

MATURATION OF PENAEID SHRIMP: DIETARY FATTY ACIDS

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ABSTRACT

Comparisons were made between fatty acid profiles of gonad, digestive gland, and tail muscle samples of immature and mature male and female Penaeid shrimp obtained at sea. The major fatty acids of the lipids from mature ovaries were C₂₀ and C₂₂ polyunsaturated fatty acids. An annelid rich in lipids containing these acids was used as a dietary supplement for shrimp grown in the laboratory, and spawning was achieved with *Penaeus setiferus*. The possible role of polyunsaturated fatty acids in ovarian maturation is discussed.

INTRODUCTION

While shrimp mariculture is practiced in several locations (Wickins, 1976), it is not yet a reality on the Texas coast. The major impediment to the commercial viability of shrimp mariculture in Texas has been the inability to obtain spawning with animals held in captivity. Previous attempts at resolving this problem were largely restricted to variation of physical parameters (salinity, temperature, photoperiod, etc.) and trial-and-error dietary modification. Such approaches were less than successful. We suspected that the problem had a biochemical rather than a physical basis and chose to explore potential dietary solutions.

Penaeid shrimp have a very high lipid content, which is maintained by dietary intake. Of the lipid components, we selected steroids and fatty acids for a preliminary assessment of their role in maturation. There are good reasons for making this choice. Steroids are used by shrimp as molting hormones, sex hormones, and membrane components, yet these animals are unable to biosynthesize the steroid nucleus. Fatty acids are also membrane components and fulfill a significant role in energy storage. A range of these components can be biosynthesized, but others ("essential fatty acids") are needed in the diet of many animals.

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Penaeus setiferus were taken from the Gulf of Mexico off Texas. *Penaeus stylirostris* and *Penaeus vannamei* were taken from the Gulf of Panama. Tissues were separated and frozen for transport to the laboratory.

Tissue samples were homogenized and saponified, and analysis of the fatty acid fractions by gas chromatography and combined gas chromatography-mass spectrometry was performed as described elsewhere (Ward et al., 1979). Steroid fractions have been stored for further investigation.

RESULTS

For most tissues, analyses were performed on samples from two individual specimens. Almost all of the samples contained C₁₄ to C₂₂ saturated and unsaturated fatty acids. Typical fatty acid profiles are given in Table 1 for one female specimen with fully developed ovary and one male specimen for each of the three species. Under the conditions employed for this phase of the project, it was not possible to distinguish the 20:4 from the 20:5 acid or the 22:5 from the 22:6 acids. We have subsequently determined (Middleditch et al., 1979) for gonads of *P. setiferus* that the 20:4 to 20:5 ratio is 0.55 for males and 0.82 for females, and that no 22:5 acid is present. These ratios are comparable to those reported by Joseph and Meyers (1975) for penaeid shrimp meals. The most prominent compounds in the gonads of most of the adult males were 20:4 and 20:5 acids and 4,7,10,13,16,19-docosahexaenoic acid (22:6). These compounds also were usually the major polyunsaturated fatty acids in tissues from the female specimens. Relative concentrations of the 20:4/5 and 22:6 acids from each of the samples analyzed are given in Table 2.

In most cases, there is a striking similarity between the fatty acid profiles of the various species and the different tissues. This is particularly remarkable considering that the specimens were taken from such different locations. This observation encourages us to develop a common dietary regimen for maturation of each of the species.

DISCUSSION

Arachidonic acid (20:4) and the 20:5 acid are precursors of prostaglandins in several animals. Experiments performed in vitro have shown that the 20:3 acid is converted to prostaglandin E₁ in low yield by lobster stomach and gill homogenates (Christ and van Dorp, 1973), but we are not aware of any report of endogenous prostaglandins in crustaceans. Since prostaglandin concentrations are particularly high in human seminal fluid (Bergström and Samuelsson, 1962; Jonsson et al., 1975, 1976), and since these compounds have been implicated in the stimulation of human uterine contractions during labor (von Euler and Eliasson, 1967), it could be suggested that a role of 20:4 and 20:5 acids in the reproduction of shrimp is mediated by prostaglandins. Formation of prostaglandins and prostaglandin analogs by homogenates of sheep vesicular gland was obtained in good yield only with C₁₉, C₂₀, and C₂₁ substrates (van Dorp, 1966b), so it is unlikely that the 22:6 acid is converted to

prostaglandins. A correlation has been noted between the sex ratio of zooplankton and the content of heneicosahexaene in algal feed at the nuplius stage (Paffenhöfer, 1970). It is tempting to speculate that docosahexaenoic acid is the active compound, while the hydrocarbon is merely a decarboxylation product.

