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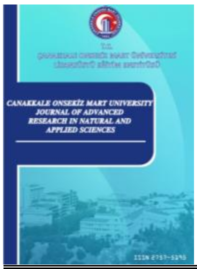

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The Changes in Biochemical Compositions of Five Different Macroalgae and Seagrass (*Halophila stipulacea (Forsskal) Ascherson 1867*) Collected from Iskenderun Bay

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Research Article

Abstract −In present study, biochemical compositions (ash, lipid and protein) of five different macroalgae ((Green Macroalgae-GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), Red Macroalgae-RMA (*Pterocladiella capilacea),* Brown Macroalgae-BMA (*Sargassum vulgare* and *Ericaria amentacea*)) and Angiosperm/Seagrass (*Halophila stipulacea*) collected from Iskenderun Bay were investigated. The differences observed between biochemical compositions such as ash, lipid and protein of five macroalgae species and Angiosperm/Seagrass (*Halophila stipulacea*) were statistically significant ($p<0.05$). The lowest and highest ash, lipid and protein values of five macroalgae were 12.19±1.15% (*Caulerpa prolifera*)- 21.38±1.53% (*Ericaria amentacea*), 1.74±0.19% (*Caulerpa prolifera*)- 5.83±0.68% (*Ericaria amentacea*), 5.56±0.06% (*Chaetomorpha linum*)- 11.45±0.53% (*Sargassum vulgare*), respectively. Ash, lipid and protein values of Angiosperms/Seagrass (*Halophila stipulacea*) were determined as 14.56±2.08%, 3.16±0.48% and 8.11±0.07%, respectively. Protein value of Angiosperms/Seagrass (*Halophila stipulacea*) was higher than those of (GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) but not RMA(*Pterocladiella capillacea)* and BMA (*Sargassum vulgare* and *Ericaria amentacea*)). Lipid value of Angiosperms/Seagrass (*Halophila stipulacea*) was similar to RMA(*Pterocladiella capillacea)*. In conclusion, the information of the biochemical compositions of five different macroalgae and Angiosperms/Seagrass (*Halophila stipulacea*) are important for the evaluation of potential sources for commercial and human consumption. In addition, biochemical compositions of tested macroalgae and seagrass could make important contributions to feed formulations and functional foods in future.

Keywords-*Green algae, brown algae, red algae, seagrass, biochemical compositions*

1. Introduction

Macroalgae known as primary producers are important for the ocean ecosystem. They include nutritional compounds used different industries such as food, agriculture, feed, cosmetic, medicine, pharmacy. Ak (2015)

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showed that macroalgae have contain different photosynthetic pigments such as Chlorophyta (Green Macroalgae-GMA), Rhodophyta (Red Macroalgae-RMA), Ochrophyta (Brown Macroalgae-BMA). Researchers revealed that biological activity potentials, fatty acids, protein and mineral substances of macroalgae were high levels (Dawczynski, Schubert & Jahreis 2007; Wells et al., 2017). Burtin (2003) and Benjama & Masniyom (2011) reported that GMA and RMA have higher protein levels (10–30%) than BMA species (5–15%). Dawczynski et al. (2007) showed that proximate compositions of the mentioned GMA, RMA and BMA change according to the geographical distribution, species, season, water temperature, salinity, light and nutrients and mineral availability.

Caulerpa is GMA genera belonging to Caulerpaceae family. Invasive algae have important effects on the ecosystems. *Caulerpa taxifolia* is an invasive alga found in the Mediterranean Sea.

Seagrasses provide an important habitat for fish and crustaceans as well as ecological contribution (Fourqurean et al., 2012). It is known that, seagrasses represent to two families, Potamogetonaceae and Hydrocharitaceae, (Hemminga & Duarte, 2000). *Halophila stipulacea* is seagrass species belonging to the family Hydrocharitaceae. There are 10 species of the genus Halophila. *Halophila stipulacea* was first observed in the Mediterranean in 1894 (Lipkin, 1975). Due to its invasive nature, there is increasing interest in understanding the ability to tolerate various environmental conditions. (Malm, 2006).

Biochemical compositions (ash, lipid, protein) of macroalgae and seagrasses are important to determine for industrial potentials. There is need to knowledge about analysis of proximate compositions of macroalgae and seagrasses belonging to different regions. Studies about nutritional composition macroalgae and seagrass tested in this study is not adequate in Iskenderun Bay. Therefore, we aimed to investigate the biochemical compositions (ash, lipid and protein) of five different macroalgae ((GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), RMA(*Pterocladiella capillacea),* BMA (*Sargassum vulgare* and *Ericaria amentacea*) and Angiosperms/Seagrass (*Halophila stipulacea*) gathered from Iskenderun Bay.

