

Seasonal effect on the biochemical composition of edible macroalgae cultivated in integrated multitrophic aquaculture

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Supplementary data

Supplementary Tables

Table S1. Elemental composition, expressed in percentage (%) of DW biomass, found for *Ulva* sp., *F. vesiculosus*, *P. dioica* and *P. palmata* along the different seasons. Values are the mean \pm standard deviation (SD) of three replicates ($n = 3$). Significant differences between the groups were revealed using one-way ANOVA with Tukey's post hoc test. Values in the same row followed by the same letter are significantly different at $p < 0.05$.

	Autumn	Winter	Spring	Summer
<i>Ulva</i> sp.				
N (%)	2.74 \pm 0.13 a,b	4.16 \pm 0.09 a,c,d	2.94 \pm 0.15 c,e	2.10 \pm 0.13 b,d,e
C (%)	29.46 \pm 0.53 a,b	33.26 \pm 0.27 a,c,d	28.11 \pm 0.21 c,e	23.91 \pm 0.96 b,d,e
H (%)	6.18 \pm 0.05 a	6.17 \pm 0.05 b	5.93 \pm 0.04 c	5.09 \pm 0.27 a,b,c
<i>F. vesiculosus</i>				
N (%)	2.16 \pm 0.24	2.43 \pm 0.18 a	2.1 \pm 0.16	1.65 \pm 0.1 a
C (%)	36.9 \pm 2.18 a,b	33.54 \pm 0.62	29.64 \pm 0.71 a	32.04 \pm 1.36 b
H (%)	6.33 \pm 0.35 a,b,c	5.59 \pm 0.19 a	5.21 \pm 0.13 b	5.31 \pm 0.17c
<i>P. dioica</i>				
N (%)	5.58 \pm 0.36 a	6.16 \pm 0.1 b	3.13 \pm 0.13 a,b,c	6.07 \pm 0.11 c
C (%)	34.33 \pm 0.36 a,b	36.17 \pm 0.43 c,d	30.65 \pm 1.21 a,c,e	39.51 \pm 0.36 b,d,e
H (%)	6.06 \pm 0.07 a,b	6.11 \pm 0.05 c,d	5.53 \pm 0.17 a,c,e	7.71 \pm 0.11 b,d,e
<i>P. palmata</i>				
N (%)	4.36 \pm 0.26 a	4.02 \pm 0.51	3.06 \pm 0.19 a	-
C (%)	30.07 \pm 1.7	29.87 \pm 2.98	31.56 \pm 1.2	-
H (%)	5.13 \pm 0.15	4.94 \pm 0.49	5.34 \pm 0.18	-

Table S2. Total of ash, carbohydrates, protein and lipids, expressed in percentage (%) of DW biomass, found for *Ulva* sp., *F. vesiculosus*, *P. dioica* and *P. palmata* along the different seasons. Total carbohydrates were determined by sum of neutral sugars and uronic acids. The values represent the mean \pm standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using one-way ANOVA with Tukey's post hoc test. Values in the same row followed by the same letter are significantly different at p -value < 0.05 .

	Autumn	Winter	Spring	Summer
<i>Ulva</i> sp.				
Ash	28.73 \pm 0.54	7.29 \pm 1.79	28.42 \pm 0.04	27.12 \pm 0.14
Carbohydrates	53.45 \pm 0.49 a,b	47.69 \pm 1.69 a,c,d	52.93 \pm 0.91 c,e	58.18 \pm 0.71 b,d,e
Protein	13.70 \pm 0.67 a,b	20.80 \pm 0.46 a,c,d	14.68 \pm 0.77 c,e	10.48 \pm 0.67 b,d,e
Lipids	4.12 \pm 0.22 a	4.22 \pm 0.05 a,b,c	3.97 \pm 0.11 b	4.21 \pm 0.1 c
<i>F. vesiculosus</i>				
Ash	26.32 \pm 1.09 a,b,c	37.32 \pm 2.44 a,d,e	19.61 \pm 0.3 b,d	21.1 \pm 0.14 c,e
Carbohydrates	60.32 \pm 1.70 a,b,c	48.18 \pm 2.00 a,d,e	67.14 \pm 0.90 b,d	67.74 \pm 0.61 c,e
Protein	10.79 \pm 1.21	12.16 \pm 0.89 a	10.49 \pm 0.82	8.24 \pm 0.51 a
Lipids	2.57 \pm 0.29	2.34 \pm 0.02 a	2.76 \pm 0.06	2.92 \pm 0.04 a
<i>P. dioica</i>				
Ash	24.71 \pm 0.1 a,b,c	22.15 \pm 0.41 a,d	22.93 \pm 0.11 b,e	16.19 \pm 0.38 c,d,e
Carbohydrates	46.30 \pm 1.95 a,b	44.67 \pm 0.31 c,d	60.03 \pm 0.50 a,c,e	52.31 \pm 0.57 b,d,e
Protein	27.91 \pm 1.79 a	30.80 \pm 0.48 b	15.66 \pm 0.64 a,b,c	30.35 \pm 0.55 c
Lipids	1.08 \pm 0.14 a	2.38 \pm 0.08 a,b,c	1.38 \pm 0.16 b	1.15 \pm 0.07 c
<i>P. palmata</i>				
Ash	28.70 \pm 1.04 a,b	38.83 \pm 0.45 a	38.87 \pm 0.23 b	-
Carbohydrates	48.12 \pm 2.20 a	39.13 \pm 2.21 a	44.02 \pm 0.63	-
Protein	21.78 \pm 1.32 a	20.10 \pm 2.57	15.32 \pm 0.95 a	-
Lipids	1.40 \pm 0.15 a	1.94 \pm 0.06 a	1.78 \pm 0.19	-

Table S3. Minerals found for *Ulva* sp. along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean \pm standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p -value < 0.05 . Ni was not detected. Co and Cu were absent or found in traces amounts (≤ 0.01 mg.g⁻¹).

