Sea urchin cultivation: controlling energy flow between somatic and gonadal growth

MARIA DEL MAR OTERO AND MAEVE S. KELLY

Sea urchin gonad or roe is a luxury food product that is highly prized in many European countries and in the Far East. Increasing demand and the high market value of these echinoderms over the last 10 years has resulted in recent landings of 110,000 tons per annum from wild sea urchin fisheries. Over-exploitation of the natural stocks has caused the market to fail to meet consumer demand. As a consequence, some countries have introduced very strict harvesting regulations. In other regions urchins with poor or variable quality roe are landed, making it difficult to guarantee both price and supply.

The quality of the gonads is extremely important; premium prices are only paid for high quality produce of the correct color, texture and flavor. In Japan, roe that is most similar to that of native species fetches the best price. It is the unsatisfied demand for good quality roe together with declining landings that has stimulated interest in increasing sea urchin production through cultivation. Current research in echinoculture now focuses on a range of topics from optimizing larval and juvenile culture conditions to developing growout technology and improving the quality of the final product, in particular roe color, through the development of prepared feeds.

As market demand continues to exceed supply, the industry has been looking for suitable new species to cultivate. Among the edible species, the green sea urchin, Psammechinus miliaris, found on the west coast of Scotland, has been identified as a new aquaculture candidate. This species is best suited to the European market where there is a demand for whole live urchins rather than processed roe. Research has already helped establish suitable microalgal diets and stocking densities for the larval stages (Kelly et al. 2000) and in identifying a range of growout options, including the potential for cultivating this species alongside the Atlantic salmon (Kelly et al. 1998).

However, one of the primary obstacles that remains to successful cultivation is the development of a sea urchin diet that promotes both somatic body growth and the production of good quality gonads. Studies of intertidal P. miliaris populations in Scottish sea lochs have shown that this urchin feeds freely on barnacles and mussel beds, in addition to kelp. However, to date, there has been little information available on the exact nutritional requirements of this species, the relative digestibility of its different foods or its dietary energy needs. The data presented here describe the influences of different diets, animal versus plant material, and their effect on the way energy is partitioned between somatic and gonadal growth.

Diets and Experimental Design

Diets were prepared from “natural” and “artificial” ingredients (Table 1). Two natural diets - the brown macroalgae, Laminaria saccharina, and the mussel, Mytilus edulis, - and two artificial diets - a commercial salmon feed and a new sea urchin diet - were tested on young sea urchins. Initial urchin diameter was 12.89±1.9 mm. The feeding trial was conducted over a period of four months. To eliminate the effects of differences in diet consistency, the feeds were first homogenized and then bound with sodium alginate to form a pellet that was stable in sea water and

| Table 1. Proximate analysis of the formulated diets (percent on a dry matter basis). |
|---------------------------------|-----------------|-------|--------|--------|
|                                | Laminaria fronds | Urchin artificial diet | Salmon feed | Mussel diet |
| Protein                        | 1.4             | 27.4      | 37.3      | 30.5      |
| Lipids                         | 14.31           | 6.83      | 31.37      | 7         |
| Carbohydrate                   | 32.41           | 46.44     | 14.06      | 22.5      |
| Ash                            | 29.54           | 18.58     | 19.4       | 17.03     |
| Energy in KJ/g                 | 11.99           | 16.10     | 23.7       | 20.58     |

Psammachinus miliaris between 40 to 50 mm test diameter.
resistant to crumbling when grazed on by the sea urchins.

Individual urchins were placed in containers designed to permit controlled feeding and feces collection. Prior to the experiment, 20 sea urchins were dissected and the calcareous tests and gonads were measured. At the end of the study these measurements were repeated on 12 sea urchins fed each of the four diets.

The mean daily feeding rate and absorption efficiency were determined over a 15 day period. The results showed how diet quality affected both parameters (Table 2). Ingestion rate was stimulated by the mussel diet, which had the highest absorption efficiency. In contrast, the digestibility of the macroalgal diet was very low, although ingestion rates were high. Little of the salmon food was ingested and it was absorbed poorly.

Somatic growth, measured as an increase in test diameter and total wet weight, was greatest in sea urchins fed the new sea urchin diet or the mussel diet (Figures 1, 2, 3). A very small increase in test size was observed when urchins were fed exclusively on the macroalgal diet. The mussel diet induced the growth of large gonads, possibly as a result of the higher proportion of animal proteins present. The commercial salmon feed, with its high lipid and fish protein content, also stimulated an increase in gonad size, although it did not promote somatic growth during this trial.

**Respiration rate**

The energy spent in other metabolic processes was examined by comparing the oxygen consumption development of gametes. Ideally, a well balanced prepared diet would promote fast somatic growth, as shown by an increase in test diameter, in small / young individuals until they reach commercial size. When market size is reached, the feeds should encourage the channelling of ingested energy into rapid gonad development just prior to harvest time.

