PREFACE

Malaysia has the potential to be a key seaweed production player in the region if proper management and possible interventions take place. Chapter One analyzes the capacity building programs in Malaysia that aim to transform conventional seaweed cultivation techniques to modern seaweed cultivation techniques by applying a scientific approach. Chapter Two studies the marine macroalgae thriving at intertidal rocky shores on the west coast of Portugal, a transition zone where the combined influence of cold waters and warmer waters may favor the development of unique macroalgal communities. In Chapter Three, the authors discuss how problems of environmental deterioration and energy demand could be alleviated by the paradigm shift from fossil to biofuel from marine algae. The chapter elaborates on the unconventional strategies developed for the farming as well as conversion of Ulva rigida to biofuels and biochemicals. Chapter Four discusses the incorporation of macroalgae or macroalgal derived ingredients as a source of both macro-nutrients and micro-nutrients for animal feed production. The biological health benefits of the macroalgal ingredients beyond basic nutrition for the development of functional feed in the aquaculture, the ruminant and the swine sectors are also discussed together with the industrial challenges of its application. To conclude, Chapter Five provides a brief review of seaweed co-culture and its environmental impact on coastal fisheries. First, the current situation and problems facing the coastal fisheries, and the plans to overcome these issues, are discussed. Finally, the positive and negative effects of seaweed culture, role of seaweed co-culture, and the overall environmental impact are addressed.

Chapter 1 - Malaysia has the potential to be a key seaweed production player in the region if proper management and possible interventions take

place. The seaweed industry in Malaysia has its own historical background as the first seaweed cultivation activity took place in 1978 in Sabah, East Malaysia. The importance of the seaweed industry has been realised when seaweed was found as an important commodity to be exported to various countries. This brings economic benefits to the country and the development of human resource in this sector. The rural people play an important role in the human resource aspect that produce and cultivate the seaweed within their respective areas. In Malaysia, Sabah is the main state for seaweed cultivation activity because of its natural abundance resources and good climate. Department of Fisheries (DOF) Sabah indicated that seaweed production in Sabah has been increased every year amounting to 32 percent from 2008-2012. This is a good opportunity for seaweed production in Sabah where it has the potential to be developed on a bigger scale. The government of Malaysia has introduced seaweed transformation initiatives through Mini Estate System (MES) and Cluster System (CS) in year 2012 in order to enhance the seaweed industry in adhering to the scientific approach and management. These capacity building programmes' objective is to transform the conventional seaweed cultivation techniques to modern seaweed cultivation techniques by applying scientific approach. In terms of community livelihood activity, the MES and CS systems provide the seaweed cultivators with knowledge and skills in order to transform their conventional seaweed cultivation techniques to new technological approach. This MES and CS systems are still new in terms of practical implications. Therefore, a study to identify the effectiveness of these programmes is needed. Thus, this study is only focused on the development of both programmes by using available secondary data sources and most importantly through the documentation of these programmes. It will benefit the future researchers that are interested in this seaweed studies in Malaysia as well as in other developing countries.

Chapter 2 - This work studied the marine macroalgae thriving at intertidal rocky shores on the west coast of Portugal (Peniche, Central Portugal). Four seashores (Baleal-Norte, Gamboa, Portinho da Areia do Norte and Consolação) located near the borderline between two adjacent types of the Portuguese coast were surveyed, the first 3 inside the northern exposed coast (type A5) and the last shore from the moderately exposed coast at the southwest coast of continental Portugal (type A6). The aim of the study was to contribute to improve knowledge on the marine macroalgal flora of this transition zone, where the combined influence of cold waters (from North Atlantic Ocean) and warmer waters (from subtropical Atlantic Ocean and the Mediterranean Sea) may favour the development of unique macroalgal

communities (different arrangement of species). The collected material was housed at herbaria and photographed (records inserted in MACOI – Portuguese Seaweeds Website), and data were compared with historical information, aiming to update the local taxonomic list of marine macroalgae, and to infer about the species evolution along a 50 years' period. Data were also used to assess the ecological quality status of the four sampled sites by applying the methodology MarMAT (Marine Macroalgae Assessment Tool). A total of 87 macroalgal species were identified in the four localities, from which 16% have been not registered 50 years ago in local surveys. Meanwhile, more *taxa* were identified after the initial campaign so no new species were recorded in the present study. Taxonomic composition showed similarities for all sites but sufficient differences were still present and Consolação (A6 typology) appeared separate from the northern shores in the MDS analysis. From the application of MarMAT to present registers and old data, resulted a similar ecological quality status. Although all sites assessed in this study resulted on High quality, MarMAT reported equally high Ecological Quality Ratio for old and some recent data, indicating that sites preserved their excellent quality along the last decades.

