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THE FATTY ACID COMPOSITION OF *ULOTHRIX AEQUALIS* LIPIDS

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Key Word Index—*Ulothrix aequalis*; Ulotrichales; chlorophyceae; fatty acids; chemotaxonomy; galactosyl diglycerides.

Abstract—Fatty acid composition of the total lipids isolated from the fresh-water green alga *Ulothrix aequalis* shows that they resemble marine green algal lipids in having a high proportion of 16:4 ω-3 but differ in having only trace amounts of 18:4 ω-3. The distribution of ω-3 acids in the MGDG and DGDG fractions resembles that in green seaweeds and higher plants with the 16:4 ω-3 distribution in the *Ulothrix* fractions resembling that of 18:4 ω-3 in the corresponding fractions of the seaweeds.

INTRODUCTION

There has been a number of investigations of the fatty acid compositions of marine phytoplankton lipids [1–5] and of seaweed lipids [6–10], but similar information on the lipids of fresh-water algae is restricted to comparatively few species [7,9,11–16]. It has been shown that algae harvested from the wild might have a different fatty acid distribution from those cultured artificially the distribution depending on the amount of storage lipid present when grown under artificial conditions [3,13,17–19]. However, differences in total fatty acid compositions among species of algae collected from natural environments may be less affected by external factors although there may be significant species differences.

In the present work the fatty acid compositions of the lipids of *Ulothrix aequalis* (Kütz) collected from the wild have been examined and the major acids of the total lipids were 16:4 ω-3 and 18:3 ω-3. It was of interest to investigate the distribution of these acids in the MGDG and DGDG and more polar lipid fractions and to compare the distribution with that of 16:4 ω-3 and 18:4 ω-3 in green marine algae [10] and with the distribution of ω-3 acids in the galactosyl diglycerides of green plants generally.

RESULTS AND DISCUSSION

The fatty acid compositions of the total lipids, the galactosyl diglycerides, and the 'more polar' lipids of *Ulothrix* are shown in Table 1. There were only small variations in the amounts of individual acids between this sample and samples taken in August 1972 and October 1974 from the same location. The total lipid fatty acids have a high mean unsaturation (2.7 C=C mol^{-1}) which can be compared with values for marine algae [10] (Chlorophyta 2.2; Phaeophyta 2.3; Rhodophyta 2.9).

A significant feature of the total lipid fatty acids is the high proportion of 16:4 ω-3 + 18:3 ω-3, these acids together account for 67% of the total acids. The fatty acids from whole cells of green algae have been reported [14,15] as being qualitatively similar to those of the leaves of higher plants, but 16:4 ω-3 has not been reported in the photosynthetic tissues of higher plants.

Table 1. Fatty acid composition of *Ulothrix* lipids

Acid	Total lipids	% by weight MGDG*	DGDG	'more polar'
10:0	tr*	tr	tr	0.1
12:0	0.1	tr	0.1	0.1
14:0	1.1	0.2	2.3	1.9
14:1	0.3	tr	0.1	tr
15:0	0.5	tr	0.1	0.1
16:0	15.1	1.2	15.0	28.8
16:1 ω-7 + 9	2.0	0.6	2.9	0.7
16:1 ω-13t	1.4	—	—	6.8
16:2 ω-6	0.1	0.3	0.4	0.4
16:3 ω-4	0.6	1.4	0.2	0.1
16:3 ω-3	2.2	0.9	6.6	1.4
16:4 ω-3	30.5	43.2	26.6	19.0
17:0	0.1	tr	tr	0.2
18:0	0.7	tr	0.4	1.6
18:1 ω-9†	2.0	0.2	1.4	2.6
18:2 ω-6	4.7	1.5	4.2	9.1
18:3 ω-6	tr	—	—	tr
18:3 ω-3	36.3	49.8	36.9	24.3
18:4 ω-3	0.1	0.1	tr	—
20:0 } 20:1	0.4	tr	0.4	0.3
20:2 ω-6	0.1	tr	tr	0.1
20:3 ω-6	0.1	tr	0.3	0.1
20:4 ω-6	0.2	tr	0.3	0.3
20:4 ω-3	tr	tr	tr	0.2
20:5 ω-3	1.0	0.6	0.8	1.0
22:0 } 22:1	0.4	tr	1.0	0.4
Total ω-3	70.1	94.5	70.9	45.9
Total ω-6	5.2	1.5	5.2	10.0

* tr—trace: †—Other isomers present; Sample taken October 1975.