More information is needed on the nutritional requirements of these echinoderms over their various life stages. Research has only begun to define the optimum levels for the major lipid, protein and carbohydrate components of the diet. Excesses or imbalances in nutrition also can be detrimental to growth. This research has shown that the poor digestibility and low protein content of the macroalgae renders it unsuitable for promoting growth in young sea urchins. In addition, the high concentrations of complex insoluble carbohydrates in the algal feed were poorly absorbed and retained by the sea urchins.

Interestingly, the ingestion rate demonstrated that certain components of the mussel diet may play a role in improving urchin food palatability through chemo-attraction, consequently increasing food intake. Considering the somatic and gonad growth attained in this trial, the data indicate that future formulations could benefit from a mussel flesh component. No significant somatic growth was observed over the time of this experiment in the group fed the commercially prepared salmon diet. This implies that the salmon diet encouraged gonad growth at the expense of somatic growth, whereas the mussel diet promoted both somatic and gonadal growth.

### Table 2. Ingestion rate and absorption efficiency on four different diets.

<table>
<thead>
<tr>
<th>Diet</th>
<th>grs dry wt/day</th>
<th>Absorption percent</th>
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<tbody>
<tr>
<td>Algae Diet</td>
<td>0.03188 ± 0.02078&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.4 ± 7.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Urchin Artificial diet</td>
<td>0.03405 ± 0.02045&lt;sup&gt;a&lt;/sup&gt;</td>
<td>64.2 ± 5.09&lt;sup&gt;b,c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Salmon diet</td>
<td>0.02298 ± 0.01880&lt;sup&gt;c&lt;/sup&gt;</td>
<td>38.09 ± 1.92&lt;sup&gt;c&lt;/sup&gt;</td>
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Figs. 1 (top), 2 (middle) and 3 (lower). Mean test diameter, wet weight and gonad dry weight (± standard deviation) for *Psammechinus miliaris* at the beginning (control group) and at the end of the experiment for the four food types.
Some authors have recommended a diet between 32 and 40 percent protein to promote somatic growth in sea urchins (McBride et al. 1998, Wallace et al. 2001). In this study, carried out over the winter, the high levels of protein and lipids from the salmon food did not appear to provide enough nutrition to help achieve acceptable somatic growth rates. More important, therefore, than the composition of the diet, is the bioavailability of the nutrients to the animals. The highest absorption rates of the feeds correlated with the highest values of energy invested in increasing body and gonad size. Lower levels of absorption, as in the urchins fed on salmon food, correlated to an input only in gonadal development.

**Conclusions**

*Psammechinus miliaris* is an omnivorous echinoderm and it appears that it has a preference for and, perhaps, better conversion efficiency from feeds formulated from animal protein. This reflects the natural feeding behavior of the species. Research continues to develop the technology for all stages of sea urchin production. For the growout phase, we need to have a better understanding of how the nutritional needs of sea urchins change with respect to size and age. In addition, it is likely that natural sources of carotenoid pigments will be required in prepared diets to enhance gonad color.

Naturally, many factors will determine the scale of sea urchin farming in

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growth in any country? Is it research centers with specialists in a range of fields? Or is it single-minded institutions focused on a very specific topic? Certainly, from the data in Mexico, the answer is not very clear.

References

Notes
1Dalila Aldana Aranda is a Professor in the Laboratory of Marine Biology at CINVESTAV IPN Mérida at Yucatán México (Center of research and advances studies of National Polytechnic Institute). She is also Chairman of the Caribbean Marine Laboratories Association, Chairman of the Gulf and Caribbean Fisheries Institute, International Coordinator of the Science and Technology for Development (CYTED). Her research interests are in the ecology and culture of bivalves and gastropods, and coordination and support for the development of research for aquaculture and restoration in marine natural reserves. She can be reached at daldana@mda.cinvestav.mx
2Erick Baqueiro Cárdenas is a Resident Scientist of the Center of Apply Research and Advanced Technology of the National Polytechnic Institute (CICATA-IPN Altamira) at Tamaulipas México. For 27 years he was the chief scientist for the National Program on Mollusks Fisheries for the National Fisheries Institute. His research interests are also bivalves and gastropods, in addition to population and community dynamics of commercial species. He can be reached at erikbaca@hotmail.com

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the future. These will depend on economic issues as well as the weight given to sea urchin research. Continued advances in developing a more detailed energy budget for this sea urchin are crucial to creating an optimal and cost-effective diet. Investigations must focus on the many different aspects of sea urchin culture, including the biology, ecology and behavior of these echinoderms. The findings of these investigations will then help standardize the culture techniques of these new aquaculture species.

Notes
1Scottish Association of Marine Science. Postal address: Dunstaffnage Marine Laboratory, Oban, Argyll, PA34 4AD. Tel: +44 (0) 1631 559232; E-mail address: mdmo@dml.ac.uk

References