第 31 卷第 3 期
2007 年 5 月

水 产 学 报
JOURNAL OF FISHERIES OF CHINA

Vol.31, No.3
May, 2007

文章编号:1000 - 0615(2007)03 - 0303 - 08

Biochemical changes during the embryonic development of redclaw crayfish, *Cherax quadricarinatus*

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Abstract: The objective of the present study was to investigate the biochemical changes during embryogenesis of *Cherax quadricarinatus*, in order to evaluate the nutritional requirements of embryos. The carbohydrate content remained a minor constituent of yolk on the whole. The total protein and the total amino acids (TAA) were all observed down-trend during embryonic development. In the essential amino acids (EAA), the content of leucine and arginine acid were relatively high, but in the non-essential amino acid (NEAA), the quantitatively most important were glutamine and aspartic acid. The content of total lipid decreased during embryonic development, and the predominant fatty acids of both neutral lipid and polar lipid were all C16:0, C18:0, C18:1ω9 and C18:3ω3. It's indicated that the carbohydrate played an important role in synthesizing many specific compounds to participate in signal transmission and to form carapace. The protein and lipid were all the dominating construction and energy substances; protein was primarily consumed in the early stages but lipid in the late stages. The saturated fatty acids (SFA) and the monounsaturated fatty acids (MUFA) (C16:0, C18:0, C16:1ω7 and C18:1ω9) were always used for energetic purpose and the polyunsaturated fatty acids (PUFA) (C20:5ω3 and C22:6ω3) were important as structural components of cell membranes and the central nervous system during the development.

Key words: *Cherax quadricarinatus*; embryogenesis; protein; amino acid; lipid; fatty acid

CLC number: S 917 **Document code**: A

1 Introduction

The redclaw crayfish, *Cherax quadricarinatus*, is one of the most important commercial aquaculture native to northwest Queensland and the northern Territory (Australia)[1]. The species' nutritional quality and high economic importance make it highly attractive to many countries. It has been introduced to China successfully since 1992, but has not large-scale commercial culture now[2-3]. The main bottleneck was its spawning rate and hatching rate. Though there is wide biological and cultural knowledge of this resource[4], and many studies have analyzed the biochemical changes in other shrimps[5-22], few studies have been conducted on the culture of the redclaw crayfish' embryonic stages[23].

The female redclaw crayfishes always hold fertilized eggs under their abdomen when hatching. The embryogenesis depends on the nutritional substances reserved in the yolk[4]. Studies on the

Received date: 07-24-2006

Foundation item: Shanghai Agricultural Science & Technology Key Grant[6 - 1(2006)]

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biochemical changes during embryonic development are indicative of the use of yolk nutritive substances during ontogeny, which allow the estimation of nutritional requirements for embryos, and thus can be used in improving brood stock conditions. Moreover, knowledge of the biochemistry and metabolic processes that occur during ontogeny is essential for a complete understanding of crustacean reproduction. Therefore, the present study investigating the carbohydrate, protein, amino acids profiles and lipid biochemistry (lipid classes and fatty acids) during embryogenesis of this species was meaningful.

2 Materials and methods

2.1 Sampling

The parent redclaw crayfishes were collected from Zhejiang Institute of Freshwater Fisheries and fed with a commercial shrimp Pellet, water temperature was controlled at (28 ± 1) ℃ with continuous aeration. Egg-bearing females of *C. quadricarinatus* were collected from March to June in 2003 after being landed in by commercial fishing vessels. Embryogenesis was studied microscopically and divided into six embryonic development stages[3]. Samples for biochemical analyses were according to following phases: Ⅰ, fertilized egg stage; Ⅱ, cleavage and blastula stage; Ⅲ, gastrula stage; Ⅳ, egg nauplius stage; Ⅴ, embryo with well-formed pigments stage; Ⅵ, hatching-preparetion stage. In order to perform the biochemical analyses, different batches of eggs at the same stage of development were pooled. 0.2 g fertilized eggs or embryos were separated from each stage, eggs from six stages in a same female formed a group (chosen randomly, total 6 parallel groups). The samples were stored in liquid nitrogen for later biochemical analyses.

2.2 Water content

For the measurement of water content, six group samples were briefly rinsed with deionized water, blotted on filter paper, put into preweighed silver cartridges, and their fresh weight (FW) was determined immediately on a Mettler UM 3 microbalance to the nearest 0.1 μg. After freeze-drying to constant weight, dry weight (DW) was measured, and the water content was calculated as difference between FW and DW.

