Fatty acid content in seaweeds from the Baltic Sea and the Indian Ocean

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Abstract

Two species of red marine macroalgae (Rhodophyceae) from the Indian Ocean, two species of brown marine macroalgae (Phaeophyceae) and one species of green marine macroalgae (Chlorophyceae) from the Baltic Sea were examined for fatty acid composition and content. Fatty acids were quantified by means of high performance liquid chromatography (HPLC) of their coumaryl esters. The total fatty acid content ranged from 220 μg g^{-1} d.w. in red algae *Grateloupia indica* to 12 600 μg g^{-1} d.w. in red algae *Acantophora spicifera*. The proportions of particular fatty acids varied considerably in these species. Palmitic acid (16:0) was dominant in all the species investigated (58–68%) except for *G. indica*, which contained only 11% of this acid. The Baltic green algae *Enteromorpha clathrata* was characterised by a high amount of linolenic acid (16.7%), whereas the red macroalgae from the Indian Ocean *A. spicifera* contained large amounts of eicosapentaenoic acid (13%) and oleic acid (11%).

1. Introduction

Aquatic environments, both fresh and marine, are populated by numerous and diverse plants and animals. The plant biomass density and number of species are the greatest in shallow water near the shore, where nutrients are abundant and adequate light conditions obtain from top to bottom.

All of the major components of plants, such as proteins, carbohydrates, nucleic acids and lipids, have been examined recently in attempts to utilise plants as sources of human nutrition and/or for their pharmacological properties (Sargent, 1976; Dembitsky *et al.*, 1991; Sardesai, 1992). Because lipids are found in relatively small amounts in algae they have not been looked upon as sources of important substrates for further processing. On the other hand it is well known that polyunsaturated fatty acids are important organic coumpounds possessing strong effects against cardiovascular and skin diseases when administered to humans (Ackman, 1989; Mabeau and Fleurence, 1993). The literature data seems to suggest that the composition of fatty acids in seaweeds in the southern (Johns *et al.*, 1979) and northern (Ackman, 1989) hemispheres differs substantially, although no final conclusions have been reached.

Many workers have contributed to the information on the fatty acid composition in different algae species, but still very little is known about their pattern in seaweeds from the Baltic Sea or from some areas of the Indian Ocean.

Data on the qualitative and quantitative content of fatty acids of red algae taken from the eastern coast of the Indian Peninsula as well as brown and green algae from the southern Baltic Sea are presented in this study. They are discussed from the point of view of their possible use as sources of fatty acids and also in the context of fundamental differences between algae inhabiting regions in different climatic zones.

2. Materials and methods

The samples of red macroalgae (*Acantophora spicifera* and *Grateloupia indica*) were collected off the Saurashera coast of India. Brown macroalgae (*Fucus vesiculosus* and *Pilayella litoralis*) and green macroalgae (*Enteromorpha clathrata*) were collected in summer 1993 from the Baltic Sea coast near Sopot.

100 g of dried material was extracted with 80% methanol in a Soxhlet extractor. The methanol was evaporated off, after which the aqueous portion was acidified with hydrochloric acid to pH ∼2.5 and hydrolysed. The mixture was filtered through GF/F and extracted repeatedly with ethyl acetate. The combined extracts were dried with anhydrous sodium

sulphate, concentrated in a rotary evaporator and the residue processed by column chromatography on silica gel. The fractions were eluted with solutions increasing in polarity, from 10 to 20% ethyl acetate in hexane.

The derivatives were formed by the addition of 4-bromomethyl-7 -methoxycoumarin according to Pazdro and Falkowski (1994).

The esters obtained were analysed by means of high performance liquid chromatography (HPLC). A Lichrospher 100 RP – 18e column and methanol: water system at linear gradient flow were applied for reversed phase chromatography. A Hypersil SI 60 column and hexane : chloroform : isopropanol (88:10:2) isocratic solvent system were applied for normal phase chromatography. The following parameters of fluorescence detection were applied: $\lambda_{\text{excitation}} = 312$ nm and $\lambda_{\text{emission}} = 399$ nm.

3. Results

The total fatty acid contents in seaweeds from the Indian Ocean and the Baltic Sea are reported in Tab. 1. They ranged from 220 μg g^{-1} d.w. (dry weight) to 12 600 μg g^{-1} d.w. The lowest contents were found in red algae *G. indica* from the Indian Ocean and in brown algae *F. vesiculosus* from the Baltic Sea. *A. spicifera* from the Indian Ocean was found to contain the highest quantity of fatty acids (12 600 μg g^{-1} d.w.), considerably exceeding the values in the other seaweeds investigated.

