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THE AMINO ACID COMPOSITION OF SOME COMMON MARINE ALGAE FROM QATAR (ARABIAN GULF)

By

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دراسة الأحماض الأمينية في بعض الطحالب البحرية التي تنمو على سواحل قطر

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يشتمل البحث على التقدير الكمي والكيفي للأحماض الأمينية الحرة والكلية التي تنتج من التحلل المائي الحمضي للبروتينات والببتيدات ، وذلك في عشرين طحلباً تمثل أكثر الأنواع انتشاراً على سواحل دولة قطر .

ولقد أجري التقدير باستعمال جهاز تحليل الأحماض الأمينية الآلي الذي يعمل بالكمبيوتر ، ولقد أثبت البحث وجود سبعة أحماض أمينية أساسية حرة وعشرة أحماض أمينية غير أساسية حرة في كل أو بعض الطحالب . كما ثبت وجود ستة أحماض أمينية أساسية كلية وتسعة أحماض غير أساسية كلية أي ناتجة من التحلل المائي الحمضي لبروتينات وببتيدات الطحالب .

وبصورة عامة وجد أن كمية الأحماض الأمينية في الطحالب أقل من الموجودة في النباتات العليا وأقل من الاحتياجات الغذائية اليومية للإنسان وعلى الرغم من ذلك فقد وجد أن لها فائدة غذائية واقتصادية كبيرة .

Key Words: Free amino acids, total amino acids in algae, Chlorophyceae, Phaeophyceae, Rhodophyceae.

ABSTRACT

The most dominant twenty algal species representing the main three groups of benthic macroalgae, Chlorophyceae, Phaeophyceae and Rhodophyceae were collected from the coastal zones of the Qatar peninsula. The algae were chemically analyzed for their free and total amino acid contents using Alpha amino acid analyzer Model 4150 LKB. The analysis revealed the presence of seven free essential and ten free non essential amino acids in all or in some of the algae. It also showed the presence of six total essential and nine total non essential amino acids in the acid hydrolyzates of the algal proteins. Generally the amounts of the amino acids are less than those present in higher plants and less than the daily dietary requirements. The nutritive and economic importances of these findings are discussed in relation to the findings reported before by the previous investigators.

INTRODUCTION

As long ago as, 1961, scientists started to be interested in the study of the amino acid contents of algae. Takemoto (1961) extracted yunain a new sulfur - containing amino acid from *Chondria crassicaulis* which is one of the Rhodophyceae.

Paper chromatographic analysis was also used by Silva *et al.* (1965); Hayashi and Nonaka (1967) for the determinations of the free and the conjugated amino acid contents of algae.

Dusheiko *et al.* (1969) determined the amino acid composition of preoteins in blue green algae using an automatic amino acid analyzer.

Margaris and Mitrakos (1973) used the technique of ion-exchange resins combined with technicon Autoanalyzer for the qualitative and quantitative determination of the free amino acid pools in eight species of blue-green, green, brown and red algae. In continuation for this work, Margaris (1974) studied the free amino acid pools in *Cladonia pyxidata* and *Peltigera* species. Lewis (1974) studied the free amino acid composition of some species of *Laurencia* from Saurashtra coast.

In (1976) Burris *et al.,* used the glycine and serine production in marine plants as a measure of photorespiration, Kokyrtsa, studied the content of amino acids in some blue-green algae of Moldavia, Munda and Gubensek (1976) studied the amino acid composition of some common marine algae from Iceland and Miyazawa *et al.* (1976) studied the amino acids and peptides in seven species of Marine green algae.

In 1981, Rashida, studied the amino acids present in some sea weeds from the Karachi coast and Portugal *et al.* (1983) studied the amino acid composition of some Philippine sea weeds.

Amblard *et al.* (1990) studied the structure and metabolism of periphytic algae in experimental streams and in (1991) Aitken *et al.,* studied the protein bound and the major free amino acids in some New Zealand sea weeds.