2.3 Carbohydrate analysis

For biochemical analyses, the eggs were homogenized in saline solution (1.2 % NaCl). Carbohydrates were then quantified from the supernatant by the Anthrone method[24], using glucose as standard, and absorbance was read at 620 nm using a Spectron Genesys Spectrophotometer.

2.4 Total protein and amino acid analysis

To quantify proteins, the homogenate was first digested with NaOH 0.5 $mol \cdot L^{-1}$. The concentration was determined by the Bradford method[25], using albumin as standard, and absorbance was read at 595 nm using a Spectron Genesys Spectophotometer.

In order to determin the total amino acid profile, egg proteins were hydrolyzed with 6 N hydrochloric acid (containing 0.1 % phenol) at 110 ℃ for 24 h. And then determin by H835-50 Amino Acid Automatic Analyzer[26].

2.5 Lipid classes and fatty acid analysis

The total lipid, lipid classes and fatty acid methyl esters composition were determined using standard analytical procedures. Total lipids were determined according to Folch *et al.*[27], Neutral lipid and Polar lipid were separated according to Skipski *et al.*[28-29]. The fatty acids methyl esters composition was analyzed by Capillary Column Gas Chromatography according to Cheng, *et al.*[30].

2.6 Statistical analysis

One-way ANOVA was performed with the content of biochemical composition of embryo at different developmental stages, and the statistically significant differences were decided using Tukey Test.

3 Results

3.1 Water content

The initial water content of fresh weight was 53.15% ± 1.35%. It increased gradually during embryonic development and reached 81.75% ± 1.79% (FW) in stage Ⅵ. The water content increased total about 28.60 % from stage Ⅰ to

stage Ⅵ (Fig.1).

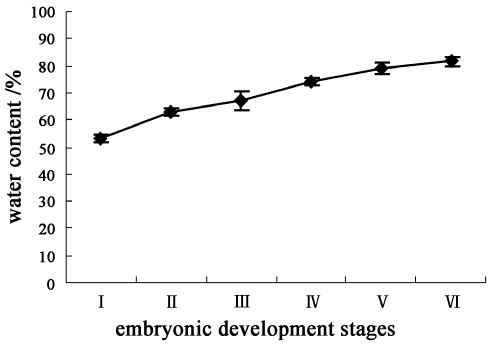

Fig.1 The water content(%, FW) of *C. quadricarinatus* during embryonic development stages. Values are means ± SD. n = 6

3.2 Carbohydrate

The carbohydrate contents remained a minor constituent of yolk on the whole. The value in stage Ⅰ was the highest, only 2.88% ± 0.25% (DW). It decreased significantly ($P < 0.01$) in the earlier stage, from 2.88% ± 0.25% (DW, stage Ⅰ) to 1.16% ± 0.11 % (DW, stage Ⅱ). And then, the carbohydrate content recovered rapidly and reached 2.11% ± 0.08% (DW, $P < 0.05$) in stage Ⅲ. After that, the carbohydrate decreased gradually and the value was only 1.05% ± 0.05% (DW) before hatching (Fig.2).

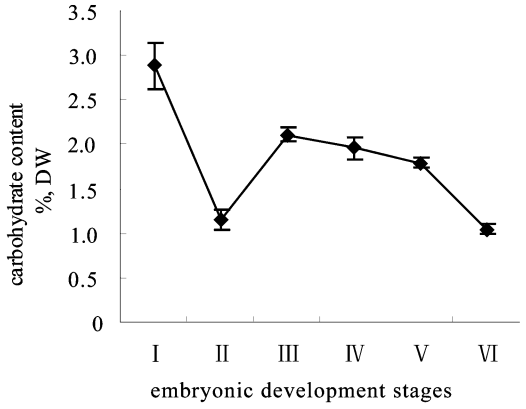

Fig.2 The carbohydrate content(%, DW)of *C. quadricarinatus* during embryonic development stages Values are means ± SD. n = 6

3.3 Total protein and amino acids

The total protein and the total amino acids (TAA) were all downtrend on the whole. The total protein content reduced from (65.32 ± 2.13)% (DW, stage Ⅰ) to (40.28 ± 0.87)% (DW, stage Ⅵ) (Fig.3). The TAA content reduced from (58.05 ±2.57)% (DW, stage Ⅰ) to (47.49 ± 2.25)% (DW, stage Ⅵ) (Table 1). It is noteworthy that the TAA, essential amino acids (EAA) and non-essential amino acid (NEAA) all slightly increased in the stage Ⅱ or Ⅲ ($P < 0.05$). In the EAA, the contents of leucine and arginine acid were relatively high, but the content of methionine was relatively low. In the NEAA, the quantitatively most important were glutamine acid and aspartic acid, and the content of cysteine was relatively low.