Vereshchagin and Klyachko-Gurvich [21] state that a comparatively high C-16 unsaturated fatty acid content is a unique characteristic of numerous green algae and that this property distinguishes these organisms from other algae and from the majority of higher plants. However, up to 17.5% 16:3 ω-3 has been found in angiosperm leaf lipids [22]. Pohl *et al.* [9] have reported that the remarkable differences between marine and fresh-water algae were the absences of 18:4 ω-3 and C-20 and C-22 polyunsaturated acids in the freshwater algae. These differences, however, are not general since appreciable amounts of 18:4 ω-3 have been found in freshwater cultured *Scenedesmus obliquus* [7,13] and the fatty acid composition of a fresh-water *Enteromorpha* species reported by Shaw [13] was similar, both qualitatively and quantitatively, to the marine *E. intestinalis* and *E. compressa* studied in our laboratory [10]; all these *Enteromorpha* species had significant amounts of 18:4 ω-3, C-20, and C-22 polyolefinic acids. Both the marine *Cladophora rupestris* [10] and a fresh-water *Cladophora* species [23] contained 18:4 ω-3 and C-20 polyolefinic acids, although the fresh-water species had higher proportions of 18:3 ω-3 and 20:5 ω-3 and a lower proportion of 16:4 ω-3 than the marine species. The fatty acid composition of *Ulothrix* is similar to that of green marine algae in having a high proportion of 16:4 ω-3 and a smaller proportion of C-20 polyolefinic acids, but is different in that 18:3 ω-6 and 18:4 ω-3 are present in only trace amounts. No C-22 polyolefinic acids were detected.

The fatty acid composition of *U. aequalis* is similar in many respects to that of a 1 week culture of the marine phytoplankton *Dunaliella tertiolecta* [3] which has 16:4 ω-3 and 18:3 ω-3 as the major fatty acids present in total amount 52.6% and in the ratio 1.15:1.00. The corresponding values for *Ulothrix* are 67.0% and 1.12:1.00. The main difference between the two species is that *D. tertiolecta* has 4% 18:3 ω-6 and *Ulothrix* has only trace amounts of this acid.

The distribution of fatty acids among the galactosyl diglycerides and the 'more polar' lipid fractions of *Ulothrix* is similar to that found for marine algae and for higher plants [10,22,24,25]. The transacid (16:1 ω-13t) is present only in the 'more polar' lipids. The galactosyl diglycerides are highly unsaturated (MGDG 3.5 and DGDG 2.6 C=C mol^{-1}) and the degree of unsaturation and the amounts of ω-3 and ω-6 acids in the different lipid classes of *Ulothrix* are similar to those found for the marine *E. intestinalis* and *Ulva lactuca* [10]. The MGDG fraction is the most unsaturated and contains the highest proportion of ω-3 acids.

The distribution of ω-3 acids in *Ulothrix* lipids is similar to that for green marine algae in that:

(a) the C-16 acid (16:4 ω-3) and the C-18 acid (18:3 ω-3) with the highest unsaturation are concentrated in the MGDG fraction;

(b) the highest proportion of 16:3 ω-3 is in the DGDG fraction;

(c) the C-20 ω-3 acids are present in similar small amounts in all three fractions.

Relative large amounts of 16:4 ω-3 are present in the DGDG and 'more polar' *Ulothrix* lipids. Such large amounts of this acid are not found in the correponding fractions of green marine algae but the overall distribution of 16:4 ω-3 in *Ulothrix* is similar to that of 18:4 ω-3 in the marine algae.

EXPERIMENTAL

Samples of *Ulothrix* were collected from a slow moving stream in the vicinity of Paisley. Lipids were extracted and separated into classes by methods described previously [10]. GLC analysis of the total lipid methyl esters and the methyl esters from each of the lipid classes were carried out on a PE.800 chromatograph using open tubular columns of different polarity [26].

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