Concentration and Composition of Astaxanthin in Black Tiger Prawn *Penaeus monodon* Postlarvae Fed *Artemia* sp. Nauplii or Mauxia Shrimp *Acetes intermedius*

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**Abstract.**—Minced Taiwan mauxia shrimp *Acetes intermedius*, an alternative to brine shrimp *Artemia* sp. nauplii, has long been used as a principal or supplemental feed in prawn hatcheries in Southeast Asia and India. In this study, black tiger prawn *Penaeus monodon* postlarvae were fed with frozen brine shrimp nauplii (diet B) or minced Taiwan mauxia shrimp (diet M) for 4 wk to compare their astaxanthin concentration and composition, survival, and growth. Diet B contained two and a half times more total carotenoid (TC) than diet M, with canthaxanthin as a major (79%) carotenoid, but without astaxanthin, a predominant carotenoid in crustaceans. Of its TC in diet M, 55% was β-carotene and 17% astaxanthin. B-prawn (postlarvae fed with diet B) had a similar growth rate as M-prawn and twice the survival rate as M-prawn. The concentrations of total astaxanthin (TA), free astaxanthin (FA), astaxanthin monoester (MA), and astaxanthin diester (DA) in B-prawn were all higher than those in M-prawn. Except for FA, no reduction of TA, MA, or DA concentration during the feeding interval was found in B-prawn. However, concentrations of TA, FA, MA, and DA in M-prawn all decreased. TC content of the experimental diets had a greater influence on resulting prawn astaxanthin concentration and composition than carotenoid compositions of the diets.

The concentration and distribution of carotenoids in penaeids are affected by intrinsic and extrinsic factors. The intrinsic factors include species (Goodwin 1960), size (Menasveta et al. 1993; Dall 1995; Pan et al. 1999), molting stage (Pan et al. 1999), and the particular tissue or organ (Chien and Jeng 1992; Negre-Sadargues et al. 1993; Dall 1995) of the animal. The extrinsic factors include rearing conditions and feeding interval (Chien and Jeng 1992; Petit et al. 1998), as well as the type and sources of carotenoids from the natural food or applied feed (Yamada et al. 1990; Howell and Matthews 1991; Chien and Jeng 1992; Menasveta et al. 1993; Petit et al. 1997).

Astaxanthin is the predominant carotenoid in penaeids (Katayama et al. 1972; Tanaka et al. 1976; Okada et al. 1994). It comprises about 90% of the total pigments in kuruma prawn *Marsupenaeus japonicus* (Ishikawa et al. 1966) and 86–98% in the exoskeleton of black tiger prawn *Penaeus monodon* (Okada et al. 1994). In penaeids, astaxanthin is present as free astaxanthin (FA), esterified astaxanthin: astaxanthin monoester (MA) and astaxanthin diester (DA), or bound to protein, as carotenoprotein. The distribution of these forms of astaxanthin also varies with species, life history stages and the organ or tissue of the animals (Okada et al. 1994; Dall 1995; Petit et al. 1998; Pan and Chien 2000).

Since crustaceans are unable to synthesize carotenoids *de novo*, astaxanthin or appropriate precursors must be supplied in the diet (Meyers and Latscha 1997). FA has been effectively incorporated into the diet to enhance pigmentation of penaeids (Yamada et al. 1990; Chien and Jeng 1992; Menasveta et al. 1993; Negre-Sadargues et al. 1993; Petit et al. 1997, 1998; Chien et al. 1999). The effectiveness of pigmentation precursors such as β-carotene, echinenone, and canthaxanthin depends on the number of steps in their biosynthesis towards astaxanthin (Tanaka et al. 1976).

