AQUABYTE SECTION

Aquabyte **is the Newsletter of the Network of Tropical Aquaculture Scientists**

EDITORIAL

During my travels to various developing countries in recent months, I have met with a number of network members and visited libraries in their institutions. All have been very appreciative of the information they are getting through *Naga* and the network. Unfortunately, libraries in some of these countries are inadequately stocked with fisheries journals and publications, limiting the availability of latest information and literature to scientists. We encourage members to write to us of their research activities which could be published in *Aquabyte* and any assistance they need with literature. This way, members would be able to exchange information - which is the objective of the network.

M.V. Gupta

Zooplankton: Its Biochemistry and Significance in Aquaculture

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Abstract

Zooplankton are an important food source for many species of fish. They can provide an inexpensive alternative to other commercial feeds. Zooplankton have several advantages, among them a faster growth and greater feed efficiency for some species. The flavor and texture of fish are also improved with zooplankton as feed. Further research is needed on the chemical composition of zooplankton, the development of zooplankton-based dry diets and the effects of the replacement of fish meal with zooplankton meal for commercial aquaculture species.

Introduction

Most fish and prawn species depend on zooplankton at some stage of their life span and some even feed exclusively on zooplankton during their entire life. For example, about 90% of herring *(Clupea harengus)* food consists of zooplankton (Arrhenius and Hanson 1993). Success in culturing planktivorous fish fry depends primarily on the zooplankton and their composition and density (Geiger 1983; Fernando 1994). Zooplankton have been used to rear fry and larvae (De Pauw et al. 1981; Watanabe et al. 1983), especially for species which normally do not accept artificial feeds (Bryant and Matty 1980). Both live and frozen zooplankton have been used in commercial and experimental aquaculture (Brett 1971; Sargent et al. 1979; Dabrowski 1984; Alam et al. 1993). Zooplankton are a valuable source of protein, amino acids, lipids, fatty acids, minerals and enzymes. They could be an inexpensive ingredient to replace expensive fishmeal and an alternative to more expensive brine shrimp. Few studies have been made on the chemical composition of zooplankton although such information is vital to evaluate a species and its suitability as feed in aquaculture (Watanabe et al. 1983; Millamena et al. 1990). This article reviews the biochemistry of zooplankton and in particular freshwater zooplankton and its significance to aquaculture.

Media for Zooplankton Culture

Various organic wastes and nutritional media have been used to grow zooplankton. *Daphnia* sp. have been mass-cultured using rice bran (De Pauw et al. 1981), horse manure (Ivleva 1973), swine manure (De Pauw et al. 1980) and algae (De Pauw et al. 1980) while different wastes have been used to rear *Moina* sp. (Ventura and Enderez 1980; Lee et al. 1983; Punia 1988; Shim 1988). Rotifers have been mass-cultured with yeast and marine *Chlorella* (Ohara et al. 1974; Kitajima and Koda 1976; Lubzens et al. 1989). In addition to culturing, zooplankton can grow abundantly in nutritionally enriched waste and

Werribee sewage treatment lagoons (WSTL) is the largest treatment plant in Australia. Zooplankton grow in abundance in the last stage of water purification process and remove phosphorus and nitrogen from the system. One hundred tons of wet zooplankton contain about 100 kg of phosphorus and 1 t of nitrogen.

sewage waters where special equipment is required to harvest the resource.

Biochemical Composition of Zooplankton

The biochemical composition of some freshwater zooplankton is presented in Tables 1 and 2. The composition of natural zooplankton can vary seasonally (Khan and Qayyum 1971; Donnelly et al. 1994) and be affected by the level of nutrients in water (Vijverberg and Frank 1976). The average protein content of different zooplankton species are: *Daphnia* sp. 63.32±10.3; *Moina* sp. 67.49±6.25; *Brachionus* sp. 62.03±3.42; and *Cyclops* sp. 63.98±13.31. The protein, lipid and phosphorus contents in most zooplankton appeared to satisfy the requirements of fish. Yurkowski and Tabachek (1979) reported that the essential amino-acid content in *Daphnia pulex*, *Diaptomus* sp. and *Cyclops* sp., for example, is equal to or greater than the requirement of Chinook salmon. Lysine and methionine, which are known to be the most limiting amino acids in feeds (Dabrowski and Rusiecki 1983; New 1987), are present in appreciable quantity in zooplankton studied (Table 2).

