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Postharvest handling of the edible green seaweed *Ulva lactuca*: mineral content, microstructure, and appearance associated with rinsing water and drying methods

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Abstract. The green macro-alga *Ulva lactuca* is commonly processed as *Ulva* chips in Gunungkidul, Yogyakarta, Indonesia. However, the postharvest handling of green alga *Ulva* sp. is often poor, so that the quality of *Ulva* sp., as the raw material for chip production, is not standardized. This research was undertaken to evaluate the effect of rinsing as a part of postharvest handling on the mineral content, morphology, and appearance of *U. lactuca.* Samples of the green alga *U. lactuca* were sorted and rinsed with tap water for varying times and dried using two different methods: under the sun and in an oven at 50°C for 18 h. As a control, *U. lactuca* samples were rinsed with seawater. The results showed that rinsing and submerging *U. lactuca* in tap water made its thallus became brittle. The mineral content (Na, Mg, S, K, Ca, I, and Fe) evaluation using Energy Dispersive X-Ray Analysis (EDAX) showed that seaweed rinsed and submerged in tap water had a lower mineral content than that of seaweed submerged in seawater. Scanning electron microscopy was used to study the morphology of the thallus, and revealed no different structure, except for the 3-h washing treatment. Different drying methods also had different effects on the appearance of *U. lactuca.* Drying under the sun caused discoloration of the thallus. This study demonstrated that rinsing in seawater and drying using an oven at 50°C for 18 h can be recommended to produce good quality *U. lactuca* for chip production.

1. Introduction

For several centuries, seaweed has been used in human diets principally in oriental countries, such as China, Japan, and Korea. Nowadays, the primary uses of seaweeds are as a source of phycocolloids, such as agar, carrageenan, and alginate. According to the French authorities, there are several algae authorized for human consumption, including species of *Ulva*. Indeed, *Ulva* sp. seaweeds have long been consumed as *aonori* in Japan and eaten in soups or salads in European countries. In Gunungkidul, Yogyakarta, *Ulva* sp. is eaten in the form of ulva chips, especially *Ulva lactuca*, commonly called sea lettuce. *U. lactuca* is harvested, sorted, dried and used as the raw material for chip production.

After harvesting, *U. lactuca* quality deteriorates; wilting and discoloration are the first symptoms of quality loss, followed by unpleasant odour and changes in texture. Postharvest handling (sorting, rinsing, drying and warehousing) is crucial, because it affects the quality of the seaweed and consequently affects the quality of ulva chips. The current postharvest handling of *U. lactuca* in

Gunungkidul, Yogyakarta has been handed down from generation to generation, and is variable. However, there is no information on the proper postharvest handling of *U. lactuca,* so that the quality of *U. lactuca* collected from the seaweed collector is not reliable or homogenous.

For the last three decades, *Ulva* research has focused on taxonomic studies, plant composition and nutrition [1,2,3,4], optimization of *Ulva* extraction systems [5,6,7,8], identification and development of *Ulva* compounds as antioxidant, anticancer, anti-allergic, anti-inflammatory and anti-hyperlipidaemia [9,10]. Some studies have developed *Ulva* sp. as a food source [11].

The postharvest handling of seaweed is a crucial stage since the quality, and the quantity of seaweed mainly depends on the postharvest treatment and its supply-chain management. However, there is no study on the postharvest handling of *Ulva* sp. and the postharvest deterioration of *U. lactuca*. In this study, the effect of postharvest activities, especially rinsing and drying on the quality of green alga *U. lactuca* were investigated. The specific objectives of this research were to determine: (i) the changes in *U. lactuca* postharvest; (ii) the effect of various rinsing and drying methods on the quality of the green alga *U. lactuca*.

2. Materials and methods

2.1. Materials

Fresh *Ulva lactuca* was collected from Sepanjang Beach, Gunungkidul (8°8′0.2″S, 110°33′11.3″E), Yogyakarta, Indonesia in September 2017 and January 2018. The seaweed was harvested, packed in a plastic bag, and immediately transported to the laboratory, where it was stored at 4°C until further treatment on the following day.

2.2. Methods

A preliminary study was carried out by performing a field study to gather information about the current postharvest handling of green alga *U. lactuca* by the seaweed collectors around Sepanjang Beach, Gunungkidul, Indonesia. Meanwhile, laboratory observation was carried out to identify critical points in the postharvest life of *U. lactuca*. Fresh algae were sorted and rinsed using tap water or seawater, drained, and dried directly under the sun or using an oven at 50°C for 18 h. Dried *U. lactuca* was packed in non-translucent plastic bags, and stored at room temperature for a few months. During storage, discoloration and other signs of deterioration in quality were observed qualitatively.