Indoor shrimp larval rearing can terminate 2–3 days after mysis stage (M2–3) or...
4–5 days after postlarval stage (PL4–5), when the animals are harvested and further reared in a nursery system for 2–4 wk before final stocking in growout ponds (Singh and Jee 1988). In the nursery, various feeds and feeding regimes are employed, depending on the culture system, natural food availability, and experience and preference of hatchery technicians. Besides artificial feed, brine shrimp nauplii (Artemia sp.) and sergestid shrimp are often used as the main or supplemental nutrition source in the prawn hatchery. In recent years brine shrimp cyst production has been low. The increasing price has further encouraged prawn hatchery managers to turn to sergestid shrimp as an alternative feed. Sergestid shrimp, a neritic epipelagic shrimp, is widely distributed in Asia and Africa coastal waters (Xiao and Greenwood 1993) and comprises 15% of the world shrimp catch (Omori 1978). In Taiwan, a sergestid shrimp, Acetes intermedius, is mainly distributed in the coastal waters of southwestern Taiwan with annual production in the Tungkang fishing port alone ranging from 519–2371 mt (Chiou et al. 2000).

Freshly hatched brine shrimp nauplii, although orange red in appearance, do not contain astaxanthin, only canthaxanthin and echinenone (Hsu et al. 1970; Mantiri et al. 1995; Petit et al. 1997, 1998). However, fresh sergestid shrimp, pale while fresh, still contain astaxanthin, as do most crustaceans (Meyers and Latscha 1997). Improved survival due to dietary astaxanthin supplementation was reported for M. japonicus (Chien and Jeng 1992) and P. monodon (Thongrod et al. 1995; Chien et al. 1999). Significant positive correlation was found between dietary astaxanthin supplementation and growth of P. monodon postlarvae (Thongrod et al. 1995). It is therefore generally accepted that dietary pigments are an important consideration in shrimp larval feeds and feeding strategies. The purpose of this study was to determine the effects of various pigment sources, from these two food organisms, on the concentration and composition of astaxanthin in P. monodon postlarvae.

**Materials and Methods**

**Experimental Design**

A completely randomized design with two treatments and four replications per treatment was used. Frozen brine shrimp Artemia sp. nauplii (diet B) and minced Taiwan mauxia shrimp Acetes intermedius (diet M) were fed to P. monodon postlarvae to compare their survival, growth, and astaxanthin concentration and composition. The resulting prawns were denoted as B- and M-prawns for those fed with brine shrimp and mauxia shrimp, respectively.

**Food and Feeding Regime**

A single batch of brine shrimp cysts (Ocean Star International, Utah, USA) was hatched, collected and quickly frozen at −70 C until ready for use. Only newly hatched brine shrimp nauplii were used since dry weight decreased by 20% and caloric value by 27% if the brine shrimp instar 1 to instar 3 (24 h after hatching) were not fed (Benijts et al. 1976). Frozen brine shrimp nauplii from one large batch were used to control the amount and to avoid batch-to-batch variation in pigment concentrations. Frozen Taiwan mauxia shrimp were bought from Tungkang fishing port. When used, they were defrosted, minced by blender for 2 min, and filtered through a 1-mm stainless steel screen. Particles retained on the screen were scraped off and fed to the shrimp. For both diets, animals were fed three times a day at 0800, 1500, and 2200 h at 5% of estimated shrimp biomass per feeding. The feeding amount was adjusted after at each sampling of shrimp.

**Rearing**

Five-d old postlarvae (PL5) were obtained from the hatchery at the Tungkang Marine Laboratory, Taiwan Fisheries Research Institute, where only dim lighting was provided. After acclimation for 7 d in
a 0.5-ton indoor tank in which nonpigmented, formulated diet was fed, the animals were then transferred to eight 30-L white (inner surface) fiberglass reinforced polyethylene (FRP) tanks to receive their respective treatments. At the beginning when treatments were applied, each tank had 25-L water and 150 animals, or a stocking density of six animals per liter. Animal size was 6.8 ± 1.3 mg. Dissolved oxygen was maintained above 6 ppm by constant aeration, salinity remained around 32 ppt, and temperature around 26 C. Culture water was passed through a 1-μm filter and sterilized by ultraviolet light to eliminate microalgae, a possible source of pigment. Tanks were siphoned daily to remove feces and uneaten feed on the bottom, and one-third of the water was exchanged. The prawns were reared for 4 wk. Every weekend, prawns in each tank were counted and weighed. Also, 10 prawns were sampled, weighed, and frozen at −70 C for later analysis of astaxanthin content.