Table 1. Total fatty acid content of the seaweeds investigated

Species analysed	Group	Origin	Total fatty acid content [μg g^{-1} d.w.]
F. vesiculosus	brown algae	Baltic Sea	385
P. litoralis	brown algae	Baltic Sea	1800
E. clathrata	green algae	Baltic Sea	2400
A. spicifera	red algae	Indian Ocean	12600
G. indica	red algae	Indian Ocean	220

Since the contents of the different groups of fatty acids (saturated, mono- and polyunsaturated) vary in different species, these were also investigated. In Fig. 1 the proportion of fatty acid groups (saturated, mono- and polyunsaturated) in the total fatty acid content found in these seaweeds is presented. The contribution of saturated fatty acids in the Baltic algae ranges from 74% (*E. clathrata*) to 80% (*F. vesiculosus*) of the total amount of fatty acids. In red algae the proportions of this group were lower – 64% in *A. spicifera* and 51% in *G. indica*. Polyunsaturated fatty acids made up 12% of the total fatty acid content in *F. vesiculosus*, 14% in *P. litoralis* and

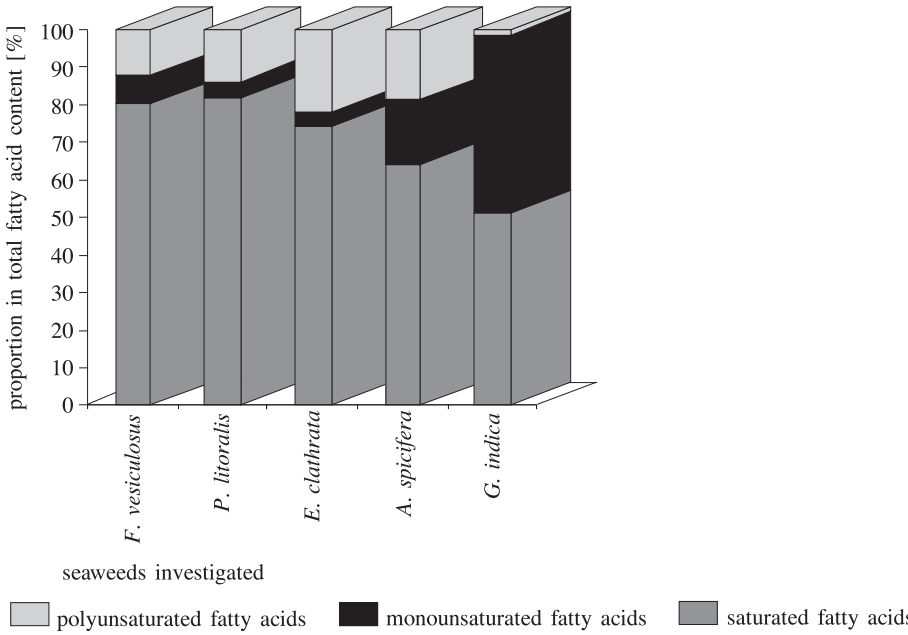

Fig. 1. Percentage of major groups of fatty acids in the total fatty acid content in the seaweeds investigated

Table 2. Fatty acid composition of the seaweeds investigated (values are wt % of total fatty acid content)

Identified acid	Brown algae		Green algae	Red algae	
	F. vesiculosus	*P. litoralis*	*E. clathrata*	*A. spicifera*	*G. indica*
12:0	–	2.12	0.92	0.50	1.60
14:0	21.67	0.85	2.45	0.27	22.36
14:1	1.05	2.06	0.29	3.36	17.67
16:0	58.11	65.78	67.05	61.30	10.40
16:1	0.5	0.89	3.05	2.10	–
16:4	–	–	–	–	–
18:0	0.25	6.85	–	1.59	3.00
18:1	5.9	1.43	1.93	11.45	20.04
18:2	1.63	2.53	0.37	2.29	–
18:3	5.27	4.76	3.04	0.60	–
20:0	0.2	6.15	16.70	0.20	13.70
20:1	0.05	–	1.96	0.10	–
20:2	–	1.67	–	0.80	–
20:4	4.25	1.64	1.02	1.76	1.45
20:5	1.05	3.28	0.35	13.06	–
22:1		–	0.88	0.10	9.80

