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Evaluation of *Eucheuma cottonii* and *Gracilaria sp.* as Food Buffer for The Ibu Kota Nusantara (IKN) Based on Proximate Analysis

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ABSTRACT

East Kalimantan Province has great opportunities as a buffer for the IKN economy based on the utilization of marine potential. Eucheuma cottonii and Gracilaria sp. are the red seaweeds (Rhodophyta) most widely cultivated in Indonesia. This study aims to analyze the proximate content in two types of red seaweed, namely E. cottonii (offshore cultivation) and Gracilaria sp. (pond cultivation) obtained from farmers in dry conditions cultivated around the waters of Balikpapan, East Kalimantan, Indonesia. The results of the analysis showed significant differences between cultivation locations. Gracilaria sp. (pond cultivation) taken from Handil (HTK) and Babulu Laut (BALUKE) is considered potential because it has low water content (HTK 26.99 ± 0.02%), and has higher ash content (BALUKE 31.18 ± 0.41%), fat (BALUKE 0.36 ± 0.01%), protein (BALUKE 10.01 ± 0.01%), and crude fiber (HTK 1.90 ± 0.16%) compared to E. cottonii. These findings provide important information for the development of seaweed as a natural resource for the food and health industries.

1. INTRODUCTION

East Kalimantan Province has been designated as the location for the development of the Indonesian Archipelago Capital (IKN), as confirmed in Republic of Indonesia Regulation Number 3 of 2022. This decision focuses on the potential of regions such as Balikpapan City, North Penajam Paser Regency, and Kutai Kartanegara Regency, to support the economic development of the new capital city (Zulfikar *et al*., 2024). Marine fishery commodities, such as red seaweed cultivation, are of concern because they have the potential to contribute to food security, economic development and environmental sustainability (Afdal, 2023). Red seaweed, with its various benefits, makes it a vital resource for IKN development (Ludher & Woo, 2024).

Seaweed is a simple multicellular photosynthetic organism that does not have flowers and vascular tissue and is generally referred to as "macroalgae" or "kelp" (Bajad *et al*., 2024). According to the Ministry of Maritime Affairs and Fisheries (KKP, 2023), Indonesian seaweed production accounts for 32.1% of global seaweed production, with a total volume of 1.91 million tons in 2021. East Kalimantan Province contributed 25,629 tons of seaweed in 2022. The types of seaweed that are widely cultivated are *Eucheuma cottonii* and *Gracilaria sp.*, both of which belong to the Rhodophyta group, which grow abundantly in tropical waters (Waldron *et al*., 2023). This success is largely due to the abundance of this species and its ability to adapt to coastal environments, as well as its wealth of valuable chemical components that are urgently needed globally (Basyuni *et al*., 2024; Yusuf & Fitriani, 2021).

Along with increasing consumer awareness of the various benefits of seaweed, especially in terms of its nutritional value and contribution to the environment, demand for seaweed has increased significantly. The polysaccharide composition of seaweed, which includes key compounds such as agar, carrageenan, and alginate, has attracted the interest of various industries, especially the food, pharmaceutical, and cosmetic sectors (Imchen *et al*., 2024). Its nutritional profile and chemical content are useful and can be used in various industrial applications, making it a target for consumers (Mendes *et al*., 2024). These qualities make seaweed an important component in the development of health supplements, skin care products, and food additives, further increasing its economic potential.

The chemical composition of seaweed varies greatly due to factors such as species, location, size, water quality, salinity, nutrient exposure, and sunlight (Djoh *et al*., 2024). This variation indicates that the quality and nutritional value of seaweed can differ from one region to another. *E. cottonii* also contains large amounts of protein, although its fat content is relatively low, making it a healthy choice for various food applications (Yousaf *et al*., 2024). Meanwhile, *Gracilaria sp.* is known to have a high carbohydrate content, especially agar-agar, which is also rich in protein and fiber which is suitable for use as a functional food and food supplement (Purwaningsih *et al*., 2024). Both types of seaweed are rich in important minerals such as calcium, magnesium, and potassium, which play an important role in maintaining bone health, muscle function, and electrolyte balance in the body (Muñoz & Díaz, 2020). This nutritional profile makes these two types of seaweed a valuable resource for a variety of industries, from food production to pharmaceuticals.

