氏　　名	Hakiki Melanie
学位の種類	博士（食料革新学）
学位記番号	博甲第　9322　号
学位授与年月	令和元年 10 月 31 日
学位授与の要件	学位規則　第４条第１項該当（昭和２８年４月１日文部省令第９号）
審査組織	グローバル教育院
学位論文題目	Valorization of Seaweeds for Novel Food and Non-Food Applications （食品および非食品の新規用途開発をめざす海藻の高付加価値化）

	（職名）	（学位）	（氏名）
主査	筑波大学教授	博士（工学）	市川　創作
副査	筑波大学特命教授	工学博士	中嶋　光敏
副査	筑波大学教授（協働大学院）	博士（農学）	植村　邦彦
副査	筑波大学准教授	博士（農学）	Marcos Antonio das Neves

Abstract of thesis

Indonesia is an archipelagic country, whereas the marine constitutes 75% of the total area. Hence, Indonesia is entitled with an abundance of tropical seaweed resources and the production is estimated at 482,400 ton per year. The commercial types of red and brown seaweeds can be widely found in Indonesia, including *Eucheumacottonii*, *Eucheumaspinosum*, and *Gracilaria* sp. These seaweed species have been utilized for the carrageenan and agar industry. Functional materials derived from seaweeds are also an appealing factor for their increased demand in food, pharmaceuticals, cosmetics, and other products. Seaweeds consist of various bioactive materials such as polysaccharides, pigments, proteins, minerals, phenols and bioactive peptides. These materials are well-known for their health benefit, emulsifying, stabilizing, and other properties.

The global demand for seaweeds is expected to further increase in coming years, owing to an increase in population, rapid industrial development and the people’s preference for natural products. According to FAO, Indonesian seaweed production is estimated at 11 million tons in 2015, which is

contributed almost 38 % of world seaweed production. However, seaweed utilization up to present in Indonesia is limited to only a few species, particularly *Eucheuma*sp, *Kappaphycus*spp and *Gracilaria* spp. Almost all collected seaweeds are exported as raw materials for industry, and small numbers of them are consumed domestically. Indonesian seaweed export is mainly dominated by edible and non-edible raw dried products (almost 60-70% of total export), having lower export value. Increasing the added value of Indonesian seaweed products is essential to increase its competitiveness in international market and fulfil the domestic market demands. In this study, the author aimed to develop the valuable products that could be generated from marine seaweed resources by utilizing their functional ingredients especially polysaccharides and pigments, which may present as potential candidates for future commercialization to support sustainable industry in Indonesia.

The author modified seaweed polysaccharides (alginate, ALG and carrageenan, CRG) with dodecenylsuccinic anhydride (DSA) in aqueous system, and then their physicochemical and stabilizing properties in oil-in-water (O/W) emulsion system were evaluated (Chapters 2 and 3). The physicochemical characteristics were determined by droplet size, interfacial tension, ζ-potential and structurally verified by Fourier Transform Infrared Spectroscopy (FTIR). Both CRG-DSA and ALG-DSA applied to O/W emulsion system exhibited smaller droplet size over the increasing of concentration and were more stable during storage than native ones. ζ-Potential of DSA-modified seaweed polysaccharides has more negative charge compared to native form due to additional carboxyl groups from modification reaction. In addition, DSA-modified seaweed polysaccharides were able to decrease the interfacial tension at a soybean oil-water interface. The successful modification reaction was confirmed by FTIR analysis. The modified seaweed polysaccharides showed bands assignable to the alkane moieties (CH_3 and CH_2) of the dodecenyl substitutions at 2900 cm^{-1}, which is as expected absent in the spectrum of native CRG. The results demonstrated that DSA-modified seaweed polysaccharide may serve as prospective emulsifier for application to food, pharmaceutical and other industrial fields.

Next, the authorinvestigated the potential of seaweed pigment such as phycobiliproteins, chlorophylls and carotenoids from Indonesian red seaweed by the extraction using different organic solvent at different temperature (Chapter 4). Samples of *Eucheumacottonii* and *Gracilaria* sp. were collected from Jeneponto, South Sulawesi. Quantitative analysis of seaweed pigments was determined by UV-visible spectrophotometry and their chemical characteristics were structurally identified by FTIR. The results showed that phycobiliproteins were more prone to a high extraction temperature (50°C) than chlorophylls. Chlorophylls in red seaweed extracts were slightly increased at 50°C. This may be due to the increasing of solubility of the solute in liquid, which is enhanced the

molecular diffusion as temperature increasing. However, the phycobiliproteins were more stable at room temperature and their concentrations slightly decreased at 50°C. By increasing the temperature, protein denaturation occured which decreased the amount of alpha helix causing a loss of pigment stability. The stability of phycoerythrins was relatively maintained at low and room temperature during long-term storage. From these results, the author proposed the natural pigments from seaweed as an alternative to synthetic pigments in the preparation of foods, cosmetics or pharmaceuticals.

Finally, the author conducted a single integrated extraction process for the recovery of pigment and polysaccharides from seaweed biomass (Chapter 5). The integrated extraction model approach presented in this study allows to distinguish the potential of seaweed feedstock for multiproduct recovery in a sequential process and supports the green and sustainability conduct of seaweed processing. The corresponding ratio for multiproduct recovery of pigments and polysaccharides increased by twofold which is more beneficial and contribute to greater value of seaweed feedstock.

The author concluded that the findings in this study provide insight and potential information for developing newly added value products from Indonesian red seaweeds. Nevertheless, this study still requires further development to commercialize in the food industry.The toxicity assessment is needed to conduct as the use of DSA and phycoerythrins in food and pharmaceutical field has yet been regulated.

Abstract of assessment result

【Review】

Seaweed is one of important marine resources in Indonesia that could improve food security and socio-economic benefits when it properly managed through the development of cultivation and processing innovation. Indonesia is one of the largest seaweed producers in the world, but the product is still exported in the form of raw materials with low selling price. Therefore, it is necessary to promote the development of sustainable high value added seaweed products in Indonesia. The applicant worked onthe development of the added-value products from seaweed by utilizing their functional ingredients especially polysaccharides and pigments, which may contribute for future commercialization in Indonesia seaweed industry.

The results could provide the insight and helpful information for the potential application of red seaweed products in the industrial. It gives some basic information for developing new added value products of Indonesian red seaweed. O/W emulsions could be stabilized by modified seaweed

polysaccharides and the emulsification ability was improved after modification with DSA. The DSA modified seaweed polysaccharides had smaller droplet sizes than native ones, and were stable up to one months of storage at different temperature. The natural colorants derived from red seaweed has potential to develop as the results showed particularly eminent amount of phycobiliproteins and their stability was relatively maintained during storage at low and room temperature. Furthermore, the integrated extraction approach may employ in the small or middle scale seaweed production to improve their products value derived not only from agar or carrageenan but also from pigments, which is normally discarded during the process. Nevertheless, for successful applications in the future, it would be important to extend the work by evaluating other properties such as toxicity assessment as the use of DSA and phycoerythrins in food and pharmaceutical field has yet been regulated.

【Result】

The final examination committee conducted a meeting as a final examination on July 4, 2019. The applicantprovided an overview of dissertation, addressed questions and comments raised during Q&A session. All of the committee members reached a final decision that the applicant has passed the final examination.

【Conclusion】

Therefore, the final examination committee approved that the applicant is qualified to be awarded Doctor of Philosophy in Food Innovation.