INVESTMENT POTENTIAL OF MACROALGAE CULTURE IN ÇANAKKALE, TURKEY

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Abstract: Macroalgae utilized in various fields during human history are recently used in medicine, pharmaceutics, and food industries. According to 2019 FAO data, macroalgae value up 30% of aquaculture and constitute all, 11.4 billion US dollars economic size. Thanks to its geomorphological salinity differences, the Çanakkale province supplies a farming possibility to many economically valued algae species. Although many academic studies are carried on, it has not been started commercially cultivation, yet. Turkey should be supported to take its place in the big market of seaweed culture technologies be exportation into algae production attended industrial projects.

Keywords: macroalgae, cultivation, investment, Çanakkale, Turkey.

Introduction

Marine macroalgae are utilized in food products, polysaccharides, functional foods, cosmeceuticals, pharmaceuticals and feedstock of biofuels (Aleman et al., 2019; Buschmann et al., 2019). Besides, both natural and cultivation sites of macroalgae locally reduce the effects of deoxygenation and ocean acidification and, they provide shelter form marine organisms (Duarte et al., 2017; Fernandez et al., 2019; Wallentinus and Nyberg, 2007). With developing technology, it is estimated that the demand for marine macroalgae will increase in the future. Consequently, the commercial cultivation of macroalgae species will also increase worldwide to meet increasing demand.

According to the FAO (2019a) statistics, aquaculture of macroalgae has been increasing over the last 15 years and it reaches nearly 30 million metric tons in 2017. Commercial production of macroalgae meets 96% of global demand and had an annual value of 11.4 billion USD. Worldwide, 16 million metric tons of red macroalgae (Rhodophyta) were cultured with an annual value of 5.1 billion USD. And, the production amount of brown macroalgae (Phaeophyta) is around 13.7 million metric tons. Although, production amounts are lower than red macroalgae, the annual value of brown macroalgae is 5.9 billion USD (FAO, 2019a). In such a large market, total production (both harvest from wild stocks and aquaculture) of Mediterranean countries is quite low. Morocco, Spain, and France, which have both coasts of the Mediterranean Sea and the Atlantic Ocean, produced 49.000 metric tons. In Italy, the total production amount was around 1.200 metric tons. Only 87 tons of this amount was obtained through aquaculture in 2017 (FAO, 2019b). In our country, macroalgae are studied at the academic level but there is no commercial production (Cirik et al., 2010a; Cirik et al., 2010b; Ak, 2015; Ak et al., 2015). Even if statistics of FAO are not precise, these numbers show us the main pattern of macroalgae production in Mediterranean countries.

In this study, we investigate the potential of macroalgae cultivation in Çanakkale/Turkey. For this purpose, macroalgae species that have economic potential for Çanakkale are defined.

Economically Important Macroalgae Species of Çanakkale

Macroalgae cultivation techniques vary according to algae species. The life cycle and growth rate of algae, quality, and quantity of substances extracted from algae are important criteria for species selection for aquaculture propose. The diversity of the marine flora of Çanakkale (İntepe: 181 taxa Gelibolu: 166 taxa, Eceabat: 153 taxa) is very rich (Taşkın et al., 2019). Among these taxa, some species which belong to Rhodophyta, Phaeophyta and Chlorophyta phylum have economic importance due to their polysaccharide contents. These species are *Gracilaria verrucosa* (Red algae), *Cystoseira barbata* (Brown algae) and *Ulva rigida* (Green algae).

***Gracilaria verrucosa* (Hudson) Pappenfuss**

Red macroalgae *Gracilaria verrucosa* is agarophyte species. The general characteristics of the thallus are finely branched and dark red color (Cirik and Cirik, 2017). This macroalga distributed in brackish water environments and dark biotopes (Ak and Yücesan, 2012). It develops well in sandy, muddy substrates with good water circulation (Cirik and Cirik, 2017). This seaweed is characterized by triphasic life history, with a diploid tetrasporophyte alternated morphological identical haploid gametophytic phase, the latter consisting of equal numbers of male and female plants (Gioele et al., 2017). *G. verrucosa* is the principal seaweed for making food grade agar and for its usage as food or food supplement for humans and various species of fish and shellfish (Bixler and Porse, 2011; Gioele et al., 2017). Also, this red seaweed is a source of important bioactive metabolites with antibiotic activity; but also, sources of different prostaglandins and other substances (De Almeida et al., 2011). Several authors have investigated biology, growth, culture, and applications of this alga in Turkey (İlyas, 1997; Ak and Cirik, 2004; Balkan et al., 2005; Aydoğmuş et al., 2008; Koru et al., 2008; Cirik et al., 2010a; Ak et al., 2011a; Ak and Yücesan, 2012). Ak (2004) examined the distribution of *G. verrucosa* in İzmir Bay. The author concluded that recovery of the wild populations was very slow because of over-harvesting and heavy epiphytism. İlyas, (1997), Balkan et al. (2005) and Aydoğmuş et al. (2008) studied the determination and extraction of biochemical compound derivatives contained in *G. verrucosa* collected from nature. Thanks to these studies, it has gained momentum in the last 10 years in the studies on the cultivation of this alga in Turkey. Koru et al. (2008), Cirik et al. (2010a) and Ak et al. (2011a) studied the influence of light and nutrients to find optimal conditions for land cultivation of this alga. These studies were done to evaluate not only the productivity of the seaweed for agar production but also its potential for chemical compounds. These results should support new cultivation trials for commercial production of *G. verrucosa* in Turkey.

