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journal or publication title	Tohoku journal of agricultural research
volume	28
number	3/4
page range	145-150
year	1978-03-29
URL	http://hdl.handle.net/10097/29739

Tohoku Journal of Agricultural Research
Vol. 28, No. 3, 4, December 1977
Printed in Japan

Differential Fatty Acid Composition of Some Marine Algae Associated with Their Habitat Depths*

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(Received, December 1, 1977)

Summary

Samples of four marine algae of the species Chlorophyta and Phaeophyta, collected from Onagawa Bay, Miyagi Prefecture, at different depths of water in the spring of 1970, were analyzed for general component and fatty acid composition. The content of crude fat, protein and ash of the seaweeds decreased with increasing depth of immersion, while carbohydrate increased.

The ratio of the percentage of unsaturated to saturated acid of the total fatty acids ranged from 2.36 to 2.50 in the oil from *Ulva pertusa*, 1.50 to 2.45 in *Laminaria religiosa*, 1.30 to 1.61 in *Undaria pinnatifida*, and 1.00 to 1.36 in *Hetrochordaria abietina*. The figures were always lower in the samples from 5 or 6 m depths than in those from shallower water levels. Myristic and palmitic acids increased progressively with the depth of immersion, while lauric, tridecanoic, and stearic acids decreased with the exception of *Heterochordaria abietina*.

Among the unsaturated acids, palmitoleic, octadecatrienoic, eicosatrienoic and -pentaenoic acids showed a progressive decline with the exception of octadecatrienoic acid in *Laminaria religiosa*. On the contrary, oleic acid increased except in *Laminaria religiosa*. It is pointed out that palmitoleic and palmitic acids seemed to be convertible to each other.

In 1925, Tsujimoto (1) showed that marine algae contain very small quantities of highly unsaturated fatty acids. Lovern (2) reported that unsaturated C_{16}- and C_{18}-acids predominantly occur in the oils from green and brown algae and unsaturated C_{20}- and C_{22}-acids in red alga. Recently Klenk et al. (3) and several other workers (4–6) determined the component fatty acid of the fat from various kinds of seaweed by means of gas chromatography, and found that the degree of unsaturation varied independently of species from the monoethenoid to the penta- or hexa-ethenoid acid. However, there is very little knowledge about the relationship between the fatty acid patterns of marine algae and their environmental

* The oral presentation of this reprot was given at the Eighth International Seaweed Symposium held in Bangor, England, August, 1974.

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conditions. This report is to present the differential fatty acid composition of some marine algae associated with their habitat depths.

Materials and Methods

Materials: *Ulva pertusa* and *Laminaria religiosa* that have grown on a rope anchoring an oyster raft were collected at different depths in Onagawa bay, at the first of April, 1970. *Undaria pinnatifida* and *Heterochordaria abietina* were kept alive with their roots in a coarse wire-net cage hanging from the anchoring rope for one month, from the first to the end of April. These algae were collected at a depth of 1, 3 and 5 m, respectively.

Extraction of oils: The materials were lyophylized, finely ground and extracted with chloroform-methanol, 2:1 (v/v). The residues were treated three times with the same solvent. The combined extracts were freed of solvent under reduced pressure.

Saponification of lipid and esterification of mixed fatty acids: The lipid was saponified with ethanolic potassium hydroxide by the usual method. Then the fatty acid mixtures were decolorized with active carbon and converted into their methylesters with diazomethane by the method of Schlenk and Gellerman (7).

Gas-liquid chromatography: Analyses of the fatty acid methylesters were performed with a Shimadzu GC–2B gas chromatograph equipped with a flame ionization detector. The fatty acid esters were identified by the retention times of standard acid esters. The quantitative values of each acid were determined from the area of each peak revealed by the triangulation procedure.

Hydrogenation of unsaturated acids: Samples of the mixed acids dissolved in ethanol were hydrogenated in the presence of palladium on carbon catalyst at room temperature. After the hydrogen was completely absorbed, the catalyst was removed by filtration and the hydrogenated acids were esterified. Their analyses were performed as described above.

