

VITAMIN A AND CAROTENOIDS IN CERTAIN INVERTEBRATES

VI. CRUSTACEA: PENAEIDEA

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Fisher (1957) has pointed out the possible connexion between the richness in vitamin A and the pelagic existence of species of the orders Amphipoda and Mysidacea of the malacostracan Crustacea. The most striking example is seen in the Eucarida, of which the more benthic Decapoda are nearly all poorer in vitamin A than the pelagic Euphausiacea. In the Decapoda, species of the suborder Natantia do, however, lead a more or less pelagic life. Of its two constituent groups the Penaeidea swim more actively than the Caridea. The Penaeidea were believed by Calman (1910) to be primitive decapods and similarities in larval development indicated a possible affinity with the Euphausiacea. Gordon (1955) has recently produced further evidence of this relationship, particularly between euphausiids and sergestids, from the structure of the petasma, spermatophores, thelycum and photophores in the two groups. Taxonomically as well as ecologically, then, the penaeids may be said to lie between the rest of the decapods and the euphausiids, and we wished to compare these groups in their biochemical relationships so far as vitamin A and carotenoids were concerned. Moreover, some species of penaeids are the basis of important fisheries and knowledge of their vitamin A content might be of some economic value.

Published work on vitamin A and carotenoids in penaeids is confined almost entirely to that of Grangaud and his colleagues at Algiers on *Aristeomorpha foliacea* and *Aristeus antennatus*. These workers reported in several papers, summarized by Grangaud (1951) and Grangaud & Massonet (1951), on the anti-xerophthalmic activity of astaxanthin isomers from these species. Grangaud, Massonet & Sansac (1954) also mentioned the presence of vitamin A in concentrations of 5-10 i.u./g in the eyes and ovaries and of 30 i.u./g in the intestines of *Aristeomorpha foliacea*, *Aristeus antennatus* and *Parapenaeus longirostris*. In an earlier paper we reported vitamin A at a concentration of 5.7 i.u./g in the eyes of *Trachypenaeus membranaceus* from Naples (Fisher, Kon & Thompson, 1953).

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MATERIAL AND METHODS

Apart from *Trachypenaeus membranaceus* just mentioned we have analysed samples of thirteen species of penaeids, of which seven belong to the family Penaeidae and six to the Sergestidae. Details of these samples are given in Table 1.

Carotenoids and vitamin A were measured by the recent modification (Fisher, Kon & Thompson, 1956) of our usual method (Fisher, Kon & Thompson, 1952). None of the groups analysed contained enough specimens for biological assay or for the separation of vitamin A isomers carried out for some other Eucarida (Fisher, Kon & Plack, 1957; Wald & Brown, 1956-7; Wald & Burg, 1956-7).

RESULTS

Detailed results for the Penaeidae are shown in Table 2 and those for the Sergestidae in Table 3.

DISCUSSION

The results in the tables show that, apart from *Gemmadas borealis*, all the species analysed contained vitamin A in at least one sample. The concentration of the vitamin in the Penaeidae was relatively low and its distribution varied. In some species it was confined to the eyes, in others to the bodies, and only in *Parapenaeopsis atlantica* was it found in both eyes and bodies. In the Sergestidae, vitamin A concentrations in most species tended to be higher than in the Penaeidae, but distribution varied in the different species.

All species of both families contained appreciable quantities of carotenoids and some, for example, *Petalidium foliaceum*, were very rich in them. The more actively pelagic sergestids usually contained only astaxanthin or its esters with an occasional trace of xanthophylls. There was a greater variety of carotenoids in the penaeids. Fisher, Kon & Thompson (1954) reported a similar difference between decapods with several different carotenoids and the more pelagic euphausiids in which only astaxanthin or its derivatives were found.

The results show that the concentration of vitamin A in penaeids is similar to those in other Natantia. Fisher (1957) has shown that, of the species we have examined, more Penaeidea (13 out of 14 listed in his paper) contain vitamin A than Caridea (29 out of 36). The results now presented indicate that Sergestidae with a more oceanic existence may be richer in vitamin A than Penaeidae, but more individuals of more species must be analysed in order to establish any such relationship.