Nutrition and fatty acid analysis

Percent moisture, crude protein (Kjeldahl nitrogen × 6.25), ash, and crude fat content in both diets were determined by standard methods (AOAC 1990). About 2 g of each diet were used for fatty acid analysis. The extraction of lipids was carried out with a mixture of chloroform and methanol (2:1, v/v; Folch et al. 1957). Mixtures of fatty acids were prepared by saponification with potassium hydrate. Fatty acid methyl esters were prepared by transesterification with boron trifluoride in methanol (Morrison and Smith 1964). The fatty acid methyl esters were analyzed on a gas liquid chromatograph (GC1000, DANI, Milano, Italy) equipped with a flame ionization detector and a Restek’s capillary column (stabilwax-preg) (30 m × 0.25 mm i.d.). Injection temperature and detector temperature was 240 C. Oven temperature was programmed with one ramp initiated at 180 C for 2 min. The rate of increment was 1 C/min and final temperature of the ramp was held at 200 C for 10 min. One μL of each sample containing methyl esters of fatty acids was injected by a microinjector (10 μL) into the GLC. The peak areas and relative retention time were compared with those of the standard methyl fatty acids (GLC68A, NuChek-Prep, Inc., Elysian, Minnesota, USA) and quantified with an integrator (Chromatography Station for Windows, Prague, The Czech Republic) for methyl esters of individual fatty acids.

Pigment Analysis

The samples (both diets and prawn) were weighed, freeze dried, and weighed again to obtain moisture content. The dried sample was ground using a porcelain grinder and placed into a 50-mL polypropylene centrifuge tube. Then, 20 mL of acetone (0.05% butylated hydroxytolune, BHT) was added as solvent (Schwartz and Patroni-Killam 1985; Khachik et al. 1986; Barimalaa and Gordon 1988), and the mixture homogenized (Polytron PT-MR-3000) at 8,000 rpm for 1 min. The contents of each tube were centrifuged (Hitachi 18 PR-52) at 4 C at 12,700 × g for 15 min. An additional 20 mL of acetone solvent was added and the contents centrifuged again. This process was repeated several times until the acetone extract was clear. The acetone extract was transferred to a 250-mL separatory funnel, partitioned with 30 mL n-hexane, which was washed three times with 10% NaCl to remove residual acetone. The hexane was put into a rotary evaporator and the volume was reduced to 10 mL, which was then filtered through a 0.2-μm Millipore filter and distributed to and stored in three 4-mL brown vials.

Astaxanthin was analyzed by high-performance liquid chromatography (HPLC), using a Hitachi L-6200 pump, a silica column (Lichrosorb Si-60 5 micro 250 × 4.6 mm column I.D., E. Merck Company), a Hitachi L-4250 UV-VIS detector at 470 nm, and a Hitachi D-2000 Chromato- Integrator. The operation conditions were: mobile phase, 14% acetone in n-hexane; solvent
flow rate, 1.5 mL/min; and injection volume, 100 µL. The pump program sequence was 0–20 min Mixture A and 20.5–40 min Mixture B. Mixture A was acetone: n-hexane, 14:86, and Mixture B was n-heptane 100%. This system was controlled by a chromatographic data system (Scientific Information Services Corporation), which also integrated the areas under the peaks.

Standards were chromatographically pure astaxanthin, astaxanthin mono- and dipalmitate, canthaxanthin, echinenone, and β-carotene donated by E Hoffmann-La Roche Ltd, Basel, Switzerland. Results were calculated as µg carotenoid/g dry mass of tissue.

