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# Lipid Content and Fatty Acid Composition of *Euphausia pacifica* (Total Body Lengths Less than 13 mm) Collected in the Water near Funka Bay

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**Abstract**

This paper reports the lipid contents and fatty acid compositions of the Krill *Euphausia pacifica* (total body lengths, <13 mm) collected in the Pacific water near Funka Bay, Hokkaido, Japan. Lipid contents were 3.2-11.0% on dry weight base, and highest in the samples of April. Most abundant fatty acids were palmitic acid (16 : 0) (20.4-23.3%), icosapentaenoic acid (20 : 5n-3, IPA) (16.5-26.9%) and docosahexaenoic acid (22 : 6n-3, DHA) (11.2-21.1%). DHA was higher in the August samples than in the April samples, whereas IPA was higher in the April. The present *E. pacifica* samples were similar in the lipid contents and concentrations of major fatty acids to those with total body lengths more than 13 mm collected in the same area.

**Key words**: *Euphausia pacifica*, Lipid, Fatty acid, DHA, IPA

## Introduction

*Euphausia pacifica* is one of the most common krill species in subarctic waters of the North Pacific Ocean and has huge biomass. However, available information on the lipids of this species seems to be limited. Saito et al. (2002) pointed out that only four previous papers reported lipid profile of *E. pacifica* including detailed fatty acid composition. Recently, Kusumoto et al. (2003) revealed the lipid profile of *E. pacifica* collected in the Pacific Ocean near Funka Bay, Hokkaido, Japan. Lipid contents of the *E. pacifica* samples with total body lengths more than 13 mm were 5.1-11.6% on dry weight base, and the lipids were rich in icosapentaenoic acid (IPA, 20 : 5n-3) and docosahexaenoic acid (DHA, 22 : 6 n-3). Spring and summer samples differed in the lipid content (spring>summer) and concentration of DHA in the lipids (spring<summer).

In the present study, additional samples of *E. pacifica* with total body lengths less than 13 mm have been subjected to the analyses of lipid content and fatty acid composition. This paper reports the analytical data.

## Materials and Methods

### *Materials*

*E. pacifica* were collected in the Pacific water near Funka Bay, Hokkaido Japan (42°00′N, 141°20′E) at the dates shown in Table 1. The *E. pacifica* were caught with modified-IKMT net or FMT net at the depth 10-35 m, except for one sample of November 18, 2002 caught at 45-110 m depth. The samples with total body lengths <9 mm and 9-13 mm were stored at −18°C for lipid analysis.

### *Lipid Analysis*

Lipid content and fatty acid composition were determined by the procedures described in the preceding report (Kusumoto et al., 2003). Lipid extraction was carried out in 2002. After the *E. pacifica* samples (<0.5 g) were lyophilized for 5.5 h, total lipids were extracted by a procedure based on the method of Bligh and Dyer (1959). Lipid contents were determined gravimetrically.

Fatty acid methyl esters were prepared by heating the total lipids with 7% $BF_3$-methanol for 1 h at 100°C, and then purified by thin-layer chromatography on a Silicagel GF plate (Analtech, Newark, USA) with toluene for development (Hara and Taketomi, 1988). Fatty acid methyl esters were analyzed by gas-liquid chromatography with a Shimadzu GC-17A instrument (Shimadzu, Kyoto, Japan) equipped with a flame ionization detector and a Supelcowax 10 capillary column (30 m×0.25 mm i.d., 0.25 mm film thickness; Supelco, Bellefonte, USA). The column temperature was 200°C. The injector and detector temperatures were 250 and

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Table 1 Lipid content of *Euphausia pacifica* collected in the Pacific Ocean near Funka Bay, Hokkaido, Japan (wt% on dry weight base)

| Date of collection | TL[a] < 9 mm | | | 9 mm ≦ TL[a] < 13 mm | | |
|---|---|---|---|---|---|---|
| | Sex | N[b] | Wt%[c] | Sex | N[b] | Wt%[c] |
| 2000 | | | | | | |
| April 26 | Mixture | N=1 | 9.2 | Mixture | N=1 | 11.0* |
| June 12 | Mixture | N=1 | 9.0 | Mixture | N=1 | 9.9 |
| July 15 | – | – | – | Mixture | N=1 | 5.6 |
| August 7 | Mixture | N=1 | 5.7 | Mixture | N=1 | 7.8 |
| December 18 | Mixture | N=1 | 3.2 | Mixture | N=1 | 5.6* |
| 2001 | | | | | | |
| June 27 | – | – | – | Mixture | N=1 | 8.1 |
| August 21 | – | – | – | Male | N=1 | 7.8 |
| August 21 | – | – | – | Female | N=1 | 5.7 |
| 2002 | | | | | | |
| August 17 | Mixture | N=1 | 7.9 | Mixture | N=1 | 7.8* |
| November 18 | – | – | – | Female | N=1 | 6.0* |

[a]Total boby length of *E. pacifica*.
[b]Number of samples.
[c]Weight %. Values with asterisk* are means of dupricate determinations for each sample.