Results and Discussions

The results of analyses on the general component and fatty acid composition of the marine algae are summarized in 2 tables. Table 1 shows that the content of crude fat ranged from 0.62 to 1.86 percent of dry matter and was lower in the seaweeds at a depth of 5 or 6 m than in those at shallower water levels. This agrees with the results on the common British brown seaweeds found by Russel-Wells (8) and Back and Cornhill (9). The percentage of protein and ash also varied similarly to that of fat. On the contrary, the carbohydrate and fiber contents were found to be higher in the seaweeds at 5 or 6 m depth than in those at shallower water levels. It is suggested that the extent of variation of these components depends on environmental conditions such as surface-light intensity,

TABLE 1. *General Component of Marine Algae on a Dry-weight Basis*

Species	Lipid (%)	Protein (%)	Carbohydrate (%)	Fiber (%)	Ash (%)
Ulva pertusa					
1 m>	1.38	28.43	44.54	4.38	20.36
5 m>	1.02	24.23	52.19	9.06	12.14
Laminaria religiosa					
1 m	0.83	9.62	58.58	4.62	26.35
6 m	0.62	7.64	60.14	5.98	25.62
Undaria pinnatifida					
1 m	1.13	14.68	52.27	7.93	20.99
3 m	1.15	14.50	58.54	7.91	17.90
5 m	0.85	14.52	59.75	8.41	16.47
Heterochordaria abietina					
1 m	1.86	20.78	50.20	12.13	15.03
3 m	1.82	21.16	51.85	12.11	15.26
5 m	1.16	19.36	51.07	13.45	14.96

TABLE 2. *Weight Percentage Distribution of Component Fatty Acids in Algal Fats*

Species		*Ulva pertusa*		*Laminaria religiosa*		*Undaria pinnatifida*			*Heterochordaria abietina*		
Depth of immersion		1 m>	5 m	1 m>	6 m	1 m	3 m	5 m	1 m	3 m	5 m
Saturated fatty acid	12:0	3.4	2.4	0.6	0.2	2.5	1.6	1.7	1.2	1.5	1.8
	13:0	0.1	trace	0.7	0.3	1.3	0.7	0.3	0.8	1.3	1.6
	14:0	1.0	1.2	9.1	14.0	4.5	5.3	6.7	8.6	9.8	11.4
	15:0	0.5	0.5	0.7	1.4	1.7	1.2	0.5	2.0	2.1	3.2
	16:0	11.4	14.8	15.5	22.5	27.3	30.8	33.0	27.5	28.2	29.8
	17:0	1.3	1.5	—	—	—	—	—	—	—	—
	18:0	10.4	8.1	1.5	0.6	1.3	2.0	0.5	1.7	2.6	2.0
	20:0	0.8	1.1	1.3	0.6	0.3	0.5	0.3	0.9	0.4	0.2
Unsaturated fatty acid	14:1	0.4	0.3	—	—	—	—	—	1.4	1.7	1.7
	14:2	0.7	0.6	—	—	—	—	—	1.0	1.4	1.3
	16:1	10.4	5.0	8.9	8.0	12.3	5.2	3.2	12.2	11.3	10.4
	16:2	0.6	0.4	—	—	—	—	—	trace	3.0	4.0
	18:1	14.3	19.8	19.1	13.9	14.6	24.3	32.2	16.6	16.8	17.2
	18:2	9.8	12.6	10.2	6.6	5.3	7.5	6.0	9.2	5.2	4.7
	18:3	17.8	16.5	6.1	7.1	7.7	5.2	4.2	4.1	3.2	2.6
	18:4	8.4	11.1	8.2	9.3	4.4	2.7	1.6	3.5	3.0	2.2
	20:2	—	—	0.9	0.7	0.7	0.6	0.8	0.6	0.5	0.6
	20:3	2.6	1.1	9.6	7.3	11.8	8.3	6.2	3.7	3.5	3.1
	20:4	4.3	2.1	1.4	1.4	0.4	0.5	0.4	1.3	1.6	0.6
	20:5	1.8	0.9	6.2	5.6	3.9	3.6	2.2	3.7	2.9	1.6
Unsaturated/ Saturated		2.50	2.36	2.45	1.50	1.61	1.38	1.30	1.36	1.21	1.00

underwater light penetration, water temperature, salinity involving nutrients, etc. This problem is discussed later.

Table 2 indicates that plamitic acid is the most abundant of saturated acids and is followed by stearic acid in *Ulva pertusa* and myristic acid in all species of brown seaweeds exmained. Small amounts of lauric, tridecanoic, pentadecanoic