The fatty acid composition of zooplankton is influenced by the fatty acid composition of their diet (Watanabe et al. 1983; Proulex and de la Noüe 1985) and may change as the seasonal succession of phytoplankton species occurs (Jeffries 1970). The high ratio of unsaturated fatty acids to saturated fatty acids of zooplankton may denote that zooplankton is a quality food for rearing commercial fish larvae (Lokman 1994). Both docosahexaenoic acid (DHA) and eicosaptaenoic acid (EPA), essential for growth and development of fish (Kanazawa et al. 1979; Tucker 1992), are present in considerable amounts in zooplankton (Lokman 1994). However, Watanabe et al. (1983) reported that some species might be deficient in DHA (eg. *Daphnia* sp.), while others might be deficient in DHA and EPA *(Moina* sp.) Enrichment of zooplankters could improve the n-3 highly unsaturated fatty acid (HUFA) content of zooplankton (Watanabe et al. 1983; Tucker 1992; Fernández-Reiriz et al. 1993).

Performance of Fish Fed on Zooplankton

Crayfish *(Cherax albidus)* (Jones et al. 1995), common carp and Atlantic salmon grew faster when fed on zooplankton (Holm and Moller 1984; Kamler et al. 1992) as compared to formulated diets. LeBrasseur (1969) observed higher growth rate and better food conversion in Chum salmon (*Oncorhynchus nerka*) fed on live zooplankton. Watanabe et al. (1983) reported an excellent protein efficiency ratio (PER) value of rainbow trout fed with *Daphnia* and *Moina*.

Herring and trout assimilated more than 90% of the dry matter when fed on frozen calanoid copepod, *Calanus finmarchicus* and were healthier (Sargent et al. 1979), with good sur-

Harvesting zooplankton from WSTL using special harvester "Baleen". Water is filtered through screens to harvest the desired zooplankton.

vival (Dabrowski et al. 1984) and growth (Fermin and Bolivar 1994). However, surprisingly, comparatively lower growth and feed efficiency were reported for sockeye salmon fed with frozen zooplankton (Brett 1971). Trout showed better growth and feed efficiency when fed on Antarctic krillmeal than fish meal. The PER was also better with the krillmeal (Koops et al. 1979).

Advantages and Disadvantages of Using Zooplankton

Zooplankton are regarded as an important source of carotene. Fish fed on copepods and krill were found to be more pigmented than those fed on commercial feed (Sargent et al. 1979; Spenelli 1979), which is important for marketing of salmonids. The flavor and texture of fish were also found to have improved with feeding zooplankton (Spenelli 1979). Live zooplankton contain enzymes (amylase, proteases, exonuclease, esterase) which play an important role in larval digestion (Munilla-Moran et al. 1990). Zooplankton enhances metamorphosis of larvae (Fluchter 1980), and are nutritious, tastier and easily digestible. In addition, the chilled and frozen zooplankters float making it easier for the fish to catch (Tucker 1992). The high content of amino acids (Dabrowski and Rusiecki 1983), enzymes (Horváth et al. 1979; Lauff and Hofer 1984) and water (Lemm 1983) in zooplankton are all positive qualities for start feeding (Holm and Moller 1984). Free amino acids are present in the frozen fluid that surround the zooplankton and these form a powerful attractant and appetite stimulant for fish (Dabrowski and Rusiecki 1983; Mearns 1986; Tucker 1992).

