Nutritional requirements in Brachyura: a review.

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Abstract

Nutritional requirements of brachyuran crabs has been understudied due to the slow development and utilization of these crabs in aquaculture. The present review will try to summarize the main findings in this area and suggest further themes of research involving the use of purified diets and the advances it will promote to further understand the role of calcium intake and biocalcification in these crabs.

Key words: diet, crab, nutrition, nutrient requirements.

Introduction

Food items are of primary importance in the energetic budget of all organisms. In spite of the great importance of nutrition, complete nutritional requirements have only been identified for a remarkably small number of living organisms. These include a variety of plants, some bacteria, fungi, the laboratory mouse and rat, domestic animals and some insects of economic importance (Louw, 1993). This occurs because analysis of individual nutritional elements is an extremely tedious and labor intensive work and involves a deep understanding of the organism's general biology and laboratory holding conditions.

Work on crustacean nutrition has been focused mainly on shrimp, due to their commercial economic importance as human food (Cuzon *et al.*, 1994). Work on nutritional requirements of brachyuran crabs has been neglected because of their slow growth rate, cannibalism and low meat/exoskeleton ratio. A few crabs from commercially important families such as Portunidae, Xanthidae and Cancridae have been cultured. They have been cultivated, however, under semi-intensive conditions. *Scylla serrata* (Forskal, 1775) for example, has been cultured as a secondary product of brackish water fish pond culture in Southeast Asia (Bardach *et al.*, 1972). In this way, minimal nutritional aspects of brachyuran crabs has accompanied the development of aquaculture in this group.

The purpose of this article is to review work that has been done in brachyuran crabs nutritional requirements using purified or semi-purified diets. The morphological and physiological diversity found in Crustacea argues against a unifying theme in this respect.

Nutritional requirements

Protein and amino acids

There are around 20 different amino acids that are the building blocks of proteins. From these, 10 are 'rat' essential, which cannot be synthesized by the organism in question. Coincidentally, it is known that fish, insects and even protozoans have the same requirement for these 10 essential amino acids (Schmidt-Nielsen, 1996). Moreover, it has been found that all 10 essentials such as arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan and valine are also essential at least for *Cancer* and *Uca* (see Dall and Moriarty, 1983).

The type of protein utilized in purified diets is also important as a source of amino acids. Free amino acids offered in the diet are not suitable for growth and increase mortality in *Carcinus maenas* studied by Ponat and Adelung (1980) and it appears that an increase in growth rate occurs if they receive protein instead of free amino acids in the diet. The protein source which best enhanced growth rate in these crabs was casein, while soybean protein did not appear to improve growth at the same level. The protein level added to the diet was constant and around 60%, although these authors did not compare different protein levels to find a quantitative requirement for this nutrient (Ponat and Adelung, 1980). Another study specifically looked at the effect of the dietary protein level in isocaloric diets on growth performance of the Chinese hairy crab, *Eriocheir sinensis*. They found that the optimum dietary protein level for improvement of some fitness parameters in these crabs ranges from 39.0 to 43% of diet dry weight (Mu *et al.*, 1998; see Table 1).

Table 1: Comparison of dietary requirements between shrimps and other three crabs for which data has been available.

Diet component (% dry weight)	**Omnivore shrimps**[1]	***Carcinus maenas*** [2]	***Scylla serrata*** [3]	***Eriocheir sinensis*** [4]
protein	50%	60%	50%	39 - 43%
complex sugar	32%[a]	6 - 10%	19-21%[c]	
sucrose		4%		
cholesterol	1.0%	1.4 - 2.1%	0.5 - 0.79%	0.6%
vegetable lipid		6 - 8%	2 - 4.5%	1%
animal lipid	10%[b]	6 - 9%	4 - 9%	0.5 - 3.0%
vitamin C	0.15%	0.2%	12.1%	

[a] values given as % maximum carbohydrate and fibers

[b] values given as % total lipids

[c] values given as total corn starch and cellulose

[1] Tocon, A. G. J. (1989) - based on average requirement for omnivore shrimps during weight gain.