Considering the many benefits of red seaweed, it is clear that the industrial cultivation of *E. cottonii and Gracilaria sp.* in East Kalimantan is very promising for economic growth and environmental sustainability. High consumer demand could be an opportunity to support the economy in East Kalimantan's proximity to IKN. However, to fully unlock this potential it is important to carry out research on its nutritional content. Understanding the chemical composition and quality of these species is critical to improving cultivation techniques, improving product quality, and increasing market access. This study aims to evaluate the potential proximate content of *E. cottonii and Gracilaria sp.* obtained from around IKN waters. The benefit of this research is knowing the proximate content of *E. cottonii and Gracilaria sp.* which is obtained from around IKN waters, so it will be very important to ensure that the East Kalimantan seaweed industry continues to develop and contribute to the sustainable development goals of Indonesia's new capital, IKN.

2. MATERIALS AND METHODS

2.1. Sample Selection and Preparation

This research was conducted in June-August 2024. *Eucheuma cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation) in dry conditions from seaweed farmers in East Kalimantan Province, Indonesia (Figure 1). The samples obtained were then put in a cool box to be taken to the IPB Inter-University Center laboratory to be characterized and analyzed for proximate content.

2.2. Proximate Analysis

Proximate analyzes such as water content, ash content, fat content, protein content and crude fiber were carried out on four samples of *E. cottonii* and three samples of *Gracilaria sp.* from the waters around IKN (Figure 1). Analysis was carried out twice and in duplicate for each sample.

2.2.1. Water Content (AOAC, 2016)

Two grams of sample was placed in a porcelain cup with a known empty weight. The cup containing the sample is then placed in the oven at a temperature of 105-110°C for 24 h. After that, the cup was removed and cooled in a desiccator and then weighed.

$$\text{Water content (\%)} = \frac{a-b}{c} \times 100\% \tag{1}$$

where *a* is weight of cup + dry sample, *b* is empty cup weight, and *c* is sample weight before drying.

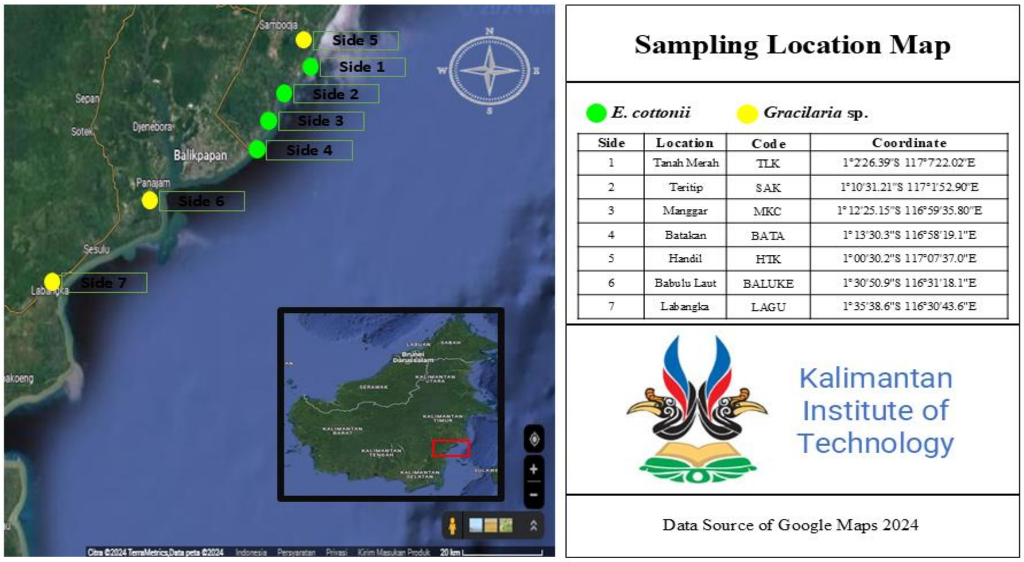

Figure 1. Sampling locations for red seaweed *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation)

2.2.2. Ash Content (AOAC, 2016)

The sample was weighed 2 grams in a porcelain cup, then placed in a furnace at a temperature of 500-600 °C. After 2 hours, the sample was placed in a desiccator to allow its temperature to stabilize, ensuring that its weight remained constant when weighed. After that, weigh the porcelain cup containing the sample.

$$\text{Ash Content } (\%) = \frac{Ash\ (gram)}{Sample\ (gram)} \times\ 100\% \tag{2}$$