Statistical Analysis

Percent survival, weight, and the concentration of TA, FA, MA, and DA were compared between B- and M-prawn for each week by t-test and between the elapsed times for each treatment by Duncan’s multiple range (DMR) tests.

Results

Nutrition, Fatty Acid, and Carotenoid

Both diets contained about 80% moisture (Table 1). Crude protein of diet B was 4.9% in fresh weight or 16.5% in dry weight less than diet M. Diet B had higher crude fat but much lower EPA and DHA than diet M.

Carotenoid composition of brine shrimp nauplii was total carotenoid (TC) 218.1 ± 6.9 µg/g; canthaxanthin 173.2 ± 1.7 µg/g, echinenone 33.0 ± 1.1 µg/g, and β-carotene 10.5 ± 0.3 µg/g. Carotenoid composition of Taiwan mauxia shrimp was TC 79.3 ± 10.2 µg/g, β-carotene 43.6 ± 5.9 µg/g, TA 13.3 ± 0.9 µg/g, DA 1.1 ± 0.6 µg/g, MA 1.1 ± 0.5 µg/g, and FA 10.7 ± 2.1 µg/g.

Survival and Growth

High mortality of shrimp occurred during wk 1 in both treatments. For B-prawn, the survival stabilized after wk 1, but for M-prawn, the survival continued to decline and reached 26.0% in wk 4; half of that for B-prawn (Table 2). For all 4 wk, survival rates of B-prawn were significantly higher than those of M-prawn.

TABLE 1. The composition (dry weight base in parentheses) and fatty acid profiles (expressed as percent of total fatty acids) of Artemia sp. nauplii and Acetes intermedius.

<table>
<thead>
<tr>
<th>Composition (%)</th>
<th>Diet B&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Diet M&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>8.6 (52.1)</td>
<td>13.5 (68.6)</td>
</tr>
<tr>
<td>Crude fat</td>
<td>2.2 (13.1)</td>
<td>1.7 (8.4)</td>
</tr>
<tr>
<td>Ash</td>
<td>1.2 (7.3)</td>
<td>2.9 (1.5)</td>
</tr>
<tr>
<td>Moisture</td>
<td>83.5</td>
<td>80.3</td>
</tr>
<tr>
<td>Fatty acid profiles</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8:0</td>
<td>nd&lt;sup&gt;c&lt;/sup&gt;</td>
<td>nd</td>
</tr>
<tr>
<td>10:0</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>12:0</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>14:0</td>
<td>nd</td>
<td>5.5</td>
</tr>
<tr>
<td>16:0</td>
<td>13.5</td>
<td>26.0</td>
</tr>
<tr>
<td>16:1</td>
<td>10.1</td>
<td>12.6</td>
</tr>
<tr>
<td>18:0</td>
<td>1.5</td>
<td>4.9</td>
</tr>
<tr>
<td>18:1</td>
<td>41.8</td>
<td>6.9</td>
</tr>
<tr>
<td>18:2n6</td>
<td>4.4</td>
<td>nd</td>
</tr>
<tr>
<td>18:3n3</td>
<td>22.2</td>
<td>nd</td>
</tr>
<tr>
<td>20:0</td>
<td>3.1</td>
<td>nd</td>
</tr>
<tr>
<td>20:1</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>20:4n6</td>
<td>nd</td>
<td>5.5</td>
</tr>
<tr>
<td>22:0</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>22:1</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>24:0</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>24:1</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>20:5n3</td>
<td>3.5</td>
<td>25.0</td>
</tr>
<tr>
<td>22:6n3</td>
<td>nd</td>
<td>13.6</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup> Brine shrimp Artemia sp. nauplii.

<sup>b</sup> Taiwan mauxia shrimp Acetes intermedius.

<sup>c</sup> nd, Not detected.

and reached 26.0% in wk 4; half of that for B-prawn (Table 2). For all 4 wk, survival rates of B-prawn were significantly higher than those of M-prawn.

