Lipid composition and fatty acid profiles of wild caught and cultured black tiger shrimp, *Penaeus monodon*, in Sri Lanka

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Abstract

Lipid levels and fatty acid profiles in the flesh of wild caught and cultured *Penaeus monodon* were analyzed using gas chromatography. The mean percentage lipid level of cultured *P. monodon* ($3.9\% \pm 0.2$ dry weight) was not significantly higher than that of the wild caught *P. monodon* ($3.7\% \pm 0.1$). The fatty acid profiles of wild caught and cultured shrimp were found to be significantly different from each other. The predominant fatty acids found in the flesh of both groups were Palmitic acid (16:0), Stearic acid (18:0), Oleic acid (18:1n-9), Vaccenic acid (18:1n-7), Linoleic acid (18:2n-6), Arachidonic acid-Omega-6 (20:4n-6), Eicosapentaenoic acid-Omega-3 (20:5n-3), and Docosahexaenoic acid-Omega-3 (22:6n-3). Total saturated fatty acids ($38.12\% \pm 1.59$) and polyunsaturated fatty acids ($18.31\% \pm 1.57$) contents were not significantly different in wild caught and reared *P. monodon* while monounsaturated fatty acid levels ($44.82\% \pm 1.41$) were significantly higher in wild caught *P. monodon*. Palmitoleic (C16:1), Heptadecenoic (C17:1), Myristoleic (C14:1), Vaccenic (C18:1n-7), Hexadecatetraenoic (C16:4n-3), Alpha linoleic Omega-3 (C18:23n-3), Stearidonic (C18:4n-3), Docosatetraenoic (C22:4n-6), Docosapentaenoic (C22:5n-6) and Arachidonic Omega-6 (20:4n-6) contents were significantly high in wild caught shrimp, while Linoleic Omega-6 (18:2n-6) and Docosahexaenoic Omega-3 (22:6n-3) were significantly high in cultured shrimp.

Introduction

At present, aquaculture is the world's fastest growing food-production sector, providing an acceptable, lipid and protein rich supplement and substitute for wild aquatic animals and plants. Over the last decade, aquatic production from capture fisheries and aquaculture has increased steadily (Subasinghe et al. 1999).

Shrimp aquaculture is one of the fastest growing export oriented industries in the South East Asian region (Yap 1999). Shrimp culture in Sri Lanka commenced in the mid 1980's in the coastal belt of the North western province (Jayasinghe 1991; Jayasinghe and Macintosh 1993). According to the MFOR (2002), 4500 ha of land has been allocated for shrimp farming in Sri Lanka. As of 2002, Sri Lankan production of shrimp from capture and culture resources was about 14,450 Mt, about 32% of which were from cultured fisheries (MFOR 2002).

Crustaceans play an important role in human nutrition and health and carries fat soluble vitamins such as vitamin A and D (Kinsella 1987, Edirisinghe et al. 1998). Crustacean lipids are a good source of both saturated and unsaturated fatty acids (O'Leary and Matthews, 1990). Some of these are Linoleic acid (18:2n-6), Arachidonic acid (20:4n-6), Eicosapentaenoic acid (20:5n-3) and Docosahexaenoic acid (22:6n-3) (Kinsella 1987). Humans need essential fatty acids, such as linoleic acid and its elongated desaturated product, arachidonic acid, for membrane structure, fluidity, skin integrity and many vital physiological functions related to cardiovascular, renal, pulmonary, secretory, digestive, reproductive and immune systems. Arachidonic acid is also the precursor of the prostanoids and leukotrienes (Kinsella 1987). It is claimed that eicosapentaenoic acid reduces the risk of heart attack by competing with arachidonic acid for the enzyme responsible for production of prostaglandins and thromboxanes (Kinsella 1986), and thus producing fewer of the platelet-aggregating eicosanoids (Johnston and Hunter 1987). Omega-3 polyunsaturated fatty acids might also have an anti-inflammatory effect (Robinson et al. 1987).

Although cultured and wild caught shrimps are frequently consumed by the people still there is a lack of information on muscle lipid composition and fatty acid profile of *P. monodon*. Therefore the present study was carried out to compare the lipid and fatty acid profiles in the flesh of wild caught and cultured *P. monodon* in Sri Lanka.

