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Distribution of Iodine in Egyptian Marine Algae

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ABSTRACT. Thirty-two species of Egyptian marine algae of Chlorophycophyta, Phaeophycophyta and Rhodophycophyta collected from the Mediterranean (17 spp.) and Red (15 spp.) Seas has been analyzed for their content of iodine.

Distribution of iodine in Egyptian marine algae showed noticeable local differences. The highest values were obtained in the species collected from the Mediterranean Sea.

Iodine contents of the investigated species exhibited significant differences according to the species and showed characteristics in relation to the division. Much higher levels of iodine were observed in brown species than in red and green species. Iodine contents in the red species were of moderate levels.

Dictyota dichotoma, D. divaricata, Dilophus fasciola and *Gelidium latifolium* were found to have considerably higher levels of iodine indicating that these species, rather than the others are potentially a better source of iodine.

Iodine was accumulated selectively by various organs of *Sargassum salicifolium* and *S. subrepandum*. Generally speaking, the leaves of two species of *Sargassum* had higher content of iodine that did the stipes. In contrast, *Turbinaria triquetra* exhibited no well marked differences in iodine levels between leaves and stipes.

Seasonal variations in iodine content were determined for the red alga *Gelidium latifolium* and brown alga *Sargassum salicifolium*. In *G. latifolium* there were well marked maximum and minimum contents of iodine. The iodine level of *S. salicifolium* showed little variation with season of the year.

Introduction

According to Vernadsky (1954), the biosphere is permeated with atoms of dispersed elements. Of these elements, only iodine and bromine are concentrated by living organisms. Seaweeds are particularly strong concentrators of iodine (Saenko *et al.*, 1978).

The early work on the concentration of iodine by marine algae has been reviewed by Blinks (1951). Brown algae, particularly those of order Laminariales, accumulate iodine in concentrations of up to 60,000 times that in seawater (Young and Langille, 1958).

Iodine and its compound find wide use in medicine. With insufficient iodine in the human and animal organisms, thyroxine synthesis is retarded and this leads to generation of an endemic goitre (Saenko *et al.*, 1978).

At present, considerable amounts of iodine are obtained from waste waters of soil and gas deposits. But, for several countries lacking reserves of iodine containing waters, seaweeds are a promising source of iodine (Dave *et al.*, 1967).

Although the Paeophycophyta species have received extensive attention for iodine content, the iodine contents of members of the Rhodophycophyta and Chlorophycophyta have received relatively little attention. In Egypt, our knowledge of iodine levels in marine algae is limited to few species of brown algae (Abdouh, 1984). A more systematic investigation of the iodine levels of Egyptian marine algae (green, brown and red) was therefore undertaken. Thirty two species of green, brown and red algae collected from Egyptian waters were evaluated for production of iodine.

Additionally, iodine content of some species was analyzed seasonally to study the effect of seasonal variation on iodine level. Also, more emphasis was imposed on the distribution of iodine in different parts of thallus.

Material and Methods

Collection and Preparation of Material

The specimens studied in the present work were collected from shores of the Mediterranean and Red Seas over two years (1989-1991). Collection of specimens was always done during the spring months of each year. These specimens represent 32 species belonging to the three major divisions of algae which occur in the collection sites.

Specimens of *Sargassum salicifolium* and *Gelidium latifolium* were also collected at regular three-monthly intervals between April 1991 and January 1992 to detect any seasonal variation in iodine content.

The algal nomenclature used is that recommended by Nasr (1947), Zinova (1967), Aleem (1978) and El-Naggar (1980).

In order to make a comparison between different parts of thallus, some samples of *Sargassum salicifolium, S. subrepandum* and *Turbinaria triquetra* were divided into stipes and leaves (blades).

After elimination of epiphytes and stones, the algal samples were thoroughly washed with running water and rinsed many times in distilled water. The samples were then dried in an oven at 105°C. Dried samples were ground and stored in stoppered bottles at room temperature.

Estimation of Iodine

Iodine was estimated by wet ash method of Borst Pauwels and Van Wesemael (1962). Wet ashing is, in general, the best approach for determination of iodine in most media in which it is difficult to determine iodine without destruction or at least partial destruction (Zak, 1978).