However, the only work regarding the chemical, nutritional, pharmaceutical and economical improtance of the algal community present in the Qatari waters was that reported by Heiba *et al.* (1990). They studied the most dominant algal species representing the main three groups of benthic macroalgae Chlorophyceae, Phaeophyceae and Rhodophyceae. These algae were screened for alkaloids, coumarins, flavonoids, saponins and tannins. The moisture, ash, protein, lipid, carbohydrate, mineral and trace element contents of the investigated algal species were also determined.

In continuation of this work the free and the total amino acid composition of these algal species are studied in the present investigation.

EXPERIMENTAL

The collection and treatment of the studied samples are similar to those reported before by Heiba *et al.* (1990).

For the extraction of the free amino acids, the algae were boiled and homogenized in ethanolic solution 80% v/v and subjected to five 10 minutes extractions with aqueous ethanol, 80, 80, 50, 50, 80% v/v (Margaris and Mitrakos, 1973; Margaris, 1974 and Tsekos *et al.,* 1975).

For the estimation of the total amino acids, a weighed sample of each of the algal species were hydrolyzed at 105°C in 6 N HCl for 48 hours (Munda and Gubensek, 1976 and Miyazawa *et al.,* 1976).

The free amino acids in the combined ethanolic extracts and the total amino acids in the acidic hydrolyzates were determined using Alpha amino acid analyzer Model 4150 LKB. In this amino acid analyzer the principle of operation is based on the continuous flow chromatography procedure developed by Spackman *et al.* (1958).

RESULTS AND DISCUSSION

The results of the total and free amino acid contents of the investigated algae are presented in Tables 1, 2 and 3.

The most abundant amino acids present in a free state in the studied algal species are alanine and glutamic acid which are present in all algae.

Leucine is only absent in one, glycine in two and threonine in three species of Rhodophyceae. Lysine, arginine, isoleucine, valine and histidine are present in the two studied species of Chlorophyceae. Leucine is absent in one of the Phaeophyceae and one of the Rhodophyceae, arginine in two and three, isoleucine in two and five, valine in three and four and histidine in four and three of the Phaeophyceae and Rhodophyceae respectively.

Each of phenylalanine, tyrosine, methionine aspartic acid, proline, serine and cysteine is absent in 7, 8, 10, 11, 11, 13 and 14 of the algal species studied (Table 1).

Accordingly the prevalency of the free amino acids in the algal species studied presently is as follows: alanine, glutamic acid, leucine, glycine, lysine, threonine, arginine, isoleucine, valine, histidine, phenylalanine, methionine, aspartic acid, proline, serine, cysteine and serine which is present only in one species of Phaeophyceae and five species of Rhodophyceae (Table 1).

In certain species of green and blue algae free aspartic acid, alanine, proline and leucine were found to be the most abundant (Serbanescu, 1971).

Pomiluiko and Stetsenko (1973) denoted that blue green algae contained predominentally aspartic acid, glutamic acid, isoleucine, leucine, tyrosine and valine.

In marine green algae Dave and Lewis (1973) demonstrated the presence of free glycine, leucine, valine, serine, threonine, aspartic and glutamic acids, arginine, lysine, ornithine, cysteic acid, cysteine, methionine, phenylalanine, tyrosine, histidine, hydroxy proline, proline, tryptophan and α and β alanine.

In (1976) Kokyrtsa denoted the presence of 17 usual amino acids together with γ aminobutyrate and alloisoleucine in the fresh water blue green algae of Maldova.

In the algal species studied presently threonine is the most abundant essential free amino acid followed by isoleucine, phenylalanine and methionine. Generally, Phaeophycease are the richest in the essential amino acids followed by Rhodophyceae then Chlorophyceae. However, there are large individual differences between the values in the different algal species within each class (Tables 1 and 3).

On the other hand, after the acid hydrolysis the most abundant total essential amino acids in the acid hydrolyzate are leucine, lysine, phenylalanine and methionine that are present in all the algal species studied. Valine and isoleucine are also present. However, valine is absent in one of the Chlorophyceae and one of the Rhodophyceae, isoleucine is missing in two of the Phaeophyceae and four of the Rhodophyceae (Table 2).