Fresh *U. lactuca* were sorted and rinsed in seawater to remove sand and other materials, then drained. The cleaned algae were rinsed and submerged in tap water for various soaking times (30 s, 30 min, and 3 h) and dried with two different methods: sun drying and oven drying (50°C, 18 h). As controls, samples of clean alga were dried immediately after being rinsed with seawater. Dried *U. lactuca* was packed in non-translucent plastic bag, and stored at room temperature until further analysis.

All samples were analyzed for ash content using a gravimetric method. One gram of treated green alga was burnt to a constant weight in a porcelain crucible at 600°C for four hours in a furnace.

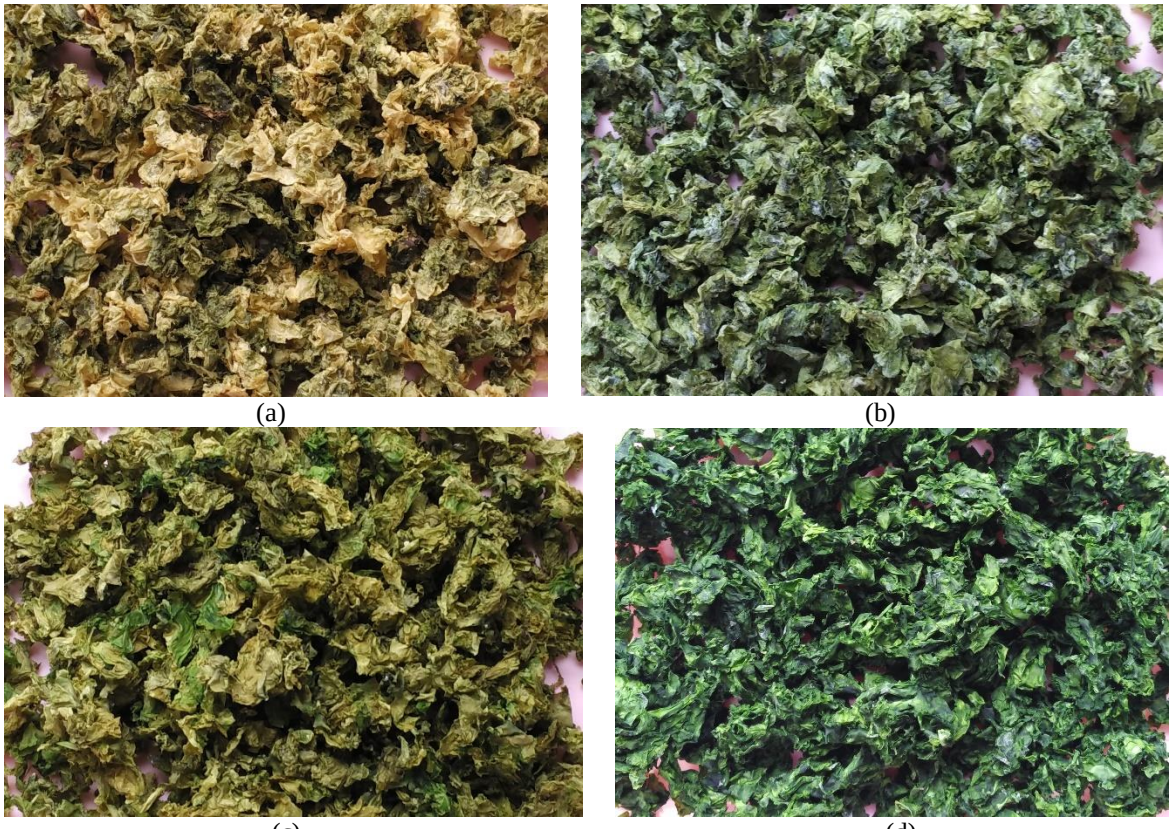
The morphology of *U. lactuca* was observed using a SEM Hitachi SU3500 unit which was equipped with an energy dispersive X-ray detector by EDAX. The EDAX analysis was used to measure the mineral composition (Na, Mg, S, K, Ca, I, and Fe) in both fresh and washed *U. lactuca.*

Quality evaluation of treated green alga was carried out to study the effect of rinsing water and drying method on the appearance and texture of *U. lactuca*. Phenomena such as discolouration and change in texture were observed during the drying process.

