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Undaria Pinnatifida as a Biofuel Feedstock: Challenges and Opportunities

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INTRODUCTION & AIM

- ***Undaria pinnatifida***, known as **wakame**, is a brown kelp that thrives in cold water.
- Given its **nutrient-rich composition** and **bioactive compounds**, it has extensive application prospects in various industries, e.g., food, cosmetics, animal feed, and bioremediation.
- One emerging application is **biofuel production**. Research on **economically** and **technically** viable approaches to successfully commercializing **third-generation renewable biofuels is crucial**.
- **Seaweed** is generally a **more efficient converter of solar energy because its cells grow in an aqueous suspension**, which gives them ready access to CO_2, water, and other nutrients.
- Its **high oil content** relative to its dry weight qualifies it as a candidate for **conversion through various processes**, e.g., transesterification, pyrolysis, and direct combustion

METHODOLOGY

PROXIMATE ANALYSES

The **thermogravimetric analyses** were performed using a **Netzsch STA 449 F3** from the **Netzsch Group** in **Wittelsbacherstrasse**, Germany. **Residual moisture** content was measured by **weight change** when **samples (5-15 mg)** heated from **40 °C to 105 °C** at **10 °C/min** under an inert atmosphere (**N_2, 40 mL/min**). **Volatile fraction** was defined as the mass variation between 105 and **600 °C (10 °C/min)** under nitrogen at **40 mL/min**. The **ashes** were calculated by combusting the sample completely at 900 °C in the presence of O_2 **(40 mL/min airflow)** until a constant weight was achieved. **Fixed carbon** content was estimated by subtracting **the percentages of residual moisture, volatiles, and ash.**

HIGHER HEATING VALUE ANALYSES

The **higher heating value (HHV)** was measured using a **Parr 6772 calorimeter**. Briefly, approximately **0.50 g** of the **sample** to be tested was subjected to a **pressure of 30 bar of oxygen** in the bomb calorimeter, and **complete combustion was achieved**. The analysis was conducted in duplicate, and the results are expressed in **kcal kg⁻¹.**

RESULTS & DISCUSSION

The **HHV** of ***U. pinnatifida*** averaged **2553.5 kcal kg^{-1}**, which can be suitable for biofuel production **(Table 1).**

Table 1. HHV in kcal·kg^{-1} for ***Undaria pinnatifida (UP).***

Sample	Test 1	Test 2	Mean	Std. Dev.
UP	2561	2546	**2553.5**	10.6

Still, these values are **lower than those of lignocellulosic biomass** (≈4500–5000 kcal kg^{-1}). However, the volatile matter fraction (approximately 50% of the combustible fraction) **(Figure 1)** indicates its suitability for thermochemical conversion via gasification, which **generates H_2- and CO_2-rich syngas**. This process is essential for the **synthesis of renewable synthetic gas**. This offsets the **low fixed-carbon concentrations** and aligns with strategies for producing **renewable synthetic gas from seaweed.**

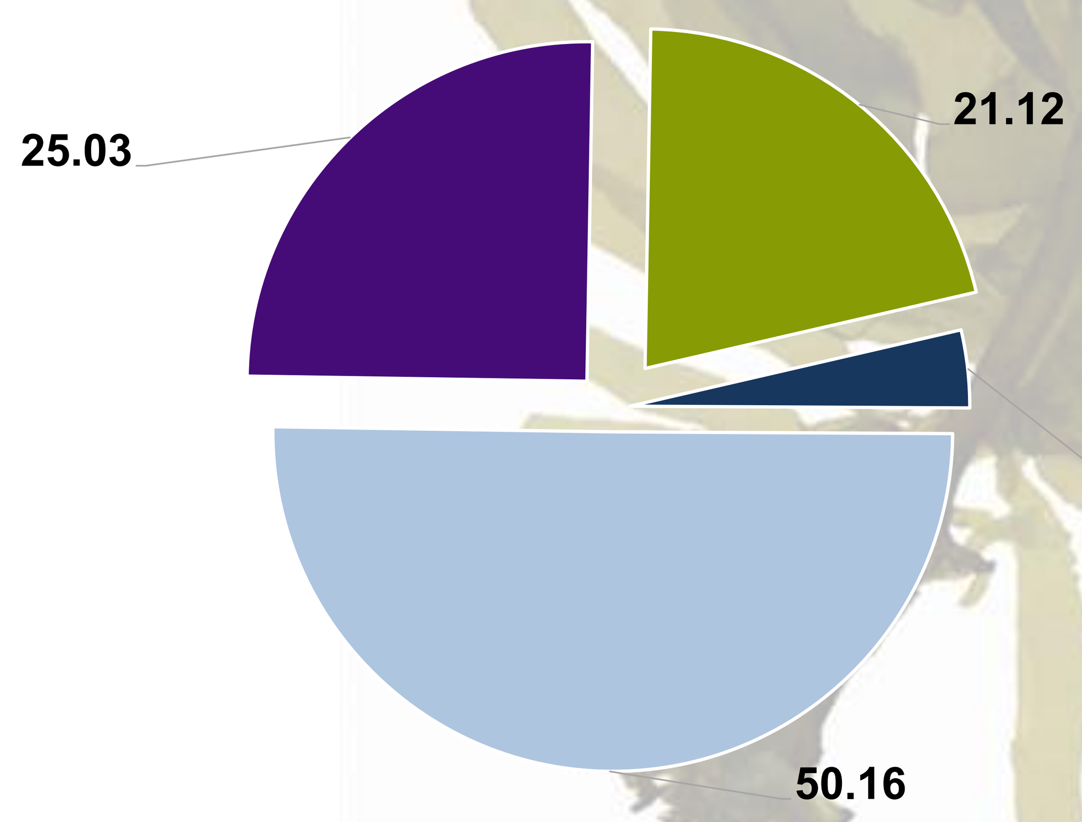

Figure 1. Thermochemical composition profile of *U. pinnatifida*.

Taking **productivity** into account, the energy yield estimate (213–320 GJ·ha^{-1}·yr^{-1}) is comparable to or, even exceeds that of terrestrial biomass sources such as wood **(188–283 GJ·ha^{-1}·yr^{-1})** **(Table 2).**

Table 2. Predicted energy productivity per hectare.

Biomass	Productivity (t·ha^{-1}·yr^{-1})	HHV (kcal·kg^{-1})	Energy yield (GJ·ha^{-1}·yr^{-1})
This study	20–30	2553.5	**213–320**
Sargassum spp.	15–25	3800	239–397
Wood	10–15	4500	**188–283**

CONCLUSION

Overall, these findings position *U. pinnatifida* as a potential **feedstock** for **thermochemical conversion routes**, particularly gasification, while emphasizing the need for **ash reduction strategies** (e.g., washing, demineralization) to improve **energy performance** and **process efficiency.**

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