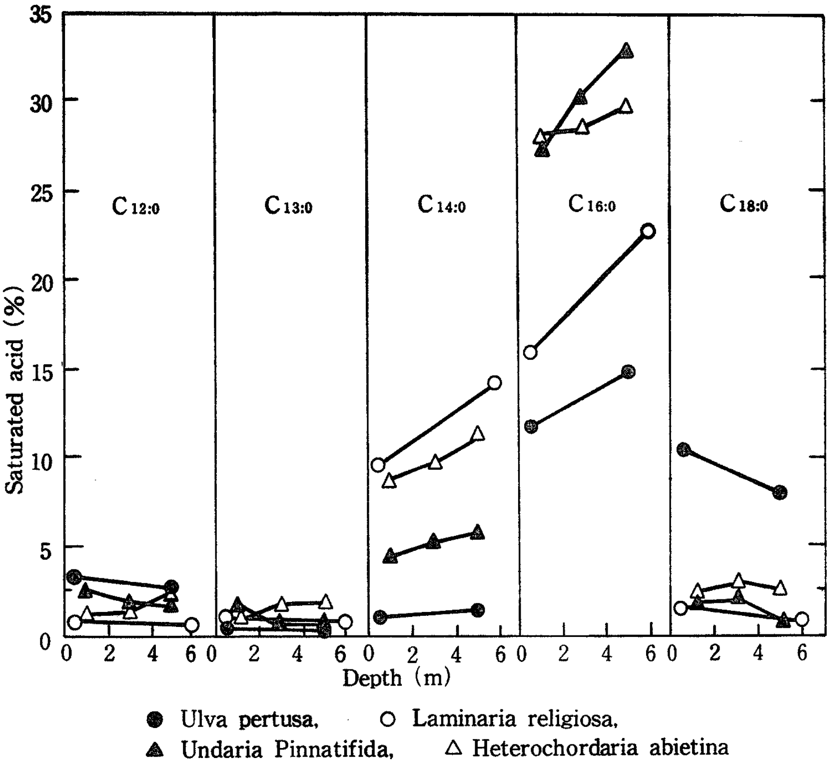
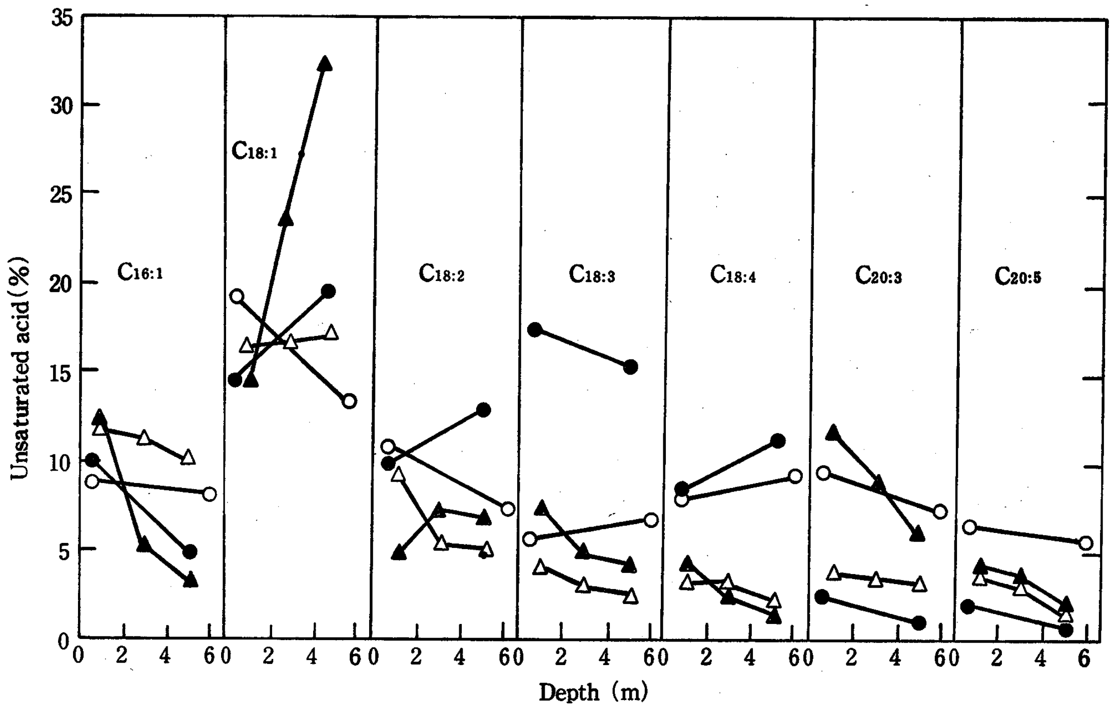


FIG. 1. Relationship between the saturated acid of fats from marine algae and the depth of immersion