2.2.3. Fat Content (AOAC, 2016)

The sample was weighed at 2 grams then refluxed for ± 5 hours until the solvent was clear. The fat flask containing the extraction results was placed in an oven at 105°C then cooled in a desiccator and weighed.

$$Fat\ content\ (\%) = \frac{Fat\ (gram)}{Sample(gram)} \times\ 100\% \tag{3}$$

2.2.4. Protein Content (AOAC, 2016)

The sample was weighed at 2 grams, then placed in a Kjeldahl flask crushed with concentrated sulfuric acid, and heated until the color became clear. The destruction results were then diluted and distilled with 10 ml of 10% NaOH. The distillate was then collected in 25 ml of 3% H_3BO_3 solution and titrated with HCL as a standard indicator until it turned pink. The titration results are used to determine the total nitrogen value. Protein content was calculated by multiplying total nitrogen by a correction factor.

$$Nitrogen\ (\%) = \frac{ml\ HCL\ x\ N\ HCL}{sample\ (grams)} \times\ 14008\ \times\ f \tag{4}$$

$$Protein\ (\%) = Nitrogen\ (\%) \times 6.25 \tag{5}$$

2.2.5. Crude Fiber Content (AOAC, 2016)

One gram of sample was added with 0.3 NH_2SO_4, then boiled for 30 minutes, shaking occasionally. The suspension is filtered with filter paper, and the residue obtained is washed with boiling water until it is no longer acidic (tested with litmus paper). The residue was transferred into an Erlenmeyer, while the residue remaining on the filter paper was washed again with 200 ml of boiling NaOH until all residue was removed. The sample was boiled again for 30 minutes and filtered while washing with 10% K_2SO_4 solution. The residue was washed with 15 ml of 95% alcohol, then dried at 110°C until the weight was constant, then weighed.

$$\text{Fiber (\%)} = [(r - s)/t] \times 100\ \% \tag{6}$$

where r is weight of filter paper + residue (g), s is initial weight of filter paper (g), and t is sample weight (g).

2.3. Data Analysis

The experimental design used was a completely randomized design (CRD) with one factor, namely the proximate composition (water content, ash content, fat content, protein content and crude fiber) between *E. cottonii* and *Gracilaria sp.* Data from testing results for water content, ash content, fat content, protein content and crude fiber were analyzed statistically using the one-way ANOVA method with a confidence level of 95%. Significant treatments were followed by Duncan's further test to determine significantly different data. Data was processed using the SPSS version 28 application.

3. RESULTS AND DISCUSSION

3.1. Characteristics of *E. cottonii* and *Gracilaria sp.*

Characteristics of *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation) obtained from farmers at each sampling location were very different in terms of physical appearance from each other (Figure 2). *E. cottonii* seaweed taken from Tanah Merah (TLK) and Manggar (MKC) (Figure 2.A & C) has a brighter color appearance compared to samples from Teritip (SAK) and Batakan (BATA) (Figure 2. B&D). Apart from that, for all seaweed *Gracilaria sp.* (pond cultivation) taken from Handil (HTK), Babulu Laut (BALUKE), & Labangka (LAGU), showed a dark color appearance (Figure 2. E, F, & G). These characteristics may be caused by physico-chemical conditions such as better water quality, optimal salinity, and sufficient exposure to sunlight. These factors can promote brighter pigmentation in seaweed.

Figure 2. Characteristics of *E. cottonii* (offshore cultivation); (A) Tanah Merah (TLK), (B) Teritip (SAK), (C) Manggar (MKC), (D) Batakan (BATA), and *Gracilaria sp.* (culture in ponds); (E) Handil (HTK), (P) Babulu Laut (BALUKE), (G) Labangka (SONG).

Charles *et al*. (2020) explained that the drying method for seaweed greatly influences its physical appearance, especially its color and antioxidant activity. The drying process plays an important role in maintaining the quality of seaweed. Drying with direct sunlight is widely used because it is cost-effective and efficient compared to controlled mechanical drying methods (Parvej *et al*., 2024). Apart from that, the cultivation location and length of storage time for *E. cottonii* and *Gracilaria sp.* by farmers is a factor that can influence the quality of seaweed besides the drying method used. Longer storage periods can result in loss of bioactive compounds, oxidation, and discoloration, all of which negatively impact the commercial appeal and nutritional value of seaweed. Therefore, optimizing drying methods and storage conditions is essential to maintain the quality and marketability of seaweed products.