2. Materials and Methods

Macroalgae and Seagrass were gathered from the coasts of İskenderun Bay (Kale and Arsuz regions in July 2019). Five macroalgae species ((GMA (*Chaetomorpha linum (O.F.Müller) Kützing 1845* and *Caulerpa prolifera (Forsskal) J.V.Lamouroux 1809*), RMA(*Pterocladiella capillacea (S.G.Gmelin) Santelices & Hommersand 1997),* BMA (*Sargassum vulgare C.Agardh, 1820* and *Ericaria amentacea (C.Agardh) Molinari & Guiry 2020*)) and Angiosperms/Seagrass (*Halophila stipulacea (Forsskal) Ascherson 1867*) were identified. The identification studies of macroalgae and seagrass were carried out with Olympus brand SZX16 model stereo zoom and BX51 model binocular light microscopes (Taşkın & Öztürk, 2013; Rodríguez-Prieto, Ballesteros, Boisset & Afonso-Carrillo, 2013; Cormaci, Furnari & Alongi, 2014)

2.1. Preparation of the samples

Five macroalgae and Angiosperms/Seagrass (*Halophila stipulacea*) collected from the coasts of Iskenderun Bay were rinsed in distilled water and then drained. Thus, sand and other unwanted objects were removed. The next step was to dry the samples at 60°C for 3 hours using a laboratory oven (Pradana, Prabowo, Hastuti, Djaeni & Prasetyaningrum, 2019). Thoroughly dried samples were ground with a laboratory type mixer and then, stored at −20°C until analyses.

2.2. Biochemical compositions

Biochemical analyses of five macroalgae species ((GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), RMA(*Pterocladiella capillacea),* BMA (*Sargassum vulgare* and *Ericaria amentacea*)) and

Angiosperms/Seagrass (*Halophila stipulacea*) gathered from the coasts of Iskenderun Bay were made according to the AOAC (2005) and Bligh & Dyer (1959) procedures.

2.3. Statistical analysis

Ash, lipid and protein results of five macroalgae species ((GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), RMA(*Pterocladiella capillacea),* BMA (*Sargassum vulgare* and *Ericaria amentacea*)) and Angiosperms/Seagrass (*Halophila stipulacea*) were submitted as mean ± standard error (SE). Statistical comparisons were were made by OneWay Analysis (ANOVA) using SPSS 12. Differences were considered statistically significant when $p<0.05$.

3. Results and Discussion

The purpose of study was to reveal biochemical compositions (ash, lipid and protein) of five different macroalgae ((GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), RMA(*Pterocladiella capillacea),* BMA (*Sargassum vulgare* and *Ericaria amentacea*)) and Angiosperms/Seagrass (*Halophila stipulacea*). The biochemical compositions of five macroalgae and Angiosperms/Seagrass (*Halophila stipulacea*) are summarized in Table 1.

Table 1

Biochemical compositions of macroalgae and seagrass (mean±SE)

	Proximate Compositions		
GMA*	**Ash (%)**	**Lipid (%)**	**Protein (%)**
Chaetomorpha linum	17,68± 0,33[bc]	4,84±1,68[b]	5,56±0,06[a]
Caulerpa prolifera	12,19±1,15[a]	1,74±0,19[a]	6,70±0,07[b]
RMA**			
Pterocladiella capillacea	20,31± 0,63[c]	3,11±0,53[ab]	9,62±0,35[d]
BMA***			
Sargassum vulgare	13,19± 0,15[a]	4,31±0,42[ab]	11,45±0,53[e]
Ericaria amentacea	21,38±1,53[c]	5,83±0,68[b]	9,75±0,07[d]
Angiosperms/Seagrass	**Ash (%)**	**Lipid (%)**	**Protein (%)**
Halophila stipulacea	14,56±2,08[ab]	3,16±0,48[ab]	8,11±0,07[c]

Different letters between the columns indicate significant difference at 5% by Duncan multiple range test.