3. Results and discussion

The appearance of dry *Ulva lactuca* obtained from the seaweed collectors around Sepanjang Beach, Gunungkidul in Yogyakarta is presented in Figure 1. This *U. lactuca* was rinsed with seawater, dried directly under the sun, packed using a transparent plastic bag and stored at room temperature for one month. The variation in appearance of treated *U. lactuca* from the preliminary and full studies is shown in Figure 2 and Figure 3.

Fig. 1. The appearance of dry *U. lactuca* obtained from seaweed collectors around Sepanjang Beach, Yogyakarta, Indonesia (photograph taken after the sample had been stored for one month)



(a) (b)

(c) (d)

Fig. 2. Appearance of dry *U. lactuca* obtained after different postharvest handling conditions: (a) Rinsed with seawater, dried in the shade, packed in a non-translucent plastic bag; (b) rinsed with seawater, dried directly under the sun covered with black cloth, packed in a non-translucent plastic bag; (c) rinsed with tap water, dried directly under the sun, packed in a non-translucent plastic bag; (d) rinsed with seawater, dried directly under the sun, packed in a vacuum and non-translucent plastic bag. Picture was taken: (a-c) after four months of storage; (d) after two weeks of storage

(a) (b)

Fig 3 Appearance of dry *U. lactuca* dried using a laboratory oven at 50°C for 18 h
(a) rinsed with seawater, packed in a non-translucent plastic bag; (b) rinsed with tap water, packed in a non-translucent plastic bag. Picture was taken after samples stored for four months.

Dried *U. lactuca* is usually stored for a long time before being processed. Chlorophyll, the pigment responsible for the green colour of *U. lactuca*, becomes degraded to an undesirable grey-brown compound during storage, and further degradation will result in a colourless compound. Moreover, the thallus of *Ulva sp*. is thin, so that it easilycomes into contact with oxygen. As a consequence, oxidation can easily occur during storage. In addition, dried *U. lactuca* easily absorbs the moisture from the environment, which can increase and accelerate the deterioration of *U. lactuca.*

Table 1 presents the difference in ash content between the fresh and washed/soaked *U. lactuca*. The ash content ranged between 13.53% and 35.62%. The ash content of the fresh *U. lactuca* was highest when dried without freshwater soaking, under both sun dried and oven dried treatments, and tended to reduce with soaking time.

Table 1. The ash content of fresh and washed green alga *U. lactuca*

Washing treatment	Ash content (%)	
	Sun drying	Oven drying (50°C, 18 h)
Seawater	35.32	34.31
Tap water (30 s)	24.10	23.37
Tap water (30 min)	18.40	14.30
Tap water (3 h)	13.63	17.46

The mineral content observation using EDAX analysis was used to measure the differences in mineral content between submerging times. The mineral composition demonstrated that magnesium is the most abundant element, followed by sodium, potassium, and calcium. The current result showed that *U. lactuca* also contains iron (Fe) and iodine (I). In this study, rinsing with tap water strongly affected the ash content of *U. lactuca*. Rinsing with and submerging the alga in fresh water can remove salty materials from the surface of the *U. lactuca* thallus, thus reducing the ash content. Furthermore, the longer washing time, the lower the expected ash content.

In general, the EDAX analysis of fresh and washed *U. lactuca* confirmed major loss of salts after soaking. For sun dried alga, the Ca content was reduced from 1.82% to 0.16% after 30-min washing, while Na, Mg, and K content were reduced from 6% to 1.49%, 9.31% to 3.41%, and 3.59% to 0.97%, respectively. Moreover, there was some loss of I and Fe, by 0.15% and 0.20% respectively. Meanwhile, the Ca content of the oven-dried alga was reduced from 1.72% to1.04% after 30-min washing; Na content was substantially reduced from 7.48% to 2.74%, and Mg and K were reduced by around 4.7% and 4.55%, respectively.

However, EDAX analysis has some disadvantages, for example only a small section of tissue is under observation, and the observations only support qualitative analysis. Meanwhile, sun-drying

method and oven drying methods had no significant effect on the ash content and the mineral content.