[2] Ponat and Adelung (1980,1983)

[3] Sheen and Wu (1999), Sheen (2000)

[4] Mu *et al.* (1998)

Field work, especially on herbivorous crabs, had found that usually crabs are nitrogen limited, and a supplementation of protein to their diets enhanced growth rate in *Uca* studied by O'Connor (1992) and *Cardisoma guanhumi* Latreille, 1852 by Wolcott and Wolcott (1987), explaining their slow growth rate in nature and the high incidence of cannibalism in these crustaceans.

Carbohydrates

There is no specific work on carbohydrate requirements in brachyuran crabs. As already known for shrimps, they should require a mixture of complex carbohydrate together with simple sugars (see Table 1 and references). The proportion between starch:protein is important for some shrimps on a ratio of 5:1 (Dall and Moriarty, 1983). McClintock *et al.* (1991) showed, however, that *Callinectes sapidus* possesses digestive carbohydrases such as galactosidases, glucosidases and maltases in the hepatopancreas demonstrating the capacity in these crabs to digest most carbohydrate sources. The Snow crab (*Chionoecetes opilio*) possesses cellulase and chitinase activity in the hepatopancreas, consistent with digestion of complex carbohydrate from vegetable material from both vegetable and animal sources (Brêthes *et al.*, 1994). Although enzyme activities usually reflect the feeding habits and dietary breadth of an animal, it is extremely diverse in different crabs (see Brêthes *et al.*, 1994; McClintock *et al.*, 1991), making it difficult to generalize any trends found. Table 1 illustrates levels of dietary carbohydrate added to *C. maenas* semi-purified diet, although the authors did not specifically looked at a quantitative level in this respect (Ponat and Adelung, 1980 and 1983).

Lipids

All the crustaceans investigated to date, including brachyurans, such as *Callinectes sapidus* and *Cancer pagurus*, lack the ability to synthesize cholesterol (see discussion in Ponat and Adelung, 1983). Quantitative measurements of cholesterol requirements in *Carcinus maenas* have shown that the best growth rates are attained when cholesterol levels are added to the diet at around 1.4 - 2.1% of diet dry weight (Ponat and Adelung, 1983; see Table 1). The Mud crab, *Scylla serrata*, showed higher weight gain when diets had cholesterol levels between 0.5 - 0.79% (Sheen, 2000).

In relation to unsaturated fatty acids, the linolenic group and the linoleic group are essentials and need to be supplied in the diet for improved growth as suggested by work in other crustaceans apart from brachyuran crabs (see references in Dall and Moriarty, 1983). Crustaceans, unlike mammals, cannot elongate linolenic acid to polyunsaturated fatty acids (PUFA) and a supply in the diet is necessary (Cuzon *et al.*, 1994). It appears that a mixture of animal oil to vegetable oil of 2:1 (w/w) at concentrations between 5.3 - 13.8% diet dry weight meet the lipid requirement for the mud crab *S. serrata* studied by Sheen and Wu (1999). Cod liver oil between 6-9% in the food promoted the best growth rate in *C. maenas*, studied by Ponat and Adelung (1983).

Vitamins

Work on vitamin requirements in crustaceans show conflicting results and no work has been done in detail for any brachyuran crab. Vitamins which are essential constituents of prosthetic groups of enzymes appear essential for animals in general, such as thiamin, riboflavin, nicotinamide, pyridoxine, pantothenic acid, biotin and folic acid (Dall and Moriarty, 1983).