From the results of the free and total essential amino acid contents of the different algae investigated presently, it is clear that although the essential amino acids are present in most of the algal species, however, the amounts are small compared with those of the non essential amino acids (Tables 1, 2 and 3). The amounts are also small as compared with the amounts reported to be the dietary daily requirements. The dietary daily requirements of isoleucine, leucine, lysine methionine (and cysteine), phenylalanine (and tyrosine), threonine, tryptophan and valine are 10, 14, 12, 13, 14, 7, 3.5 and 10 mg/kg body weight/d,respectively (Munro and Crim, 1980).

Similarly Margaris and Mitrakos (1973) observed a great lack of essential amino acids except for serine indicating that algae are not suggested as animal foods. They also reproted that the total amount of free amino acids in algae is generally very low compared to that of higher plants. They observed that

Table 1
Free amino acids in ug/g fresh weight

Classes and Species	Essential amino acids							Non essential amino acids										
	L threonine	L valine	L methionine	L isoleuine	L leucine	L phenyl alanine	L lysine	L aspartic acid	L serine	L glutamic acid	L proline	glycine	L alanine	L cysteine	L tyrosine	L histidine	L arginine
Chlorophyceae:																	
Cladophora serocoids	12.6	8.8	-	1.4	0.9	5.9	2.7	17.0	-	21.7	2.5	8.0	40.7	-	5.4	0.1	10.7
Dictyosphaeria cavernosa	21.0	3.6	0.2	0.8	0.6	-	4.6	-	-	46.2	-	15.1	42.7	0.6	-	0.1	7.6
Mean ± S.E.	16.8 ± 4.2	6.2± 2.6		1.1± 0.3	0.7± 0.1		3.6± 1.0			33.9± 12.4		11.5± 3.6	41.7± 1.0			0.1±	9.1± 1.6
Phaeophyceae:																	
Colopomenia sinuosa	70.4	13.7	-	2.8	2.5	58.5	2.8	24.6	-	39.4	-	4.3	62.8	-	43.3	0.1	-
Cytoseira trinodis	29.4	2.6	-	-	0.4	-	0.4	-	-	7.5	-	1.2	3.4	-	-	-	0.4
Dictyota cervicornis	10.7	3.3	-	0.3	0.4	-	-	-	-	7.5	-	1.8	10.9	-	-	-	1.5
Hormophysia triquetra	25.8	6.5	-	0.9	1.2	11.5	1.1	-	-	41.8	-	7.8	27.2	-	5.9	-	1.9
Padina gymnospora	98.6	6.4	-	8.3	6.0	130.0	6.7	35.8	107.2	21.8	29.1	8.5	119.0	0.6	57.5	2.8	15
Sargassum binderi	40.2	-	2.8	0.8	0.6	0.4	0.1	-	-	9.5	-	3.2	15.6	0.5	0.1	-	-
Sargassum boveanum	21.6	-	3.1	-	0.8	-	0.2	5.0	-	36.4	1.2	9.9	19.5	-	0.7	-	0.2
Sargassum denticulatum	27.1	-	2.7		1.9	0.8	0.2	-		41.7	2.6	0.9	39.8		1.1		0.9
Mean ± S.E.	40.5± 10.5	6.5± 2.0	2.9± 0.1	2.6± 1.5	1.7± 0.7	40.2± 25.0	1.6± 0.9	21.8± 9.2		25.6± 5.7	11.0± 9.2	4.7± 1.3	37.3± 13.5	0.55± 0.05	18.1± 10.6	1.0± 0.9	3.3± 2.4
Rhodophyceae:																	
Amphiroa fragillissima	-	3.0	-	5.4	5.1	6.0	2.6	10.8	154.8	26.4	5.0	19.3	30.5	-	20.4	0.1	5.5
Digenia simplex	-	-	1.0	-	0.3	-	1.3	17.1	110.2	13.8	1.6	31.8	26.3	-	-	1.6	1.3
Spyridia filamentosa	-	1.7	1.4	-	7.6	4.8	0.1	-	181.6	16.3	2.8	-	39.5	-	5.3	0.1	-
Chondria cillinsiana	33.7	5.1	-	0.8	0.7	15.6	0.9	6.6	-	16.1	2.4	27.2	11.6	-	8.9	1.6	1.4
Laurencia paniculata	76.5	9.8	-	19.2	15.3	20.0	10.0	-	90.3	40.1	3.0	8.7	72.2	0.4	70.4	1.0	20.7
Laurencia papillosa	33.8	-	5.6	0.1	7.4	59.7	5.2	-	39.2	3.0	-	27.5	170.3	0.5	-	6.4	49.5
Polysiphonia broadia	40.8	-	4.5	-	1.7	1.8	0.1	65.4	-	47.5	-	-	61.4	-	1.3	-	-
Polysiphonia crassicollis	20.4	2.6	-	-	-	4.2	1.2	-	-	25.6	-	9.3	9.3	-	-	0.7	2.7
Polysiphonia ferulacea	16.9	-	0.5	-	0.2	-	-	-	-	2.1	-	0.5	3.3	-	-	-	-
Polysiphonia kempsaxii	36.3	1.8	-	0.4	0.3	-	0.2	-	-	12.2	-	3.0	0.4	-	-	-	1.7
Mean ± S.E.	36.9 ± 7.5	4.0± 1.3	2.6± 1.0	5.2± 3.2	4.3± 1.7	16.0± 7.8	2.4± 1.1	25.0± 13.6	115.2± 25.3	20.3± 4.6	3.0± 0.6	15.9± 4.3	42.5± 15.9	0.4± 0.05	21.3± 12.9	1.5± 0.8	11.8± 6.9
Total mean ± S.E.	31.4± 7.5	5.6± 0.8	1.9± 0.9	3.0± 1.2	2.8± 1.0	20.7± 10.4	2.5± 0.6	21.3 2.4	111.2± 4.0	26.6± 4.0	5.5± 2.8	10.7± 3.3	40.5± 1.6	0.5± 0.06	14.9± 4.9	0.9± 0.4	8.0± 2.6