	Autumn	Winter	Spring	Summer
P	2.42 \pm 0.01	3.11 \pm 0.05 a	1.59 \pm 0.02 a	2.75 \pm 0.00
Mg	34.08 \pm 0.66	34.27 \pm 0.89	37.03 \pm 0.37	35.71 \pm 0.70
Na	28.12 \pm 0.35	24.51 \pm 0.22 a	25.69 \pm 0.40	31.40 \pm 0.66 a
K	20.86 \pm 0.06 a	25.56 \pm 0.11	28.22 \pm 0.52	37.43 \pm 0.36 a
Ca	3.77 \pm 0.05	9.75 \pm 0.01 a	4.27 \pm 0.09	3.59 \pm 0.07 a
Fe	0.17 \pm 0.00	0.80 \pm 0.01 a	0.20 \pm 0.00	0.07 \pm 0.00 a
Zn	0.03 \pm 0.00a	0.05 \pm 0.00 a	0.03 \pm 0.00	0.03 \pm 0.00
B	0.05 \pm 0.00	0.04 \pm 0.00 a	0.05 \pm 0.00	0.06 \pm 0.00 a
Mn	0.04 \pm 0.00	0.34 \pm 0.00 a	0.02 \pm 0.00 a	0.04 \pm 0.00
Al	0.14 \pm 0.00	0.41 \pm 0.00 a	0.14 \pm 0.00 a	0.16 \pm 0.00
Na/K molar ratio	2.29 \pm 0.02 a	1.63 \pm 0.01	1.55 \pm 0.02 a	1.43 \pm 0.02

Table S4. Minerals found for *F. vesiculosus* along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at *p-value* < 0.05. Ni, Co and Cu were absent or found in traces amounts (≤ 0.01 mg.g⁻¹).

	Autumn	Winter	Spring	Summer
P	2.55±0.02	2.79±0.02 a	1.06±0.02 a	1.40±0.01
Mg	7.82±0.19 a	9.17±0.26	11.8±0.07 a	8.07±0.09
Na	43.75±0.41	40.64±0.12	66.22±0.67 a	38.14±0.36 a
K	46.12±0.30 a	45.63±1.11	9.34±0.08 a	39.50±0.37
Ca	5.11±0.19	5.81±0.19	6.78±0.05 a	3.61±0.13 a
Fe	0.17±0.00 a	0.80±0.01	1.61±0.01 a	0.40±0.00
Zn	0.01±0.00 a	0.1±0.00 a	0.05±0.00	0.04±0.00
B	0.11±0.00 a	0.13±0.00	0.27±0.00 a	0.22±0.00
Mn	0.40±0.01	0.53±0.01 a	0.12±0.00 a	0.40±0.01
Al	0.13±0.00 a	0.76±0.01 a	0.57±0.01	0.19±0.00
Na/K molar ratio	1.61±0.02	1.52±0.03 a	12.06±0.23 a	1.52±0.03

Table S5. Minerals found for *P. dioica* along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at *p-value* < 0.05. Ni and Co were not detected. Cu was found in traces amounts in all seasons (≤ 0.01 mg.g⁻¹).

	Autumn	Winter	Spring	Summer
P	6.49±0.01 a	6.38±0.03	5.35±0.02 a	5.83±0.01
Mg	6.75±0.31	3.22±0.16 a	7.20±0.38 a	6.11±0.03
Na	52.12±0.48	27.62±0.6 a	57.48±0.67 a	54.28±0.33
K	44.57±0.27 a	24.74±0.35 a	31.66±0.07	35.69±0.04
Ca	4.49±0.02 a	6.00±0.03 a	4.51±0.01	5.51±0.01
Fe	0.30±0.00	0.63±0.00 a	0.10±0.00	0.08±0.00 a
Zn	0.04±0.00	0.03±0.00	0.04±0.00	0.03±0.00
B	0.01±0.00	0.01±0.00 a	0.02±0.00 a	0.01±0.00
Mn	0.06±0.00	0.05±0.00 a	0.06±0.00 a	0.05±0.00
Al	0.14±0.00 a	0.50±0.00 a	0.21±0.00	0.18±0.00
Na/K molar ratio	1.99±0.01	1.9±0.03 a	3.09±0.03 a	2.59±0.02

Table S6. Minerals found for *P. palmata* along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at *p-value* < 0.05. ND – not detected.