Vitamin C (ascorbic acid) seems to be essential for some shrimps such as *Penaeus* but for other shrimps it did not improve growth rate, and the same is seen for water-soluble as well as fat-soluble vitamins (Dall and Moriarty, 1983). Fat soluble vitamins such as A, D, E and K were shown to be essential for penaeid shrimps (He *et al.*, 1992). The only work on vitamin requirements in Brachyura was performed in *C. maenas*, the findings showing that addition of water-soluble vitamins are essential for growth and reduced intermolt period (Ponat and Adelung, 1983). Vitamin C, for example, was added to the diet and held constant at 0.2% diet dry weight (see Table 1). For fat-soluble vitamins the results were conflicting because these authors added cod liver oil simultaneously, whose constituent already contain vitamins from this group.

Minerals

It is generally recognized that crustaceans have the same general mineral requirements as most other animals, although their exact dietary mineral requirements have not been delineated.

Aquatic crabs of marine origin have unlimited mineral supply in sea water. Direct uptake of minerals is usually branchial although dietary entry is another route, even though the two routes have not been specifically compared (Dall and Moriarty, 1983). Terrestrial crabs, on the other hand, obtain their mineral supply mainly from the food. It has been shown that *Birgus latro*, a terrestrial crab, is able to maintain salt balance on very low intakes of salt (Taylor *et al.*, 1993); the same is true for *Gecarcinus lateralis* supplied with low dietary intake of salt (Wolcott and Wolcott, 1988). Low sodium availability in the laboratory did not affect the sodium balance of *Gecarcoidea natalis*, another terrestrial crab (Greenaway, 1994). Although assimilation of salts from the food depends to a great extent on the source of food and its mineral content, work on *G. natalis* has shown that assimilation of salts from fallen leaves was less than 50% for K, Na and Ca and above 50% for Mg. Interestingly, fallen leaves had high Ca and Mg content in contrast to K and Na which are in short supply in these leaves (Greenaway and Linton, 1995). Much work needs to be done with mineral intake in crabs, mainly with Ca and Mg which are the main components of the exoskeleton.

Perspectives for the use of purified diets

Purified or semi-purified diets are an important tool for manipulation of specific dietary nutrient requirements. In this way, physiological responses can be assessed when a specific element is added in excess or in short supply. Calcium carbonate (CaCO3), for example, is the main component of the crustacean exoskeleton and needs to be replaced every molt when the exoskeleton is shed and most of the Ca is lost to the environment. Uptake of Ca during postmolt occurs mainly through the gills for aquatic crabs and through the diet for terrestrial or semi-terrestrial crabs (Wheatly, 1999). To study the specific role of calcium uptake through the digestive system, in contrast to other exchange epithelia such as gills or antennal gland, it is essential to control the intake and output of this mineral and purified diets are excellent instruments for this purpose.

Diversity in crustacean feeding and more specifically within Brachyura poses interesting questions in relation to the most appropriate form that purified or semi-purified diets should be offered to these animals. In aquaculture, feeding via pellets appears to work well for aquatic crustaceans. On the other hand, terrestrial or semi-terrestrial crabs would probably more effectively utilize diets delivered with added agar since it retains more moisture, ameliorating any problems related to hydric balance in terrestrial crabs.

There are some interesting points about the use of brachyuran crabs in aquaculture. For example, the low exoskeleton/meat ratio found in these crabs could be overturned by the use of softshell crabs (postmolt), where the animal can be consumed as a whole because their exoskeleton is still soft. In this aspect, work on calcification and Ca ingestion, which is responsible for hardening of the new exoskeleton, and the understanding of its control mechanisms is essential. Knowledge of factors that can retard the process of calcification and render the animals soft for longer could be potentially interesting avenues for further research.

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References

Bardach, J. E.; Ryther, J. H. and McLarney, W. O. 1972. Aquaculture - The farming and husbandry of freshwater and marine organisms, pp. 868. New York: John Wiley and Sons.

Brêthes, J.; Parent, B. and Pellerin, J. 1994. Enzymatic activity as an index of trophic resource utilization by the snow crab *Chionoecetes opilio* (O. Fabricius). Journal of Crustacean Biology 14: 220-225.

