequently in marine aquaculture. Live microalgae were traditionally used for bivalves feeding in commercial mollusc hatcheries. Such intensive cultures are costly for producers and many alternatives have been proposed to reduce the cost and to simplify production procedures. Nonliving food such as microalgae pastes, dried microalgae, microencapsulated lipids, bacteria or yeasts were tested in hatcheries and laboratories with various level of success. [(4-5)] It involves raising fish commercially in tanks or enclosures, usually for food for human consumption. Fish species raised by fish farms include salmon, catfish, tilapia, cod, carp, trout and others. Fish farming, or "aquaculture," has become a billion-dollar industry, and more than 30 percent of all the sea animals consumed each year are now raised on these "farms." The United

Nations' Food and Agriculture Organization reports that the aquaculture industry is growing three times faster than land-based animal agriculture, and fish farms will surely become even more prevalent as our natural fisheries become exhausted. Over 1100 species of fishes, molluscs and crustaceans directly contribute to production of the world's major fisheries. There are many additional species contributing to small scale fisheries. In aquaculture, although the majority of production comes from a few species, there are over 300 species, which do contribute. Most growers prefer monocultural production and go to considerable lengths to maintain the purity of their cultures. With mixed cultures, one species comes to dominate over time and if a non-dominant species is believed to have particular value, it is necessary to obtain pure cultures in order to cultivate this species. Individual species cultures are also needed for research purposes. A common method of obtaining pure cultures is serial dilution. Most hatcheries grow a variety of species that serve different needs throughout the production cycle with respect to size, digestibility, culture characteristics, and nutritional value. [(6)]

ALGAE USED AS AQUACULTURE FEED

Water, carbon dioxide, minerals and light are all important factors in cultivation, and different algae have different requirements. The basic reaction in water is carbon dioxide + light energy = glucose + oxygen. Along with adequate calcium and magnesium in the water (especially for marine organisms), *Spirulina* helps insure proper electrolyte function, calcium levels over calcium and other minerals that are added to fish food as an afterthought to make up for poor quality ingredients. Several studies [(7-9)] have shown that macroalgae cultivated in residual aquaculture waters absorb and store large amounts of nutrients. This results in improved water quality for the cultivated animals, as well as for the environment, given that the water returned to the sea contains a lower concentration of nutrients. Several studies have demonstrated that it is possible to economically cultivate valuable seaweeds using wastewater from aquaculture.[(10)] Micro-algae are also cultured in aquaculture hatcheries as food for juveniles. These species, mainly haptophytes and diatoms, have been selected for their nutritional value, ease of culture, and proven performance. Cell size, culture vigour, and nutritional value may change over time in culture and preservation of these isolates and strains is therefore desirable. Spirulina 20 flakes contain a full 20% Spirulina and provide a complete high protein diet for freshwaterfish, saltwater fish, goldfish, crustaceans, and invertebrates. Several companies produce aquaculture feeds using *Chlorella* and *Spirulina*, or a mixture thereof. Some examples of the use of microalgae for aquaculture includes; Microalgae species *Hypneacervicornis* and *Cryptonemia crenulata* particularly rich in protein were tested in shrimp diets. [(11)] Algae were collected, rinsed, dried and ground up for the feed formulations. The marine cyanobacterium *Phormidium valderianum* was shown to serve as a complete aquaculture feed source, based on the nutritional qualities and non-toxic nature with animal model experiments. [(12)] In 1999, the production of microalgae for aquaculture reached 1000 ton (62% for molluscs, 21% for shrimps and 16% for fish) for a global world aquaculture production.[(6)] The nutritional value of any algal species for a particular organism depends on its cell size, digestibility, production of toxic compounds, and biochemical composition. Microalgae grown to late-logarithmic growth phase typically contain 30 to 40%

protein, 10 to 20% lipid and 5 to 15% carbohydrate. [(13-14)] The content of highly unsaturated fatty acids (HUFA), in particular eicosapentaenoic acid (EPA), arachidonic acid (ARA) and docosahexaenoic acid (DHA), is of major importance in the evaluation of the nutritional composition of an algal species to be used as food for marine organisms. In late-logarithmic phase, prymnesiophytes, on average, contain the highest percentages of saturated fats (33% of total fatty acids), followed by diatoms and eustigmatophytes (27%), prasinophytes and chlorophytes (23%) and cryptomonads (18%). [(13)] The content of vitamins can vary between microalgae. Ascorbic acid shows the greatest variation, i.e. 16-fold (1 to 16 mg / g dry weight. [(15)] The use of biofiltering grown seaweed eliminates the need for a destructive harvest of natural seaweed beds. The chemical composition of the culture seaweed is controllable. Algae, and in particular seaweed, allow the creation of flexible integrated sustainable mariculture operations.

WHY ALGAE ARE USED IN AQUACULTURE?

