

THE ROLE OF SYMBIOTIC ZOOXANTHELLAE ON GIANT CLAM NUTRITION

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ABSTRACT

Zooxanthellae, Symbiodinium sp, are single cell dinoflagellate algae known to live in association with many marine invertebrates such as hermatypic corals, sea anemones, jellyfish and giant clams (family Tridacnidae). In giant clams, these photosynthetic algae are located in a tubular system (known as Z tube system) which occurs within the clams. Apart from filter feeding, the nutrition of the clams is provided by zooxanthellae. These algae are capable of translocating part of their photosynthetic products to the host. CZAR values are also discussed.

Keywords : zooxanthellae, giant clams, nutrition, symbiosis.

I. Introduction

Many invertebrates, such as hermatypic corals, anemones, jellyfish and giant clams, are known to live in association with endosymbiotic algae, usually referred to as zooxanthellae. There are several different species of zooxanthellae, such as *Amphidinium chattonii* which live in coelenterates, *Amphidinium klebsii* known to live in platyhelminthes and *Amphidinium sp.* in protozoans (Taylor, 1974). Furthermore, Trench and Blank (1987), reported three other species of zooxanthellae, ie. *Symbiodinium goereauii* which live in the Caribbean sea anemone *Ragactis lucida*; *S. kawagutii* isolated from Hawaiian stony coral

Montipora verrucosa and *S. pilosum* known to live in Caribbean zoanthid *Zoanthus sociatus*. The species of zooxanthellae in giant clams have been believed to be *Symbiodinium (Gymnodinium) microadriaticum*. However, lately scientists tend to refer these algae as *Symbiodinium sp* since no study (especially by using latest technique such as PCR or Polymerase Chain Reaction) has been done to investigate the possibility of the species of zooxanthellae from tridacnids being not as what people thought before.

It has been reported by many scientists that zooxanthellae play an important part on the nutrition requirement of their host which directly influence the

growth. This review describes the role of symbiotic zooxanthellae on giant clam nutrition. Contribution of zooxanthellae to daily clams and other marine invertebrates energy requirements for respiration will also be discussed.

1.1. Giant clams zooxanthellae association

Apart from giant clams, there are only three other bivalves which live in association with symbiotic zooxanthellae. These are *Corculum cardissa*, *Fragum fragum* and *F. unedo* (Kawaguti, 1983).

There are two different ways on how symbiotic zooxanthellae enter into the host. Firstly, the parent directly transmit these cells through their eggs or known as enclosed system, and secondly the host has to acquire zooxanthellae from surrounding environment or known as open system.

Unlike in hermatipyc corals, giant clams parents do not pass their zooxanthellae to their offspring (see eg. LaBarbera, 1975). Therefore, newly hatched tridacnids have to acquire algae from the water usually after metamorphosis (Jameson, 1976; Fitt *et al.*, 1984).

Zooxanthellae find the hosts using dissolved nitrogen compounds, such as ammonium and amino acids, which leak from the potential hosts (Fitt *et al.*, 1984). In clams larvae the algae can be found in the mantle after 11 days (Heslinga *et al.*, 1984). While Beckvar (1981) found that a newly metamorphosed juveniles of *Tridacna derasa* had between three to eight zooxanthellae. During zooxanthellae acquisition all *Symbiodinium* sp strains are accepted by giant clams, however only the fast

growing strains will stay in the host (eg. Fitt *et al.*, 1986).

In giant clams, zooxanthellae are located inside a tubular system which is known as Z tube system (Norton *et al.* 1992), and not in the haemal sinuses of the siphonal tissue as previously thought (Yonge, 1953). This Z tube system has tertiary branches at the mantle of the clams. This mantle can be extended, usually during day time when the animal opens the valves, to allow zooxanthellae to perform photosynthesis.

The number of zooxanthellae in clams depends on the size of the animal, with positive correlation occurs between them. For example, *Tridacna maxima* with 12 cm shell length contains approximately $1-2 \cdot 10^8$ cells (Ambariyanto, unpublished).

1.2. The role of zooxanthellae

There are two ways that previously believed on how giant clams can get benefit from zooxanthellae. Firstly, giant clams benefit by directly digest zooxanthellae (Frankboner, 1971) and secondly by receiving photosynthates from zooxanthellae (eg. Muscatine, 1967; Streamer *et al.*, 1988). However, the first possible benefit has been questioned by several scientists. Although zooxanthellae have been found in the stomach, digestive gland and faeces of giant clams (Frankboner and Reid 1981; Trench *et al.*, 1981; Fitt *et al.*, 1986), these cells, however, were still intact, viable, photosynthetically functional, and can be used to initiate cultures. These reports suggested that the zooxanthellae were not digested by the clams (Trench *et al.* 1981).