* Green Macroalgae; ** Red Macroalgae; *** Brown Macroalgae

The values found between biochemical compositions such as ash, lipid and protein of five macroalgae species and Angiosperms/Seagrass (*Halophila stipulacea*) were statistically significant ($p<0.05$). The lowest and highest ash, lipid and protein values of five macroalgae were 12.19±1.15% (*Caulerpa prolifera*)- 21.38±1.53% (*Ericaria amentacea*), 1.74±0.19% (*Caulerpa prolifera*)- 5.83±0.68% (*Ericaria amentacea*), 5.56±0.06% (*Chaetomorpha linum*)- 11.45±0.53% (*Sargassum vulgare*), respectively. Ash, lipid and protein values of Angiosperms/Seagrass (*Halophila stipulacea*) were determined as 14.56 ±2.08%, 3.16±0.48% and 8.11±0.07%, respectively. Ash, lipid and protein values of *Ericaria amentacea* were the highest except for protein value of BMA *Sargassum vulgare*. Protein values of BMA were higher than those of GMA (*Chaetomorpha linum* and *Caulerpa prolifera*), RMA(*Pterocladiella capillacea)* and Angiosperms/Seagrass (*Halophila stipulacea*). Protein value of Angiosperms/Seagrass (*Halophila stipulacea*) was higher than those of GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) but not RMA (*Pterocladiella capillacea)* and BMA (*Sargassum vulgare* and *Ericaria amentacea*)). Lipid value of Angiosperms/Seagrass (*Halophila stipulacea*) was similar to RMA (*Pterocladiella capillacea)*. Ash and lipid values of *Caulerpa prolifera* except for protein value were lower than that of *Chaetomorpha linum*. Ash and lipid values of *Ericaria amentacea* except for protein value were lower than that of *Sargassum vulgare*. Ash and protein values of RMA (*Pterocladiella capillacea)* except for lipid value were higher than those of GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) and Angiosperms/Seagrass (*Halophila stipulacea*).

According to the results of our study, protein levels of RMA(*Pterocladiella capillacea),* BMA (*Sargassum vulgare* and *Ericaria amentacea*)) were higher than those of GMA (*Chaetomorpha linum* and *Caulerpa prolifera*). Protein value of RMA(*Pterocladiella capillacea)* were similar to *Ericaria amentacea* but lower than that of BA (*Sargassum vulgare*).

It is known that, GMA and RMA contain higher protein contents (10–30%) than BMA (5–15%) (Burtin, 2003; Benjama & Masniyom, 2011). Dawczynski et al. (2007) revealed that protein levels of RMA was higher than those of BMA. However, Aras & Sayın (2020) showed that the protein ratio of *Ellisolandia elongata*, which is the only RMA species is similar to *Sargassum vulgare* and lower than *Dictyota dichotoma* from BMA.

Wahbeh (1997) showed that the protein content of the macroalgae *Padina pavonica* collected at the beach in Aqaba, Jordan was 17.4%. Tabarsa et al. (2012) found a protein content of 11.83% in *Padina pavonica*, which they collected in April in southern Iran (Persian Gulf). Ozgun & Turan (2015) showed that the protein levels of eight brown macroalgae collected from Iskenderun Bay was varied from 2.897±0.373% to 6.519±0.432%. Gür (2015) determined that protein value of *Dictyota dichotoma* was between 4.42-6.15%. Pakawan, Suriyan, Kriengkrai, & Jintana, (2015) biochemical compositions of 9 macroalgae species belonging to the GMA and RMA *Chaetomorpha crassa, Chaetomorpha linum, Ulva rigida, Caulerpa racemosa, Caulerpa brachypus, Caulerpa lentillifera, Caulerpa taxifolia, Gracilaria tenuistipitata and Gracilaria fisheri* showed as 12.68–33.83% protein. Uslu et al. (2021) determined that the protein amounts of the macroalgae *Sargassum vulgare* and *Cystoseira compressa* were 6.29±0.12% and 9.50±0.3%, respectively. Protein levels of *Sargassum vulgare* and *Cystoseira compressa* revealed by Uslu et al. (2021) were lower and similar to report from current study, respectively.

Protein levels of BMA (*Sargassum vulgare* and *Ericaria amentacea*)) tested in current study was lower than those of protein levels revealed by Wahbeh (1997) and similar to Tabarsa et al. (2012). However, protein levels of BMA tested were higher than those of Ozgun & Turan (2015), Gür (2015) and Aras & Sayın (2020).

Khairy & El-Shafay (2013) revealed that the highest protein of *Pterocladia capillacea* in the different seasons was 23.72±0.03% Mazlum, Yazıcı, Sayın, Habiboğlu & Ugur, (2021) and Aras & Sayın (2020) revealed that protein level of *Jania rubens* and *Ellisolandia elongata* from red macroalgae was 5.99±0.773% and 6.05±0.03%, respectively. Protein level of RMA(*Pterocladiella capillacea)* tested were higher than those of the levels determined by Mazlum et al. (2021) and Aras & Sayın (2020) but not Khairy & El-Shafay (2013) and Pakawan et al. (2015).

