Report

Michigan Sea Grant

Dimethylsulfide in Giant Clams and Its Manipulation for Food-Value Enhancement

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The goal of this Sea Grant research was to investigate the rapid development of off-flavors during storage of tridacnid clam meat and to test the hypothesis that dimethylsulfide (DMS) originating from algal symbionts is the cause. Several species of "giant" clams in the Family Tridacnidae are favored for their meat by indigenous peoples throughout the Indo-Pacific region (where the clams occur) and are viewed as gourmet fare in certain developed countries such as Taiwan and Japan. The people who have traditionally eaten giant clams are well aware that the meat, while appetizing soon after clams are killed, can develop a repulsive smell and taste within hours after death. This unusual property has implications for giant clam aquaculture. Starting 2-3 decades ago, aquaculture projects for giant clams were initiated in many Pacific Island nations, some of which – like the Federated States of Micronesia (FSM) – have close ties to the United States. These projects had two important objectives: (1) to serve as new sources of income for developing nations by providing giant clams to commercial markets and (2) to relieve fishing pressure on wild populations of giant clams, which often are overexploited by indigenous fishing. A major factor thwarting the economic success of the aquaculture projects has been the tendency of the giant clam meats to develop off-flavors rapidly after death.

In the FSM, to illustrate the problem, several restaurants catering to tourists were persuaded during the 1990s to carry giant clams from government-sponsored aquaculture projects on their menus. However, it was quickly discovered that neither refrigeration nor freezing would assure delivery of a satisfactory product to the consumer. Thus, clams had to be delivered to restaurants alive, and each restaurant needed an aquarium to maintain them until they were served. Clams that died during transportation or storage were total losses. These realities pushed costs upward. Unlike American lobsters, which also require live delivery, giant clams do not yet command a premium price. Thus, even though the FSM and United States governments subsidized the aquaculture and commercialization efforts, the cost of clams to the restaurants could not be kept low enough for profits to justify keeping the clams on menus. By 2000, when my colleagues and I visited the FSM as part of this Sea Grant, no restaurants were carrying giant clams, and giant clam aquaculture in the FSM was surviving only in the form of a single, scaled-down demonstration project.

My colleagues and I believed that we could improve prospects for the economic success of giant clam aquaculture if we could determine the cause of the off-flavors that prevent clam meat from being stored prior to consumption. We, in fact, had a specific

hypothesis, based on the fact that giant clams are highly dependent for their nutrition on photosynthesis by algae that live symbiotically within the clams. These algae are dinoflagellates and thus are members of one of the groups of algae most noted for synthesis of the important tertiary sulfonium compound dimethylsulfoniopropionate (DMSP). Although DMSP itself is virtually tasteless and odorless, it is broken down by many sorts of bacteria to produce DMS, a gas with a strong, often highly objectionable taste and odor. We hypothesized that giant clams accumulate DMSP from their algal symbionts while alive and that the breakdown of this DMSP to form DMS after death is responsible for the repulsive taste and odor of dead clams.

Our Sea Grant research has conclusively demonstrated the accuracy of our hypothesis. We found that most tissues of giant clams have concentrations of DMSP that are higher than any ever previously reported in animals, plants, or microbes. These high DMSP concentrations endow the tissues with an enormous chemical potential to produce DMS by decomposition after death. We have, in fact, directly observed that after death, giant clam tissues generate quantities of DMS that are well known to render other sea foods inedible. Our research strongly indicates that DMSP and DMS are responsible for the rapidly developing postmortem off-flavors in giant clams. The research thus sets the stage for a rational approach to solving a key problem that has blocked the economic success of giant clam aquaculture.

The specific objectives achieved by this research were:

1. We collected six different tissues (adductor muscle, byssal mantle, gill, gonad, kidney, and siphonal mantle) from multiple specimens of six of the eight known species of giant clams: *Hippopus hippopus, Tridacna crocea, T. derasa, T. gigas, T. maxima,* and *T. squamosa.* Samples were quick-frozen in the Federated States of Micronesia or the Republic of Palau, and were returned to the United States at liquid-nitrogen temperature.

2. All tissue samples were analyzed for their content of DMSP by gas chromatography and mass spectrometry. The latter analyses provided a major, unexpected revelation for future research; namely, that giant clam tissues often exhibit high concentrations of a series of betaines, including glycine betaine and proline betaine.

3. DMS production during normal postmortem change was directly observed and quantified in tissues of several species.

4. Several types of information were gathered to better interpret and understand the production, transport, and accumulation of DMSP in giant clams. These studies included:

a) measurement of DMSP concentrations in purified cultures of algal symbionts

b) measurement of DMSP concentrations in the blood of giant clams

c) comparative studies of tissue water content in various giant clam species (water content must be normalized for valid interspecific comparisons because species exhibit wide variation)

d) determination of the relationships between DMSP accumulation and body size within species

e) comparisons of tissue DMSP concentrations in clams from widely separated geographical locations, to determine if species show geographical variation in DMSP accumulation

f) research to detect changes in DMSP production between day (when algal symbionts are photosynthetically active) and night

5. Scuba diving was employed to study all six of our focal species of giant clams (listed earlier) in their natural settings on coral reefs so as to better understand the contexts in which the species function. The species are very diverse in their natural history, and the differences among them must be considered in all giant clam research, including that on algal products.

6. Three aquaculture projects (one defunct) in the FSM and Palau were visited, and my colleagues and I interviewed not only the scientists in charge of these operations but also restaurant operators who had participated in the initial commercialization effort. From our observations and interviews, we greatly increased our knowledge of the practical challenges that remain to be faced by giant clam aquaculture and commercialization. We also created several professional relationships that will be useful in future research.

This Sea Grant research was carried out in a highly collaborative fashion. My two principal collaborators were John W. H. Dacey (Woods Hole Oceanographic Institution) and Ahser Edward (College of Micronesia). Douglas Gage and. Wayne Hicks (both of Michigan State University) designed the mass spectrometry analyses, and Ethan Daniels (University of Guam) led the field studies. Important logistical support was provided by Belau Aquaculture in Koror. Personnel at the FSM National Aquaculture Center on the island of Kosrae and the Palau Mariculture Center in Koror were generous with their time and knowledge. Funds from Michigan Sea Grant were matched with funds from a companion grant awarded by Woods Hole Oceanographic Institution Sea Grant. Major additional funding was provided by a grant from the Frey Foundation to Woods Hole Oceanographic Institution.

Respectfully submitted,

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