In this method, 200 mg of oven-dried algal sample is transferred to a 50-ml flask. 7.5 ml Neumann acid (sulfuric acid-nitric acid, 1:1) and 1 ml perchloric acid is then added. The mixture is heated on a hot plate for 1 hr at 160-190°C, and the temperature then raised to 275°C until the solution turns yellow. The digest is cooled and diluted (dilution solution, 3.0 N sulfuric acid) to 40 ml, and 1 ml arsenite solution is then added (in sequence, 9.8 arsenious oxide is dissolved in 14 ml 10 N sodium hydroxide, 600 ml water added and the solution is neutralised with 10 N sulfuric acid, – 42 ml concentrated sulfuric acid added and diluted to 1 liter). The solution is allowed to stand at room temperature for one to two days and 5 ml aliquots placed in colorimeter tubes containing 0.4 ml arsenite solution. The equilibrium mixture is then incubated in a 30°C water bath, and 1 ml ceric ammonium sulfate solution added (5 g ceric ammonium sulfate dissolved in 70 ml 5 N sulfuric acid by heating gently, then filtered and diluted to 100 ml with distilled water. 25 ml diluted to 100 ml with 3.5 N sulfuric acid) to each tube and the absorbance measured at 420 nm at 30 sec and 20 min.

The iodine concentration is then determined against a standard calibration curve using standards carried through the same procedure in amounts of 0-0.5 ml of the standard iodate solution (1 mg as iodide per litre of water). Absorbance is measured using spectronic 20 D, Milton roy company spectrophotometer.

Results

Iodine contents of Egyptian marine algae from the Mediterranean and Red Seas are given in Tables 1 and 2 respectively.

As shown in Table 1, the concentrations of iodine in green species of the Mediterranean Sea were quite different and ranged between 0.004 and 0.070% of dry weight. All species of order Ulvales examined here contained high amounts of iodine. The highest amount of it was found in *Ulva lactuca* (0.070%). In this connection, we should mention that no obvious differences in iodine concentrations could be distinguished in samples of *Ulva rigida* taken from different locations. In general, a lower iodine content was measured in *Cladophora dalmatica*.

The levels of iodine in the brown algae taken from the Mediterranean coast varied between 0.080 and 0.290%. In general, the brown species had high iodine content as

TABLE. 1. Concentration of iodine (% of dry wt) in marine algae of the Mediterranean Sea. Data are means of 3 replicates.

Algal species	Site of collection	Concentration (%)
Chlorophycophyta		
Enteromorpha linza (L.) J. Ag.	Ras El-Barr	0.065
Ulva rigida Ag.	Port Said	0.060
U. rigida Ag.	Ras El-Barr	0.055
U. lactuca L.	Alexandria	0.070
Codium dichotomum (Huds.) Gray	Alexandria	0.045
Cladophora dalmatica Kütz.	Ras El-Barr	0.004
Chaetomorpha sp.	Alexandria	0.031
Phaeophycophyta		
Dictyota dichotoma (Huds) Lamour.	Alexandria	0.290
Dilophus fasciola (Roth) Howe	Alexandria	0.150
Padina pavonia (L.) Gaill.	Alexandria	0.090
Colpomenia sinuosa (Roth) Derb. et Sol.	Alexandria	0.120
Cystoseira barbata (Good et Wood) Ag.	Alexandria	0.130
Sargassum salicifolium (Bert.) J. Ag.	Alexandria	0.080
Rhodophycophyta		
Gelidium latifolium (Grev.) Born. et Thur.	Alexandria	0.145
Gelidium crinale (Turn) Lamour.	Ras El-Barr	0.020
Jania rubens (L.) Lamour.	Alexandria	0.065
Hypnea musciformis (Wulfen) Lamour.	Ras El-Barr	0.110
Laurencia papilosa (Forsk.) Grev.	Alexandria	0.045

Statistical analysis showed that no standard deviation exceeded 10%.

compared with the green and red species examined (Table 1). *Sargassum salicifolium* and *Padina pavonia* differ greatly from other brown algae in their iodine contents. In these two algae, iodine was present in lowest amount (Table 1). Species of order Dictyotales were distinguished by high iodine contents. The percentage of iodine for *Dictyota dichotoma* was 0.290% and for *Dilophus fasciola* 0.150%.