Weight gains after 1 wk were 1,363% and 1,338% for B-prawn and M-prawn, respectively (Table 2). For both prawns, the growth halted in wk 2 but resumed at a fast pace thereafter. The average final weight gains were 4,679% and 4,121% for B-prawn and M-prawn, respectively. There were no significant differences in growth between B-prawn and M-prawn.

Pigmentation

For B-prawn, the decline in TA was only significant until wk 2 (Table 2). TA re-
Table 2. Average ($N = 4$) survival, growth, and concentration of total astaxanthin, free astaxanthin, astaxanthin monoester, and astaxanthin diester in black tiger prawn *Penaeus monodon* postlarvae fed with frozen brine shrimp *Artemia sp.* nauplii (B-prawn) or minced Taiwan mauvia shrimp *Acetes intermedius* (M-prawn) for 4 wk. Values represent mean (SD). Different lower left alphabet indicates significant difference between two prawns at each week. Different upper right alphabet indicates significant difference between time periods of the same prawn.

<table>
<thead>
<tr>
<th>Week</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survival rate (%)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-prawn</td>
<td>100b (0.0)</td>
<td>60.7b (4.7)</td>
<td>56.0b (7.7)</td>
<td>54.0b (8.8)</td>
<td>53.2b (6.9)</td>
</tr>
<tr>
<td>M-prawn</td>
<td>100b (0.0)</td>
<td>50.0b (3.8)</td>
<td>37.7c (2.2)</td>
<td>33.0c (1.7)</td>
<td>20.6c (1.1)</td>
</tr>
<tr>
<td><strong>Weight (mg)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-prawn</td>
<td>6.8d (0.3)</td>
<td>99.5c (50.1)</td>
<td>97.5c (8.5)</td>
<td>195.5b (17.3)</td>
<td>325.0b (41.2)</td>
</tr>
<tr>
<td>M-prawn</td>
<td>6.8d (0.3)</td>
<td>97.8c (19.1)</td>
<td>110.3c (24.1)</td>
<td>220.0b (45.5)</td>
<td>287.5b (51.2)</td>
</tr>
<tr>
<td><strong>Astaxanthin concentration (µg/g)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>67.5c (11.8)</td>
<td>66.1ab (1.4)</td>
<td>62.4b (4.5)</td>
<td>62.3a (4.6)</td>
<td>63.8ab (2.7)</td>
</tr>
<tr>
<td></td>
<td>67.5c (11.8)</td>
<td>41.9ab (5.8)</td>
<td>32.3a (2.8)</td>
<td>34.0a (5.9)</td>
<td>24.9a (5.1)</td>
</tr>
<tr>
<td>Free</td>
<td>3.2a (0.9)</td>
<td>2.2a (0.9)</td>
<td>2.0a (0.5)</td>
<td>1.6a (0.5)</td>
<td>1.5b (0.1)</td>
</tr>
<tr>
<td></td>
<td>3.2a (0.9)</td>
<td>1.3a (0.2)</td>
<td>0.8a (0.0)</td>
<td>0.7a (0.2)</td>
<td>0.6a (0.0)</td>
</tr>
<tr>
<td>Monoester</td>
<td>28.1 (3.6)</td>
<td>27.5 (1.6)</td>
<td>25.0 (4.9)</td>
<td>24.9 (3.4)</td>
<td>25.0 (3.9)</td>
</tr>
<tr>
<td></td>
<td>28.1 (3.6)</td>
<td>18.4a (2.4)</td>
<td>10.5a (3.3)</td>
<td>12.1a (1.2)</td>
<td>8.2b (0.9)</td>
</tr>
<tr>
<td>Diester</td>
<td>37.1 (2.3)</td>
<td>36.4 (3.6)</td>
<td>35.3 (4.1)</td>
<td>35.9 (5.5)</td>
<td>37.2 (1.2)</td>
</tr>
<tr>
<td></td>
<td>37.1 (2.3)</td>
<td>22.3a (3.3)</td>
<td>20.8a (3.1)</td>
<td>21.2a (3.0)</td>
<td>16.1c (4.2)</td>
</tr>
</tbody>
</table>

Remained relatively stable from wk 1 to wk 4. For M-prawn, TA dropped over time, except for wk 3. At the end of wk 4, TA in M-prawn was 39.0% (24.9 µg/g versus 63.8 µg/g) that of B-prawn.