Seaweeds such as *E. cottonii* and *Gracilaria sp.* can grow and develop well in ideal environmental conditions (Yala, 2022). Degradation of color in seaweed is an indicator of quality reduction. Storage at room temperature with fluctuating temperatures can result in a color degradation process thereby affecting the stability of the active compound and antioxidant activity (Sánchez-García *et al*., 2021). Therefore, farmers must pay close attention to these factors to ensure optimal seaweed quality for both consumption and industrial use.

3.2. Water content

Water content in *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation) can be seen in Figure 3. Based on one-way/single factor ANOVA analysis, it is known that the value of F = 0.00112 is smaller than F crit = 4.256495 which gives results that are not significantly different. The conclusion is that the difference in sampling location did not have a significant effect on the water content of *E. cottonii* and *Gracilaria sp.*

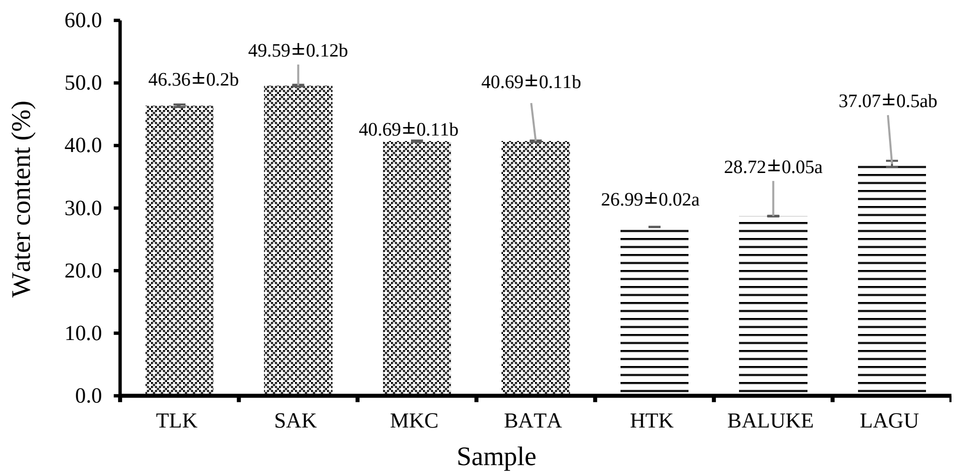

Figure 3. Water content (%) of *E. cottonii* (offshore cultivation) (▩) and *Gracilaria sp.* (pond cultivation) (▤). Numbers with different letters are significantly different (p<0.05) based on one-way ANOVA analysis with Duncan's follow-up test

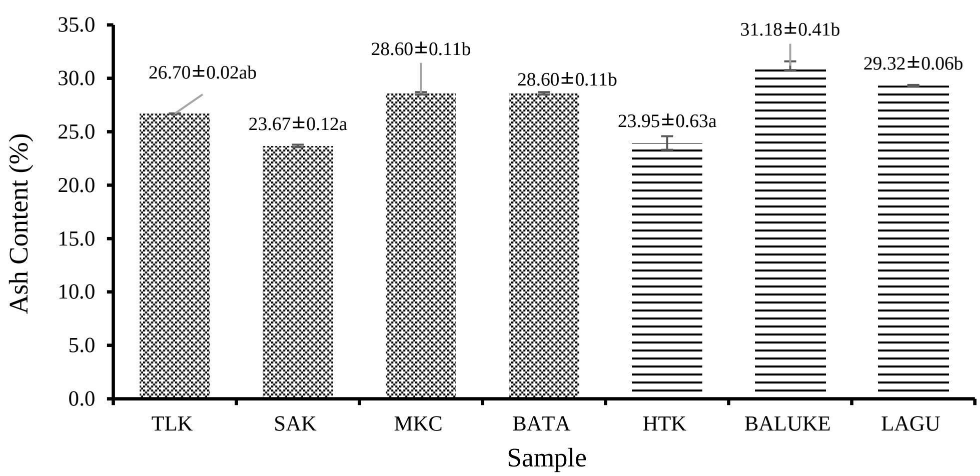

Figure 4. Ash content (%) of *E. cottonii* (offshore cultivation) (▩) and *Gracilaria sp.* (pond cultivation) (▤). Numbers with different letters are significantly different (p<0.05) based on one-way ANOVA analysis with Duncan's follow-up test