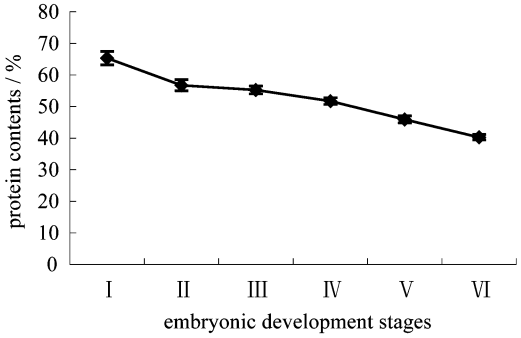

Fig.3 The total protein contents (%, DW) of *C. quadricarinatus* during different embryonic development stages. Values are means ± SD. n = 6

3.4 Lipid classes and fatty acids

The content of total lipid (FW and DW) decreased significantly during embryonic development as a whole. In total lipid, the content of neutral lipid decreased significantly, but the content of polar lipid kept stable during embryonic development (Tab.2).

The fatty acid composition of *C. quadricarinatus* embryos in different developmental stages is shown in Tab.3 and Tab.4. The most important fatty acids of both neutral lipid and polar lipid were the saturated fatty acids (SFA) C16:0 and C18:0, the monounsaturated fatty acids (MUFA) C18:1ω9, and the polyunsaturated fatty acids (PUFA) C18:3ω3, the content of them was predominant. In neutral lipid, the total content of SFA was stable in the early stages, but significantly

increased in the last stage. The total contents of MUFA and PUFA all went down. But in polar lipid, the total contents of SFA and MUFA all decreased during embryonic development, the total content of PUFA was stable in the earlier stages and significantly increased in the last stage.

Tab.1 The contents of amino acids in *C. quadricarinatus* during different embryonic development stages **%, DW, n = 6**