TABLE 1. Relative Concentrations (% total fatty acids) of Fatty Acids in Gonads of Selected Specimens: Adult Male and Female with Fully Developed Ovary^a

Acid	<i>P. setiferus</i>		<i>P. stylirostris</i>		<i>P. vannamei</i>	
	Male	Female	Male	Female	Male	Female
14:0	0.2	3.5	--	4.8	0.8	4.0
15:0	0.5	1.2	--	1.2	1.0	1.3
16:1 ^b	2.4	9.7	2.3	8.2	3.5	9.4
16:0	8.3	20.0	6.7	20.0	41.1	22.3
18:1 ^c	10.8	13.0	12.7	14.0	15.7	14.8
18:0	7.8	9.6	7.5	10.3	26.3	8.9
20:4 ^d	30.4	14.6	26.7	12.5	0.3	13.1
20:3	0.9	0.8	--	1.6	2.7	1.1
20:2	4.4	4.8	8.3	3.6	--	2.7
20:1	--	0.9	--	0.8	--	0.9
20:0	0.6	0.3	0.7	0.4	--	0.5
22:6	8.9	18.4	9.0	--	--	9.5
22:4	5.1	5.1	5.9	6.2	--	4.5
22:3	0.9	1.2	1.1	1.1	--	0.7

^aTotals are not 100% because some samples contain acids not listed.

^bNot resolved from 16:2. ^cNot resolved from 18:2.

^dNot resolved from 20:5.

There is strong circumstantial evidence to suggest that the 20:4, 20:5 and 22:6 acids are involved in some capacity in the reproductive process. This prompted us to supplement the diets of shrimp maintained in the laboratory with an annelid (*Glycera dibranchiata*) which is rich in polyunsaturated fatty acids. These experiments (described elsewhere by Brown et al., 1979) led to ovarian maturation and spawning of both ablated and unablated specimens of *P. setiferus*. More than 3 million eggs were obtained during a 10-week period from tanks and raceways containing 200 females and 200 males.

Our success in achieving ovarian maturation and spawning in this manner does not prove that the unsaturated fatty acids have an obligatory role in this process. Further biochemical investigations are in progress to elucidate their significance.

TABLE 2. Relative Concentrations (% total fatty acids) of 20:4 plus 20:5 Acids, and of the 22:6 Acid Tissue Samples

Specimen ^a	Tissue ^b	<i>P. setiferus</i>		<i>P. stylirostris</i>		<i>P. vannamei</i>	
		20:4/5	22:6	20:4/5	22:6	20:4/5	22:6
Female U	G	18.2	11.6	14.3	8.8	NA	NA
		28.8	8.4	13.6	6.7	NA	NA
	DG	13.9	7.1	8.6	6.9	12.8	8.8
		1.5	3.2	8.4	4.2	NA	NA
TM	17.4	13.2	21.3	14.3	19.8	15.8	
	17.5	9.6	22.0	15.3	NA	NA	
Female ED	G	5.1	1.7	10.5	8.6	1.9	0.1
		21.6	8.5	13.5	11.9	14.0	9.7
	DG	6.7	2.8	9.8	8.3	7.9	4.6
		23.9	8.5	6.8	5.1	12.2	7.3
TM	NA	NA	20.7	15.1	8.7	4.4	
	22.7	8.9	20.0	15.9	14.6	9.9	
Female LD	G	13.4	8.5	13.7	9.9	15.5	13.2
		9.9	5.1	14.0	10.8	12.7	8.5
	DG	10.6	6.2	9.9	6.4	9.9	8.0
		10.3	5.7	7.0	4.3	7.4	5.7
TM	20.5	12.7	17.9	10.9	15.1	12.0	
	11.2	4.8	17.0	11.4	12.6	10.1	
Female D	G	14.6	8.9	12.5	9.0	13.1	9.5
		15.0	7.5	9.9	14.4	11.2	
	DG	12.5	6.6	9.5	5.3	9.9	5.8
		22.2	10.2	7.7	5.1	10.4	6.8
TM	15.0	11.1	15.8	11.7	10.9	9.1	
	18.6	10.7	17.6	12.9	11.3	8.2	
Male	G	30.4	22.5	26.7	18.4	2.7	--
		32.7	18.3	27.5	17.6	NA	NA
	DG	14.7	8.2	12.8	11.4	5.5	3.7
		17.6	7.6	13.0	11.4	5.3	3.2
TM	19.5	2.5	19.5	15.8	18.2	13.9	
	NA	NA	21.2	16.4	19.1	14.3	

^aU = undeveloped ovary, ED = early developing ovary, LD = late developing ovary, D = developed ovary.

^bG = gonad, DG = digestive gland (hepatopancreas), TM = tail muscle. Data are given for samples from two individual specimens in most instances.

SUMMARY

Male and female specimens of *P. setiferus*, *P. stylirostris*, and *P. vannamei* caught at sea contain lipids with relatively high concentrations of 20:4, 20:5 and 22:6 acids. Since these compounds were suspected of having a role in the reproductive process, the feed of laboratory animals (*P. setiferus*) was supplemented with annelids rich in polyunsaturated fatty acids. Ovarian maturation and spawning were obtained.

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