3.3. Ash Content

Results of analysis of ash content in seaweed types *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation) can be seen in Figure 4. Based on one-way/single factor ANOVA analysis, it is known that the value of F = 0.00139 is smaller than F crit = 3.6823 which gives results that are not significantly different. The conclusion is that differences in sampling locations have no significant effect on the ash content of *E. cottonii* and *Gracilaria sp.*

3.4. Fat Content

Results of fat content in seaweed types *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation) can be seen in Figure 5. Based on one-way/single factor ANOVA analysis, it is known that the value of F = 0.30743 is smaller than F crit = 3.68232 which gives results that are not significantly different. The conclusion is that the difference in sampling location did not have a significant effect on the fat content of *E. cottonii* and *Gracilaria sp.*

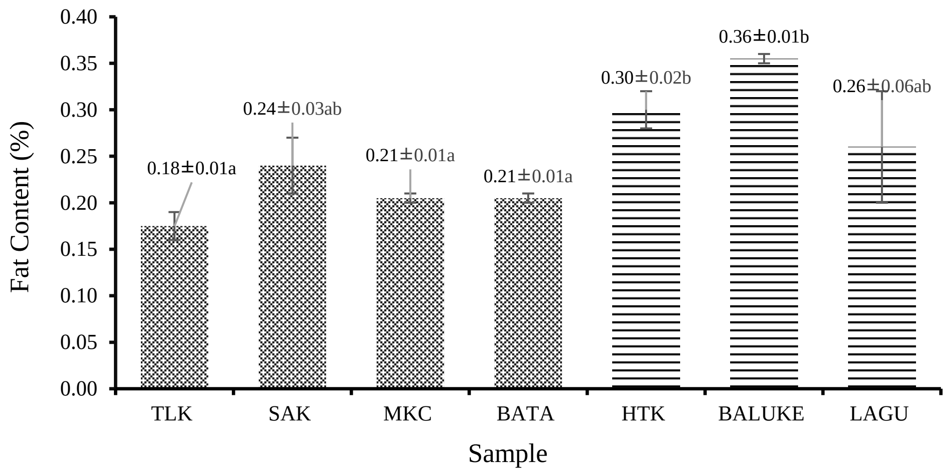

Figure 5. Fat content (%) of *E. cottonii* (offshore cultivation) (▩) and *Gracilaria sp.* (pond cultivation) (▤). Numbers with different letters indicate are significantly different (p<0.05) based on one-way ANOVA analysis with Duncan's follow-up test

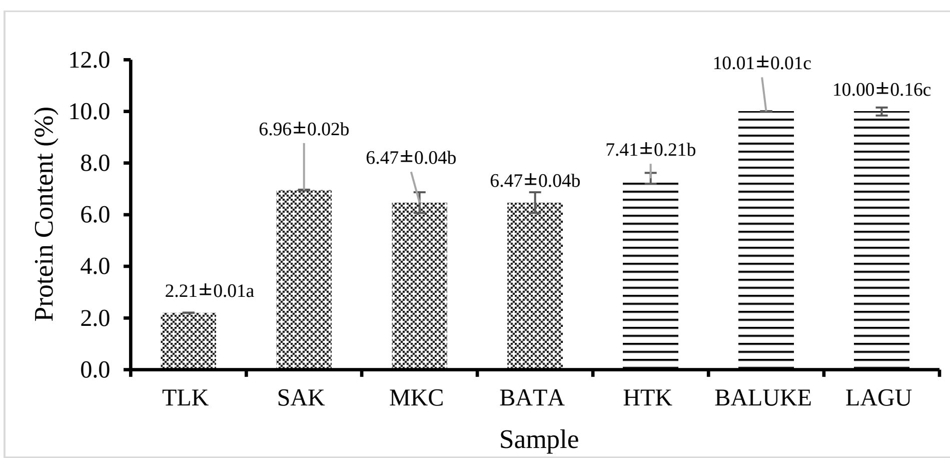

Figure 6. Protein content (%) of *E. cottonii* (offshore cultivation) (▩) and *Gracilaria sp.* (pond cultivation) (▤). Numbers with different letters are significantly different (p<0.05) based on one-way ANOVA analysis with Duncan's follow-up test

3.5. Protein Content

Results of protein content of *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (cultivation in ponds) can be seen in Figure 6. Based on one-way/single factor ANOVA analysis, it is known that the value of F = 0.030756 is smaller than

F crit = 3.68232 which gives results that are not significantly different, so the difference in sampling location does not have a significant effect on protein levels in *E. cottonii* and *Gracilaria sp.*

3.6. Crude Fiber Content

Based on one-way/single factor ANOVA analysis, it is known that the value of F = 0.102381 is smaller than F crit = 3.68232 which gives results that are not significantly different. The conclusion is that differences in sampling locations have no significant effect on crude fiber content in *E. cottonii* and *Gracilaria sp.* (Figure 7).