In general, the red species of the Mediterranean Sea had moderate levels of iodine as compared with brown and green species (Table 1). Iodine content of red species ranged from 0.020% to 0.145%. *Gelidium latifolium* and *Hypnea musciformis* were characterized by having high amounts of iodine (0.145 and 0.110% respectively).

A comparison of iodine contents in two species of *Gelidium* showed that the levels of iodine in the two species were quite different. *Gelidium latifolium* was found to have a considerably higher level of iodine (Table 1).

The data recorded in Table 2 indicated that varying levels of iodine were detected in the 15 different species collected from the Red Sea coast.

It is obvious that the green species were found to have considerably lower values of iodine. The values varied between 0.0045 and 0.0230%. Higher values were observed in *Caulerpa serrulata*. It is interesting to notice that level of iodine in members of order Ulvales here were much lower than that reported for members of Ulvales taken from the Mediterranean coast (Tables 1 & 2).

TABLE. 2. Concentrations of iodine (% of dry wt) in marine algae of the Red Sea. Data are means of 3 replicates.

Algal species	Site of collection	Concentration (%)
Chlorophycophyta		
Enteromorpha clathrata (Roth) Grev.	Ghardaka	0.0045
Ulva lactuca L.	Ghardaka	0.0057
Caulerpa serrulata (Forsk.) Borg.	Abu Shaar	0.0230
Halimeda opuntia (L.) Lamour.	Safaga	0.0191
Cladophora heteronema (C. Ag.) Kütz	Safaga	0.0060
Phaeophycophyta		
Dictyota divaricata Lamour.	Ghardka	0.203
Padina boryana Thivy	Safaga	0.079
Hydroclathrus clathratus (C. Ag.) Howe	Ghardaka	0.069
Hormophysa triquetra (C. Ag.) Kütz.	Ghardaka	0.076
Turbinaria triquetra (J. Ag) Ag.	Ghardaka	0.084
Sargassum subrepandum (Forsk.) C. Ag.	Safaga	0.127
Rhodophycophyta		
Actanthophora najadiformis (Delile) Papenfuss	Sharm El Naga	0.053
Digenea simplex (Wulfen) C. Ag.	Ghardaka	0.116
Laurencia obtusa (Huds.) Lamour.	Safaga	0.017
Hypnea musciformis (Wulfen) Lamour.	Safaga	0.032

Statistical analysis showed that no standard deviation exceeded 10%.

The results listed in Table 2 indicated that iodine content of the brown species ranged from 0.069% to 0.203%. *Dictyota divaricata* and *Sargassum subrepandum* were characterized by having high amount of iodine (0.203 and 0.127% respectively). As shown in species from the Mediterranean Sea, the brown species of Red Sea had much higher amounts of iodine than red and green species.

As regard to red species, the level of iodine varied between 0.017 and 0.053% in all species except in *Digenea simplex* where it was found in comparatively large amount (0.116%).

Comparison of Leaf and Stipe

Iodine concentrations in different parts of *Sargassum salicifolium*, *S. subrepandum* and *Turbinaria triquetra* are compared in Table 3.

A comparison of iodine amounts in different parts of the two species of *Sargassum* showed higher values in the leaves compared to stipes. In other studies, leaves had

TABLE. 3. Comparison of iodine levels (% of dry wt) of leaf and stipe of *Sargassum salicifolium*, *S. subrepandum* and *Turbinaria triquerta*. Data are means of 3 replicates.

Organ	Algal species		
	S. salicifolium	*S. subrepandum*	*T. triquetra*
Leaf	0.053	0.063	0.0134
Stipe	0.021	0.016	0.0106

higher content of iodine that did the stipes of *Sargassum pallidum* (Saenko *et al.*, 1978) and *Laminaria digitata* (Young and Langille, 1958).

In contrast, it was noted that the fluctuations in iodine content of the different parts of *Turbinaria triquetra* were comparatively small (Table 3).

Seasonal Variation

The seasonal variations in iodine content of *Sargassum salicifolium* (brown) and *Gelidium latifolium* (red) are shown in Table 4. It is clear that iodine level in *S. salicifolium* exhibited fluctuations but did not appear to have any distinct relation to the time of year, except that a higher value was found during Spring.

