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Energetic physiology of the Caribbean scallops *Argopecten nucleus* and *Nodipecten nodosus* fed with different microalgal diets

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Abstract

The Caribbean scallops *Argopecten nucleus* and *Nodipecten nodosus* are currently being placed into mass culture in Colombia. The limited availability of wild seed upon which to base these cultures has promoted research into the development of artificial production of this seed in hatcheries. In support of this effort, we studied the effects of different diets on the physiology of the two scallop species in order to determine the optimal feeding regimes for maintenance of adult specimens in the laboratory. Seven monoalgal diets were tested, including *Chaetoceros calcitrans*, *Chaetoceros muelleri*, *Isochrysis galbana* (Ig), *Nannochloris oculata* (No), *Phaeodactylum tricornutum* (Pt), *Tetraselmis chui* (Tc) and *Tetraselmis tetrahele* (Tt). Four mixed diets were also tested, including *I. galbana*+*C. calcitrans* (Ig+Cc), *I. galbana*+*N. oculata* (Ig+No), *I. galbana*+*T. tetrahele* (Ig+Tt), and *I. galbana*+lipid emulsion of docosahexanoic acid DHA (Ig+lip). All the dietary trials were carried out under uniform conditions of temperature (25 °C), salinity (36‰) and algal concentration (0.45 mg L^{-1}). Physiological variables measured in association with each diet included feeding rates (clearance, ingestion and absorption), oxygen consumption and ammonium excretion rates as well as their scope for growth. The results showed that the best scope for growth for both scallops was obtained with diet Ig since this diet induced the highest feeding rates, accompanied by the lowest oxygen consumption and ammonium excretion. The feeding rates and scope for growth of *A. nucleus* were greater than those of *N. nodosus* for the majority of the diets, which was attributed to a higher rate of water pumping by the former species. Greater capacity for branchial food retention by *A. nucleus* was discarded as a possibility since *N. nodosus* had a greater branchial surface area per unit dry weight than *A. nucleus*. In spite of these differences, the oxygen consumption and the excretion rates were similar between the two scallops which suggested that *A. nucleus* was more efficient in its use of oxygen and retention of body proteins for physiological functioning. Mixed diets or addition of DHA did not permit increases in scope for growth in either of the scallops over that observed using monoalgal diet *Ig*, which suggest that biologically and economically this diet is optimal for the feeding of adult scallops in the laboratory.

Keywords: Scallop; Broodstock maintenance; Microalgae diets; Physiology; Scope for growth; *Argopecten nucleus*; *Nodipecten nodosus*; Caribbean Colombia

1. Introduction

Food quality is one of the most important factors which affect the growth and maturation in scallops (Heasman et al., 1994, 1996; Laing and Psimopoulous, 1998; Bayne and Newell, 1983; Utting and Millican, 1998). According to Epifanio (1979), the presence or absence of certain microalgal species in a diet is more important than its overall content of proteins, lipids, carbohydrates, or amino acids. The best results in experimentation with growth and maturation of scallops have been obtained

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when using diets composed of mixtures of living microalgae (Epifanio, 1979; Navarro and Thompson, 1995; Albentosa et al., 1997; Milke et al., 2004), which are: (a) in the exponential growth phase (Ryan et al., 1999), (b) with diameters between 1 and 15 μm for juvenile and adult specimens (Møhlenberg and Riisgård, 1978) and up to 7 or 8 μm for larvae (Alix et al., 1996); and (c) which are easily digested (Hildreth, 1980; Williams, 1981; Crosby et al., 1989, Alix et al., 1996). It has also been established that the development of the gonad can be increased and the development of larvae promoted by the addition of microalgae rich in polyunsaturated essential fatty acids such as eicosapentanoic (EPA; 20:5$n-3$), docosahexanoic (DHA; 22:6$n-3$), and arachidonic (AA; 20: 4$n-6$) acids (Soudant et al., 1996; Wikfors et al., 1996; Samain et al., 1997; Utting and Millican, 1997; Krupski et al., 1998; Martínez et al., 2000) as well as some lipidic or vitamin supplements (Tian et al., 1993; Coutteau et al., 1996; Navarro et al., 2000).