Taken as a whole the vitamin A values for the Sergestidae would place them between the other Penaeidea (and other Decapods) and the Euphausiacea, a biochemical classification in agreement with current taxonomical views. *Penaeus aztecus*, the basis of an important shrimp fishery in Texas, contained modest amounts of vitamin A, all in the eyes and so of no importance in human nutrition.

TABLE 1. SPECIES, NUMBERS, SOURCES AND METHODS OF PRESERVATION OF PENAEIDS ANALYSED

Sample no.	Species	No. of specimens per sample	Locality	Ship	Date	How caught	Method of preservation
1	<i>Amalopenaeus elegans</i> Smith	16	39° 39' N., 12° 08' W.	<i>Discovery II</i>	16. xi. 1954	2 m stramin net	BF
2	<i>A. elegans</i> Smith	4	Bay of Biscay	<i>Sarsia</i>	18-24. vii. 1955	2 m stramin net	BF
3	<i>Funchalia woodwardi</i> Johnson	3	Madeira	—	17. v. 1955	From stomach of sword-fish	DA
4	<i>Gemadas borealis</i> Rathbun	7	32° 45' N., 117° 38' W.	<i>Paolina T</i>	4. iv. 1956	Isaacs-Kidd mid-water trawl	BF
5	<i>G. parvus</i> Bate	4	Bay of Biscay	<i>Sarsia</i>	28-30. iv. 1955	2 m stramin net	BF
6	<i>G. parvus</i> Bate	27	North Atlantic	<i>Discovery II</i>	vi. 1955	2 m stramin net	BF
7	<i>G. parvus</i> Bate	107	Bay of Biscay	<i>Sarsia</i>	18-24. vii. 1955	2 m stramin net	BF
8	<i>Parapenaeopsis atlantica</i> Balss	25	Gold Coast	—	Spring 1955	—	DS
9	<i>Penaeus aztecus</i> Ives	44	Gulf of Mexico	—	24. vi. 1952	—	DA
10	<i>Plesiopenaeus edwardsianus</i> (Johnson)	1	Madeira	—	1. vi. 1955	Deep fishing line	DA
11	<i>Petalidium foliaceum</i> Bate	29	32° 45' N., 117° 38' W.	<i>Paolina T</i>	4. iv. 1956	Isaacs-Kidd mid-water trawl	BF
12	<i>Sergestes arcticus</i> Kröyer	4	North Atlantic	<i>Discovery II</i>	16. xi. 1954	2 m stramin net	BF
13	<i>S. arcticus</i> Kröyer	4	North Atlantic	<i>Discovery II</i>	vi. 1955	2 m stramin net	BF
14	<i>S. arcticus</i> Kröyer	1	58° 54' N., 13° 44' W.	<i>George Bligh</i>	20. vii. 1955	Prawn trawl	BF
15	<i>S. arcticus</i> Kröyer	289	Bay of Biscay	<i>Sarsia</i>	18-24. vii. 1955	2 m stramin net	BF
16	<i>S. atlanticus</i> Milne Edwards	2	North Atlantic	<i>Discovery II</i>	16. xi. 1954	2 m stramin net	DA
17	<i>S. atlanticus</i> Milne Edwards	12	North Atlantic	<i>Discovery II</i>	vi. 1955	2 m stramin net	DA
18	<i>S. bisulcatus</i> Wood-Mason	6	32° 45' N., 117° 38' W.	<i>Paolina T</i>	4. iv. 1956	Isaacs-Kidd mid-water trawl	BF
19	<i>S. robustus</i> Smith	6	North Atlantic	<i>Discovery II</i>	16. xi. 1954	2 m stramin net	BF
20	<i>S. robustus</i> Smith	12	Bay of Biscay	<i>Sarsia</i>	18-24. vii. 1955	2 m stramin net	BF
21	<i>S. similis</i> Hansen	15	North Pacific	<i>Horizon</i>	26. v. 1953	1 m silk net	DS
22	<i>S. similis</i> Hansen	25	32° 45' N., 117° 38' W.	<i>Paolina T</i>	4. iv. 1956	Isaacs-Kidd mid-water trawl	BF

BF: boiled (Fisher, Kon & Thompson, 1952) and kept frozen until arrival at Shinfield laboratory.