	Autumn	Winter	Spring
P	24.48±0.16 a	19.34±0.16 a	19.92±0.02

Mg	23.85±0.06 a	5.31±0.06 a	5.89±0.14
Na	177.91±0.49 a	67.78±0.49 a	77.66±0.38
K	287.23±3.5 a	425.98±3.5 a	380.38±0.98
Ca	4.49±0.00	ND	ND
Fe	7.99±0.03 a	1.56±0.03 a	2.56±0.03
Zn	0.00±0.00 a	0.04±0.00 a	0.03±0.00
Ni	0.04±0.00 a	0.02±0.00 a	0.03±0.00
Co	0.05±0.00 a	0.01±0.00 a	0.03±0.00
B	0.01±0.00 a	0.02±0.00	0.02±0.00 a
Mn	13.36±0.02 a	2.26±0.02 a	4.27±0.01
Al	2.96±0.00 a	0.71±0.00 a	0.91±0.00
Na/K molar ratio	1.05±0.00 a	0.27±0.00 a	0.35±0.00

Table S7. Carbohydrate composition of *Ulva* sp., *F. vesiculosus*, *P. dioica* and *P. palmata* along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using one-way ANOVA with Tukey's post hoc test. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
<i>Ulva</i> sp.				
Rha	51.1±4.7	58±2.1 a	42.7±3.4 a	56.4±6.5
Xyl	17.1±1.1	17.4±0.8	17.0±1.2	17.0±0.8
Gal	10.5±1.4 a	20.7±1.6 a,b,c	13.0±0.9 b	13.2±1.2 c
Glc	109.1±3.8 a	91.4±6.3 b	62.2±4.8 a,b,c	87.7±9.0 c
UA	146.2±2.4 a	140.4±6 b	99.9±3.6 a,b,c	144.2±5.0 c
<i>Fucus vesiculosus</i>				
Fuc	58.3±6.2 a	56.3±1.6 b	150.1±6.4 a,b,c	79.1±14.1 c
Xyl	3.9±0.7 a,b,c	6.8±0.3 a,d	12.9±0.8 b,d,e	7.1±1.0 c,e
Gal	14.1±1.5 a	13.3±0.1 b,c	19.2±1.2 a,b	16.8±0.6 c
Glc	4.4±0.5 a,b,c	40.5±1.2 a	55.6±4.3 b	59.9±10.6 c
UA	157.4±19.3 a	133.3±9.4 b	86.3±4.2 a,b,c	121.5±10.1 c
<i>Porphyra dioica</i>				
Ara	4.4±0.3 a	4.9±0.4 b	1.5±0.2 a,b,c	5.5±0.4 c
3,6 anhydroGal	27.7±1.4 a,b	59.5±12.5 a,c,d	15.9±0.4 b,c	20.2±3.3 d
Xyl	8.8±1.3 a,b	15.6±3.0 a	15.3±0.7 b	14±2.8
6-metilGal	21.8±2.9 a	46.0±3.3 a	31.2±0.9	31.5±7.7
Man	11.9±1.9 a,b	18.1±2.1 a	17.4±0.6	25.0±4.2 b
Gal	141±2.7 a,b	202.2±23.7 a	203.8±5.2 b	183.1±22.1
Glc	1.7±1.1 a,b	7.5±0.8 a,c	60.8±1.8 b,c,d	5.6±2.7 d
<i>Palmaria palmata</i>				
Xyl	259.8±4.4 a	257.7±6.4 b	292.8±1.8 a,b	-
Man	7.7±1.2 a	6.7±2.3	3.7±0.5 a	-
Gal	42.5±1.7 a	43.4±4.4 b	67.1±5.0 a,b	-
Glc	39.1±2.4 a	26.4±2.7 a	34.0±5.1	-

Table S8. Free alditols found from *F. vesiculosus* along the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed one-way ANOVA with Tukey's post hoc test. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
Mannitol	47.2±3.4 a,b	67.5±9.5 c	6.4±1.8 a,c,d	95.1±7.2 b,d

Table S9. Amino acids profile from *Ulva* sp. across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
Alanine	0.81 ± 0.02	0.00 ± 0.00a	3.81 ± 0.07a	1.02 ± 0.02
Arginine	1.39 ± 0.02a	1.92 ± 0.02	2.14 ± 0.04a	1.75 ± 0.00
Aspartic acid	1.36 ± 0.02a	2.44 ± 0.03	2.64 ± 0.03a	1.71 ± 0.02
Cysteine	1.08 ± 0.02	0.00± 0.00a	0.13 ± 0.00	1.33 ± 0.03a
Glutamic acid	1.27 ± 0.02a	2.09 ± 0.02	2.32 ± 0.03a	1.63 ± 0.02
Glycine	1.09 ± 0.01a	1.91 ± 0.03	2.21 ± 0.04a	1.36 ± 0.01
Serine	0.27 ± 0.01	2.33 ± 0.03a	2.23 ± 0.03	0.22 ± 0.00a
Tyrosine	1.61 ± 0.02	1.23 ± 0.02	1.15 ± 0.02a	2.03 ± 0.01a
NEA	8.86 ± 0.04 a	11.91 ± 0.05	16.64 ± 0.25 a	11.03 ± 0.02
Methionine	1.78 ± 0.02	2.28 ± 0.04a	0.54 ± 0.02	2.24 ± 0.01
Isoleucine	1.29 ± 0.01	1.37 ± 0.02	1.58 ± 0.03a	1.24 ± 0.00a
Leucine	1.25 ± 0.02a	2.39 ± 0.03a	1.78 ± 0.04	1.57 ± 0.01
Lysine	0.39 ± 0.01	1.27 ± 0.02	0.83 ± 0.03	0.5 ± 0.01
Phenylalanin	0.63 ± 0.01	1.75 ± 0.02	0.64 ± 0.02	0.82 ± 0.01
e Threonine	1.66 ± 0.02	1.44 ± 0.03	1.54 ± 0.04	1.77 ± 0.48
Valine	1.38 ± 0.01a	1.59 ± 0.02	1.86 ± 0.03a	1.73 ± 0.00
EAA	8.38 ± 0.1 a	12.09 ± 0.11 a	8.76 ± 0.2	9.87 ± 0.49