Each figure represents the mean of five replicates, values were not statestically significantly differnt (-) amino acid was not detectable.

Table 2
Total amino acids ug/g fresh weight

Classes and Species	Essential amino acids						Non essential amino acids								
	L valine	L methionine	L isoleuine	L leucine	L phenyl alanine	L lysine	L serine	L glutamic acid	L proline	glycine	L alanine	L cysteine	L tyrosine	L histidine	L arginine
Chlorophyceae:															
Cladophora serocoids	-	365	22	275	235	215	-	-	5821	-	-	378	81	52	130
Dictyosphaeria cavernosa	453	29	294	421	241	364	-	318	2251	-	876	16	102	62	187
Mean ± S.E.		197± 170	158± 338	348± 74	238± 3.0	289.5± 75.3			4036± 1803			197± 62	91.5± 10.6	57± 5	158.5± 28.8
Phaeophyceae:															
Colopomenia sinuosa	261	27	6	206	126	157	-	130	12730	-	538	-	320	40	90
Cytoseira trinodis	447	32	324	464	225	290	-	739	55218	-	825	-	76	83	186
Dictyota cervicornis	311	38	226	336	155	159	-	1528	1461	-	553	-	126	32	133
Hormophysia triquetra	503	35	-	410	256	333	-	1260	7409	1	1086	88	-	79	212
Padina gymnospora	348	40	-	276	161	208	-	659	15848	-	693	46	-	48	123
Sargassum binderi	578	57	446	657	304	362	-	769	3212	-	974	-	998	100	235
Sargassum boveanum	292	35	22	317	151	181	-	198	1505	-	525	42	-	49	118
Sargassum denticulatum	573	54	411	626	256	350	-	409	34550	-	994	-	73	87	254
Mean ± S.E.	414.0± 45.7	39.7± 3.7	239.2± 79.3	411.5± 57.9	204.2± 23.0	255± 31.4		711.5± 174.3	16492± 6816		773.5± 81.1	58.7± 15	318.6± 178.6	64.8± 9.0	169± 22.0
Rhodophyceae:															
Amphiroa fragilissima	322	21	-	241	160	213	-	461	1249	4.0	652	377	54	47	143
Digenia simplex	274	27	-	388	251	520	-	1236	60668	-	1245	-	87	94	157
Spyridia filamentosa	430	58	306	433	222	278	-	923	19730	3.0	811	-	59	63	213
Chondria cillinsiana	121	675	59	696	470	1518	1.0	-	8853	43.0	-	640	-	178	376
Laurencia paniculata	692	24	446	661	355	550	-	-	26372	-	1161	589	165	94	321
Laurencia papillosa	670	39	462	638	316	634	-	926	27780	5.0	1262	-	152	171	274
Polysiphonia broadia	581	32	428	577	339	4.41	7.0	-	23533	-	962	-	143	108	262
Polysiphonia crassicollis	901	70	643	873	492	645	-	1064	3549	-	1534	-	199	167	367
Polysiphonia ferulacea	-	40	-	476	300	355	-	10	19398	7.0	-	506	38	110	147