260°C, respectively. Peak area percentages were obtained with a Shimadzu C-R6A integrator.

## Results

### *Lipid content*

The catching-months of the *E. pacifica* samples were varied from April to December (Table 1). The *E. pacifica* subjected to lipid analysis were five samples with total body lengths less than 9 mm and ten samples with the lengths of 9–13 mm.

The lipid contents of the *E. pacifica* samples were 3.2–11.0% on dry weight base. In the samples with total body lengths <9 mm, the contents were 3.2–9.2%. In the samples with 9–13 mm total body lengths, the lipid contents were 5.6–11.0%. The highest lipid contents were found in the samples of April (9.2 and 11.0%), followed by the samples of June (8.1–9.9%). Lipid contents of the July and August samples ranged from 5.7–7.9%, and those of November and December were 3.2–6.0%. Lipid contents of the *E. pacifica* samples were highest in spring compared with other seasons.

### *Fatty acid composition*

Table 2 shows the fatty acid compositions of samples collected in April, August and November. In all of the samples analyzed, the most abundant fatty acids were 16 : 0 (20.4–23.3%), IPA (16.5–26.9%) and DHA (11.2–21.1%). Other major fatty acids found at more than 5% were 14 : 0 (2.3–6.1%), 16 : 1 n-7 (3.1–8.1%), 18 : 1n-9 (7.3–9.6%) and 18 : 1 n-7 (5.9–7.8%). Fatty acids of the *E. pacifica* samples were rich in n-3 HUFA. Contents of IPA plus DHA were 30.2–39.1% of total fatty acids.

The concentrations of 16 : 0 were almost consistent in all of the eight samples. By contrast, IPA was higher in the April samples (26.9 and 26.0%) than in the August and November samples (16.5–18.1%). DHA was higher in the August and November (13.7–21.1%), and lowest in the April samples (11.2 and 11.7%). Concentrations of IPA were higher in spring, whereas those of DHA were lowest in the same season.

## Discussion

Lipids of the present samples of *E. pacifica* (total body lengths, <13 mm) can be summarized as follows: (i) Lipid contents were 3.2–11.0% on dry weight base. (ii) The lipids were rich in IPA and DHA. (iii) Seasonal variations were found in the lipid contents (high in spring) and concentrations of IPA and DHA (high and low in spring, respectively).

Table 3 shows the lipid contents and concentrations of major fatty acids of *E. pacifica* reported in the previous papers (Yamada, 1964; Pierce et al., 1969; Van der Veen et al., 1971; Takahashi and Yamada, 1976; Kayama et al., 1976; Saito et al., 2002; Kusumoto et al., 2003). Kusumoto et al. (2003) reported the lipid profile of the *E. pacifica* (total body lengths, ≧13 mm) collected together with the samples of this study (Table 3, No. 14). Lipid contents reported

Table 2 Fatty acid composition of total lipids in *Euphausia pacifica* collected in the Pacific Ocean near Funka Bay, Hokkaido, Japan (wt%)