On the other hand, free and protein bound amino acids could be lost from frozen zooplankton through freeze-damaged cells (Anon. 1970; Grabner et al. 1981/1982) which might affect the growth of fish (Brett 1971). Rapid freezing might avoid both soluble and insoluble organic loss from fragmented pieces (Anon. 1970). The rate of leaching (Grabner et al. 1981/1982) could be reduced by producing the freeze-dried zooplankton in pellet form. The high fiber content in some zooplankton may depress the digestibility of other nutrients (Koops et al. 1979). The sulphur amino acids (methionine and cysteine) found in most zooplankton are not sufficient to meet the expected requirements of fishes (Yurkowski and Tabachek 1979; Dabrowski and Rusiecki 1983).

Conclusion

Diets deficient in essential nutrients, especially lipids (D'Abramo and Lovell 1991), are thought to be the main reason for the high mortality rate of young fish. Zooplankton are rich in essential amino and fatty acids (EPA and DHA) and should be sufficient as a first source of nutrients required by fish for growth (Kanazawa et al. 1979). Zooplankton have been widely used for rearing larvae and fry, and most studies indicated that the fry performed better when fed with live zooplankton than with dry artificial diets (Dabrowski 1984; Dabrowski et al.

Table 1. Biochemical composition of zooplankton (percentage of total organic matter on dry matter basis (Mois=moisture; CP=crude protein; CF=crude fat; CHO=carbohydrate; P=protein; Ca=calcium).

	Mois.	CP	CF	CHO	Ash	P	Ca	Source
Cladocerans								
Daphnia spp.	89.3	70.1	13.07	-	6.53	1.40	0.19	1
Daphnia spp.	-	45.0	04.5	-	-	-	-	8
Daphnia sp.	89.3	70.1	13.07	-	6.54	1.46	0.21	11
D. magna	-	68.0	13.1	17.9	-	-	-	5
D. magna	-	45-50	-	-	-	-	-	16
D. magna	-	56.3	10.7	-	-	-	-	9
D. pulex (pond)	91.2	65.6	23.6	-	-	-	-	6
D. pulex	94.0	50.0	16.66	-	20.0	-	-	1
D. pulex	94.0	49.7	16.3	4.9	19.3	-	-	2
D. pulex (horse manure)	89.8	66.8	20.9	-	-	-	-	6
D. pulicaria	-	78.1	14.6	7.30	-	-	-	5
D. longispina	-	75.6	12.2	12.2	-	-	-	5
D. obtusa	-	67.5	8.60	23.9	-	-	-	5
D. hyalina	-	69.4	24.3	6.3	-	2.0	-	7
D. carinata (sewage)	92.9	54.3	7.29	27.1	11.3	1.14	-	10
Moina spp. (bakers' yeast)	87.2	68.55	22.13	-	-	1.41	0.08	1
Moina spp. (yeast + manure)	89.0	77.85	11.81	-	-	1.1	0.09	1
Moina spp. (poultry manure)	87.9	59.12	27.22	-	-	1.32	0.16	1
M. micrura	-	65.1	8.7	-	-	-	-	4
M. australiensis (sewage)	93.7	64.8	7.73	20.65	6.82	1.11	-	10
M. micrura (chicken manure)	-	69.53	9.94	-	6.80	-	-	14
Copepods								
Cyclops spp.	-	69.3	14.8	-	-	-	-	9
C. vicinus	-	69.2	6.0	24.8	-	-	-	5
C. sphacricus	-	73.2	18.5	8.4	-	-	2.1	7
Diaptomus spp.	92.4	57.89	25.06	-	5.26	-	-	1
D. gracills	-	76.0	9.4	14.6	-	-	-	5
D. castor	-	85.0	9.5	5.5	-	-	-	5
Tigriopus japonicus (natural)	88.6	71.00	22.80	4.38	0.79	0.09	-	1
T. japonicus (yeast)	87.2	69.48	20.48	4.67	0.94	0.16	-	1
T. japonicus (yeast+chlorella)	86.6	67.16	23.81	3.73	0.97	0.15	-	1
Calanus plumchrus	89.0	58.20	21.80	0.50	9.40	-	-	15
Rotifers								
Brachionus plicatilis (yeast)	90.8	64.3	15.1	-	10.9	1.11	0.16	11
B. plicatilis (yeast+ chlorella)	87.9	63.7	23.1	-	6.78	1.38	0.11	11
B. plicatilis (chlorella)	86.4	58.1	27.4	-	6.62	1.54	0.15	11
B. plicatilis	-	56.92	12.8	16.68	13.60	1.42	-	17
Euphausids								
Krillmeal	-	56.2	9.2	-	15.9	2.08	4.00	3
Krillmeal	-	41.8	13.0	11.3	-	1.48	-	13
Euphausia pacifica	82.0	33.33	27.77	-	27.77	1.61	2.57	1
E. superba	-	56.3	10.7	-	15.0	2.0	3.6	12
Recommended dietary nutrient levels for fish								
Omnivorous fish								
Fry (0.05g)	-	42	8	-	-	1.0	2.5	18
Fingerling (0.5-10g)	-	39	7	-	-	0.9	2.5	18
Juvenile (10-50g)	-	37	7	-	-	0.8	2.0	18
Carnivorous fish								
Fry (0.05g)	-	52	16	-	-	1.0	2.5	18
Fingerling (0.5-10g)	-	49	14	-	-	0.8	2.5	18
Juvenile (10-50g)	-	47	14	-	-	0.8	2.0	18