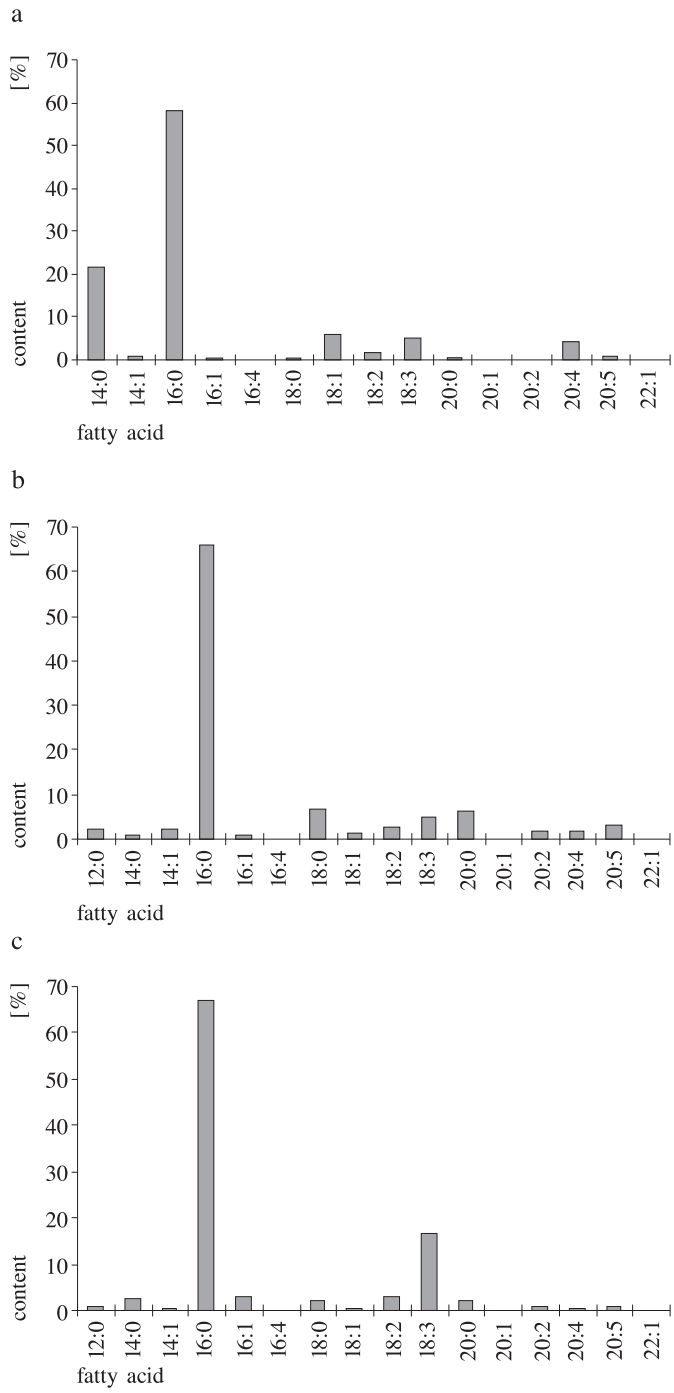

Fig. 2. Percentage of individual fatty acids in brown and green algae from the Baltic Sea: *F. vesiculosus* (a), *P. litoralis* (b), *E. clathrata* (c)

21% in *E. clathrata*. In *A. spicifera* and *G. indica* the respective values are 18% and 2%. The red algae contained high amounts of monounsaturated fatty acids, up to 47% of the total fatty acid content in *G. indica*.

The detailed results concerning the fatty acid composition in the species examined are summarised in Tab. 2 and in Figs. 2 and 3. Palmitic acid (16:0) was the dominant one in all the species investigated (58–68%) except *G. indica*, which contained only 11% of this acid. *F. vesiculosus* contained an appreciable amount of unsaturated C18 compounds (18:1, 18:3) together with arachidonic acid 20:4. The other brown algae investigated, *P. litoralis*, was characterised mainly by the presence of saturated acids 18:0, 20:0 and polyunsaturated linolenic acid (18:3). The content of this last acid (18:3) in