The second benefit of giant clams by having symbiotic zooxanthellae has been supported by many authors (see for example, Muscatine, 1967; Goreau *et al.*, 1973; Taylor, 1974; Streamer *et al.*, 1988). As in many other marine algae, these dinoflagellate are capable to perform photosynthesis. These scientists state that zooxanthellae are also capable of translocate part of their photosynthetic products to the clam host, in the form of mainly glucose, and oligosaccharides and amino acids (Lucas, 1994). The energy gained from photosynthesis is spent by zooxanthellae for maintenance and growth. The rest of the energy is likely to be translocated to the host.

The contribution of these symbiotic algae to the host depends on the availability of light (thus includes depth and seasons; through photosynthesis), the clams size (in relation to the number of zooxanthellae and their proportion which can be reached by the light) (Heslinga and Fitt, 1987). The photosynthetic contribution of zooxanthellae to the clams will reach a maximum value in day time and the minimum value at night time (Muscatine, 1990). Furthermore, the addition of inorganic nutrient such as ammonium assists zooxanthellae photosynthesis, as has been reported in clam tissue slices (Summons *et al.*, 1986).

The amount of zooxanthellae contribution to the host is also depending on the host species. In corals (*Pocillopora damicornis*) and giant clams (*Tridacna crocea*) for example, zooxanthellae are capable of translocating up to 40% to the host (Muscatine, 1967). Streamer *et al.* (1988) found that by using ^{14}C labelled-bicarbonate, zooxan-

thellae transferred 30% of photosynthetically fixed carbon of juvenile *T. gigas* just after 10 minutes incubation. While in sea anemone (*Anemonia sulcata*), these algae are capable of transferring over 60% of the total photosynthetic fixed carbon to the host (Taylor, 1969).

Muscatine (1967) reported that the compound translocated by zooxanthellae to the host mainly was glycerol. Similarly, Griffiths and Streamer (1988), and Streamer *et al.* (1988) also found a high amount of glycerol as a photosynthetic product of isolated symbiont in the presence of host tissue extracts, but stated that glucose was the major product transferred to the host.

II. CZAR

CZAR or Contribution of Zooxanthellae to Animal daily energy requirements for Respiration is widely used to study the photosynthetic contribution of zooxanthellae to their host, and was introduced by Muscatine *et al.* (1981). It was based on the measurement of oxygen production and consumption through photosynthesis and respiration which were converted into units of organic carbon. Several parameters had to be measured in order to calculate the value of CZAR, such as specific growth rate, carbon and protein content of zooxanthellae, daily carbon fixation by zooxanthellae and carbon respired by zooxanthellae and the host (see Muscatine *et al.* 1981).

The value of CZAR also depends on the percentage translocation by zooxanthellae. By assuming that zooxan-

thellae translocate 40% of their photosynthetic products, the CZAR of zooxanthellae in corals, *Pocillopora damicornis* can be as high as 86.8% which almost cover all energy required for respiration (Muscatine and Porter 1977). Using the values of 40% and 95% translocation, the mean value of CZAR of zooxanthellae in *Tridacna gigas* were 83% and 197% (Fisher *et al* 1985). While CZAR in *Hippopus hippopus* were reported to vary between 7% and 137% assuming that the percentage translocation were 40% and 98% (Fitt *et al* 1986). Therefore, when the percentage translocation value of 95% is used, the CZAR values is well above 100% for giant clams (eg. Fisher *et al* 1985; Klumpp and Lucas 1994).

Seasonal differences on the contribution of zooxanthellae to the host was reported by Hoegh-Guldberg *et al.* (1986). They found that zooxanthellae from the nudibranch *Pteraeolidia ianthina* contributed 79%, 121% and 173% to the host in winter, spring and summer respectively, which was mainly due to the differences of the availability of light. Trench *et al.* (1981) reported that the CZAR values of *Tridacna maxima* during sunny and cloudy periods were 84.77% and 63.62%. Another example, Muscatine *et al.* (1984) found that in the presence of light zooxanthellae in the corals *Stylophora pistillata* had higher value of CZAR (ie. 143%) than in shaded condition (58%).

III. Conclusions

Symbiotic zooxanthellae in giant clams play an important role on the nutrition of the host. Apart from filter feeding, giant clam nutrition is provided by zooxanthellae through photosynthates translocation.

The values of the contribution of zooxanthellae to animal daily energy requirements for respiration (CZAR) are influenced by percentage of translocation and the availability of light.

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