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主論文の要旨

論文題目　**Thalassic Methane Fermentation of Different Seaweeds and Rice Straw**
(様々な海藻と稲わらを用いた海洋条件下でのメタン発酵)

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論文内容の要旨

Fossil fuel dependence has been linked to the unprecedented faster rate of climate change, thereby forcing us to look into other viable renewable resources such as biomass energies. However, sustaining the increasing biomass demand for biofuel production can be challenging due to the world's limited freshwater and land resources. Seaweeds are identified as a sustainable biomass that can potentially support biofuel production demands. The most suitable biomass-to-biofuel technology in rural areas is anaerobic digestion for biogas production. Hence, utilization of seaweed biomass for biogas production was explored in this study.

Biogas production of seaweed is commonly patterned to conventional digester wherein the anaerobic condition is optimized for terrestrial biomass. The high salt content of seaweed and its different structural component than the terrestrial plants may contribute to low conversion efficiency. Hence, freshwater (FW) and thalassic (TH) anaerobic digestion of *Ulva* spp. (anaaosa) were compared to determine the more suitable condition. Biological hydrolysis pretreatment (BHP) was done to improve methane yield, while NaOH pretreatment (CNP) was employed to minimize the limitation of biological hydrolysis. Higher biogasification efficiencies based on the theoretical methane yield (285.2 ml CH_4/ g Volatile Solids [VS]) were obtained using biological hydrolysis pretreatment (FW: 27.2%, TH: 63.4%). However, the biogasification time of BHP was twice as long as that of NaOH. Heating the seaweed before biological hydrolysis pretreatment increased the methane yield and shortened the digestion time. Nonetheless, the methane yield of all pretreatments under thalassic (BHP= 180.9 ml CH_4/ g VS, CNP= 158.2 ml CH_4/ g VS, and Heat + BH= 195.7 ml CH_4/ g VS) was higher than freshwater's (BHP= 77.7 ml CH_4/ g VS, CNP= 61.7 ml CH_4/ g VS, and Heat + BH= 78.0 ml CH_4/g VS), suggesting a superior methane fermentation under thalassic condition. Therefore, thalassic (TH) biogas production using seawater as liquid substrate and marine bacteria as microbial inoculum can be used as an alternative to conventional (FW) biogas production in the utilization of seaweed feedstock in coastal communities where seaweed is an abundant feedstock for household biogas digester.

The seasonal availability of seaweed may pose problem in the continuous operation of a thalassic household biogas digester. Utilization of biomass other than the seaweed may be needed to support the continuous thalassic biogas production. Rice straw is commonly available biomass among the archipelagic Asian countries. However, the marine microorganisms used under thalassic condition may not perform well using a terrestrial biomass. Hence, we tested the methane fermentation of rice straw under thalassic condition. The performance of the co-digestion of rice straw and *Ulva* spp. (anaaosa) was also investigated. The biological hydrolysis pretreatment (BH) of rice straw under TH condition obtained the highest methane yield (75.8 ± 5.7 ml CH_4/ g VS), thereby applying the BH to the co-digestion. All co-digestion set-ups gave higher methane yield (*Ulva*:Rice straw, 25:75 = 107.6 ± 8.0 ml CH_4/ g VS, 50:50 = 130.3 ± 10.4 ml CH_4/ g VS, and 75:25 = 121.7 ± 2.8 ml CH_4/ g VS) than the expected yields of either rice straw or *Ulva* alone. The 50% *Ulva*-50% Rice straw ratio showed the highest (152.8%) methane enhancement. While the biogasification efficiency (BE) of the biologically hydrolyzed-rice straw in terms of its theoretical methane yield (327.9 ml CH_4/ g VS) was low (23.1%), the 50:50 co-digestion of rice straw and *Ulva* increased the BE to 46%. This study successfully demonstrated the thalassic biogas production of rice straw as mono-substrate, and the improvement of its methane yield when co-digested with *Ulva*.

On the other hand, suitable pH is necessary for successful biogas start-up and stable biogas production. NaOH is commonly used pH buffer but its acquisition to isolated coastal areas proved to be difficult. Cheaper and more accessible buffer is needed to further encourage the use of biogas technology in rural communities. Hence, *Venerupis* sp. (asari) shell was tested as pH buffer on the biogas production of *Undaria pinnatifida* (wakame). Addition of 3% and 5% powdered shell (w/w) at the start of anaerobic digestion successfully started biogas production (86.4 ml CH_4/ g VS and 109.5 ml CH_4/ g VS, respectively). Biogasification efficiencies of shells (3%Shell= 24.2%, 5%Shell= 30.7%, and 'BH then 5%Shell'= 19.4%) were lower than in 'BH then NaOH' (68.3%). However, biogas start-up failed when shells were not added. Therefore, powdered shell can be a potential cheaper pH buffer to successfully start biogas production and sustain stable anaerobic digestion, targeting coastal communities.

Moreover, the potential commercial application of thalassic condition using marine microbial inoculum and seawater for biogas production was evaluated using a pilot-scale (120 L) semi-continuous fixed-bed biogas digester. The brown seaweed *Ecklonia* spp. (arame) was used as the biomass feedstock in the 10-L substrate mixture feed, with 5% total solid. The biogasification efficiency obtained for *Ecklonia* in terms of its theoretical methane yield (345.6 ml CH_4/ g VS) was 68.5%. This is higher than obtained in a 1-L batch digester (5.8%). The successful thalassic biogas production of *Ecklonia* may help develop optimized condition for continuous operation. Thalassic platform for biogas production can be used as a cheaper alternative to conventional biogas platform, targeting suitable areas to maximize net energy gain.