amino acid	embryonic development stages					
	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
EAA						
Thr	2.33 ± 0.21^{a}	2.66 ± 0.17^{a}	2.58 ± 0.22^{a}	2.48 ± 0.18^{a}	2.35 ± 0.15^{a}	2.00 ± 0.42^{b}
Val	3.79 ± 0.18^{a}	4.06 ± 0.32^{b}	4.09 ± 0.15^{b}	3.91 ± 0.26^{a}	3.43 ± 0.24^{a}	3.00 ± 0.31^{c}
Met	0.92 ± 0.29^{a}	1.97 ± 0.18^{b}	2.09 ± 0.14^{b}	2.10 ± 0.22^{b}	1.76 ± 0.33^{b}	1.56 ± 0.12^{ab}
Leu	4.98 ± 0.23^{a}	5.42 ± 0.28^{b}	5.51 ± 0.19^{b}	5.21 ± 0.17^{ab}	4.63 ± 0.28^{a}	4.04 ± 0.26^{c}
Phe	3.80 ± 0.32^{a}	3.89 ± 0.24^{a}	4.06 ± 0.28^{a}	3.56 ± 0.24^{ab}	3.14 ± 0.19^{c}	2.71 ± 0.16^{d}
Lys	4.11 ± 0.15^{a}	4.32 ± 0.12^{a}	4.35 ± 0.15^{a}	4.21 ± 0.16^{a}	3.80 ± 0.18^{ab}	3.28 ± 0.19^{b}
Ile	3.08 ± 0.24^{a}	3.48 ± 0.24^{b}	3.51 ± 0.19^{b}	3.37 ± 0.15^{b}	2.99 ± 0.16^{a}	2.59 ± 0.12^{c}
His	2.42 ± 0.09^{a}	2.51 ± 0.09^{a}	2.61 ± 0.08^{a}	2.23 ± 0.09^{a}	1.99 ± 0.08^{b}	1.72 ± 0.09^{b}
Arg	4.81 ± 0.16^{a}	5.13 ± 0.15^{a}	5.23 ± 0.18^{a}	5.01 ± 0.15^{a}	4.59 ± 0.17^{b}	3.97 ± 0.14^{c}
∑EAA	30.24 ± 1.02^{a}	33.44 ± 1.21^{b}	34.03 ± 1.46^{b}	32.08 ± 1.25^{b}	28.68 ± 1.55^{c}	24.87 ± 1.05^{d}
NEAAA						
sp	7.36 ± 0.22^{a}	7.35 ± 0.19^{a}	7.51 ± 0.39^{a}	7.03 ± 0.55^{b}	6.05 ± 0.44^{c}	5.40 ± 0.39^{d}
Glu	9.17 ± 0.56^{a}	9.46 ± 0.28^{ab}	9.63 ± 0.56^{b}	9.30 ± 0.42^{ab}	7.99 ± 0.46^{c}	7.19 ± 0.53^{d}
Ser	1.62 ± 0.09^{a}	2.73 ± 0.09^{b}	1.92 ± 0.09^{c}	1.82 ± 0.08^{c}	1.43 ± 0.04^{a}	1.45 ± 0.07^{a}
Pro	1.98 ± 0.08^{a}	1.83 ± 0.08^{a}	2.04 ± 0.08^{a}	1.36 ± 0.08^{b}	1.60 ± 0.07^{ab}	1.46 ± 0.09^{a}
Gly	2.56 ± 0.10^{a}	2.57 ± 0.11^{a}	2.65 ± 0.13^{a}	2.57 ± 0.09^{a}	2.24 ± 0.11^{b}	2.10 ± 0.11^{b}
Ala	2.81 ± 0.21^{a}	2.93 ± 0.25^{a}	3.03 ± 0.19^{a}	2.92 ± 0.24^{a}	2.65 ± 0.20^{b}	2.35 ± 0.16^{c}
Cys	0.29 ± 0.02^{a}	0.55 ± 0.02^{b}	0.54 ± 0.05^{b}	0.59 ± 0.06^{b}	0.50 ± 0.02^{b}	0.48 ± 0.05^{b}
Tyr	1.86 ± 0.15^{a}	2.29 ± 0.09^{b}	2.30 ± 0.09^{b}	2.19 ± 0.15^{b}	1.67 ± 0.13^{a}	1.95 ± 0.15^{a}
CRN	0.16 ± 0.03^{a}	0.19 ± 0.02^{ab}	0.15 ± 0.04^{a}	0.24 ± 0.05^{b}	0.22 ± 0.03^{b}	0.24 ± 0.06^{b}
∑NEAA	27.81 ± 2.21^{a}	29.90 ± 2.28^{b}	29.77 ± 2.44^{b}	28.02 ± 2.68^{a}	24.35 ± 2.75^{c}	22.62 ± 1.98^{d}
∑TAA	58.05 ± 2.57^{a}	63.34 ± 3.11^{b}	63.80 ± 3.02^{b}	60.10 ± 2.31^{ab}	53.03 ± 2.53^{c}	47.49 ± 2.25^{d}

Notes: Values are means ± SD. Different superscript letters within rows represent significant differences. ($P < 0.05$, a < b < c < d)

Tab.2 Proportion of lipid during embryonic development of *C. quadricarinatus* **%, *n* = 6**

embryonic development stages	total lipid/ fresh weight	total lipid/ dry weight	neutral lipid/ total lipid	polar lipid/ total lipid
Ⅰ	15.23 ± 0.92^{a}	32.51 ± 1.56^{a}	60.79 ± 2.74^{a}	38.21 ± 1.24^{a}
Ⅱ	10.59 ± 0.67^{b}	28.47 ± 1.32^{b}	59.77 ± 2.38^{ab}	39.23 ± 1.56^{a}
Ⅲ	6.86 ± 0.69^{c}	30.21 ± 1.75^{b}	59.09 ± 2.13^{b}	40.91 ± 1.29^{b}
Ⅳ	7.02 ± 0.87^{c}	27.35 ± 1.63^{b}	48.24 ± 1.84^{c}	41.76 ± 1.35^{c}
Ⅴ	5.21 ± 0.77^{c}	24.67 ± 1.23^{c}	47.72 ± 1.32^{c}	42.27 ± 1.76^{c}
Ⅵ	3.53 ± 0.86^{d}	19.32 ± 1.37^{d}	46.19 ± 1.46^{c}	42.81 ± 1.24^{b}