Materials and Methods

Monthly samples of *P. monodon* of the size group (17.1 - 18.4 cm) were collected from the wild and culture facilities along the North Western coast of Sri Lanka from November 1999 to December 1999. The samples were immediately chilled in crushed ice, packed in polythene bags and

transported to the laboratory at NARA. From each group twenty samples (total of 202 wild caught individuals and 267 cultured individuals) were analysed. Four replicates were taken from each sample. In the laboratory, the total length and weight of each individual were measured and the carapace and tail were removed.

Lipid was extracted and purified using the modified Bligh and Dyer method (Radin 1981). About 2 g of flesh were blended in a cold hexane:isopropanol mixture (3:2 v/v, 2ml), filtered (medium porosity sintered glass Buchner funnel) and the filtrate was extracted once with 0.47 M Na_2SO_4 to remove isopropanol. The hexane layer was removed, concentrated by γ -vaporation at -18°C under nitrogen and vacuum-dried (0.58 bar, 50°C) for two days. After weighing, samples were suspended in hexane (5ml) and held at -20°C (Hanson and Olly 1965).

The fatty acid methyl esters (FAMES) of these lipids were prepared by base hydrolysis followed by trans-esterification (Berner and Berner 1994) and these FAMES were separated by capillary column gas chromatography (Shimadzu GC-14A gas chromatograph) on a supelco wax 10 fused silica capillary column (length 30 m, 0.32 mm ID, 0.25 μm film thickness).

The percentage lipid and fatty acid composition between the two groups of shrimps were compared statistically using the student t-test (Mead and Curnow 1987).

Results

Mean body weight and mean length of cultured and wild caught *P. monodon* were not significantly different from each other ($P > 0.05$). The muscle lipid content of cultured *P. monodon* ranged from 3.7% to 4.1% dry weight while that of wild caught shrimp ranged from 3.6% to 3.8%. The mean lipid content in cultured shrimp ($3.9\% \pm 0.2$) was not significantly higher than that of wild caught shrimp ($3.7\% \pm 0.1$) ($P > 0.05$) (Table 1).

The percentage compositions of saturated, monounsaturated and polyunsaturated fatty acids of the wild caught and cultured *P. monodon* are given in Table 2. The most abundant fatty acids in both groups were Palmitic (16:0), Stearic (18:0), Oleic (18:1n-9), Linoleic (18:2n-6), Arachidonic (20:4n-6), Eicosapentaenoic (20:5n-3) and Docosahexaenoic (22:6n-3) acid. Among these Palmitic (16:0) was the most abundant (18-21% of total fatty acids). Saturated fatty acids (SFAs) contributed to the major proportion of the fatty acid profile and ranged from 35%-39% of total fatty acids. The percentage of saturated fatty acids in wild caught *P. monodon* ($38.12\% \pm 1.59$ of total fatty acids) was not significantly different from that of the cultured individuals ($37.29\% \pm 1.09$ of total fatty acids) ($P > 0.05$). This saturated fatty acid group consisted of Myristic acid (C14:0), Pentadecanoic acid (C15:0), Palmitic acid (C16:0), Margaric acid (C17:0) and Stearic acid (C18:0).

Table 1. Mean $\pm$ SD of whole body weight, length, moisture and lipid contents of wild caught and cultured *P. monodon*.

	Weight (g)	Total Length (cm)	Moisture (%)	Lipid (%)
Wild caught	45.92 $\pm$ 6.8 ^a	18.1 $\pm$ 0.7 ^a	75.9 $\pm$ 0.1 ^a	3.7 $\pm$ 0.1 ^a
Cultured	36.70 $\pm$ 0.6 ^a	18.5 $\pm$ 0.1 ^a	74.8 $\pm$ 0.3 ^a	3.9 $\pm$ 0.2 ^a

In the same column, the values indicated with the same superscript are not significantly different from each other.