Algae are the basis of primary production in the aquatic food chain. In the marine realm, algae sustain the production of a hundred million tons per year of marine fisheries and a large portion of the aquaculture production (seaweeds, molluscs, larval rearing, etc.), securing a stable human food supply. On a daily basis, a wide array of high-value substances derived from marine algae, such as phycocolloids and pigments, is used.

1. To increase dissolved oxygen and to decrease toxic gases like ammonia, nitrite, hydrogen sulfide, methane, carbon dioxide in pond water.
2. To stabilize pond water quality and to lower the content of toxic compounds.
3. To make use of microalgae as a natural feed.
4. To provide shade and to decrease cannibalism.
5. To increase and stabilize water temperature.
6. To minimize pathogenic and unwanted microbial population by competing with the available nutrients in the water.

So, Phytoplankton plays a significant role in stabilizing the whole pond ecosystem and in minimizing the fluctuations of water quality. Another potential large-scale application of microalgae is the cultivation of *Haematococcus* for the production of the carotenoid astaxanthin, which gives salmon flesh its reddish color. In the long-term microalgae biomass high in lipids (omega-3 fatty acids) may be developed as substitutes for fish oil-based aquaculture feeds. In shrimp ponds the indigenous algal blooms supply a part of the dietary requirements of the animals, but it is difficult to maximize algal productivities. The microalgae used as feed in hatcheries vary in size, environmental requirements, growth rate, and nutritional value (Fig. 1). [(16)] When selecting a species for culture, it is important to take all of these parameters into consideration.

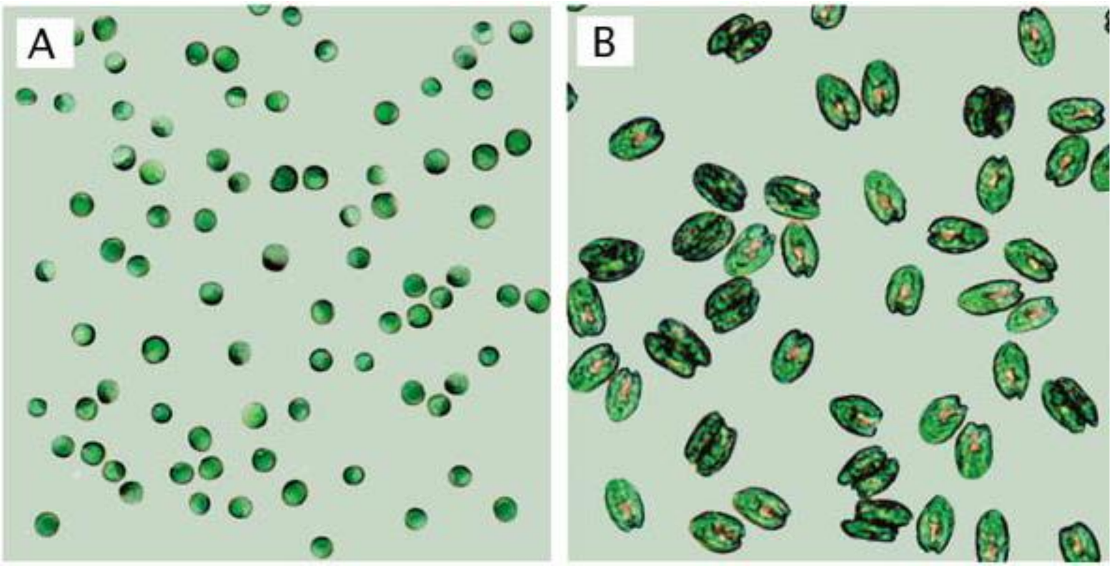

Figure 1. Photomicrographs of two popular species of microalgae commonly cultured in bivalve hatcheries. A) *Isochrysis* sp. (4–6 µm x 3–5 µm, and B) *Tetraselmis* sp. (14–20 µm x 8–12 µm).[16]

Table 1: Temperature, light, and salinity ranges for culturing selected microalgae species. [17]

Species	Temperature	Light (Lux)	Salinity (ppt-%)
Chaetoceros muelleri	25 – 30	8,000 – 10,000	20 - 35
Phaeodactylum tricornutum	18 – 22	3,000 – 5,000	25 – 32
Dicrateria sp.	25 – 32	3,000 – 10,000	15 – 30
Isochrysis galbana	25 – 30	2,500 – 10,000	10 – 30
Skeletonema costatum	10 – 27	2,500 – 5,000	15 – 30
Nannochloropsis oculata	20 – 30	2,500 – 8,000	0 - 36
Pavlova viridis	15 – 30	4,000 – 8,000	10 – 40
Tetraselmis tetrathele	5 – 33	5,000 – 10,000	6 – 53
Tetraselmis subcordiformis	20 – 28	5,000 – 10,000	20 - 40
Chlorella ellipsoidea	10 – 28	2,500 – 5,000	26 - 30