Notes: Values are means ± SD. Different superscript letters within lines represent significant differences. ($P < 0.05$, a < b < c < d)

4 Discussion

Water is the essential substance of life. In the present study, a significant increasing of water in the eggs during embryogenesis of *C. quadricarnatus* was noted. The embryo swelling was directly related to the decrease of yolk, accompanied by the forming of tissues, organs and systems. High water content is characteristic of aquatic invertebrates. More water can not only maintain the water pressure, but also transport all kinds of nutritional material assisting embryonic metabolism[5,19]. When hatching occurs, additional water enters in the egg as a means to facilitate larvae breaking out from chorion by increasing the internal

pressure[13].

Tab.3　Variation in fatty acid composition of neutral lipid during embryonic development stages of *C. quadricarinatus*　　% , total fatty acids n = 6

fatty acid	embryonic development stages					
	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
C16:02	4.49 ± 1.98^{a}	25.83 ± 1.35^{a}	25.87 ± 1.28^{a}	26.34 ± 1.46^{a}	25.10 ± 1.57^{a}	31.02 ± 2.17^{b}
C18:0	11.08 ± 0.58^{a}	11.67 ± 0.47^{a}	9.79 ± 0.72^{b}	10.07 ± 0.23^{ab}	8.63 ± 0.41^{c}	15.33 ± 0.33^{d}
C16:1ω7	8.16 ± 0.24^{a}	8.33 ± 0.28^{a}	6.99 ± 0.27^{b}	10.07 ± 0.31^{c}	13.05 ± 0.38^{d}	5.66 ± 0.36^{e}
C18:1ω9	32.65 ± 1.57^{a}	30.83 ± 1.52^{b}	34.27 ± 1.29^{a}	33.31 ± 0.89^{a}	33.13 ± 1.78^{a}	29.20 ± 1.64^{b}
C18:3ω3	15.16 ± 0.97^{a}	15.83 ± 0.93^{a}	17.48 ± 0.94^{b}	12.39 ± 0.87^{c}	13.05 ± 0.81^{c}	15.69 ± 0.78^{a}
C20:5ω3	5.19 ± 0.43^{a}	5.42 ± 0.38^{a}	3.85 ± 0.24^{b}	5.65 ± 0.38^{a}	5.42 ± 0.41^{a}	3.10 ± 0.27^{b}
C22:6ω3	3.27 ± 0.19^{a}	2.08 ± 0.17^{b}	1.75 ± 0.28^{c}	2.17 ± 0.19^{b}	1.61 ± 0.13^{c}	—
∑SFA	35.57 ± 2.47^{a}	37.50 ± 2.61^{b}	35.66 ± 2.68^{a}	36.41 ± 2.34^{ab}	33.73 ± 2.37^{c}	46.35 ± 3.02^{d}
∑MUFA	40.81 ± 2.61^{a}	39.16 ± 2.32^{a}	41.26 ± 2.44^{a}	43.38 ± 2.34^{ab}	46.18 ± 2.37^{b}	34.86 ± 2.08^{c}
∑PUFA	23.62 ± 1.78^{a}	23.33 ± 1.64^{a}	23.08 ± 1.28^{a}	20.21 ± 1.35^{b}	20.08 ± 1.37^{b}	18.79 ± 1.27^{c}

Values are means ± SD. Different superscript letters within rows represent significant differences. ($P < 0.05$, a < b < c < d)

Tab.4　Variation in fatty acid composition of polar lipid during embryonic development stages of *C. quadricarinatus*　　% , total fatty acids n = 6