Polysiphonia kempsaxii	333	20	-	282	176	210	-	183	15146	-	610	0.6	28	56	106
Mean ± S.E.	468± 90	101± 63	391± 81	526± 62	308± 35	536± 119	4.0± 3.0	686± 180	20628± 5244	12.4± 8.0	1030± 116	422.5± 116	102.8± 21	109± 15.0	237± 31.0
Total mean ± S.E.	445.0± 16.0	112.6± 47.0	262.7± 70.0	428.5± 53.0	250± 31.0	360± 90.1	4.0± 3.0	572± 129	13719± 5080	6.7± 6.0	893± 76.0	226.0± 108	171± 75.0	77.0± 16.0	188± 25.0

Each figure represents the mean of five replicates, values were not statistically significantly differnt (-) amino acid was not detectable.

aspartic acid, threonine, serine, glutamic acid, glycine and alanine represent 70% of the total amino acid content, a result that is similar to that reported before by Landsberger *et al.*, (1969).

Table 3

Classes and Species	Free amino acids			Total amino acid		
	E.A.A.	Non E.A.A.	E/nE	E.A.A.	Non E.A.A.	E/nE
Chlorophycease:						
Cladophora serocoids	32.3	106.1	0.30	1112	6462	0.17
Dictyosphaeria cavernosa	30.8	112.3	0.27	1802	3812	0.47
Mean ± S.E.	31.5± 0.8	109.2± 3.1	0.28± 0.01	1457± 358	5137.5± 1338	0.32± 0.15
Phaeophyceae:						
Colopomenia sinuosa	150.7	174.5	0.86	783	13848	0.06
Cytoseira trinodis	32.8	12.2	2.69	1782	57127	0.03
Dictyota cervicornis	14.7	21.2	0.69	1225	3833	0.32
Hormophysia triquetra	47.3	84.8	0.56	1537	8875	0.17
Padina gymnospora	256.0	397.3	0.64	1033	17417	0.06
Sargassum binderi	44.9	28.9	1.55	2404	6288	0.38
Sargassum boveanum	25.7	31.6	0.81	998	2437	0.41
Sargassum denticulatum	32.7	87.0	0.38	2270	36367	0.06
Mean ± S.E.	56.8± 29.3	104.7± 46.3	1.0± 0.27	1504± 215.6	18274± 6814.6	0.19± 0.06
Rhodophyceae:						
Amphiroa fragillissima	22.1	272.8	0.08	957	2987	0.32
Digenia simplex	2.6	203.7	0.01	1460	63487	0.02
Spyridia filamentosa	15.6	245.6	0.06	1727	21802	0.08
Chondria cillinsiana	56.8	75.8	0.75	3539	10048	0.35
Laurençia paniculata	150.8	306.8	0.49	2728	28702	0.09
Laurencia papillosa	111.8	296.4	0.38	2759	30570	0.09
Polysiphonia broadia	48.9	175.6	0.28	2398	25008	0.10
Polysiphonia crossicollis	28.4	47.6	0.60	3624	6880	0.53
Polysiphonia ferulacea	17.6	5.9	3.00	1171	20216	0.06
Polysiphonia kempsaxii	39.0	17.3	2.25	1021	16130	0.06
Mean ± S.E.	49.4± 14.7	164.7± 37.0	0.79± 0.32	2138± 315	22583± 5327	0.17± 0.05