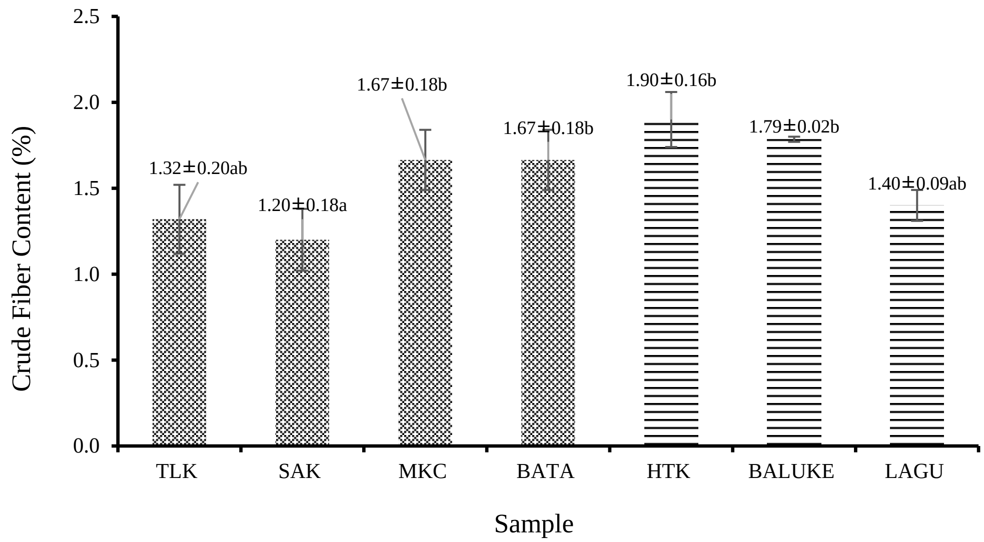

Figure 7. Crude fiber content (%) *E. cottonii* (offshore cultivation) (▩) and *Gracilaria sp.* (pond cultivation) (▤). Numbers with different letters are significantly different ($p<0.05$) based on one-way ANOVA analysis with Duncan's follow-up test

3.7. Discussion

East Kalimantan has great potential in developing seaweed production, especially *Eucheuma cottonii* and *Gracilaria sp.*, considering the coastline is 3,925 km long which stretches from Berau Regency in the North to Paser Regency in the South (Sumendar *et al*., 2024). The potential production of red seaweed in East Kalimantan reaches 4,449.57 tons in 2020 (BPS, 2021). Cultivating this seaweed will produce products with a high proximate composition, especially the red seaweed types *E. cottonii* and *Gracilaria sp.* The high proximate content makes it an important nutritional source and a raw material for various food, pharmaceutical and cosmetic industries. Utilizing the production potential of red seaweed *E. cottonii* and *Gracilaria sp.* can strengthen the economic sector of East Kalimantan province based on natural resources of high quality seaweed products.

The results of water content analysis showed that SAK had a water content of 49.59 ± 0.12%, which was the highest among other *E. cottonii* samples. The higher water content in SAK is likely related to the environmental conditions of the cultivation site such as temperature, salinity and water discharge which can affect the ability of seaweed to retain water. On the other hand, HTK has a water content of 26.99 ± 0.02% which is relatively low compared to the *Gracilaria sp.* sample the other and was the lowest water content for all samples of *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (cultivation in ponds). This lower water content is likely caused by the drying process and storage methods that have been carried out by seaweed cultivators.

Natural drying methods, such as drying directly in the sun, are generally used by farmers but can cause temperature and humidity fluctuations during the drying process (Nurhaslina *et al*., 2022). These fluctuations can have a significant impact on the physical properties of seaweed, leading to variations in water retention. Thamkaew *et al*. (2021) stated that temperature instability during drying can cause seaweed to lose water content unevenly, resulting in higher water content in some parts of the seaweed and less uniform overall quality.