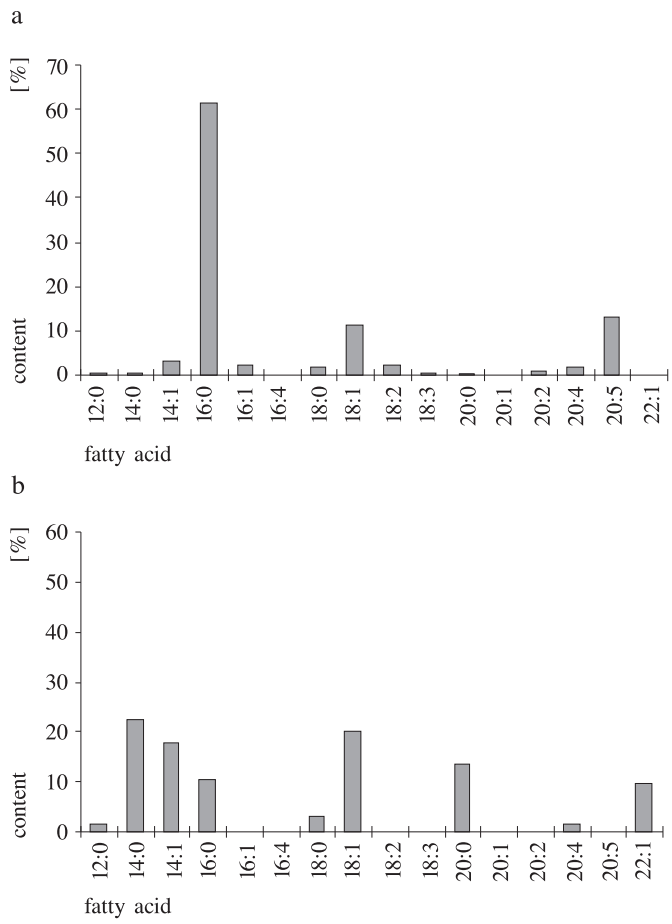

Fig. 3. Percentage of individual fatty acids in red algae from the Indian Ocean: *A. spicifera* (a), *G. indica* (b)

the green algae *E. clathrata* was 16.7%. The contents of all the other acids were rather low. *A. spicifera* contained large quantities of eicosapentaenoic acid (20:5 – 13%) and oleic acid (18:1 – 11%). In *G. indica*, however, the fatty acid distribution pattern was quite different: it contained large amounts of oleic acid 18:1 (20%) and arachidic acid (13.7%), together with a considerable amount of erucic acid (22:1 – 9.8%).

4. Discussion and conclusion

As in all other organisms, fatty acids are important constituents of seaweeds. The abundance and composition of individual fatty acids in algae are species-dependent, and depend strongly on environmental factors such as growth conditions (light, temperature and the availability of nutrients), growth phase and age (Chuecas and Riley, 1974; Sato *et al.*, 1974; Ackman, 1989; Kayama *et al.*, 1989). Different species have different fatty acid patterns, which may also be important for taxonomic purposes (Sargent *et al.*, 1980; Kato and Ariga, 1983).

The fatty acid distribution of a large number of marine algae originating from various locations has been reported. According to Dembitsky *et al.* (1990) the composition of fatty acids of brown algae from the Black Sea is characterised by relatively high amounts of polyunsaturated fatty acids with 18 and 20 atoms (in particular 20:5 and 20:4) – up to 33% of an individual compound. This pattern of fatty acid distribution has also been reported by some other authors (Jamieson and Reid, 1972; Johns *et al.*, 1979; Stefanov *et al.*, 1988) investigating brown algae in different seas. By contrast, Fleurence *et al.* (1994) found that five brown algae from the Brittany coast of France had high contents of 18:1, 18:2 and 18:3 acids but low contents of the 20:5 acid. A distribution of fatty acids similar to that given by Fleurence *et al.* (1994) was found in the brown algae *F. vesiculosus* and *P. litoralis* investigated in the present study.

The fatty acid compositions of different species of macroscopic marine green algae have been determined in several studies (Jamieson and Reid, 1972; Johns *et al.*, 1979; Kayama *et al.*, 1989). The results showed that the dominant fatty acids in these seaweeds were C16 and C18, while C20 acids were scarce. The fatty acid composition of green macroalgae reported by Fleurence *et al.* (1994) and Dembitsky *et al.* (1990) are substantially the same as those described by Kayama *et al.* (1989). The fatty acid composition in the Baltic *E. clathrata* examined in this study closely resembles the results mentioned above. In particular, *E. clathrata* from the Baltic has a characteristically high proportion of 18:3 acid.