| | 2000 | | | 2001 | | 2002 | | |
|---|---|---|---|---|---|---|---|---|
| | Apr 26 | | Aug 7 | Aug 21 | | Aug 17 | | Nov 18 |
| Fatty acid | <9[a)] Mix | 9-13 Mix | 9-13 Mix | 9-13 Male | 9-13 Female | <9 Mix | 9-13 Mix | 9-13 Female |
| 14 : 0 | 2.3 | 2.5 | 5.4 | 6.1 | 4.4 | 2.6 | 3.4 | 3.2 |
| iso-15 : 0 | 0.1 | 0.1 | 0.3 | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 |
| 15 : 0 | 0.3 | 0.3 | 0.5 | 0.5 | 0.5 | 0.4 | 0.5 | 0.6 |
| 16 : 0 | 23.3 | 21.1 | 21.1 | 21.3 | 20.4 | 21.1 | 21.1 | 20.9 |
| 16 : 1n-7 | 6.8 | 8.1 | 6.7 | 7.5 | 5.5 | 3.4 | 4.4 | 3.1 |
| 16 : 1n-5 | 0.2 | 0.2 | 0.4 | 0.3 | 0.3 | 0.2 | 0.2 | 0.3 |
| iso-17 : 0 | 0.4 | 0.3 | 0.4 | 0.3 | 0.5 | 0.4 | 0.5 | 0.6 |
| anteiso-17 : 0 | 0.2 | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 |
| 16 : 2n-4+phytanic | 1.3 | 2.0 | 2.3 | 1.6 | 1.1 | 0.6 | 0.9 | 1.1 |
| 17 : 0 | 0.2 | 0.2 | 0.4 | 0.5 | 0.5 | 0.5 | 0.5 | 0.6 |
| 16 : 3n-4+17 : 1 | 0.4 | 0.7 | 0.6 | 0.6 | 0.6 | 0.5 | 0.6 | 0.8 |
| iso-18 : 0 | 0.2 | 0.3 | 0.3 | 0.3 | 0.4 | 0.3 | 0.4 | 0.6 |
| 16 : 4n-1 | 0.4 | 0.6 | 0.3 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 |
| 18 : 0 | 1.7 | 1.5 | 1.4 | 1.6 | 1.9 | 1.4 | 1.2 | 1.4 |
| 18 : 1n-9 | 7.6 | 7.3 | 9.5 | 7.6 | 7.9 | 9.0 | 8.9 | 9.6 |
| 18 : 1n-7 | 7.4 | 7.8 | 6.3 | 5.9 | 6.4 | 6.8 | 7.1 | 6.4 |
| 18 : 1n-5 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| 18 : 2n-6 | 1.1 | 1.2 | 2.4 | 2.3 | 2.7 | 2.7 | 2.6 | 2.5 |
| 19 : 0 | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 | 0.2 | 0.2 | 0.2 |
| 18 : 3n-3 | 0.3 | 0.4 | 1.8 | 1.4 | 1.7 | 1.7 | 1.7 | 1.5 |
| 18 : 4n-3 | 0.8 | 1.3 | 2.6 | 1.4 | 1.3 | 1.0 | 1.1 | 1.6 |
| 20: 1n-11+20: 1n-13 | 0.2 | 0.2 | 0.4 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| 20 : 1n-9 | 0.3 | 0.3 | 0.3 | 0.2 | 0.3 | 0.4 | 0.3 | 0.3 |
| 20 : 1n-7 | 0.2 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| 20 : 2n-6 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 |
| 20 : 4n-6 | 1.2 | 1.2 | 1.7 | 2.7 | 2.8 | 3.9 | 3.3 | 2.8 |
| 20 : 4n-3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 20 : 5n-3 (IPA) | 26.9 | 26.0 | 16.5 | 18.1 | 18.1 | 18.0 | 17.8 | 16.5 |
| 22 : 1n-9 | 0.2 | 0.2 | 0.2 | 0.2 | 0.1 | 0.0 | 0.1 | 0.0 |
| 22 : 3n-6 | 1.1 | 0.9 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| 22 : 5n-6 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.3 | 0.3 | 0.4 |
| 22 : 5n-3 | 0.6 | 0.4 | 0.3 | 0.3 | 0.4 | 0.4 | 0.4 | 0.3 |
| 22 : 6n-3 (DHA) | 11.7 | 11.2 | 13.7 | 14.6 | 17.3 | 21.1 | 19.2 | 20.4 |
| Others (<0.2 %) | 1.9 | 2.2 | 2.5 | 2.2 | 2.6 | 1.8 | 1.7 | 2.4 |

[a)]Total body length (mm) of the *E. pacifica* sample.

were 5.1-11.6% on the dry weight base, and concentrations of IPA and DHA in total lipids were 15.3-24.7% and 8.4-20.7%, respectively. The same authors concluded that the lipid profile of *E. pacifica* (≧13 mm) collected near Funka Bay was not very different from that fragmentarily reported for the same species varied in catching-locations, seasons, and years (Nos. 1-13). The lipid content and fatty acid composition observed in the present study (No. 15) were close to those of the ≧13 mm samples (No. 14).

In the samples of *E. pacifica* (≧13 mm) collected near Funka Bay, seasonal changes in the lipid content and DHA concentrations were also reported (Kusumoto et al., 2003). The highest lipid content was observed for the April and May samples (8.0-11.6%). Lipid contents decreased in spring to summer. The samples of August were higher in DHA concentrations (15.7-20.7%) than those of April and May (8.4-11.0%). In the