DA: eyes dissected off and both parts preserved separately in alcohol; kept at low temperature, sent by air to London and immediately taken to Shinfield.

DS: dissected as above and preserved in alcohol, but sent by sea to England. *Parapenaeopsis atlantica* was stored in ship's refrigerator but *Sergestes similis* came by ordinary surface mail.

TABLE 2. OIL, VITAMIN A AND CAROTENOIDS IN SOME PENAELIDAE

Sample no.	Species	Av. wt. (mg)	Oil (%)	Vitamin A				Total carotenoids		β -carotene ($\mu\text{g/g}$)	Other carotenoids
				$\mu\text{g/spec.}$	$\mu\text{g/g}$	% ester	% alcohol	$\mu\text{g/spec.}$	$\mu\text{g/g}$		
1	<i>Amalopenaeus elegans</i>										
	Eyes (pairs)	0.14	9.1	0	0	0	0	0.28	2000	0	A
	Bodies	66	4.1	0.054	0.83	100	0	17	260	0	AE
	Total	66	4.1	0.054	0.82	100	0	17	270	0	AE
2	<i>A. elegans</i>										
	Eyes (pairs)	0.10	—	0	0	0	0	0.075	750	0	A
	Bodies	74	0.34	0	0	0	0	3.7	50	0	A
	Total	74	0.34	0	0	0	0	3.8	50	0	A
3	<i>Funchalia woodwardi</i>										
	Eyes (pairs)	240	3.1	0	0	0	0	2.8	12	0	A
	Bodies	17500	10	1.7	0.098	100	0	506	29	0.19	AE, C
	Total	17800	11	1.7	0.097	100	0	509	29	0.19	AE, C
4	<i>Gennadas borealis</i>										
	Eyes (pairs)	0.40	11	0	0	0	0	1.4	3500	0	A
	Bodies	350	12	0	0	0	0	9.0	26	0	AE
	Total	350	12	0	0	0	10	30	0	AE	
5, 6	<i>G. parvus</i>										
	Eyes (pairs)	0.13	19	0.012	88	0	100	0.38	2900	0	AE
	Bodies	69	3.2	0	0	0	0	3.9	57	0	AE, X
	Total	69	3.3	0.012	0.17	0	100	4.3	62	0	AE, X
7	<i>G. parvus</i>										
	Whole specimens	12	4.6	0	0	0	0	2.3	190	0	AE, X
8	<i>Parapenaepsis atlantica</i>										
	Eyes (pairs)	57	2.9	0.11	1.9	100	0	0.53	9.3	0	AE
	Bodies	6100	0.73	0.19	0.032	0	100	93	15	0.086	AE, C, X
	Total	6100	0.77	0.30	0.049	37	63	94	15	0.085	AE, C, X
9	<i>Penaeus aztecus</i>										
	Eyes (pairs)	51	11	0.22	4.3	67	33	0.96	19	0	A
	Bodies	4000	0.66	0	0	0	0	56	14	0.013	AE, C, X
	Total	4000	0.79	0.22	0.054	67	33	57	14	0.013	AE, C, X
10	<i>Plesiopenaeus edwardsianus</i>										
	Eyes (pairs)	470	3.5	0.69	1.5	100	0	50	150	0	AE
	Body	138000	10	0	0	0	0	19000	140	Trace	AE, C, X
	Total	138500	10	0.69	0.0050	100	0	19000	140	Trace	AE, C, X
—	<i>Trachypenaeus membranaceus*</i>										
	Eyes (pairs)	100	3.0	0.23	2.2	—	—	0.54	5.3	0	A
	Bodies	8700	—	—	—	—	—	—	—	—	—
	Total	8800	—	—	—	—	—	—	—	—	—

* Result previously reported by Fisher *et al.* (1953) for comparison.

A = astaxanthin; AE = astaxanthin or its esters; C = carotene; X = xanthopyll.