Burtin (2003) revealed that protein levels of GMA were generally between 10-30%. Fırat, Öztürk, Taşkın & Kurt (2007) showed that protein value of *Caulerpa racemosa* were 12.94-20.18%. Manivannan, Thirumaran, Devi, Hemalatha & Anantharaman (2008) found that protein value of *Ulva intestinalis* was 16-17%. Manas et al. (2017) showed that protein value of *Caulerpa species* were 9.21-17.19%. Magdugo et al. (2020) showed that protein of *Caulerpa racemosa* was 19.9%.Protein level of *Ulva intestinalis* by Aras & Sayın (2020) determined as 15.77±0.16%. Protein value of *Ulva lactuca* belonging to GMA was determined as 16.89±0.12% by Mazlum et al. (2021). The protein values observed for GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) in present study were lower than the values mentioned by Burtin, (2003); Fırat, et al. (2007); Manivannan et al. (2008); Pakawan et al. (2015); Manas et al. (2017); Magdugo et al. (2020); Aras & Sayın (2020) and Mazlum et al. (2021).

McDermid & Stuercke (2003) reported that lipid content of macroalgae was less than 4%. Polat & Ozogul (2008) showed that lipid levels of RMA and BMA were between 1.10-11.53%. Lipid level is generally low in macroalgae, between 1-5% (Peng et al., 2015).

Wahbeh (1997) revealed that the lipid content of the macroalgae *Padina pavonica* collected at the beach in Aqaba, Jordan was 4.4%. Gür (2015) and Sultana, Ambreen, & Tarıq (2012) showed that lipid levels of *Dictyota dichotoma* from BMA was 0.9-5.13% and 6.8%. Aras & Sayın (2020) revealed that lipid values of

Dictyota dichotoma and *Sargassum vulgare* were 5.43±0.23% and 12.21±0.52%, respectively. Ahmad, Sulaiman, Saimon, Yee, & Matanjun, (2012) stated that BMA species have higher lipid content than RMA and GMA species. Lipid levels in our study were between 1.74±0.19% (*Caulerpa prolifera*)-5,83±0,68% (*Ericaria amentacea*) levels stated by Peng et al. (2015) . Uslu et al. (2021) determined that the lipid amounts of the macroalgae *Sargassum vulgare* and *Cystoseira compressa* were 2.58±0.4% and 2.00±0.5%, respectively. Lipid levels of *Sargassum vulgare* and *Cystoseira compressa* revealed by Uslu et al. (2021) were lower than present study. The results of our study were supported by Ahmad et al. (2012), Polat & Ozogul (2008), Peng et al. (2015), Gür (2015) but not Aras & Sayın (2020).

Mazlum et al. (2021) and Aras & Sayın (2020) revealed that lipid level of *Jania rubens* and *Ellisolandia elongata* from RMA were 0.39±0.103% and 0.43±0.09%, respectively. Lipid level of RMA(*Pterocladiella capillacea)* tested was higher than those of Mazlum et al. (2021) and Aras & Sayın (2020).

Khairy & El-Shafay (2013) showed that *Ulva lactuca* (4.09 ± 0.2%) contained more lipids than *Jania rubens* and *Pterocladia capillacea*. Manas et al. (2017) showed that lipid value of Caulerpa species were 1.29-2.44%. Magdugo et al. (2020) determined that lipid value of *Caulerpa racemosa* was 4.5%. Mazlum et al. (2021) and Aras & Sayın (2020) revealed that lipid levels of *Ulva lactuca* and *Ulva intestinalis* were 1.08±0.33% and 1.04±0.37%, respectively. Lipid levels of GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) tested were higher than those of Mazlum et al. (2021) and Aras & Sayın (2020). Results were supported by Polat & Ozogul (2008) and Peng et al (2015) and similiar to Khairy & El-Shafay (2013) except for *Caulerpa prolifera*.

According to the literatures, macroalgae have low lipid potential (Ratana- arporn & Chirapart, 2006). Chakraborty & Bhattacharya (2012) mentioned that lipid contents of macroalgae may vary depending on the type and amount of nutritive elements in the environment. Also, Peng et al. (2015) indicated that low lipid contents of macroalgae depends on light intensity, salinity and temperature conditions. Studies have shown that seasonal changes have caused changes in the biochemical compositions of macroalgae.

Tabarsa et al. (2012) revealed that the ash content of macroalgae varies between 8-40% of their dry weight. Polat & Ozogul (2013) determined that the ash levels varies between 2.28-51.63%. On the other hand, Liu (2017) showed that algae can contain as high as 70% dry matter ash in different locations.