Direct determination of the effectiveness of given microalgae and supplements which permit maximization of maturation and growth require numerous long-term experiments which place important demands on physical facilities, time, labor, and economic resources. The use of physiological measurements is an alternative method for estimating comparative value among diets, with greater simplicity and in less time, as well as providing more information on the factors responsible of the organism's responses (Widdows, 1985a). The scope for growth is an index very precise and sensible to stress conditions when the measurements are made carefully (Widdows, 1985a; Grant and Cranford, 1991) which is positively correlated with the bivalve growth rate (Bayne et al., 1979; Riisgård and Randlov, 1981) and gonadic ripeness (MacDonald and Bourne, 1987; Navarro et al., 2000).

Various studies of physiological responses related to different types of microalgae have been carried out with filter feeding bivalves, including *Mytilus edulis* (Møhlenberg and Riisgård, 1978; Hildreth, 1980; Ward et al., 2003), *Pecten opercularis*, *Musculus niger*, *Venerupsis pullastra* (Møhlenberg and Riisgård, 1978), *Crassostrea virginica* (Romberger and Epifanio, 1981; Shumway et al., 1985; Riisgård, 1988; Ward et al., 2003) *Ostrea edulis*, *Ensis directus*, *Mya arenaria*, *Arctica islandica*, *Placopecten magellanicus* (Shumway et al., 1985), *Geukensia demissa*, *Spisula solidísima*, *Mercenaria mercenaria* (Riisgård, 1988), *Argopecten purpuratus* (Díaz and Martínez, 1992), *Ruditapes decussatus* (Albentosa et al., 1996), *Argopecten ventricosus* (Lora-Vilchis and Maeda-Martínez, 1997), *Pecten maximus* (Laing, 2004) and *Pteria sterna* (Martínez-Fernández et al., 2004). These studies showed that the physiological rates varied according to the type of microalgae, food supplement and species of bivalve.

Argopecten nucleus and *Nodipecten nodosus* are two scallop species common in the Caribbean Sea bordering Colombia. Culture of these scallops and production of their "seed" under hatchery conditions have come under investigation based on positive results which were produced in preliminary studies on their growth, production, and markets (Urban, 1999). These species are epibenthic filter feeders, which are functional hermaphrodites, inhabiting bottoms between 10 and 100 m in depth. *A. nucleus* is a species of moderate size (~50 mm) and free-living, while *N. nodosus* is a large species (~150 mm) which lives attached to hard substrates. No natural banks of these species have been recorded in the Caribbean off Colombia, and the only large populations are those maintained in culture, produced from the scarce wild seed obtained in artificial collectors (Urban, 1999). Since the lack of naturally occurring seed prevents major development of commercial cultures of these scallops, attempts are now being made in Colombia to produce the necessary seed under hatchery conditions.

The present study is part on an effort to determine the optimal laboratory conditions for maintaining adults of *A. nucleus* and *N. nodosus*, some of whose physiological variables were evaluated during experimental feeding with different monospecific and mixed microalgal diets. These variables included particle clearance rates, ingestion rates, absorption rates, oxygen consumption, ammonium excretion, absorption efficiency and scope for growth.

2. Materials and methods

2.1. Collection and maintenance of test individuals

Each month, about 30 specimens of *A. nucleus* (length 44±4.9 mm and dry tissue weight 1.25±0.4 g) and *N. nodosus* (length 71±11 mm and dry tissue weight 2.45±1.33 g) were obtained from at the bivalve culture station at Neguanje Bay (Lat. 11°20′ N., Long. 74.05′ W.), in the Tayrona National Natural Park (PNNT), Colombia. The sea in this region has water temperatures between 22 and 30 °C, salinities between 33 and 37‰ and seston concentrations between 0.2 and 4.7 mg L^{-1}. Organic content of the seston varies between 15 and 60% (Urban, 1999). The scallops were transported in humid conditions to the Moluscos y Microalgas Laboratory of the Universidad de Magdalena, Taganga (Lat. 11° 16′ N, Long. 74° 11′ W) where their shells were cleaned of encrustations and sediments and each