Source: 1. Creswell 1993; 2. Yurkowski and Tabachek 1979; 3. Koops et al. 1979; 4. Tay et al. 1991; 5. Blazka 1966; 6. Mims et al. 1991; 7. Vijverberg and Frank 1976; 8. Anon. 1996; 9. Aqua Company,U.K (pers. comm.); 10. Kibria et al. (unpubl.); 11. Watanabe et al. 1983; 12. Lukowicz 1979; 13. Hilge 1979; 14. Alam et al. 1993; 15. Brett 1971; 16. De Pauw et al. 1981; 17. Millamena et al. 1990; 18. Tacon 1990.

Table 2. Essential amino acid composition of zooplankton (% total amino-acid as dry matter) compared with essential amino acid requirements of omnivorous and carnivorous fish. (Arg=arginine; His=histidine; Iso=isoleucine; Leu=leucine; Lys=lysine; Met=methionine; Phe=phenylalanine; Thr=threonine; Try=trypsin; Val=valine)

	Arg	His	Iso	Leu	Lys	Met	Phe	Thr	Try	Val	Source
Cladocerans											
Daphnia sp.	5.7	1.9	5.6	7.4	7.5	2.5	4.2	-	1.3	6.2	1
Daphnia sp.	5.7	2.6	3.9	7.9	7.4	1.7	9.2	3.5	-	5.2	
Daphnia sp. (*Chlorella*+yeast)	4.91	1.23	7.09	10.8	8.37	1.29	3.78	3.87	0.67	10.1	10
D. pulex	5.6	2.1	5.6	8.2	8.8	2.3	4.7	5.2	-	6.4	2
D. pulex (807-946 µm)	2.67	1.15	1.72	2.8	3.34	0.94	2.31	2.67	-	2.44	4
D. pulex (854-1360 µm)	14.4	7.6	1.4	1.4	2.4	2.2	1.3	2.1	-	2.2	4
D. magna (waste water)	2.23	0.57	0.91	1.51	1.84	0.03	1.84	1.64	-	1.85	7
D. carinata (sewage grown)	3.37	1.65	2.60	5.22	3.35	1.46	2.52	2.86	0.71	3.27	9
Moina sp.	5.1	1.6	2.5	6.0	5.8	1.0	3.6	-	1.2	3.2	1
Moina sp.	5.1	1.6	2.5	6.0	5.8	1,0	3.6	3,8	1.2	3.2	6
Moina sp.	7.0	2.2	3.4	8.3	8.0	1.4	4.9	5.2	1.6	4.4	8
Moina sp. (*Chlorella*+yeast)	11.7	1.94	5.9	11.1	6.9	1.11	3.31	6.1	0.95	8.42	10
M. australiensis (sewage grown)	3.01	1.37	2.67	4.54	3.34	1.13	2.67	2.79	0.76	3.56	9
Copepods											
Cyclops strenus (540-730 µm)	4.69	1.45	2.69	4.29	5.52	1.14	2.97	2.88	-	3.31	4
C. strenus (810-1147 µm)	2.41	0.98	1.79	2.69	2.26	0.88	1.98	2.00	-	2.75	4
Tigriopus japonicus	5.2	1.6	2.5	5.0	5.7	1.1	3.5	-	1.1	3.2	1
T. japonicus	5.2	1.6	2.5	5.0	3.3	1.1	3.5	3.8	-	3.3	5
T. japonicus	6.9	2.1	3.3	6.6	7.5	1.5	4.6	5.0	1.5	4.3	8
Rotifers											
Bachionus sp. 200 µm	4.04	3.16	2.9	4.89	5.87	1.48	4.11	2.83	-	4.46	4
B. plicatilis	4.6	1.5	3.5	6.0	5.9	0.9	3.8	-	1.3	6.2	1