fatty acid	embryonic development stages					
	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ
C16:0	27.09 ± 1.06^{a}	26.81 ± 1.24^{a}	24.51 ± 0.97^{b}	28.18 ± 0.95^{a}	23.71 ± 0.87^{b}	17.19 ± 0.86^{c}
C18:0	4.63 ± 0.42^{a}	4.36 ± 0.29^{a}	3.50 ± 0.35^{b}	5.85 ± 0.42^{c}	5.47 ± 0.37^{c}	5.88 ± 0.36^{c}
C16:1ω7	10.24 ± 0.95^{a}	11.3 ± 0.93^{ab}	9.45 ± 0.86^{a}	12.28 ± 0.82^{b}	9.73 ± 0.84^{a}	—
C18:1ω9	36.30 ± 2.16^{a}	35.44 ± 2.18^{a}	38.52 ± 2.07^{b}	35.40 ± 2.05^{a}	32.22 ± 3.14^{c}	30.77 ± 2.46^{c}
C18:3ω3	17.51 ± 1.27^{a}	16.81 ± 1.25^{a}	20.66 ± 1.12^{b}	12.28 ± 1.17^{c}	26.14 ± 1.08^{d}	46.15 ± 2.07^{e}
C20:5ω3	2.71 ± 0.13^{a}	3.82 ± 0.17^{b}	2.45 ± 0.16^{a}	4.34 ± 0.13^{b}	2.74 ± 0.14^{a}	—
C22:6ω3	1.49 ± 0.08^{a}	1.41 ± 0.07^{a}	0.91 ± 0.08^{b}	1.66 ± 0.08^{a}	—	—
∑SFA	31.71 ± 2.04^{a}	31.17 ± 2.09^{a}	28.01 ± 2.14^{a}	34.03 ± 2.13^{b}	29.18 ± 2.04^{a}	23.07 ± 1.89^{c}
∑MUFA	46.58 ± 2.37^{a}	46.80 ± 2.46^{a}	47.97 ± 2.78^{a}	47.68 ± 2.19^{a}	41.95 ± 2.43^{b}	30.77 ± 2.45^{c}
∑PUFA	21.71 ± 1.25^{a}	22.04 ± 1.14^{a}	24.02 ± 1.47^{ab}	18.28 ± 1.04^{c}	28.88 ± 1.05^{b}	46.15 ± 1.42^{d}

Values are means ± SD. Different superscript letters within rows represent significant differences. ($P < 0.05$, a < b < c < d)

The carbohydrate content found in embryos of redclaw crayfish was very low, the highest value was only 2.88% ± 0.25% (DW, stage Ⅰ). It suggested that carbohydrate was probably not the main energy source during embryogenesis of *C. quadricarinatus*. Similar results have been reported in other crustaceans[6,10,13,18]. The carbohydrate content decreased significantly from stage Ⅰ to stage Ⅱ because that earlier stages of embryogenesis were eggs cleavage and cells differentiation stages[3]. The embryos needed to hydrolyze carbohydrates and synthesize many specific compounds to participate in signal transmission[6-7]. After abundant depletion, the adjusting and accumulating process of the carbohydrate was observed (stage Ⅲ). Developing with the emerging of carapace, the carbohydrate was absolutely necessarily to construct it, and then the content of carbohydrates decreased gradually again.

It is generally considered that protein is the main component and lipid is the main energy source for embryonic development[6]. Similar studies made on crustacean eggs also confirmed that lipid was the major energy reserve[5-6,10-13,16,18]. On the contrary, Babu[7] considered that the protein was the main energy source for embryos after studying on the crab *Xantho bidentatus*. In the present study, protein decreased (about 25.04%, DW) rapidly than lipid (about 13.19%) from stage Ⅰ to stage Ⅵ (Fig.3 and Tab.2). It was obviously that the content of protein was consumed more than that of lipid. Especially in

the earlier stages, protein decreased significantly in contrast to lipid. It is well known that crustaceans are the aquatic invertebrates, whose metabolic end product was ammonia. Most ammonia must come from the protein and dissolves in water very easily[31]. That is to say, redclaw crayfish utilizing protein as energy source is beneficial to its metabolism during embryogenesis. It suggested that the protein probably played a central role in the embryonic metabolism and represented the most important energy source during embryonic development of *C. quadricarinatus*.

Amino acids are precursors of protein and may be used as construction and energy source during embryogenesis. It was noteworthy that the TAA, EAA, NEAA all slightly increased in the stage Ⅱ or Ⅲ. According to the study on the spider crab *Hyas arenus*[13], in the gastrula, and from about 3 months after the onset of organ differentiation until 1 or 2 months before hatching, low embryonic respiration rates as well as microscopically observations indicated the existence of developmental resting periods. The embryos would utilize these period to restore nutrient material and prepare for the forming of tissues, organs and systems in next stages. In the present study, the relatively high contents of leucine acids and arginine acid in EAA, glutamine acid and aspartic acid in NEAA were noted. According to the previous studies on other marine invertebrates[32], glycine, proline, taurine, glutamic and alanine acid were all the dominant nonessential amino acids. Alanine, glycine and arginine acid were proven to be crucial in energy metabolism by maintaining glycolysis through the formation of opines under hypoxic conditions.