CONCLUSION

Aquaculture can be defined as tending the confined water for growing aquatic organisms and harvesting the production for human benefits. The first use of algae by humans dates back 2000 years to the Chinese, who used *Nostoc* to survive during famine. Algae are important to the aquatic food chains because they are primary producers. Nowadays, there are numerous commercial applications of algae. The importance of algae in this domain is not surprising as they are the natural food source of these animals. The main applications of algae for aquaculture are associated with nutrition, being used fresh as sole component or as food additive to basic nutrients and for inducing other biological activities. Algae are required for larval nutrition during a brief period, either for direct consumption in the case of molluscs and shrimp or indirectly as food for the live prey fed to small fish larvae. In order to be used in aquaculture, a algal strain has to meet various criteria. It has to be easily cultured and nontoxic. It also needs to be of the correct size and shape to be ingested and to have a high nutritional qualities and a digestible cell wall to make nutrients available. Protein content is a major factor determining the nutritional value of algae. In addition, highly unsaturated fatty acid (e.g., eicosapentaenoic acid (EPA), arachidonic acid (AA) and docosahexaenoic acid (DHA)) content is of major importance. Thus Algae play a crucial role in aquaculture.

REFERENCES

1. Webb, K. L., Chu, F. E. (1983), Phytoplankton as a food source for bivalve larvae. In: G. D. Pruder, C. J. Langdon and D. E. Conklin (Editors), Proceedings of the Second International Conference on Aquaculture Nutrition: Biochemical and Physiological Approaches to Shellfish Nutrition, Louisiana State University, Baton Rouge, LA. pp. 272–291.
2. Jeffrey, S. W., LeRoi, J. M., Brown, M. R. (1992), Characteristics of microalgal species for Australian mariculture. In: G. L. Allan and W. Dall (Editors), Proceedings of the National Aquaculture Workshops, Pt. Stephens, NSW Australia, April 1991, pp. 164-173.
3. Kawamura, T., Roberts, R. D., Nicholson, C. M. (1988), Factors affecting the food value of diatom strains for post-larval abalone Haliotis iris. *Aquaculture*., 160, 81-88.
4. Knauer, J. and Southgate, P. C. (1999), *Rev. Fish Sci.,* 7, 241-280.
5. Robert, R. & Trintignac, P. (1997) , Aquat. Living Resour. 10, 315-327.
6. Muller-Feuga, A. (2004), Microalgae for aquaculture. The current global situation and future trends. In Richmond , A. (ed). Handbook of microalgae culture. Blackwell, Oxford.
7. Neori, A., Ragg, N. I. C., Shpigel, M. (1998), The integrated culture of seaweed, abalone, fish and clams in modular intensive landbased systems: II. Performance and nitrogen partitioning within an abalone (Haliotis tuberculata) and macroalgae culture system. *Aquacult Eng.*, 17, 215–39.
8. Buschmann, A. H., Troell, M., Kautsky, N., Kautsky, L. (1996), Integrated tank cultivation of salmonids and Gracilaria chilensis (Graciariales, Rhodophyta). *Hydrobiologia.*, 326–327, 75–82.

9. Herna´ndez, I., Martı´nez-Ara´gon, J. F., Tovar, A., Perez-Llore´ns, J. L., Vergara, J. J. (2002), Biofiltering efficiency in removal of dissolved nutrients by three species of estuarine macroalgae cultivated with sea bass (Dicentrarchus labrax) waste waters 2. Ammonium. *J Appl Phycol.*, 14, 365–74.
10. Neori, A., Chopin, T., Troell, M., Buschmann, A. H., Kraemer, G. P., Halling, G. (2004), Integrated aquaculture: rationale, evolution and state of the art emphasizing seaweed biofiltration in modern aquaculture. *Aquaculture.*, 231,362–91.
11. Da Silva, R. L., Barbosa, J. M. (2008), Seaweed meal as a protein source for the white shrimp Lipopenaeus vannamei. *Journal of Applied Phycology.*, 21,193-197.
12. Thajuddin, N., Subramanian, G. (2005), Cyanobacterial biodiversity and potential applications in biotechnology. *Current Science.*, 89, 47-57.
13. Brown, M. R., Jeffrey, S. W., Volkman, J. K., Dunstan, G. A. (1997), Nutritional properties of microalgae for mariculture. *Aquaculture*., 151, 315-331.
14. Renaud, S. M., Thinh, L. V., Parry, D. L. (1999), The gross composition and fatty acid composition of 18 species of tropical Australian microalgae for possible use in mariculture. *Aquaculture.*, 170, 147-159.
15. Brown, M. R., Miller, K. A. (1992), The ascorbic acid content of eleven species of microalgae used in mariculture. *Journal of Applied Phycology*., 4, 205-215.
16. Helm, M. M., Bourne, N., Lovatelli, A. (2004), Hatchery Culture of Bivalves: A Practical Manual. FAO Fisheries Technical Paper Number 471. Rome, Italy. 200 pp.
17. Hoff, F. H. & Snell, T. W. (2008), *Plankton Culture Manual*. Florida Aquafarms, Inc., Dade City, Florida. 186 pp.

****