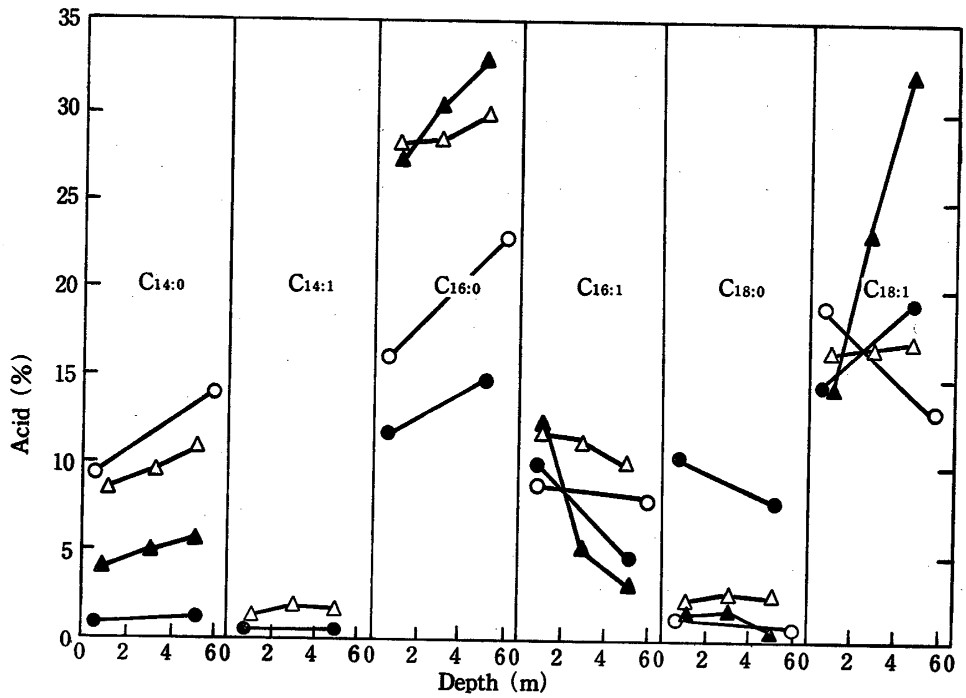
and arachidic acids were also found to be common in all of the fats from marine algae. However, a small amount of heptadecanoic acid was present in *Ulva pertusa* alone. These saturated acids showed a wide variation in different depths. Palmitic and myristic acids increased progressively with depth. On the other hand, lauric, tridecanoic and stearic acids decreased with the exception of *Heterochordaria abietina* (Fig. 1).

Oleic acid was dominant over all other unsaturated fatty acids of the oils from marine algae. A moderate amount of palmitoleic, octadeca-dienoic, -trienoic, -tetraenoic or eicosatrienoic acid was found to be common in all the marine algae as well as small amounts of eicosa-tetraenoic and -pentaenoic acids. A trace amount of eicosadienoic acid occurred in all species, except *Ulva pertusa*. Besides, tetradecenoic, tetradecadienoic and hexadecadienoic acids that are very small in quantity were present in *Ulva pertusa* and *Heterochordaria abietina*. Through all samples of the algal fats, palmitoleic, eicosatrienoic and -pentaenoic acids showed a progressive decline with increasing depth of immersion (Fig. 2). Octadecatrienoic acid also decreased except for *Laminaria religiosa*. On the contrary, oleic acid increased with the exception of *Laminaria religiosa*. However, octadeca-dienoic and -tetraenoic acids varied regardless of the depth. It is clearly seen that mono-unsaturated C_{16}-acid, palmitoleic acid, invariably decreased as in compensation for a rise of saturated C_{16}-acid, plamitic acid (Fig. 3). Total amount of the two



● Ulva pertusa, ○ Laminaria religiosa, ▲ Undaria Pinnatifida, △ Heterochordaria abietina

FIG. 2. Relationship between the unsaturated acid of fats from marine algae and the depth of immersion



● Ulva pertusa, ○ Laminaria religiosa, ▲ Undaria Pinnatifida, △ Heterochordaria abietina

FIG. 3. Relationship between the saturated and monounsaturated acids in marine algae

acids generally remained at a constant level. Thus they seemed to be interchangeable, that is, each converting to the other. However, this compensation-relationship was not always recognzied in the other two cases: oleic-stearic acids and tetradecenoic-myristic acids. The ratio of the percentage of unsaturated to saturated acid ranged from 2.36 to 2.50 in the oil from *Ulva pertusa*, 1.50 to 2.45 in *Laminaria religiosa*, 1.30 to 1.61 in *Undaria pinnatifida*, and 1.00 to 1.36 in *Heterochordaria abietina*. The figures show that the smaples from 5 or 6 m depth were always lower than those from shallower water levels.

As already stated, the fat content and fatty acid composition of the marine algae varied by the different depths of immersion under the conditions employed. The mechanism that involves many interrelationships between photosynthesis and acid, carbohydrate, protein and fat metabolisms is very complicated. However, the water temperature observed at 10 a.m. in Onagawa Bay slightly fluctuated from 6.6 to 11.8°C at the surface and 6.7 to 11.8°C at a depth of 5 m during the period of April, 1970. The difference of water temperature between surface and 5 m depth was at most 1°C. Thus, it is thought in this case that light is the most important factor exerting a great influence on the metabolisms of the seaweeds concerned, although the experimental data are unavailble for it.

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