E.A.A. = Essential amino acids
Non E.A.A. = Non essential amino acids
E/nE = Essential/non essential amino acid ratio

Strusi (1962) studied the alkaline and acid hydrolyzates of the proteins of four sea weeds for their amino acid contents. He reported the presence of cysteine, lysine, arginine, histidine aspartic and glutamic acids, glycine, serine, threonine, alanine, tyrosine, proline, methionine valine, phenylalanine, isoleucine, leucine and tryphophan.

Presently the most prevalent amino acids found in the acid hydrolyzates of the algal species studied are methionine, leucine, phenylalanine, lysine, proline, histidine and arginine that are present in all the algal species. Valine is absent in one of the Chlorophyceae and one of the Rhodophyceae, alanine in one and two and glutamic acid in one and three of the Chlorophyceae and Rhodophyceae respectively. Tyrosine is absent in three of the Phaeophyceae and one of the Rhodophyceae, isoleucine in two and four and cysteine in four and five of the Phaeophyceae and Rhodophyceae respectively, glycine is only present in two species of Rhodophyceae (Table 2).

Accordingly the prevalence of the total amino acids in our acid hydrolyzates are as follows: proline, valine, leucine, lysine, phenylalanine, arginine, methionine, histidine, valine, alanine, tyrosine, glutamic acid, isoleucine, cysteine, glycine and serine.

The discrepancies in the results of the amino acid contents of algae as reported by various investigators has been discussed by Margaris (1974) who ascertained the presence of at least 18 amino acids in the algae he investigated. This was consistent with the results of Fujikawa (1970) but inconsistent with those of Badhe and Patwardhan (1972). Particularly the large quantity of glutamic acid is in complete contrast with the results of Badhe and Patwardhan (1972). Margaris (1974) thought that this is due to the imperfect techniques used by Badhe and Batwardhan (1972). He also referred to the substantial quantity of glutamic acid as pointed out by a number of papers on algal free amino acids (Margaris and Mitrakos, 1972; Landsberger *et al.*, 1969) where glutamic acid ranks among the most abundant amino acids.

In our present investigation, aspartic acid is rpesent in the free form in only one species of Chlorophyceae, three species of Phaeophyceae and four species of Rhodophyceae. It disappeared completely from all the algae after the acid hydrolysis indicating its destruction under these conditions which destroyed also all the threonine that was present before hydrolysis and disappeared from the acid hydrolyzates (Table 1 and 2). This confirms the descripancies in the results obtained using different analytical techniques.

However, in th present investigation the amounts of the rest of the amino acids increased after acid hydrolysis than before the hydrolysis (Tables 1 and 2). This result is in consistance with that of Miyazawa *et al.*, (1976) who studied the amino acid contents in seven species of marine green algae and observed increased amino acid contents after hydrolysis. Similarly, the amino acids in some common marine algae from Iceland, after hydrolysis of the proteins and peptides were also determined by Munda and Gubensek (1976). Their values were also found to be higher than those reported for free amino acids determined without hydrolysis of the proteins.