Table S10. Amino acids profile from *Fucus vesiculosus* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
Alanine	0.76 ± 0.00 a	0.89 ± 0.03 a	0.81 ± 0.03	0.78 ± 0.00
Arginine	0.97 ± 0.48	0.55 ± 0.01	1.39 ± 0.05	1.34 ± 0.00
Asparagine	0.00 ± 0.00 a	2.16 ± 0.04 a,b	0.00 ± 0.00 b	0.66 ± 0.00
Aspartic acid	1.97 ± 0.00	1.29 ± 0.02	1.36 ± 0.02	1.30 ± 0.01
Cysteine	1.00 ± 0.00	0.00 ± 0.00 a	1.07 ± 0.03 a	1.03 ± 0.00
Glutamic acid	1.18 ± 0.00 a	2.41 ± 0.03 a	1.27 ± 0.03	1.22 ± 0.00

Glycine	1.03 ± 0.01 a	1.84 ± 0.04 a	1.09 ± 0.02	1.05 ± 0.00
Serine	0.16 ± 0.00	0.00 ± 0.00 a	0.27 ± 0.01 a	0.17 ± 0.00
Tyrosine	1.51 ± 0.00	0.86 ± 0.02 a	1.61 ± 0.04 a	1.55 ± 0.01
NEAA	8.57 ± 0.46	10 ± 0.19	8.87 ± 0.22	8.66 ± 0.61
Methionine	1.67 ± 0.00	0.59 ± 0.02 a	1.79 ± 0.05 a	1.72 ± 0.01
Isoleucine	1.33 ± 0.00	0.85 ± 0.03 a	1.28 ± 0.05	1.37 ± 0.01 a
Leucine	0.84 ± 0.47	1.09 ± 0.03 a	1.25 ± 0.05 a	1.20 ± 0.01
Lysine	0.38 ± 0.01	0.81 ± 0.03	0.39 ± 0.02	0.38 ± 0.02
Phenylalanine	0.59 ± 0.01 a	1.02 ± 0.03 a	0.63 ± 0.03	0.60 ± 0.01
Threonine	1.55 ± 0.00	0.74 ± 0.02 a	1.66 ± 0.06 a	1.60 ± 0.00
Valine	1.30 ± 0.00	1.31 ± 0.04	1.38 ± 0.04	1.32 ± 0.00
EAA	7.66 ± 0.44	6.41 ± 0.19 a	8.38 ± 0.29 a	8.18 ± 0.03

Table S11. Amino acids profile from *Porphyra dioica* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
Alanine	0.49 ± 0.00 a	2.23 ± 0.07	5.41 ± 0.53 a	1.81 ± 0.02
Arginine	0.2 ± 0.01 a	2.38 ± 0.09	1.25 ± 0.07	3.12 ± 0.02 a
Asparagine	2.89 ± 0.02 a	2.03 ± 0.07	0.00 ± 0.00 a	1.54 ± 0.03
Aspartic acid	5.79 ± 0.02 a	2.58 ± 0.06	0.91 ± 0.10 a	3.04 ± 0.01
Cysteine	0.00 ± 0.00 a	0.00 ± 0.00 b	0.10 ± 0.01	2.39 ± 0.03 a,b
Glutamic acid	3.57 ± 0.02 a	2.20 ± 0.08	1.21 ± 0.09 a	2.84 ± 0.01
Glutamine	1.97 ± 0.00 a,b	0.27 ± 0.01	0.00 ± 0.00 a	0.00 ± 0.00 b
Glycine	2.49 ± 0.02 a	1.66 ± 0.06	1.50 ± 0.16 a	2.22 ± 0.22
Serine	0.00 ± 0.00 a	0.00 ± 0.00 b	0.01 ± 0.00	0.39 ± 0.03 a,b
Tyrosine	0.08 ± 0.00 a	1.04 ± 0.04	0.70 ± 0.07	3.61 ± 0.02 a
NEA	17.48 ± 0.02	14.39 ± 0.49	11.05 ± 0.97 a	20.22 ± 1.05 a
Methionine	3.74 ± 0.02	2.26 ± 0.07	0.34 ± 0.03 a	3.96 ± 0.04 a
Isoleucine	3.02 ± 0.02 a	1.21 ± 0.05	0.66 ± 0.08 a	1.37 ± 0.01
Leucine	0.19 ± 0.01 a	2.46 ± 0.08	1.74 ± 0.15	2.78 ± 0.01 a
Lysine	0.87 ± 0.48	1.98 ± 0.07	0.83 ± 0.08	0.87 ± 0.06
Phenylalanine	2.03 ± 0.02 a	1.27 ± 0.05	0.81 ± 0.07 a	1.44 ± 0.02
Threonine	0.00 ± 0.00 a	0.00 ± 0.00 b	0.90 ± 0.08	15.39 ± 17.41 a,b
Valine	0.00 ± 0.00 a	0.00 ± 0.00 b	1.04 ± 0.10	3.08 ± 0.02 a,b
EAA	9.84 ± 0.52	9.18 ± 0.33	6.32 ± 0.58 a	16.59 ± 0.54 a