For B-prawn, the decrease in FA was only significant from wk 0 to wk 1. There was no difference in FA from wk 1 to wk 4. For M-prawn, FA in wk 1 decreased 59.4% ((3.2 - 1.3)/3.2). In wk 4, FA in M-prawn had decreased further to 40.0% (0.6/1.5) of that in B-prawn.

For B-prawn there was no significant change in MA throughout the study. For M-prawn, the decline in MA concentration was significant from wk 0 to wk 1 and from wk 1 to wk 2. No further change occurred thereafter. In wk 4, MA in M-prawn was 32.8% of that in B-prawn.

For B-prawn, there was no significant change in DA throughout the study. For M-prawn, the decline was significant from wk 0 to wk 1 and from wk 3 to wk 4. In wk 4, DA in M-prawn was 43.3% of that in B-prawn.

**Discussion**

**Growth**

The rapid weight gain in wk 1 can be attributed to the cannibalistic activity of the shrimp. Daily bottom siphoning revealed that the debris contained few shrimp bodies and mostly unconsumed food and feces. Although diet B had less crude protein and much less EPA and DHA than diet M, there was no difference in growth between B-prawn and M-prawn.

**Survival**

Low survival rates for shrimp in both treatment during wk 1 could be attributed to post-handling mortality and from canni-
balism. During the 7 d before the study began, the postlarvae were transferred twice and experienced a change in diet. Handling stress likely contributed to the high mortality. During wk 1, the postlarvae also could not acclimate to brine shrimp nauplii or minced mauxia shrimp from their original artificial feed. It was observed during the daily bottom siphoning that the debris contained mostly unconsumed food and feces. After wk 1, both kinds of food were readily consumed, little food residue was collected, and cannibalism was minimal.

**Pigmentation**

Several studies have confirmed that brine shrimp cyst, freshly hatched nauplii, and adults contained mainly canthaxanthin and echinenone but no astaxanthin (Hsu et al. 1970; Mantiri et al. 1995; Petit et al. 1997, 1998). Pigment composition of brine shrimp nauplii used in this study was canthaxanthin (79.4% of TC), echinenone (15.1%), and β-carotene (4.8%). These results are similar to those reported by Petit et al. (1997, 1998): canthaxanthin (77%), echinenone (about 15%), and β-carotene (5%). Sergestid shrimp have less astaxanthin than penaeid shrimp. The particular sergestid species used in this study contained mainly β-carotene, 55.0% (of TC), and 33.0% TA. However, astaxanthin is the predominant carotenoid in penaeids (Katayama et al. 1972; Tanaka et al. 1976; Okada et al. 1994).

The decline in TA concentration in M-prawn over time indicates that the dietary pigment source was insufficient to counteract the dilution effect caused by growth. Several studies on the pigmentation of crustaceans suggest that the increase in size, as a result of growth, dilutes the carotenoid concentration when weight and surface area increase faster than the uptake of carotenoid. This dilution effect was observed during development from ovary to protozoea I of *P. semisulcatus* (Dall 1995), during the larval development (Mantiri et al. 1995) and in early postlarvae (stage IV) (McKay 1987) of European lobster *Homarus gammarus*, as well as in juvenile (Pan et al. 1999) and adult (Menasveta et al. 1993) *P. monodon*.