Wild caught *P. monodon* showed a significantly higher content of monounsaturated fatty acids (MSFAs) (18.31% $\pm$ 1.57 of total fatty acids) than that of cultured individuals ($P < 0.05$). Of all the monounsaturated fatty acids, only Myristoleic acid (C14:1) (0.93% $\pm$ 0.22), Palmitoleic acid (C16:1) (4.76% $\pm$ 0.97), Heptadecenoic acid (C17:1) (0.81% $\pm$ 0.27) and Vaccenic acid (C18:1n-7) (3.59% $\pm$ 0.64) were significantly higher in wild caught shrimps than in cultured shrimp ($P < 0.05$).

Polyunsaturated fatty acids (PUFAs) were the predominant group of the fatty acids in *P. monodon*. Although cultured shrimp recorded a high percentage of PUFAs (44.82% $\pm$ 1.41 of total fatty acids) than wild caught shrimps (38.77% $\pm$ 2.05), the difference was not found to be statistically significant ($P > 0.05$). Comparison of the PUFAs showed that the cultured shrimp has significantly higher ($P < 0.05$) percentage of Linoleic acid Omega-6 (18:2n-6), (14.32% $\pm$ 3.1 of total fatty acids) and Docosahexaenoic acid-Omega-3 (DHA) (22:6n-3) (13.35% $\pm$ 1.16 of total fatty acids) while wild caught *P. monodon* has significantly higher ($P < 0.05$) percentage of Hexadecatetraenoic acid (16:4n-3), Alpha linolenic acid-Omega-3 (18:3n-3), Stearidonic acid (18:4n-3), Arachidonic acid Omega-6 (20:4n-6), Docosatetraenoic acid (22:4n-6) and Docosapentaenoic acid (DPA) (22:5n-3).

Amounts of n-3 PUFAs which recorded in wild caught and cultured *P. monodon* were not significantly different from each other ($P > 0.05$). However, the amount of n-6 PUFAs in cultured *P. monodon* was significantly higher than that of wild caught *P. monodon* ($P < 0.05$). However, the n3/n6 ratios among the two groups were not significantly different from each other ($P > 0.05$).

Table 2. Fatty acid composition (Mean % $\pm$ SD) in wild caught and cultured shrimp.

Fatty acid		Wild caught	Cultured
Saturated fatty acids			
Myristic	14:0	2.03 $\pm$ 1.17	1.13 $\pm$ 0.02
Pentadecanoic	15:0	0.99 $\pm$ 0.35	0.38 $\pm$ 0.02
Palmitic	16:0	18.60 $\pm$ 3.09	21.38 $\pm$ 0.73
Margaric	17:0	3.88 $\pm$ 1.50	2.22 $\pm$ 0.05
Stearic	18:0	12.60 $\pm$ 4.19	11.72 $\pm$ 0.38
Total		38.12 $\pm$ 1.59	37.29 $\pm$ 1.09
Monounsaturated fatty acids			
Myristoleic*	14:1	0.93 $\pm$ 0.22	0.30 $\pm$ 0.02
Palmitoleic*	16:1	4.76 $\pm$ 0.97	1.74 $\pm$ 0.17
Heptadecenoic*	17:1	0.81 $\pm$ 0.27	0.36 $\pm$ 0.02
Oleic	18:1n-9	7.66 $\pm$ 2.37	8.46 $\pm$ 2.51
Vaccenic*	18:1n-7	3.59 $\pm$ 0.64	2.59 $\pm$ 0.04
Gondoic	20:1n-9	0.70 $\pm$ 0.16	1.10 $\pm$ 0.26
Total*		18.31 $\pm$ 1.57	14.46 $\pm$ 0.40
Polyunsaturated fatty acids			
Hexadecadienoic	16:2n-4	0.67 $\pm$ 0.32	0.59 $\pm$ 0.16
Hexadecatetraenoic*	16:4n-3	2.98 $\pm$ 1.63	1.08 $\pm$ 0.78
Linoleic Omega-6*	18:2n-6	3.25 $\pm$ 0.60	14.32 $\pm$ 3.1
Alpha linolenic Omega-3*	18:3n-3	0.98 $\pm$ 0.50	0.52 $\pm$ 0.38
Stearidonic*	18:4n-3	1.21 $\pm$ 0.52	0.62 $\pm$ 0.25
Arachidonic Omega-6*	20:4n-6	8.28 $\pm$ 1.17	3.22 $\pm$ 0.51
Eicosapentaenoic Omega 3	20:5n-3	10.85 $\pm$ 2.17	10.24 $\pm$ 0.86
Docosatetraenoic	22:4n-6	1.11 $\pm$ 0.29	0.40 $\pm$ 0.08
Docosapentaenoic*	22:5n-3	1.63 $\pm$ 0.45	0.77 $\pm$ 0.18
Docosahexaenoic Omega-3*	22:6n-3	9.39 $\pm$ 2.56	13.35 $\pm$ 1.16
Total		38.77 $\pm$ 2.05	44.82 $\pm$ 1.41
n-3 PUFA		25.56 $\pm$ 1.62	26.34 $\pm$ 0.97
n-6 PUFA*		11.53 $\pm$ 0.47	17.56 $\pm$ 0.49
n-3 / n-6		2.21 $\pm$ 0.05	1.55 $\pm$ 0.05