B. plicatilis	6.3	2.1	4.8	8.2	8.2	1.2	5.3	4.7	1.6	5.5	8
B. plicatilis (yeast)	4.2	1.4	2.9	5.5	5.7	0.8	3.5	3.5	3.0	3.6	6
B. plicatilis (yeast+*Chlorella*)	4.5	1.4	2.8	5.3	5.8	0.8	3.4	3.1	3.0	3.5	6
Euphausiacea											
Antarctic krill, *Euphausia superba*	6.22	2.30	5.10	7.77	8.58	3.03	6.47	4.70	1.50	5.90	5
Minimum essential amino acid requirements in fish											
Omnivorous fish											
Fry (0.05 g)	1.81	0.76	1.18	2.15	2.48	0.81	1.22	1.35	0.25	1.40	11
Fingerling (0.5-10 g)	1.68	0.71	1.09	1.99	2.31	0.75	1.13	1.26	0.23	1.30	11
Juvenile (10-50 g)	1.59	0.67	1.04	1.89	2.19	0.71	1.07	1.19	0.22	1.23	11
Carnivorous fish											
Fry (0.05 g)	2.24	0.95	1.46	2.66	3.08	1.00	1.61	1.67	0.31	1.73	11
Fingerling (0.5-10 g)	2.11	0.89	1.37	2.50	2.90	0.94	1.42	1.58	0.29	1.63	11
Juvenile (10-50 g)	2.02	0.85	1.32	2.40	2.78	0.90	1.36	1.51	0.28	1.56	11

Source: 1. Herpher 1988; 2. Yurkowski and Tabachek 1979; 3. Block 1959; 4. Dabrowski and Rusiecki 1983; 5. Suzuki 1981; 6. Watanabe et al. 1983; 7. Allen and Allen 1981; 8. Creswell 1993; 9. Kibria et al. (unpubl.); 10. Kokova et al. 1990; 11. Tacon 1990.

1984; Dave 1989). In larviculture, artificial diets may perform poorly due to poor digestibility (Dabrowski 1984; Lauff and Hofer 1984), deficiency of growth factors (Higgs et al. 1985), insufficient stimulation of feeding behavior (Holm 1986) or pollution due to overfeeding (Dave 1989). Carotenoids in zooplankton may function as an antioxidant in eggs and larvae (Tacon 1981) in addition to pigmenting the flesh.

Further research is needed for the development of zooplankton-based dry diets in the form of pellets in order to avoid the possible leaching of nutrients from frozen zooplankton. Experiments should also be carried out to study the effects of total or partial replacement of fish meal with zooplankton meal for commercial aquaculture species. It is also essential to test for the existence of heavy metals, pesticides and other contaminant levels in fish carcass fed on waste/sewage grown zooplankton.

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