TABLE 4. Seasonal variations in iodine content (% of dry wt) of *Sargassum salicifolium* and *Gelidium latifolium*. Data are means of 3 replicates.

Algal species	Month of collection			
	April 1991	July 1991	October 1991	January 1992
Sargassum salicifolium	0.080	0.045	0.040	0.050
Gelidium latifolium	0.145	0.035	0.070	0.025

In contrast, definite fluctuations were shown in *Gelidium latifolium*. The data indicated that iodine content of this alga was at maximum during Spring and at minimum during Winter.

Discussion

The data presented in this paper show that amounts of iodine in all taxa studied varied considerably according to the species and showed characteristic relations to Division. Vinogradov (1965) pointed out the dependence of iodine and bromine content in organisms upon the systematic position of the latter. One of the most striking examples of this is the iodine content in seaweeds.

In general, the concentration of iodine appears to be highest in the Phaeophycophyta and lowest in the Chlorophycophyta. Similar results were obtained by Young and Langille (1958), Koppanna and Rao (1962) and Khalil and El Tawil (1982). These results contrast with those reported for seaweeds of Goa region of India by Solimabi (1977) who found that lower iodine contents were observed in the brown algae than in the red and green algae. Solimabi used caustic potash method for determination of iodine.

Dictyota dichotoma, D. divaricata, Dilophus fasciola and *Gelidium latifolium* were found to have considerably higher levels of iodine, indicating that these species, rather than other species, are potentially a better source of iodine. In this connection, it may be mentioned that moderate amounts of iodine were notable in *Cystoseira barbata, Sargassum subrepandum, Colpomenia sinuosa, Digenea simplex* and *Hypnea musciformis.* This finding is in general agreement with that of Khalil and El Tawil (1982).

The results summarized in Table 5 indicated that percentage of iodine varied greatly from site to site. With regard to the Chlorophycophyta and Rhodophycophyta species, the iodine concentrations in the species from the Mediterranean Sea tended to be much higher than in the species from the Red Sea, and this also applied to the brown species but exhibited no well marked differences. These variations may be connected with the influence of environmental factors and characteristic features of algal species. In addition to being a taxonomical feature of some species, iodine contents are subjected to modification due to ecological factors (Vinogradov, 1953; Kovalsky, 1974).

TABLE 5. The mean value of iodine (%) in the algal divisions occurring in the Mediterranean and Red Seas.

Location	Algal division		
	Chlorophycophyta	Phaeophycophyta	Rhodophycophyta
Mediterranean Sea	0.0471 ± 0.009	0.1433 ± 0.034	0.0770 ± 0.025
Red Sea	0.0117 ± 0.004	0.1063 ± 0.021	0.0545 ± 0.025

Although *Sargassum salicifolium, S. subrepandum* and *Turbinaria triquetra* belong to the same family (Sargassaceae), the variations in iodine content of different parts of thallus were more pronounced in the two species of *Sargassum* than in *Turbinaria triquetra.* This is probably a result of difference in the morphological and anatomical structures. *Sargassum* shows a high degree of morphological differentiation (Prince and O'Neal, 1979; Dawes, 1981). This differentiation extends to anatomical features as well, and ultrastructural features can be quantitatively correlated with physiological aspects of various tissues (Fagerbeg *et al.*, 1979)

Iodine was shown to be accumulated selectively by various organs of *Sargassum* spp., with maximum concentrations in the leaves. In *Turbinaria triquetra* slightly higher values were observed in leaves (fronds) than in stipes. Previous observations have shown differences in the concentrations of iodine between leaves (fronds) and stipes of several species of brown algae (Wort, 1955; Young and Langille, 1958; Saenko *et al.*, 1978).

The distribution of iodine in different parts of *Sargassum* spp. follows the same trends as those reported for alginic acid (El-Naggar, 1987) with high values in leaves. Rosell and Srivastava (1985) reported that tissue nitrogen and carbon showed higher values in the blades than in stipes of *Macrocystis integrifolia* and *Nereocystis luetkeana*. The higher content of iodine and other constituents in leaves compared to stipe tissues is probably related to higher pigment of photosynthetic enzyme level in leaves compared to stipes (Rosell and Srivastava, 1985).