TABLE 3. OIL, VITAMIN A AND CAROTENOIDS IN SOME SERGESTIDAE

Sample no.	Species	Av. wt. (mg)	Oil (%)	Vitamin A				Total carotenoids		Carotenoids present
				µg/spec.	µg/g	% ester	% alcohol	µg/spec.	µg/g	
11	<i>Petalidium foliaceum</i>									
	Eyes (pairs)	0.57	27	0	0	0	0	0.51	900	AE
	Bodies	180	14	0.37	2.0	10	90	60	330	AE, X
	Total	180	14	0.37	2.0	10	90	60	330	AE, X
12	<i>Sergestes arcticus</i>									
	Eyes (pairs)	0.88	2.9	0	0	0	0	5.0	5700	AE
	Bodies	170	2.2	0	0	0	0	11	65	AE
	Total	170	2.2	0	0	0	0	16	94	AE
13	<i>S. arcticus</i>									
	Eyes (pairs)	0.40	—	0	0	0	0	0.17	420	A
	Bodies	31	3.2	0	0	0	0	1.8	58	AE
	Total	31	3.2	0	0	0	0	2.0	63	AE
14	<i>S. arcticus</i>									
	Eyes (pairs)	1.0	30	0	0	0	0	0	0	—
	Body	23	17	0	0	0	0	3.0	130	AE
	Total	24	18	0	0	0	0	3.0	120	AE
15	<i>S. arcticus</i>									
	Eyes (pairs)	0.65	12	0.0065	10	50	50	0.0048	7.4	A
	Bodies	99	2.1	0.024	0.24	25	75	3.7	37	AE, X
	Total	100	2.1	0.031	0.31	32	68	3.7	37	AE, X
16	<i>S. atlanticus</i>									
	Eyes (pairs)	1.3	—	0.24	184	100	0	1.1	820	A
	Bodies	320	3.4	0	0	0	0	47	140	A
	Total	320	3.4	0.24	0.74	100	0	48	150	A
17	<i>S. atlanticus</i>									
	Eyes (pairs)	0.33	—	0.078	238	100	0	0.12	360	A
	Bodies	91	1.3	0	0	0	0	4.1	44	AE
	Total	91	1.3	0.078	0.85	100	0	4.2	46	AE
18	<i>S. bisulcatus</i>									
	Eyes (pairs)	6.3	9.5	0	0	0	0	1.4	220	A
	Bodies	510	5.1	3.4	2.3	80	20	127	84	AE, X
	Total	520	5.2	3.4	2.2	80	20	128	84	AE, X
19	<i>S. robustus</i>									
	Eyes (pairs)	0.37	4.5	0	0	0	0	0.63	1700	AE
	Bodies	74	0.22	0	0	0	0	11	140	AE
	Total	74	0.25	0	0	0	0	11	150	AE
20	<i>S. robustus</i>									
	Eyes (pairs)	0.84	—	0	0	0	0	0	0	—
	Bodies	230	6.0	0.092	0.40	67	33	5.7	25	AE, X
	Total	230	6.0	0.092	0.40	67	33	5.7	25	AE, X
21	<i>S. similis</i>									
	Whole specimens	52	2.9	0	0	0	0	0.65	12	AE
22	<i>S. similis</i>									
	Eyes (pairs)	2.7	—	0.076	28	63	37	0	0	—
	Bodies	210	3.1	0.55	2.6	83	17	20	97	AE, X
	Total	210	3.1	0.63	3.0	80	20	20	96	AE, X

β-carotene absent from all groups.

A = astaxanthin; AE = astaxanthin or its esters; X = xanthophyll.

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SUMMARY

Vitamin A and carotenoids were measured in six species of Penaeidae and seven species of Sergestidae.

Vitamin A was present in at least one sample of all species except *Gennadas borealis* at concentrations mostly of the same order as previously found in other Decapoda, but usually higher in the Sergestidae than in the Penaeidae.

Carotenoids in the Penaeidae included astaxanthin and its esters, carotenes and xanthophylls, but only astaxanthin or its esters with occasional traces of xanthophylls were found in the Sergestidae.

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