Table 3 Comparison of lipid contents (wt%) and concentration of major fatty acids (wt% of total fatty acids) in *Euphausia pacifica*

| No. | Location | Date | Lipid content (wt%) | | Concentration of major fatty acids (wt%) | | | | | | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dry base | Wet base | (Class) | 16 : 0 | 18 : 1n-9 | 18 : 1n-7 | IPA | DHA | |
| 1. | Sennzaki | - | 7.0 | 1.5 | - | - | - | - | - | - | a) |
| 2. | Kesennuma | - | 7.9 | 1.0 | - | - | - | - | - | - | a) |
| 3. | 44°20'N, 147°30'E | - | - | 1.3 | - | - | - | - | - | - | a) |
| 4. | Unknown | - | - | - | TL | 20.1 | 16.4*[1] | | 25.9 | 14.7 | a) |
| 5. | Unknown | - | - | - | TL | 18.3 | 13.6*[1] | | 20.5 | 12.8 | a) |
| 6. | Washington | Aug 1967 | 18.9 | - | TL | 22.8 | 13.9*[1] | | 27.9 | 16.1 | b) |
| 7. | Eurika | Sep 1966 | 23.8 | - | TL | 28.5 | 15.1*[1] | | 30.9 | 27.9 | b,c) |
| | | | | | NL | 22.5 | 15.3*[1] | | 22.8 | 10.9 | |
| | | | | | PE | 15.1 | 10.4*[1] | | 22.0 | 34.6 | |
| | | | | | PC | 25.7 | 12.0*[1] | | 32.5 | 15.5 | |
| 8. | 42°N, 146°E | Sep 1971 | - | 1.4 | TAG | 19.3 | 16.2*[1] | | 6.3 | 4.4 | d) |
| | | | | | PL | 19.7 | 15.5*[1] | | 18.7 | 22.9 | |
| 9. | Kesennuma | Mar 1972 | - | 1.3 | TAG | 16.4 | 12.1*[1] | | 8.3 | 4.6 | d) |
| | | | | | PL | 21.1 | 17.8*[1] | | 16.1 | 26.1 | |
| 10. | 39°58.6'N, 135°58.9'E | May 1972 | - | 1.9-3.5 | WE | 7.5-8.3 | 16.9-17.5*[1] | | 8.6-9.6 | 20.9-23.0 | e) |
| 11. | 42°01.5'N, 135°43.7'E | Oct 1973 | - | 1.1 | - | - | - | - | - | - | e) |
| 12. | Onagawa | Mar 1993 -Dec 1993 | - | 0.6-1.8 | TAG | 12.9-18.3 | 5.0-11.2 | 4.8- 7.1 | 5.1-19.1 | 2.7- 5.7 | f) |
| | | | | | PE | 9.2-15.1 | 2.7- 7.1 | 6.0-10.0 | 12.8-25.9 | 24.8-42.2 | |
| | | | | | PC | 13.5-24.3 | 6.8-14.0 | 4.4- 6.5 | 19.0-35.1 | 10.3-25.3 | |
| 13. | Sanriku | Feb 1997 -Apr 1997 | - | 3.3-6.2 | TAG | 12.5-13.9 | 4.6- 6.9 | 3.4- 5.7 | 15.0-23.2 | 1.5- 6.3 | f) |
| | | | | | PE | 12.1-15.3 | 3.4- 4.1 | 8.5-10.8 | 18.4-24.9 | 30.1-38.4 | |
| | | | | | PC | 14.4-21.3 | 6.6- 9.0 | 4.5- 5.2 | 31.5-42.2 | 9.4-21.3 | |
| 14. | Funka Bay*[2] | Apr 2000 -Nov 2002 | 5.1-11.6 | - | TL | 19.0-24.5 | 7.5-10.0 | 6.3- 8.1 | 15.3-24.7 | 8.4-20.7 | g) |
| 15. | Funka Bay*[3] | Apr 2000 -Nov 2002 | 3.2-11.0 | - | TL | 20.4-23.3 | 7.3-9.6 | 5.9-7.8 | 16.5-26.9 | 11.2-21.1 | h) |

TL, total lipids; NL, neutral lipids; PL, polar lipids; TAG, triacylglycerols; WE, wax esters; PE, phosphatidylethanolamines; PC, phosphatidylcholines

*[1]Reported in the combined form of 18 : 1n-9 and 18 : 1n-7.

*[2]Total body length, ≧13 mm.

*[3]Total body length, <13 mm.

[a)]Yamada (1964), [b)]Pierce et al. (1969), [c)]Van der Veen et al. (1971), [d)]Takahashi and Yamada (1976), [e)]Kayama et al. (1976), [f)]Saito et al. (2002), [g)]Kusumoto et al. (2003), [h)]the present study.

present study, similar changes were found in the <13 mm samples.

In general, lipid profile obtained in the samples with total body lengths less than 13 mm seems to be similar to that reported for the samples with longer total body lengths (≧13 mm). Both of the longer and smaller length samples were collected at the same times in one area. From the result of this study, there seems to be no significant differences in the lipids of *E. pacifica* varied in their total body lengths in the Pacific water near Funka Bay.

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