In addition to protein use for major energy, lipid was also an important energy source and required for tissue synthesis and for other metabolic tasks during embryonic development. It was mainly used after stage Ⅲ, which was key time of forming the tissues, organs and systems[3]. An obvious decrease in the total lipid and fatty acid contents was also observed in *C. quadricarinatus* embryos. There was a clear trend of decreasing neutral lipids during embryogenesis, because they were also the major energy source and the predominant form of energy storage in the eggs[9,14]. Nevertheless, the content of polar lipid kept stable during embryonic development. Phospholipids were one of the main polar lipid, important as emulsifying agents in biological systems and made up a significant fraction of all biological membranes. They also played an active role in the transport of lipid in the hemolymph and in the absorption of fatty acids within the body. Especially in the later stage, the stable content of polar lipid could be diverted to growth at any point in larval development[17].

The results concerning the utilization of fatty acid classes during embryonic development revealed that SFA and MUFA (C16:0, C18:0, C16:1ω7 and C18:1ω9) were always metabolized at a high rate, being preferentially used for energetic purposes. In concordance with Rosa, *et al*.[20-22], Petersen and Anger[13], Wehrtmann and Graeve[15]. PUFA from the ω3 series, especially C20:5ω3 (DHA) and C22:6ω3 (EPA), has been considered as one of the important fatty acids in decapods eggs[8,15]. EPA is important as structural components of cell membranes and as precursors of prostaglandins, DHA is present in extremely high amounts in the brain and retina, indicating that it may play an important role in the development of the central nervous system of crustaceans[8,33-34].

In summary, the present study suggested that protein was the major component during the embryonic development of *C. quadricarinatus*, followed by lipid and carbohydrate. The protein and lipid were all the dominating construction and energy substances; protein was primarily consumed in the earlier stages but lipid in the later stages. The SFA and MUFA were always used for energetic purpose but PUFA were important as structural components of cell membranes and the central nervous system. The embryos needed to hydrolyze carbohydrate and synthesize many specific compounds to participate in signal transmission. Since the culture of *C. quadricarinatus* is still far from success in many countries, the data presented in this study may be helpful to estimate the biochemistry and metabolic processes and understand the reproduction of

crustacean.

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红螯螯虾胚胎发育过程中的生化成分变化

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摘要:采用生物化学方法对红螯螯虾胚胎发育过程中主要生化成分(糖类、蛋白质及氨基酸、脂类及脂肪酸)进行了测定和分析,以期了解胚胎形态发生与营养需求的关系。结果显示:红螯螯虾胚胎发育过程中糖类总体含量很低。总蛋白与总氨基酸(TAA)的含量在胚胎发育过程中均呈下降趋势。在必需氨基酸(EAA)中亮氨酸(Leu)和精氨酸(Arg)的含量较高,而在非必需氨基酸中谷氨酸(Glu)和天冬氨酸(Asp)的含量较高。总脂在胚胎发育过程中的含量总体呈下降趋势,其中性脂和磷脂的主要脂肪酸均为 C16:0、C18:0 、C18:1ω9 和 C18:3ω3。研究认为:在红螯螯虾胚胎发育过程中,糖类主要参与多种特异复合物的合成以及甲壳构建,这些特异复合物在细胞分化中起着重要的信号传递作用。蛋白质和脂类都是红螯螯虾胚胎发育过程中主要的结构和能源物质,蛋白质主要在早期被利用而脂类主要在晚期起作用。饱和脂肪酸(SFA)和单不饱和脂肪酸(MUFA)(C16:0,C18:0,C16:1ω7 和 C18:1ω9)主要作为能源物质被消耗而高不饱和脂肪酸(PUFA)(20:5ω3 和 22:6ω3)在胚胎发育过程中对于构建细胞膜以及调节中枢神经系统的发育起重要作用。

关键词:红螯螯虾;胚胎发育;蛋白质;氨基酸;脂肪;脂肪酸
中图分类号:S 917 **文献标识码**:A

收稿日期:2006-07-24
资助项目:上海市科技兴农重点攻关项目[6 – 1(2006)]
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