Chapter 3 - Problems of environmental deterioration and energy demand could be alleviated by the paradigm shift from fossil to biofuels. Innovative strategies, such as the use of microwave irradiation, sonochemical treatment and solar irradiation were recently developed for the exploitation of biomass for biofuel production. The concept of biomass itself can be understood in an unconventional sense. Apart from terrestrial plant resources, nowadays, seaweed, industrial emissions such as CO_2, and organic remains such as glycogen are being explored as new feedstock for biofuels/chemicals production. The authors' research group in Israel is working on converting biomass (terrestrial and marine) to biofuels (bioethanol) and biochemicals (levulinic acid, furfural, formic acid) using microwave, sonochemical, and hydrothermal methods. Among several types of biomass, marine algae are a promising choice due to several advantages. Marine algae form an abundant and rich source of biomass. Bioethanol production process based on marine algae could be sustainable. A mild sonication-assisted simultaneous saccharification and fermentation (SSF) process for the conversion of *Ulva rigida* to bioethanol in a single step is developed in the current study. Bioethanol is a potential biofuel owing to the similarity of its energy density value (23 MJ/L) to that of gasoline (35 MJ/L). Bioethanol could also be a feedstock for the production of C_2 hydrocarbons. Any progress in the direction of development of a marine-algae-based bioethanol process would open up a

new avenue towards sustainable biorefinery. *Ulva rigida*, comprising 37 wt% carbohydrate was used as a feedstock for the SSF process. Initially, saccharification process of *Ulva rigida* (with amylases and cellulases) was carried out under mild sonication conditions (40 kHz, 37°C); 3.1 times higher glucose yield was obtained using sonication of *Ulva rigi*da relative to conventional incubation. The hydrolysate was found to contain glucose exclusively. Subsequently, the SSF process for converting the algae (*Ulva rigida*) to bioethanol in a single step was also accelerated using sonication. The improvement was observed in the total carbohydrate content of the algae using multi-tropic aqua culture. 27-41 times higher specific growth rates were achieved using this approach. Under specific optimal conditions of growth, a starch amount as high as 32 wt% was accumulated. The high-carbohydrate algae were subjected to the sonication- based SSF process. Under optimal process conditions, an ethanol yield as high as 16 wt% was achieved. A unique solar-energy-based continuous flow process for the direct conversion of *Ulva rigida* to bioethanol is outlined. The conversion of macroalgae to the strategically significant chemical, levulinic acid is discussed. In an acid-catalysed hydrothermal process, 12.8 wt% levulinic acid was produced from *Ulva rigida*. The authors therefore elaborate in this chapter on the unconventional strategies developed for the farming as well as conversion of *Ulva rigida* to biofuels and biochemicals.

Chapter 4 - Plant and animal derived products are the main ingredients currently used by the feed industry to produce concentrate feed. There is a need of novel feed ingredients to meet the demand of high quality products by the aquaculture, ruminant and swine production systems, together with the challenge of implementing new sustainable and environmentally friendly processes and ingredients demanded by the modern society. Macroalgae are a large and diverse group of marine organisms that are able to produce a wide range of compounds with unique biological properties. This chapter discusses the incorporation of macroalgae or macroalgal derived ingredients as a source of both macro-nutrients (i.e., proteins, polysaccharides and fatty acids) and micro-nutrients (i.e., minerals and pigments) for animal feed production. The biological health benefits of the macroalgal ingredients beyond basic nutrition for the development of functional feed in the aquaculture, the ruminant and the swine sectors are also discussed together with the industrial challenges of its application.

Chapter 5 - This chapter provides a brief review of seaweed co-culture and its environmental impact on coastal fisheries. First, the current situation and problems facing the coastal fisheries, and the plans to overcome these issues,

are discussed. Finally, the positive and negative effects of seaweed culture, role of seaweed co-culture, and the overall environmental impact are addressed. Although worldwide mariculture production has increased steadily, productivity has tended to decline due to continued aquaculture activity in confined areas and natural disasters, such as, typhoons and outbreaks of red tide. In particular, the nutrient loading from unconsumed feed waste results in the deterioration of the water quality and outbreaks of diseases. To overcome these problems, integrated multi-trophic aquaculture has been suggested. In the integrated culture of seaweed and fish, seaweed plays an important role as both a CO_2 sink and biofilter, greatly reducing the environmental impacts on coastal fisheries. The addition of the integrated culture of lugworms to this system could also have further benefits because of its potential for waste recycling and value as bait, which is expected to contribute towards a more sustainable and productive form of aquaculture. Furthermore, the use of cultured seaweed and their waste has been expanded based on the development of useful microbes, reducing their environmental impact.