Cuzon, G.; Guillaume, J. and Cahu, C. 1994. Composition, preparation and utilization of feeds for Crustacea. Aquaculture 124: 253-267.

Dall, W. and Moriarty, D. J. W. 1983. Functional aspects of nutrition and digestion. In The Biology of Crustacea. Internal Anatomy and Physiological Regulation, Volume 5 (ed. Bliss, D. E. and Mantel, L. H.), pp. 215-261. New York: Academic Press.

Greenaway, P. 1994. Salt and water balance in field populations of the terrestrial crab *Gecarcoidea natalis*. Journal of Crustacean Biology 14: 438-453.

Greenaway, P. and Linton, S. M. 1995. Dietary assimilation and food retention time in the herbivorous terrestrial crab *Gecarcoidea natalis*. Physiological Zoology 68: 1006-1028.

He, H.; Lawrence, A. D. and Liu, R. 1992. Evaluation of dietary essentiality of fat-soluble vitamins A, D, E and K for penaeid shrimp (*Penaeus vannamei*). Aquaculture 103: 177-185.

Louw, G. N. 1993. Physiological Animal Ecology, pp. 288. England: Longman Scientific and Technical.

Mu, Y. Y.; Shim, K. F. and Guo, J. Y. 1998. Effects of protein level in isocaloric diets on growth performance of the juvenile Chinese hairy crab, *Eriocheir sinensis*. Aquaculture 165: 139-148.

McClintock, J. B.; Klinger, T. S.; Marion, K. and Hsueh, P. 1991. Digestive carbohydrases of the blue crab *Callinectes sapidus* (Rathbun): implications in utilization of plant-derived detritus as a throphic resource. Journal of Experimental Marine Biology and Ecology 148: 233-239.

O'Connor, N. J. 1992. Influence of dietary nitrogen on body chemical composition of the salt-marsh fiddler crabs *Uca pugilator* and *U. pugnax*. Bulletin of Marine Science 50: 404-410.

Ponat, A. and Adelung, D. 1980. Studies to establish an optimal diet for *Carcinus maenas*. II. Protein and lipid requirements. Marine Biology 60: 115-122.

Ponat, A. and Adelung, D. 1983. Studies to establish an optimal diet for *Carcinus maenas*. 3. Vitamin and quantitative lipid requirements. Marine Biology 74: 275-279.

Schmidt-Nielsen, K. 1996. Fisiologia Animal: Adaptação e Meio Ambiente, pp. 600. Livraria Santos Editora.

Sheen, S. S. 2000. Dietary cholesterol requirement of juvenile mud crab *Scylla serrata*. Aquaculture 189: 277-285.

Sheen, S. S. and Wu, S. W. 1999. The effects of dietary lipid levels on the growth response of juvenile mud crab *Scylla serrata*. Aquaculture 175: 143-153.

Taylor, H. H.; Greenaway, P. and Morris, S. 1993. Adaptations to a terrestrial existence by the robber crab Birgus latro L. VIII. Osmotic and ionic regulation on freshwater and saline drinking regimens. Journal of Experimental Biology 179: 93-113.

Tocon, A. G. J. 1989. Nutricion y Alimentacion de Peces y Camarones Cultivados - Manual de Capacitacion. Proyecto Aquila II - Documento de Campo no. 4. Programa Cooperativo Gubernamental FAO – Italia.

Wheatly, M. G. 1999. Calcium homeostasis in Crustacea: the evolving role of branchial, renal, digestive and hypodermal epithelia. Journal of Experimental Zoology 283: 620-640.

Wolcott, D. L. and Wolcott, T. G. 1987. Nitrogen limitation in the herbivorous land crab *Cardisoma guanhumi*. Physiological Zoology 60: 262-268.

Wolcott, T. G. and Wolcott, D. L. 1988. Availability of salts is not a limiting factor for the land crab *Gecarcinus lateralis* (Freminville). Journal of Experimental Marine Biology and Ecology 120: 199-219.

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