Table S12. Amino acids profile from *Palmaria palmata* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring
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Alanine	0.99 ± 0.00	0.81 ± 0.00a	1.62 ± 0.02a
Arginine	1.14 ± 0.00	1.14 ± 0.00	1.12 ± 0.02
Aspartic acid	1.62 ± 0.02	1.34 ± 0.00a	2.69 ± 0.02a
Cysteine	0.97 ± 0.00	0.97 ± 0.00	0.97 ± 0.00
Glutamic acid	1.53 ± 0.00	1.25 ± 0.00a	2.51 ± 0.02a
Glutamine	1.91 ± 0.01	1.56 ± 0.00a	3.15 ± 0.01a
Glycine	1.31 ± 0.01	1.09 ± 0.01a	2.20 ± 0.02a
Serine	0.21 ± 0.00	0.17 ± 0.00a	0.34 ± 0.01a
Tyrosine	1.95 ± 0.00	1.59 ± 0.00a	3.22 ± 0.02a
NEA	11.63 ± 0.02	9.92 ± 0.00 a	17.71 ± 0.18 a
Methionine	1.17 ± 0.02a	1.77 ± 0.00a	1.52 ± 0.01
Isoleucine	1.36 ± 0.00	1.28 ± 0.01a	2.55 ± 0.02a
Leucine	1.51 ± 0.00	1.22 ± 0.02a	2.52 ± 0.02a
Lysine	0.46 ± 0.01	0.39 ± 0.01a	0.78 ± 0.02a
Phenylalanine	0.78 ± 0.01	0.64 ± 0.01	0.96 ± 0.47
Valine	1.68 ± 0.01	1.35 ± 0.01a	2.73 ± 0.03a
EAA	6.96 ± 0.02	6.66 ± 0.02 a	11.05 ± 0.46 a

Table S13. Fatty acids profile from *Ulva* sp. across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
FA 14:0	0.12 ± 0.01 a	0.04 ± 0.00	0.03 ± 0.00 a	0.05 ± 0.01
FA 15:0	0.02 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00
FA 16:0	2.72 ± 0.05	2.33 ± 0.20	1.99 ± 0.03 a	3.49 ± 0.35 a
FA 16:1	0.02 ± 0.00 a	0.01 ± 0.00 a,b,c	0.02 ± 0.00 b	0.02 ± 0.00 c
FA 16:1n-7	0.23 ± 0.01	0.13 ± 0.01	0.08 ± 0.00 a	0.26 ± 0.02 a
FA 16:1n-9	0.32 ± 0.01	0.26 ± 0.03	0.23 ± 0.01 a	0.40 ± 0.03 a
FA 16:2n-4	0.02 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.01 ± 0.00
FA 16:4 n-3	2.38 ± 0.10	2.69 ± 0.22 a	0.84 ± 0.01 a	2.29 ± 0.21
FA 18:0	0.44 ± 0.08	0.32 ± 0.18	0.53 ± 0.16	0.16 ± 0.02
FA 18:1n-9	0.14 ± 0.00	0.06 ± 0.00	0.07 ± 0.00	0.14 ± 0.01
FA 18:1n-7	1.16 ± 0.01	1.27 ± 0.09	0.76 ± 0.01	1.28 ± 0.11
FA 18:2n-6	0.25 ± 0.00	0.14 ± 0.01 a	0.17 ± 0.00	0.30 ± 0.02 a
FA 18:3 n-6	0.05 ± 0.00	0.04 ± 0.00	0.03 ± 0.00 a	0.10 ± 0.01 a
FA 18:3 n-3	1.55 ± 0.01	1.42 ± 0.10	0.91 ± 0.02 a	2.16 ± 0.2 a
FA 18:4 n-3	3.27 ± 0.01	3.25 ± 0.20	1.27 ± 0.02	3.21 ± 0.25
FA 20:4 n-6	0.05 ± 0.00	0.02 ± 0.00	0.01 ± 0.00 a	0.07 ± 0.00 a
FA 20:4 n-3	0.08 ± 0.00	0.12 ± 0.01 a	0.06 ± 0.00 a	0.10 ± 0.01
FA 20:5 n-3	0.24 ± 0.01	0.11 ± 0.01	0.07 ± 0.00 a	0.27 ± 0.02 a
FA 22:0	0.05 ± 0.01 a	0.05 ± 0.01	0.11 ± 0.00 a	0.08 ± 0.00
FA 22:5 n-3	0.28 ± 0.01 a	0.39 ± 0.04	0.47 ± 0.00 a	0.40 ± 0.03
SFA	3.33 ± 0.08	2.76 ± 0.37	2.67 ± 0.13	3.79 ± 0.38
MUFA	1.86 ± 0.03	1.73 ± 0.13	1.15 ± 0.03 a	2.09 ± 0.18 a