While the content of iodine in *Gelidium latifolium* is subjected to a marked seasonal variation, the iodine content of *Sargassum salicifolium* showed little variation with season of the year. In general, these variations showed maxima in Spring. A possible explanation for this seasonal fluctuation could be the fact that these plants depend on light as a source of energy for the photosynthetic process and changes in light intensity and duration due to season make their impression on the metabolism and growth of the algae (Wort, 1955).

According to Vinogradov (1965), iodine is concentrated in the organism due to the formation of the linkages I-C. Both inorganic iodine compounds (Kisewetter, 1938; Trofimov, 1938) and organic iodine compounds have been detected in algae; for instance, amino acids contain iodine (Coulson, 1953; Scott, 1954).

It may be concluded from these analyses that there are many species of Egyptian marine algae characterized by having high amounts of iodine. Not only iodine, but also others constituents of the algae could be obtained from these species. Saenko *et al.* (1978) reported that iodine could be obtained from seaweeds after agar and other substances have been removed. Thus, multiple utilization of plant resources could be achieved. On the other hand, the use of powders from algae which are effective concentrators of iodine may prove highly effective due to the presence of vitamins and vitally essential microelements, whose combined actions could produce a positive effects (Vernadsky, 1965; Saenko *et al.*, 1978).

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توزيـــع اليـــود في الطحـــالب البحريـــة المصريـــة

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المستخلص . في ضوء اهتمامنا بدراسة التركيب الكيميائي للطحالب البحرية المصرية تم في هذا البحث دراسة تواجد اليود وكيفية توزيعه في عديد من الطحالب البحرية .

أجريت هذه الدراسة على **٣٢** نوعًا تنتمي إلى الطحالب الخضراء والبنية والحمراء ، وجمعت هذه الأنواع من البحر الأبيض المتوسط (١٧ نوعًا) وكذلك من البحر الأحمر (**١٥** نوعًا) .

أظهرت هذه الدراسة أن توزيع اليود في الطحالب المصرية عامة اتسم باختلافات بيئية واضحة ، فالأنواع المجمعة من مياه البحر الأبيض المتوسط تميزت بمستوى عال من اليود إذا ماقورنت بتلك التي تم جمعها من البحر الأحمر .

وضح أن كميات اليود في الأنواع المدروسة تتباين بشدة تبعًا لنوع الطحلب ، وأن هناك علاقة بين كمية اليود والقسم الطحلبي ، فكان أعلى مستوى لليود في الطحالب البنية وأقلها في الطحالب الخضراء ، بينما تميزت الطحالب الحمراء عامة بكميات متوسطة من اليود .

تميزت كل من ديكتيوتا ديكوتوما ، و ديكتيوتا دايفريكاتا ، دلفس فاسيولا و جليديم لاتيفوليم باحتوائها على كميات عالية من اليود ، مما يكسب هذه الأنواع أفضلية أن تكون مصدرًا لليود عما سواها من الأنواع الأخرى .

وبدراسة توزيع اليود في الأجزاء المختلفة للطحلب وجد أن توزيع اليود في أجزاء الثالوس يكون توزيعًا انتقائيًا عامة ، وقد ظهر ذلك بوضوح عند دراسة كل من سرجاسم ساليسيفوليم و سارجاسم سبريباندم حيث تميزت الأجزاء الورقية بمحتوى عال من اليود عما هو موجود في الأعناق . هذه الصورة لم تتضح بهذه الدرجة عند دراسة الأجزاء المختلفة لطحلب تربياناريا ترايكترا ، حيث وجد أن الفرق بين الأجزاء المختلفة ليس كبيرًا .

في هذا البحث أيضًا تمت دراسة التغيرات الموسمية لكميات اليود في كل من الطحلب الأحمر جليديم لاتيفوليم والطحلب البني سارجاسم ساليسفوليم . ودلت النتائج أن التغيرات الموسمية ارتبطت بصورة عامة بنوع الطحلب ، فكانت كميات اليود أكثر تفاوتًا بين موسم وآخر في الطحلب الأحمر وأقل تقلبًا في الطحلب البني .