Ackman (1989) revealed that the major fatty acid in red macroalgae was eicosapentaenoic acid (20:5) with relatively small amounts of C16

and C18 polyunsaturated compounds. Similar results were obtained by Fleurence *et al.* (1994) for French coast macroalgae and Stefanov *et al.* (1988) for algae from the Black Sea. Johns *et al.* (1979) studied ten red algae collected off the Australian coast and described compositions of fatty acid somewhat different from those of seaweeds from northern latitudes. In almost all the red algae he studied, the 20:4 rather than the 20:5 acid was the dominant one. The results obtained for *A. spicifera* in this study are in good agreement with these results. In particular, 20:5 is present in large quantities. *A. spicifera* is the one of the seaweeds investigated that contains the highest amount of total fatty acids. The fatty acid distribution in *G. indica*, presented in Fig. 3, differs significantly from those reported in the literature for red algae (Johns *et al.*, 1979, Fleurence *et al.*, 1994). This species is characterised by large amounts of oleic acid (18:1) arachidic acid (20:0), together with significant amounts of erucic acid (22:1).

Insufficient data are available to reach definitive conclusions on the differences in fatty acid content and composition among the species tested, because a large number of environmental factors influence the pattern of fatty acids in algae from different parts of the world. On the other hand, the presence of particular acids as an abundant component of certain investigated species appears to be interesting for nutritional and pharmacological purposes. *A. spicifera* from the Indian coast is interesting, owing to its high total fatty acid content and the high percentage of eicosapentaenoic acid (20:5).

The green alga *E. clathrata* from the Baltic Sea seems to be good source of linolenic acid (18:3).

References

Ackman R. G., 1989, *Fatty acids*, [in:] *Marine biogenic lipids, fats and oils*, R. G. Ackman (ed.), CRC Press Inc., Boca Raton, Florida, I, 36 pp.

Chuecas L., Riley J. P., 1974, *Compontent fatty acids of the total lipids of some marine phytoplankton*, J. Mar. Biol. Ass., 49, 97–116.

Dembitsky V. M., Rozentsvet O. A., Pechenkina E. E., 1990, *Glycolipids, phospholipids and fatty acids of brown algae species*, Phytochemistry, 29, 3417–3421.

Dembitsky V. M., Pechenkina-Shubina E. E., Rozentsvet O. A., 1991, *Glycolipids, phospholipids and fatty acids of some seaweeds and marine grasses from the Black Sea*, Phytochemistry, 30, 2279–2283.

Fleurence J., Gautbier G., Mabeau S., Leray C., 1994, *Fatty acids from 11 marine macroalgae of the French Brittany coast*, J. Appl. Phycol., 6, 527–532.

Jamieson G. R., Reid E. H., 1972, *The component fatty acids of some marine algal lipids*, Phytochemistry, 11, 1472–1481.

Johns R. B., Nichols P. D., Perry G. J., 1979, *Fatty acids composition of ten marine algae from Australian water*, Phytochemistry, 18, 799–806.

Kayama M., Araki S., Sato S., 1989, *Lipids of marine plants*, [in:] *Marine biogenic lipids, fats and oils*, R. G. Ackman (ed.), CRC Press Inc., Boca Raton, Florida, II, 3–46.

Kato N., Ariga N., 1983, *Studies on lipids marine algae, sterol and fatty acids composition of marine algae*, Bull. Gen. Edu. Gifu Univ., 18, 53–64.

Mabeau S., Fleurence J., 1993, *Seaweed in food products: biochemical and nutritional aspects*, Trends Food Sci. Technol., 4, 103–107.

Pazdro K., Falkowski L., 1994, *Determination of free fatty acids in marine environment by means of HPLC (applying their UV absorbing and fluorescent esters)*, Stud. i Mater. Oceanol., 67, 15–26.

Sardesai V. M., 1992, *Nutritional role of polyunsaturated fatty acids*, J. Nutr. Biochem., 3, 154–166.

Sargent J. R., 1976, *The structure, metabolism and function of lipids in marine organisms*, [in:] *Biochemical and biophysical perspectives in marine biology*, D. C. Malins and J. R. Sargent (eds.), Acad. Press, London–New York–San Francisco, 151–207.

Sargent J. R., Bell M. V., Henderson R. J., Tocher D. R., 1980, *Polyunsaturated fatty acids in marine and terrestrial food webs*, [in:] *Animal nutrition and transport processes*, J. Mellinger and S. Kargen (eds.), Birkhäuser Verlag, Basel, 142–153.

Sato S., Kayama M., Mashiba M., 1974, *Effects of environmental factors on the lipid components of Porphyra sp.*, Bull. Jap. Soc. Sci. Fish., 40, 326–339.

Stefanov K., Konaklieva M., Brechany E. Y., Christie W. W., 1988, *Fatty acid composition of some algae from the Black Sea*, Phytochemistry, 27, 3495–3497.