PUFA	8.17 ± 0.09	8.19 ± 0.58	3.87 ± 0.06	8.93 ± 0.75
PUFA/SFA	2.45 ± 0.07	2.99 ± 0.22 a	1.45 ± 0.08 a	2.36 ± 0.07
PUFA n-3	7.80 ± 0.08	7.99 ± 0.57	3.63 ± 0.05	8.44 ± 0.72
PUFA n-6	0.35 ± 0.01	0.19 ± 0.01 a	0.22 ± 0.00	0.48 ± 0.03 a
n-6/n-3	0.04 ± 0.00	0.02 ± 0.00 a	0.06 ± 0.00 a	0.06 ± 0.00
AI	0.32 ± 0.00	0.25 ± 0.01	0.42 ± 0.00	0.33 ± 0.01
TI	0.07 ± 0.00	0.04 ± 0.00	0.09 ± 0.00	0.08 ± 0.00
h/H	0.79 ± 0.02	0.74 ± 0.02	0.61 ± 0.00	0.84 ± 0.03

Table S14. Fatty acids profile from *Fucus vesiculosus* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
FA 14:0	1.16 ± 0.16	0.54 ± 0.12 a	0.75 ± 0.10	1.57 ± 0.00 a
FA 15:0	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0.01	0.07 ± 0.00
FA 16:0	1.53 ± 0.26	1.03 ± 0.19	1.33 ± 0.16	2.34 ± 0.21
FA 16:1	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.02 ± 0.01
FA 16:1n7	0.13 ± 0.02	0.10 ± 0.02	0.13 ± 0.02	0.21 ± 0.02
FA 16:1n-9	0.02 ± 0.00	0.02 ± 0.00	0.01 ± 0.00	0.02 ± 0.00
FA 17:0	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.00	0.03 ± 0.00
FA 17:1n-9	0.01 ± 0.00 a	0.04 ± 0.01	0.02 ± 0.00	0.09 ± 0.00 a
FA 18:0	0.31 ± 0.02	0.14 ± 0.00 a	0.24 ± 0.02	0.40 ± 0.00 a
FA 18:1n-9	3.96 ± 0.70	1.82 ± 0.37	3.41 ± 0.33	4.67 ± 0.16
FA 18:1	0.00 ± 0.00 a	0.03 ± 0.01	0.10 ± 0.02 a	0.02 ± 0.00
FA 18:2n-6	0.66 ± 0.13	0.70 ± 0.13	0.42 ± 0.06 a	1.17 ± 0.07 a
FA 18:3n-6	0.05 ± 0.01	0.05 ± 0.01	0.03 ± 0.00 a	0.08 ± 0.02 a
FA 18:3n-3	0.69 ± 0.14	0.73 ± 0.15	0.17 ± 0.03	0.85 ± 0.03
FA 18:4n-3	0.28 ± 0.05	0.48 ± 0.10 a	0.07 ± 0.01 a	0.34 ± 0.01
FA 20:0	0.05 ± 0.01	0.02 ± 0.01 a	0.05 ± 0.01	0.09 ± 0.00 a
FA 20:3n-6	0.06 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.07 ± 0.00
FA 20:4n-6	1.94 ± 0.36	1.47 ± 0.32	0.93 ± 0.13 a	2.78 ± 0.13 a
FA 20:5n-3	0.75 ± 0.15	0.90 ± 0.19	0.20 ± 0.03 a	1.27 ± 0.06 a
SFA	3.09 ± 0.42	1.77 ± 0.32	2.43 ± 0.30	4.50 ± 0.21
MUFA	4.12 ± 0.73	2.02 ± 0.41	3.69 ± 0.37	5.03 ± 0.20
PUFA	4.44 ± 0.86	4.38 ± 0.92	1.85 ± 0.27 a	6.55 ± 0.31 a
PUFA/SFA	1.42 ± 0.08	2.47 ± 0.13 a	0.76 ± 0.02 a	1.46 ± 0.00
PUFA n-3	1.72 ± 0.34	2.11 ± 0.45	0.44 ± 0.07	2.46 ± 0.09
PUFA n-6	2.71 ± 0.52	2.27 ± 0.47	1.41 ± 0.20 a	4.10 ± 0.22 a
n-6/n-3	1.58 ± 0.01	1.07 ± 0.02 a	3.22 ± 0.11 a	1.67 ± 0.02
AI	0.72 ± 0.03	0.5 ± 0.03	0.78 ± 0.02	0.75 ± 0.01
TI	0.33 ± 0.02	0.18 ± 0.01	0.55 ± 0.01	0.34 ± 0
h/H	2.97 ± 0.09	3.57 ± 0.13	2.47 ± 0.04	2.74 ± 0.04

Table S15. Fatty acids profile from *Porphyra dioica* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc

comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
FA 14:0	0.01 ± 0.00 a	0.36 ± 0.06 a	0.06 ± 0.02	0.02 ± 0.00
FA 16:0	0.98 ± 0.20	1.18 ± 0.12	0.8 ± 0.09	1.02 ± 0.04
FA 16:1 n-7	0.01 ± 0.00 a	0.30 ± 0.03 a	0.05 ± 0.01	0.06 ± 0.00
FA 16:1 n-9	0.08 ± 0.02	0.07 ± 0.01	0.04 ± 0.01	0.06 ± 0.00
FA 16:2 n-6	0.00 ± 0.00 a	0.09 ± 0.01 a	0.01 ± 0.00	0.02 ± 0.00
FA 16:3 n-4	0.00 ± 0.00 a	0.08 ± 0.01 a	0.02 ± 0.00	0.04 ± 0.00
FA 16:4 n-1	0.00 ± 0.00 a	0.31 ± 0.03 a	0.04 ± 0.01	0.02 ± 0.00
FA 18:0	0.15 ± 0.06	0.12 ± 0.03	0.08 ± 0.01	0.07 ± 0.01
FA 18:1 n-9	0.09 ± 0.02	0.16 ± 0.01	0.17 ± 0.02	0.10 ± 0.00
FA 18:1 n-7	0.03 ± 0.01 a	0.06 ± 0.01 a	0.03 ± 0.00	0.05 ± 0.00
FA 18:2 n-6	0.05 ± 0.01 a	0.17 ± 0.01 a	0.10 ± 0.02	0.08 ± 0.00
FA 18:3 n-6	0.02 ± 0.01	0.05 ± 0.00	0.02 ± 0.00	0.02 ± 0.00
FA 18:3 n-3	0.00 ± 0.00 a	0.04 ± 0.00	0.00 ± 0.00 b	0.08 ± 0.00 a,b
FA 18:4 n-3	0.01 ± 0.00 a	0.14 ± 0.01 a	0.03 ± 0.01	0.05 ± 0.00
FA 20:1 n-9	0.06 ± 0.01 a	0.08 ± 0.01 a	0.09 ± 0.02	0.06 ± 0.00
FA 20:2 n-6	0.02 ± 0.01 a	0.03 ± 0.00 a	0.03 ± 0.00	0.02 ± 0.00
FA 20:3 n-6	0.11 ± 0.02 a	0.64 ± 0.05 a	0.23 ± 0.04	0.15 ± 0.00
FA 20:4 n-6	0.32 ± 0.06	0.64 ± 0.05 a	0.44 ± 0.06	0.32 ± 0.01 a
FA 20:4 n-3	0.02 ± 0.01	0.09 ± 0.01 a	0.03 ± 0.00 a	0.05 ± 0.00
FA 20:5 n-3	1.74 ± 0.33	2.96 ± 0.22 a	1.36 ± 0.19 a	1.64 ± 0.05
SFA	1.14 ± 0.16	1.67 ± 0.20 a	0.94 ± 0.11 a	1.11 ± 0.05
MUFA	0.26 ± 0.06 a	0.67 ± 0.06 a	0.37 ± 0.05	0.33 ± 0.01
PUFA	2.30 ± 0.44	5.24 ± 0.42	2.33 ± 0.33	2.49 ± 0.08
PUFA/SFA	2.00 ± 0.13 a	3.14 ± 0.21 a	2.48 ± 0.06	2.26 ± 0.02
PUFA n-3	1.77 ± 0.34	3.23 ± 0.25 a	1.43 ± 0.20 a	1.82 ± 0.06
PUFA n-6	0.53 ± 0.10 a	1.61 ± 0.13 a	0.83 ± 0.13	0.61 ± 0.02
n-6/n-3	0.30 ± 0.00 a	0.50 ± 0.00	0.58 ± 0.01 a	0.34 ± 0.00
AI	0.39 ± 0.01	0.48 ± 0.04	0.39 ± 0.01	0.39 ± 0.00
TI	0.13 ± 0.00	0.13 ± 0.01	0.14 ± 0.00	0.12 ± 0.00
h/H	2.23 ± 0.05	2.57 ± 0.16	2.42 ± 0.04	2.14 ± 0.02

Table S16. Fatty acids profile from *Palmaria palmata* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring
FA 14:0	0.18 ± 0.03	0.28 ± 0.04	0.28 ± 0.01
FA 15:0	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
FA 16:0	0.89 ± 0.12	1.33 ± 0.11	1.25 ± 0.06
FA 16:1 n-7	0.10 ± 0.01	0.06 ± 0.01 a	0.32 ± 0.02a
FA 16:1 n-9	0.03 ± 0.00 a	0.08 ± 0.01a	0.04 ± 0.00
FA 16:3 n-4	0.02 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
FA 16:4 n-3	0.04 ± 0.00	0.01 ± 0.00	0.00 ± 0.00

FA 16:4 <i>n</i> -1	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.00
FA 18:0	0.21 ± 0.05	0.15 ± 0.01	0.13 ± 0.00
FA 18:1 <i>n</i> -9	0.10 ± 0.01 a	0.21 ± 0.02 a	0.15 ± 0.01
FA 18:1 <i>n</i> -7	0.08 ± 0.01	0.07 ± 0.01	0.03 ± 0.00
FA 18:2 <i>n</i> -6	0.06 ± 0.01	0.03 ± 0.00	0.03 ± 0.00
FA 18:3 <i>n</i> -6	0.02 ± 0.00	0.01 ± 0.00 a	0.02 ± 0.00 a
FA 18:3 <i>n</i> -3	0.14 ± 0.01 a	0.05 ± 0.00	0.02 ± 0.00 a
FA 18:4 <i>n</i> -3	0.18 ± 0.02 a	0.09 ± 0.01	0.07 ± 0.01 a
FA 20:4 <i>n</i> -6	0.07 ± 0.01 a	0.06 ± 0.01	0.04 ± 0.01 a
FA 20:5 <i>n</i> -3	2.13 ± 0.28 a	4.51 ± 0.35 a	2.75 ± 0.15
SFA	1.29 ± 0.20	1.76 ± 0.15	1.66 ± 0.07
MUFA	0.31 ± 0.04	0.41 ± 0.04	0.55 ± 0.04
PUFA	2.69 ± 0.33	4.79 ± 0.37 a	2.99 ± 0.17 a
PUFA/SFA	2.10 ± 0.09	2.72 ± 0.03 a	1.80 ± 0.03 a
PUFA <i>n</i> -3	2.48 ± 0.31 a	4.65 ± 0.36 a	2.84 ± 0.16
PUFA <i>n</i> -6	0.15 ± 0.02	0.09 ± 0.01	0.09 ± 0.01
<i>n</i> -6/ <i>n</i> -3	0.06 ± 0.00 a	0.02 ± 0.00 a	0.03 ± 0.00
AI	0.54 ± 0.01	0.47 ± 0.01	0.68 ± 0.02
TI	0.05 ± 0.01	0.03 ± 0.00	0.04 ± 0.00
h/H	2.34 ± 0.04	3.03 ± 0.05	1.96 ± 0.03