Wahbeh (1997) indicated that the ash content of the macroalgae *Padina pavonica* collected at the beach in Aqaba, Jordan was 23.1%. Ozgun & Turan (2015) showed that the ash levels of 8 BMA gathered from Iskenderun Bay was varied from 1.66±0.29% to 18.19±2.66%. Uslu et al. (2021) determined that the ash amounts of the macroalgae *Sargassum vulgare* and *Cystoseira compressa* were 27.05±0.5% and 21±0.1%, respectively. Aras & Sayın (2020) found that the ash levels of BMA (*Dictyota dichotoma* and *Sargassum vulgare*) were 27.34±0.72% and 14.79±0.19%, respectively. BMA (*Sargassum vulgare* and *Ericaria amentacea*)) results were similar to the values determined by Wahbeh (1997), Ozgun & Turan (2015), and Aras & Sayın (2020) and Uslu et al. (2021) except for *Sargassum vulgare.*

Fırat et al. (2007) revealed that ash value of *Caulerpa racemosa* were 8.02-19.50%. Manas et al. (2017) showed that ash value of *Caulerpa species* were 23.90-40.27%. Magdugo et al. (2020) revealed that ash value of *Caulerpa racemosa* was 29,4%. Aras & Sayın (2020) and Mazlum et al. (2021) revealed that the ash levels of GMA (*Ulva intstinalis*) and *Ulva lactuca*) were 27.49±0.43% and 26.47±0.20%. Aras & Sayın (2020) and Mazlum et al. (2021) determined that the ash levels of RMA (*Ellisolandia elongata* and *Janie rubens*) were 76.75±0.20% and 78.740±0.066%, respectively. Khairy & El-Shafay (2013) indicated that ash content of *Jania rubens* species were quite high (50.54%). Liu (2017) reveal that algae can contain as high as 70% dry matter ash in different locations. Results belonging to GMA (*Chaetomorpha linum* and *Caulerpa prolifera*) and RMA(*Pterocladiella capillacea)* were lower than those of Khairy & El-Shafay (2013), Liu (2017), Manas et al. (2017), Magdugo et al. (2020), Aras & Sayın (2020) and Mazlum et al. (2021). Factors such as geographical location and season might be important factors in change the ash content of macroalgae (Renaud and Luong-Van, 2006; Mohamed, Hashim & Rahman, 2012; Cabrita et al., 2016)

Aketa & Kawamura (2001) found that protein values of *Halophila ovalis* was 6,2%. Coria-Monter & Durán-Campos (2015) showed that the protein, lipid and ash values of three seagrass species (*Thalassia testudinum*, *Halodule wrightii*, and *Syringodium filiforme*) were 8.47%-8.10%-10.43%; 0.83%,-2.33%-2.13%; 38.77%-27.23%-23.43%, respectively. Protein level of Angiosperms/Seagrass (*Halophila stipulacea*) was similar to Aketa & Kawamura, (2001), Kannan, Arumugam & Anantharaman, (2010) and Coria-Monter & Durán-Campos (2015). However, lipid and ash values of *Halophila stipulacea* were higher and lower than those of seagrasses species reported by Kannan et al. (2010) and Kannan, Arumugam, Iyapparaj, Thangaradjou & Anantharaman (2013), respectively. Renaud & Luong-Van (2006) indicated that geographic location, environmental conditions, seasons, and sampling conditions changed the biochemical composition of seagrass.

4. Conclusion

In conclusion, the information of the biochemical compositions of five different macroalgae ((**GMA** (*Chaetomorpha linum* and *Caulerpa prolifera*), **RMA** (*Pterocladiella capillacea),* **BMA** (*Sargassum vulgare.* and *Ericaria amentacea*)) and Angiosperms/Seagrass (*Halophila stipulacea*) are important for the evaluation of potential sources for commercial and human consumption. Biochemical compositions of tested macroalgae and seagrass could make important contributions to feed formulations and fuctional foods in future.

Author Contributions

Mehmet Naz: planned the study and statistical analyzes and evaulating the results and writing

Selin Sayın: planned the study and the writing of the manuscript

Zafer Çetin: biochemical analyses of macroalgae and the writing of the manuscript

Eyüp İlker Saygılı: biochemical analyses of macroalgae and the writing of the manuscript

Ergun Taşkın: collection of macroalgae and the writing of the manuscript

Oktay Söyler: collection of macroalgae and the writing of the manuscript

Conflicts of Interest

The authors declare no conflict of interest.

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