The mean % of fatty acids marked with asterisks are significantly different between wild caught and cultured *P. monodon* ($P < 0.05$).

Discussion

The lipid content of shrimp is recorded to vary with the species, season, location, physiological status, diet, location in the body and age (Ackman 1982; Kinsella 1988). The mean lipid content of wild *P. monodon* observed in the present study ($0.9\% \pm 0.1$ ww) is comparable to values reported for other penaeid species. Guary et al. (1974) reported a level of 1.2% ww in *P. japonica* while Gopakumar and Nair (1975) have reported 1.3% ww lipids in *P. indicus*. Chanmugan et al. (1983) have observed a level of 1.0% ww in *P. aztecus*. O'Leary and Matthews (1990) have reported that in *P. monodon*, lipid levels in the head were higher than the muscle lipids.

This study revealed that the total lipid level of cultured *P. monodon* is not significantly higher than that of wild caught *P. monodon*. O'Leary and Matthews (1990) have reported similar observations. However, the values reported by O'Leary and Matthews (1990) (4.4%) are slightly higher than those recorded in the present study (3.7%). The variable lipid levels of wild and cultured *P. monodon* could be mainly due to the dietary differences. Ackman (1982) and Kinsella (1988) have shown that the lipid content in body tissue varies with the diet. Under cultured conditions, *P. monodon* is mainly fed with lipid rich formulated diets. Several workers have shown that the high content of lipid in cultured *P. monodon* is due to the formulated diets given to them, which are higher in Carbohydrate:Lipid ratio (Ackman 1982; Kinsella 1988; Catacutan 1991).

The result of the present study shows that Myristoleic (C14:1), Palmitoleic (C16:1), Heptadecenoic (C17:1), Hexadecatetraenoic (16:4n-3), Alpha linolenic Omega-3 (18:3n-3), Stearidonic (18:4n-3), Docostetraenoic (22:4n-6), Vaccenic (C18:1n-7), Arachidonic Omega-6 (20:4n-6) and Linoleic Omega-6 (C18:2n-6) levels significantly differ in cultured and wild caught *P. monodon*. Higher levels of Linoleic acid (18:2n-6) in cultured *P. monodon* than in wild caught *P. monodon* have also been reported by Sargent et al. (1999). Studies carried out by O'Leary and Matthews (1990) have shown that the wild *P. monodon* had lower levels of Oleic acid (18:1n-9) (8.4%), Linoleic acid-Omega-6 (18:2n-6) (1.9%) and higher levels of Palmitoleic acid (C16:1) (5.3%) than in cultured *P. monodon*. In the present study, the levels of Oleic acid were not significantly different in wild caught and cultured *P. monodon*. However, the results with respect to Linoleic Omega-6 (18:2n-6) and Palmitoleic (C16:1) acids are found to be similar to those observed by O'Leary and Matthews (1990).

Of the n-3 PUFAs, Docosapentaenoic acid (DPA) (20:5n-3) and Docosahexaenoic acid-Omega-3 (DHA) (22:6n-3) are reported to contribute to a high proportion of total n-3 PUFAs (Edirisinghe et al. 1998). The present investigation shows that the flesh of *P. monodon* is also a rich source of Docosapentaenoic (20:5n-3) and Docosahexaenoic-Omega-3 (22:6n-3) acids.