The water and rinsing time affected texture. The thalli became brittle when the alga was rinsed with tap water; the longer the rinsing time, the more brittle the thalli. On the contrary, rinsing with seawater had no impact on the texture; the thalli remained strong and firm. As observed by SEM, there were no differences in the morphology of the *U. lactuca* thalli, except after 3-h soaking in fresh water (Figure 4). Washing *U. lactuca* with tap water for 3 h appeared to result in some breaking down of the cell wall; this decreased the firmness of the thalli which became brittle.

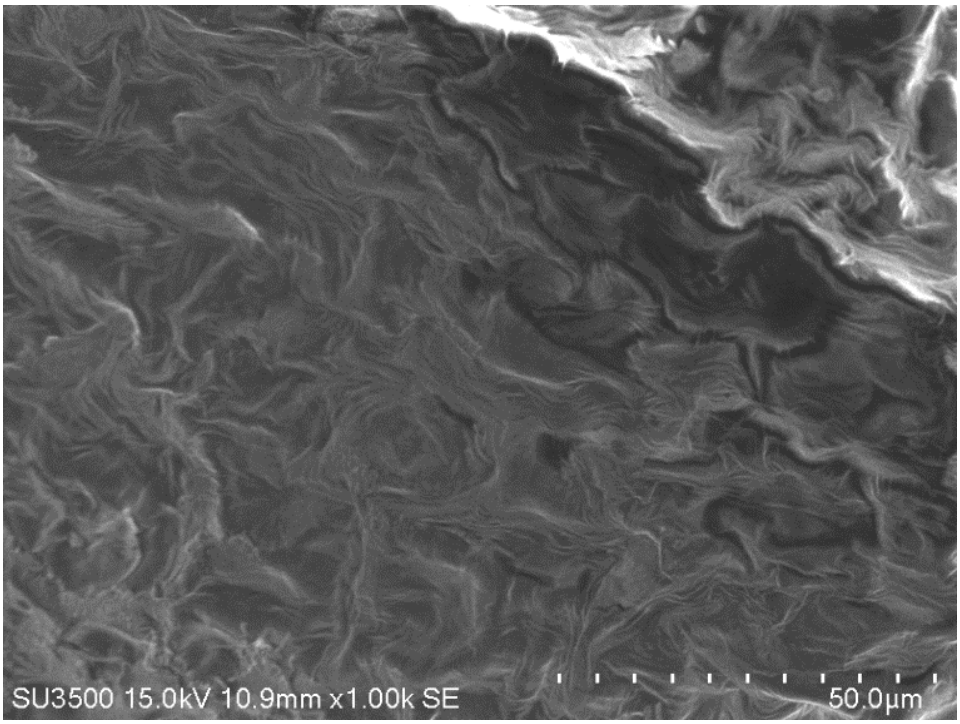


Fig. 4 SEM of *U. lactuca* thallus after 3-h soaking in fresh water

In general, drying under the sun caused a yellowing of the thallus of *U. lactuca*. When the seaweed was rinsed with fresh water and dried directly under the sun, the thallus of the dry *U. lactuca* became discolored from green to pale green or even yellowish green. Meanwhile, when the alga was rinsed with seawater and dried under the sun, there was only a slight change in the thallus colour. In general, it takes four up to five days to obtain dried *U. lactuca* with a moisture content less than 20%. According to [12], bright light accelerates the degradation of pigments, causing significant discoloration. As a consequence, at the end of the drying process, the color of *U. lactuca* had begun to change from fresh green to pale green or yellowish green.

On the other hand, drying the seaweed in an oven (50°C for 18 h) apperared to prevent or delay discoloration, so that the product retained the appearance of *U. lactuca*, Whether the alga was rinsed with seawater or with fresh water, there was no discoloration of the thallus after oven drying, with the *U. lactuca* remaining green to dark green in appearance.

4. Conclusion

After harvest, the postharvest handling will affect the quality of seaweed in general, and *Ulva lactuca* in particular. We found that rinsing the alga with fresh water reduced the ash and mineral content, and lead to discoloration and reduced firmness of the thallus. Conversely, rinsing the seaweed with seawater delayed discoloration and prevented the thallus becoming brittle. Drying under the sun accelerated colour loss in the thallus; this reduced the visual attractiveness of *U. lactuca* as a raw

material for ulva chips. Oven dried *U. letuca* (50°C for 18h) retained a good colour, improving the product appearance. Therefore, rinsing with seawater and drying in an oven at 50°C for 18h is recommended to obtain good quality *U. lactuca* as raw material for the production of ulva chips.

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