Similarly Tsekos *et al.* (1975) recorded the presence of the following amino acids in green, brown and red marine algae; aspartic acid, asparagine, glutamic acid, glutamine, alanine, glycine, valine, cysteine, leucine, isoleucine, tyrosine, threonine, serine, phenylalanine, lysine histidine and arginine. They also observed great fluctuations in the total amino acid contents from 19-795 ug/gm fresh weight. A high proportion 63-80% is due to aspartic acid, asparagine, glutamic acid, glutamine, glycine, alanine, threonine and serine, whereas the remaining amino acids cysteine, leucine, isoleucine, tyrosine, phenylalanine lysine, histidine and arginine are completely absent or exist in low proportions. Methionine is completely absent in all the samples studied. They denoted that their results are consistent with those of Landsberger *et al.* (1969), Madgwick and Ralph (1972) and Margaris and Mitrakos (1973). They, together with other workers (Landsberger *et al.*, 1969; Madwick and Ralph 1972; Lewis 1973; Margaris and Mitrakos, 1973) denoted that glutamic acid, aspartic acid and alanine are consistently the highest in green algae. This is similar to our present finding added to it threonine (Table 1). They considered it unusual to find that aspartic acid is missing in *Dictyopterus* which is again in consistence with our present result, that showed the absence of aspartic acid in *Dictyosphaeria.*

The high content of the dicarboxylic acids, glutamic and aspartic acids, and alanine is probably the result of a close relationship with tricarboxylic acid cycle metabolism (Tsekos *et al.*, 1975). Accordingly, it is concluded that, a comparison of our results with those of other authors sometimes reveals similarities and sometimes reveals quantitative and/or qualitative deviations, an observation that was also recorded by Tsekos *et al.*, (1975) and thus, suggested that the harvesting of the respective material seems to play a considerable rate in this respect. This was also noted before by Madgwick and Ralph, 1972. Thus Tsekos *et al.*, (1975) stressed on the fact that the chemotaxonomic investigations should be based upon analysis of algal samples which have been harvested regularly throughout the year.

Similarly Fadeel *et al.*, (1987) confirmed the improtance of the role of temperature, light intensity and nutrient availability at different sites along the costal lines of Kuwait on the overall tissue analysis of four species of Chlorophyceae of Kuwait.

Amblard *et al.*, (1990) studied the effect of a pulp and paper mill effluent on the structure and metabolism of periphytic algae in experimental streams. Their results suggested that the dissolved organic carbon in the effluent acted as a eutrophication factor for periphytic algal communities. Thus they stressed its impact in species richness and diversity and in changes in the taxonomic structure of the algal community.

Also, Aitken *et al.* (1991) reported that the protein bound amino acids and the major free amino acids showed specific seasonality, in their study on the seasonal protein variation in some New Zealand Sea weeds.

The results of our present investigation as well as the results discussed for the previous investigators indicate that, although, generally the amounts of the essential amino acids present in algae are low, however, their presence even in these small amounts is the basis of their historic important use as diets or food additives.

Medvedeva *et al.* (1969a) manufactured an amino acid rich product form algae. Similarly Medvedeva *et al.* (1969b) reproted that amino acids prepared form algae improve bread quality when used as an additive to flour and are comparable to those obtained from dry milk or fish.

Also, Dusheiko *et al.* (1969) determined the amino acid composition of protein in blue-green algae using an automated amino acid analyzer. Their results showed the presence of essential amino acids and thus they concluded that the proteins of algae might be considered biologically valuable for animal feeding as well as for microbiological pruposes.

Balasubramanyan and Rangaswami (1972) supplemented the food of rats and chicks with some algae. The rate of growth increased with the increase of the percentage of algal supplements in the animals diet.

Mariculture of the red alga *Porphyra* and its processing into thin, purple-black sheets called "horshi nori" is a prominent food industry in Japan (Miura, 1975 and Nisizawa *et al.*, 1987). *Porphyra* is used as a food in other parts of the world. It is farmed in China where it is known as "Zicia" (Tseng, 1981) and in Korea where it is known as "Kim" (Mumford and Miura, 1984). It is consumed in smaller quantities in Wales and New Zealand where it is known as "Laver" and "Karengo" respectively (Chapman 1969 and Chapman and Chapman 1980). *Porphyra* is also a traditional food of the Maori. It grows on rocky substrate in the intertidal zone on most of the coastline around New Zealand (Nelson, 1984). Maricultures of *Porphyra* has been also investigated by Brown *et al.*, (1990).

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