Astaxanthin conversion efficiency of various carotenoids in crustaceans generally follows the biosynthesis scheme. The metabolic pathway from β-carotene to astaxanthin in shrimp, crab, and lobsters is through the stepwise conversion to isocryptoxanthin, echinenone, canthaxanthin, and phoenicoxanthin (Katayama et al. 1971, 1972, Tanaka et al. 1976). The results of several studies indicate that, for pigmentation purposes in cultured crustaceans, astaxanthin is more efficiently absorbed than canthaxanthin (Yamada et al. 1990; Negre-Sadargues et al. 1993; Petit et al. 1998) or β-carotene (Chien and Jeng 1992). Delivery of astaxanthin in pellets is more efficient for maintaining pigmentation than natural canthaxanthin (Petit et al. 1998). The configuration of astaxanthin allows the pigment to be assimilated immediately with low energetic expense (Choubert and Storebakken 1996). Conversion of canthaxanthin to astaxanthin can be fast, although it takes two oxidative steps. As pointed out by Petit et al. (1998), very low amounts of canthaxanthin were found in postlarvae receiving frozen brine shrimp nauplii, probably due to its rapid oxidative transformation into astaxanthin within the animal, as already reported for various crustaceans (Tanaka et al. 1976; Yamada et al. 1990; Negre-Sadargues et al. 1993). Although brine shrimp nauplii did not contain as much astaxanthin as mauxia shrimp, B-prawn had much more TA than M-prawn. This apparent ambiguity can be explained as follows. First, brine shrimp nauplii had 175% more TC than mauxia shrimp. Second, 55.0% of TC in mauxia shrimp was β-carotene, which required more steps to become astaxanthin than did echinenone and canthaxanthin, which together occupied 94.5% of TC in brine shrimp nauplii. Third, despite more efficient uptake of astaxanthin than canthaxanthin, the concentration of total astaxan-
thin in mauxia shrimp, 26.2 µg/g, was far less than canthaxanthin in brine shrimp nauplii, 173.2 µg/g.

The high concentration of carotenoids in brine shrimp nauplii kept up with the dilution effect for each form of astaxanthin in B-prawn. DMR tests found there were no differences in TA, FA, MA, and DA between each 2 wk from wk 1 to wk 4. On the contrary, in M-prawn there was a decreasing trend in TA, FA, MA, and DA concentration from wk 1 to wk 4; the dilution effect applied on each form of the astaxanthin.

The distribution and concentration of different forms of astaxanthin can vary with species, stages, organ or tissue of the animals, as well as food sources. Astaxanthin and its esters were found to be the principal carotenoids in P. monodon, with only small or trace amounts of other carotenoids (Scheidt 1990; Howell and Matthews 1991; Okada et al. 1994). Yamada et al. (1990) examined the effect of dietary carotenoids, i.e., β-carotene, astaxanthin, and canthaxanthin, on pigmentation of M. japonicus. After 8-wk rearing, all three carotenoid sources were deposited mainly as astaxanthin esters (> 84% of TC) in the tissue of around 12-g animal. Mantiri et al. (1995) demonstrated that FA represented the bulk of carotenoids in the embryo, while larval, postlarval, and juvenile stages of H. gamarus exhibited the typical adult carotenoid pattern, in which esterified forms (diester and monoester) of astaxanthin predominate, accounted for 57.7% of total carotenoid in 80-mg postlarvae at stage V. Our results also showed that more than 95% of TA was esterified astaxanthin in prawn from both treatments at all sampling intervals. However, these findings that esterified astaxanthin predominates in whole prawn tissue were not in accord with the pattern of carotenoid composition in tail exoskeleton of 9.9–19.6 g adult P. monodon, which had 49% esterified astaxanthin and 51% FA in average (Okada et al. 1994).

Conclusion

P. monodon postlarvae receiving diet B with 218.1 µg/g of TC were able to maintain tissue levels of total and esterified astaxanthin, but postlarvae receiving diet M with 79.3 µg/g of TC were not able to do so.

TC content of the experimental diets had a greater influence on resulting prawn astaxanthin concentration and composition than carotenoid fractions of the diets.

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Literature Cited