Table S17. Pigments (chlorophylls and carotenoids) profile from *Ulva* sp., *Fucus vesiculosus*, *Porphyra dioica* and *Palmaria palmata* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using Kruskal-Wallis test followed by Dunn's post-hoc comparisons. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
<i>Ulva</i> sp.				
Chlorophyl <i>a</i>	9.482±0.106	9.484±0.065	14.412±0.509 a	3.272±0.111 a
Chlorophyl <i>b</i>	1.146±0.038 a	1.322±0.013	24.305±0.932 a	3.444±0.207
β-Carotene	0.260±0.010	0.109±0.000	2.448±0.350 a	0.000±0.000 a
Lutein	0.311±0.002	0.625±0.006	1.088±0.041 a	0.000±0.000 b
Neoxanthin	0.176±0.001	0.2607±0.0014 a,b	0.000±0.000 a	0.000±0.000 b
Violaxanthin	0.050±0.000	0.078±0.001 a,b	0.000±0.000 a	0.000±0.000 b
Zeaxanthin	0.005±0.000	0.014±0.000 a,b	0.000±0.000 a	0.000±0.000 b
Total carotenoids	0.802±0.013	1.085±0.008	3.536±0.357 a	0.000±0.000 a
<i>Fucus vesiculosus</i>				
Chlorophyl <i>a</i>	0.122±0.001 a	0.146±0.001	23.371±1.262 a	7.033±0.284
β-Carotene	0.057±0.000	0.158±0.001 a	0.006±0.001	0.000±0.000 a
Canthaxanthin	0.054±0.001 a,b	0.051±0.001	0.000±0.000 a	0.000±0.000 b
Fucoxanthin	1.344±0.018	1.554±0.015 a	0.335±0.009 a	0.000±0.000
Lutein	0.009±0.000	0.010±0.000	0.000±0.000	0.000±0.000
Violaxanthin	0.102±0.001	0.111±0.001 a,b	0.000±0.000 a	0.000±0.000 b
Zeaxanthin	0.000±0.000 a	0.0023±0.000 a,b,c	0.000±0.000 b	0.000±0.000 c
Total carotenoids	1.513±0.020	1.835±0.018 a	0.341±0.010	0.000±0.000 a
<i>Porphyra dioica</i>				
Chlorophyl <i>a</i>	1.646±0.049	1.295±0.004 a	21.580±0.405 a	3.055±0.088
β-Carotene	0.283±0.001 a	0.332±0.001	1.731±0.050	2.155±0.079 a
Lutein	0.687±0.010	0.561±0.008 a	0.641±0.062	0.908±0.027 a

Neoxanthin	0.000±0.000 a	0.026±0.000 a,b,c	0.000±0.000 b	0.000±0.000 c
Violaxanthin	0.022±0.000	0.043±0.000 a,b	0.000±0.000 a	0.000±0.000 b
Zeaxanthin	0.019±0.000 a,b	0.009±0.000	0.000±0.000 a	0.000±0.000 b
Total carotenoids	1.004±0.017	0.944±0.009 a	2.372±0.016	3.063±0.105 a
<i>Palmaria palmata</i>				
Chlorophyl <i>a</i>	1.042±0.002	1.417±0.004	7.491±0.206	-
β-Carotene	0.086±0.002	0.153±0.002	0.295±0.001	-
Lutein	0.274±0.003	0.402±0.012	0.261±0.001	-
Violaxanthin	0.031±0.000	0.007±0.000	0.000±0.000	-
Zeaxanthin	0.003±0.000	0.007±0.000	0.000±0.000	-
Total carotenoids	0.394±0.005 a	0.569±0.014 a	0.556±0.002	-

Table S18. Phycobiliproteins profile from *Porphyra dioica* and *Palmaria palmata* across the different seasons, expressed in mg.g⁻¹ of DW biomass. The values represent the mean ± standard deviation (SD) of three replicates (n=3). Significant differences between the groups were revealed using one-way ANOVA with Tukey's post hoc test. Values in the same row followed by the same letter are significantly different at p-value < 0.05.

	Autumn	Winter	Spring	Summer
<i>Porphyra dioica</i>				
<i>R</i> -phycoerythrin	5.35±0.17 a,b,c	1.82±0.24 a,d	7.21±0.17 b,d,e	1.71±0.05 c,e
Phycocyanin	3.35±0.1 a,b	1.29±0.29 a,c	4.50±0.15 c,d	1.10±0.03 b,d
<i>Palmaria palmata</i>				
<i>R</i> -phycoerythrin	11.8±1.24 a	15.46±0.60 b	0.45±0.04 a,b	-
Phycocyanin	2.10±0.35 a	1.98±0.16	0.14±0.01 a,b	-