Banach *et al*. (2020) explained that high water content in seaweed can be a serious problem in further processing, especially when trying to produce products from dry biomass. High moisture content requires additional energy and resources for drying, which increases processing costs and can affect the quality of the final product (Belwal *et al*., 2024). The higher the water content, the more energy is required to remove excess water before seaweed can be used in various industrial applications. Therefore, careful management of drying and storage methods is essential to control moisture content and optimize the quality of seaweed for commercial use. This includes choosing the right drying technique and ensuring consistent environmental conditions throughout the drying process.

The ash content in BALUKE is higher, namely 31.18 ± 0.41%, which is classified as the highest category among all other samples. According to the Indonesian National Standards 01-2891-1992, the ash content in dried seaweed types *E. cottonii* and *Gracilaria sp.* recommended no more than 30% (BSN, 1992). Based on the standards set, the ash content in TLK, SAK, MKC, BATA, HTK, and LAGU is classified as safe for consumption, because it is still within the recommended range. However, Gracilaria seaweed from BALUKE exceeds standards, which can raise concerns regarding its quality for consumption. Olsson *et al*. (2019) reported that the high ash content in seaweed is caused by polysaccharides in the cell walls and proteins containing anionic carboxyl, sulfate and phosphate groups, which can absorb various metal and mineral particles from the surrounding environment. High ash content can also affect the taste, texture and overall quality of seaweed, making it less desirable for certain applications. Therefore, careful monitoring of ash content is necessary to ensure seaweed meets food safety standards and remains suitable for consumption.

Similar to the ash content, the fat content in BALUKE is higher, namely 0.36 ± 0.01%, which is classified as the highest category among all samples. Meanwhile, the fat content in TLK was 0.18 ± 0.01%, which was the lowest for all samples of *E. cottonii* (offshore cultivation) and *Gracilaria sp.* (pond cultivation). Rosemary *et al*., (2019) reported in their research that Gracilaria corticate and Gracilaria edulis have a fat content of 4.76 ± 0.73 g/100 g. This value is much higher than the fat content observed in this study, indicating that the fat content in *Gracilaria sp.* can vary significantly depending on the species and cultivation environment. Therefore, the fat content in *Gracilaria sp.* can be a valuable indicator of its potential as a source of essential fatty acids and a nutritious addition to the diet.

As with ash content and fat content, BALUKE showed the highest protein content of 10.01 ± 0.01%, followed by LAGU with a protein content of 10.00 ± 0.01%. Kaziir *et al*. (2018) reported that *Gracilaria sp.* can have a high protein content of up to 24.8% DW-1, depending on the species and environmental factors. The protein content in *Gracilaria sp.* may not always peak during the growth period (Salas *et al*., 2023). Thus, the protein content in *E. cottonii* and *Gracilaria sp.* can vary significantly depending on the species and cultivation conditions. It is important to monitor these factors closely to optimize protein yield and ensure that seaweed reaches its full nutritional potential. Understanding the balance between environmental conditions, farming practices, and harvesting techniques is critical to maximizing the protein content and overall quality of seaweed for both consumption and industrial applications.

The fiber content in *Gracilaria sp.* of HTK is in the high category for all seaweed samples, with a percentage of 1.90 ± 0.16%. Apart from that, *E. cottonii* from SAK is a type of seaweed that has the lowest fiber content, with a percentage of 1.32 ± 0.20%. Crude fiber in seaweed plays an important role in its survival, because it stores food reserves in the form of carbohydrates such as polysaccharides (Winarni *et al*., 2021). Differences in fiber content across sampling locations can provide valuable insight into the health and growth patterns of seaweed (Rogelcastillo *et al*., 2023). By understanding the factors that influence fiber content, such as water quality, light exposure, and nutrient availability, seaweed farming practices can be optimized to improve crop quality and yield.

4. CONCLUSION

Seaweed *E. cottonii* and *Gracilaria sp.* obtained from different locations under dry conditions, showed varying proximate contents due to drying methods and water conditions. Analysis shows that *Gracilaria sp.* has lower water content and higher ash, fat, protein and crude fiber content compared to *E. cottonii*. The proximate composition of dried seaweed of the *Gracilaria corticata* type showed a higher carbohydrate content (8.30 g/100 g), total crude protein (22.84 g/100 g) and lipid content (7.07 g/100 g). These findings highlight the potential of *Gracilaria sp.* for development, offering valuable insights for its use in the food and health industries.

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