The present study indicates that the low level of Linoleic-Omega-6 (18:2n-6) acid and high level of Palmitoleic (C16:1), Heptadecenoic (17:1), Vaccenic (18:1n-7) and Arachidonic Omega-6 (20:4n-6) acids could be used to distinguish the wild caught *P. monodon* from cultured *P. monodon*.

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References

- Akman, R.G. 1982.
Nutritional Evaluation of Long-chain Fatty Acids in Fish. Academic press, New York. 82 pp.
- Berner, L. & J. Berner 1994.
FF - FAME - GC method, Lyngby, Denmark. 20 p.
- Chanmugan, P., J. Donovan, C.J. Wheeler & Hwang 1983.
Differences in the lipid composition of fresh water prawn (*Macrobrachium rosenbergii*) and marine shrimp. Food science 48: 1440-1442.
- Catacutan, M.R. 1991.
Growth and fatty acid composition of *Penaeus monodon* juvenile fed on various lipids. Aquaculture 43: 47-56.
- Edirisinghe, E.M.R.K.B., W.M.K. Perera, S. Jayasoriya & A. Bamunuarachchi 1998.
Health related fatty acids in some pelagic fishes in Sri Lanka. Sri Lanka Journal of Aquatic Sciences 3: 97-107.
- Gopakumar, K & M.R. Nair 1975.
Lipid composition of five species of Indian Prawns. Journal of Food Science & Agriculture 26: 319-325.
- Guary, J., M. Kayama & Y. Murakami 1974.
Lipid class distribution and fatty acid composition of prawn, *Penaeus japonicus* Bulletin of Japanese Social Science and Fisheries 40(10): 1027-1032.
- Hanson, S.W.F. & J. Olly 1965.
Application of the Bligh & Dyer method of Lipid Extraction to tissue homogenates. Biochemical Journal 89: 101-102.

- Jayasinghe, J.M.P.K. 1991
The Utilization of Acid Sulphate Soils for Shrimp Culture on the West Coast of Sri Lanka. Ph.D. thesis, University of Strirling, UK.
- Jayasinghe J.M.P.K. & D.J. Macintosh 1993.
Disease outbreak in the shrimp culture grow-out systems in Sri Lanka. Tropical Agricultural Research 5: 337-348.
- Johnston, P., & J.E. Hunter 1987.
Perspectives on omega-3 fatty acids. Journal of the American Oil Chemistry Society 64: 716-717.
- Kinsella, J.E. 1986.
Food components with potential therapeutic benefits. The *n*-3 polyunsaturated fatty acids of fish oils. Food Technology 42(2): 89-97.
- Kinsella, J.E. 1987
Seafood and fish oil in human health and diseases. Marcel Dekker Inc., New York. 240 pp.
- Kinsella, J.E. 1988.
Fish and seafoods: nutritional implication and quality issue. Food Technology 42(5): 146-150.
- Mead, R. & R.N. Curnow 1987.
Statistical Methods in Agriculture and Experimental Biology, Chapman and Hall, London. 23 pp.
- MFOR 2002.
Annual Report 2002. Ministry of Fisheries and Ocean Resources, Colombo, Sri Lanka.
- O'leary, C.D. & A.D. Matthews 1990.
Lipid class distribution and fatty acid composition of wild and farmed prawn, *Penaeus monodon* (Fabricius). Aquaculture 89: 65-81.
- Radin, N.S. 1981.
Extraction of tissue lipid with a solvent of low toxicity - Methods. Enzymology 72: 5-7.
- Robinson, D.R., S. Tateno & A. Hirai 1987.
Polyunsaturated fatty acids and eicosanoids. American Oil Chemists Society 25: 139-147.
- Sargent, J., L. Meevov, A. Estevez, G. Bell, M. Bell, J. Henderson & D. Tocher 1999.
Lipid nutrition of marine fish during early development: current status and future directions. Aquaculture 179: 217-229.
- Subasinghe, R.P., D.M. Bartley, S. McGladdery & U. Barg 1999.
Sustainable shrimp culture development: biotechnological issues and challenges. In: Advances in Shrimp Biotechnology (Flegel T.W. ed.). National Centre for Genetic Engineering and Biotechnology, Bangkok.

Yap, W.G. 1999.

Shrimp culture: A global overview. SEAFDEC Asian Aquaculture 21
(4): 18-37.