***Cystoseira barbata* (Stackhouse) C.Agardh**

Brown macroalgae *Cystoseira barbata* is alginophyte species. Canopy-forming algae are widely distributed, colonizing from shallower water to the sublittoral in the Black Sea, the Marmara Sea, and the Aegean Sea (Manev et al., 2013; İrkin and Erduğan, 2014a; Cirik and Cirik, 2017). Thallus of *C. barbata* consists of a perennial cauloid and a dendroid frond. And, within its broad geographical range, this brown alga may show considerable morphological variation, related to environmental conditions (Falace and Bressan, 2006). *C. barbata* is monoecious, with seasonal maturation of conceptacles and release of gametes (Roberts 1967; Arenas et al. 1995). After settlement, many small rhizoids develop for attachment, with the apical growth of the thallus (Cirik and Cirik, 2017). *C. barbata* is used for biomonitoring, for calculation of indexes that help to determine the ecological status and eutrophication level of a given habitat (Manev et al., 2013). Also, this macroalga is one of the most important species with economical value in the Black Sea region due to the high content of alginic acid (Dimitrova-Konaklieva, 2000). Besides, it has functional food properties, brown alga *C. barbata* is also known to have antioxidant, antimicrobial, antihypertensive, and antibacterial constituents (Ozdemir et al., 2006; Çolakoğlu and Ak, 2017; Sellimi et al., 2017; Ak and Türker, 2018a; Ak and Türker, 2018b). Despite, the number of studies on the cultivation of this alga was limited, culture conditions for sexual reproduction of *C. barbata* were developed (Tok and Ak, 2015). Cirik et al. (2010b) and Topçu Öztaşkent and Ak (2017) examined the effect of nutrient sources on the growth and biochemical composition of *C. barbata*. These authors concluded that the nitrogen sources and their amounts influence the growth rate and biochemical composition of this brown alga. Furthermore, it has been reported by Ak and Öztaşkent (2016) that the alginate and fatty acid content of this seaweed changed according to the wavelength of the light used in land-based systems of *C. barbata* culture. In all the studies summarized above, it is mentioned that commercial algae studies should be cultivated due to its economic importance in Çanakkale/Turkey.

***Ulva rigida* C. Agardh**

Green macroalgae *Ulva rigida* is a cosmopolite species is distributed widely in coastal zones. The thallus is one-piece and is attached to the floor with a small holdfast (Cirik and Cirik, 2017). This alga occurs in shallow waters with very low current velocity (Coffaro and Sfriso, 1997). The alga has multiple reproduction modes, such as the diplohaplontic life history based on sexual reproduction and the heterogeneous life history based on parthenogenetic reproduction (Phillips, 1990). *U. rigida* grows extremely fast when nutrient enrichment coincides with optimal temperatures and the bloom of this alga is called "green tide" (Dural and Demir, 2001; Chávez-Sánchez et al., 2017). This alga is also used in human nutrition since it contains protein, pigments, vitamins and, minerals (Yildiz et al., 2012; İrkin and Erduğan, 2014b; Ak et al., 2015; Çolakoğlu and Ak, 2017; Berik and Çankırılıgil, 2019; Uzun and Berik, 2019). Researches on novel properties and applications for *U. rigida* have been conducted to support the development of commercial cultivation in Turkey. Nowadays, researchers focus on their studies to investigate antioxidant, antigenotoxic, anticlastogenicity, antidiabetic, antimicrobial and, antihyperlipidemic properties of *U. rigida* to promote new industrial applications (Çelikler et al., 2008; Taş et al., 2011; Yildiz et al., 2012; Çelikler et al., 2014; Gümüş and Ünlüsayın, 2016; Ak and Türker, 2018a; Ak and Türker, 2019). *U. rigida* was studied in integrated aquaculture with Grey Mullet (Topçu et al., 2012). It was found that this green alga is an effective biofilter for inorganic nitrogen compounds. Ak et al., (2011b) proved that organic carbon sources are more effective on the growth rate of *U. rigida* than inorganic carbon sources. Ak et al. (2015) verified that organic carbon sources not only affect the growth rate but also affect the fatty acid composition of *this seaweed*. *U. rigida* was cultured in outdoor tanks to use as a source of Turkish mezze by Turan and Tekoğul (2014). According to their data, they suggest that this green alga can be produced 30 – 45 tons dry weight ha^{-1} y^{-1}. Ak (2015) stated that the cultivation of *U. rigida* in Çanakkale was economically viable due to its high growth rate and, simple cultivation techniques.

Conclusion

According to TUIK (Turkish Statistical Institute) data, with 516 tons of alginic acid salts and esters were imported with an annual value of 10.8 million USD in 2018. The total imports of alginic acid and unprocessed seaweed material were worth 12 million USD (TUIK, 2018). In the future, imports of alginic acid and unprocessed seaweed materials will continue unless we build the seaweed aquaculture industry. Çanakkale province could play an important role in the developing of small-scale macroalgae culture. The province is located between the Aegean Sea in the southwest and the Marmara Sea in the northeast (Türkoğlu et al., 2006). The coast of the Aegean and Marmara seas makes the province of Çanakkale suitable for the cultivation of three algae species with different salinity degrees. And, cultivation of red, brown, and green macroalgae should be promoted in Çanakkale due to the increasing demand for raw materials both animal and human nutrition, and the development of new industrial applications.

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