Substitution of red seaweed (*Porphyra*) with other seaweeds in nori making

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Abstract. Nori foodstuffs can be consumed and familiar in Indonesia. Nori products are generally based on *Porphyra* spp (red seaweed). Indonesia lies on the tropical region, while *Porphyra* spp commonly grows in the sub-tropical regions so that it is very limited in Indonesia. For this reason, an alternative nori raw materials from other seaweeds, such as *Gracilaria*, *Caulerpa*, *Ulva*, or a mixture of these seaweeds must be found. This study aimed to utilize *Gracilaria*, *Caulerpa*, and *Ulva* as *Porphyra* substitute to make nori analog based on their nutritional content, i.e., protein, fat, carbohydrate, moisture content, and its microstructure using SEM. Results showed that Nori from *Porphyra* spp had the highest protein content. Based on the microstructure analysis result showed that product sheets of film F522 (*Gracilaria*, *Ulva*, and *Caulerpa* mixed) were similar to the commercial nori. Protein fortification was necessary to increase the protein content of the nori analog.

1. Introduction
Nori is a foodstuff made from seaweed (usually red seaweed) that is dried or baked [1]. Nori is a famous Japanese food from a group of marine vegetables that are rich in nutritional sources such as protein, minerals, crude fiber, and vitamins needed by the body. Processed seaweed also contains several essential amino acids such as glutamate, glycine, and alanine, which play a role in creating a distinctive taste of nori and iodine minerals required for the thyroid's normal functioning gland in the body [2]. In Indonesia, nori products are famous and favorite food amongst children. Generally, nori in the market is still imported from Japan, Korea, Thailand, and China. Therefore, it is necessary to have the original product made in Indonesia alternative materials that can replace nori import both in terms of nutritional value and in terms of availability of ingredients in tropical Indonesia.

The raw material that usually used to make nori, *Porphyra* sp. that is rare and seasonal in Indonesia only grows in Ambon. It is known that *Porphyra* spp. only grows in subtropical waters [3][4]; therefore, it is necessary to have an alternative to *Porphyra* sp. both in terms of nutritional value and in terms of availability of ingredients in tropical Indonesia [5].

*Gracilaria* seaweed in Indonesia can be developed as a raw material for making Nori because this seaweed is abundant and has been cultivated in Indonesia [6]. *Gracilaria* has a property such as a binder,
the gelling agent for making nori analog formulation similar to original nori [7][8][9]. The use of different types of seaweed can affect the resulting nori characteristics such as different appearance, color, texture, and nutrition. This research used Gracilaria, Ulva, and Caulerpa in the nori analog formulation. The novelty of this research is that we used Gracilaria, Ulva, and Caulerpa as the raw material for nori analog instead of Porphyra sp., since Gracilaria and Ulva are abundant in Indonesian waters. This study aimed to utilize these seaweeds as Porphyra sp.’s substitute for nori analog based on nutritional content.

2. Materials and Methods

2.1. Materials
Dried Gracilaria seaweeds were obtained from Brebes, Central Java, then Ulva and Caulerpa were obtained from Binuangeun, Banten. The seasoning ingredients were salt, sesame oil, oil, oyster sauce, white rice vinegar, and commercial nori were purchased from local market.

2.2. Methods
The procedure for making Nori from Gracilaria, Ulva, and Caulerpa was modified from Teddy (2009), as follows [10]: 100 g dried Gracilaria, soaked in 8% white rice vinegar solution for five hours as much as one litre, seaweeds were rinsed with fresh water, then incubated in a chilling room before use. Fresh Caulerpa and Ulva were rinsed with fresh water. The formulation of nori is shown in Table 1. The seasoning ingredients were 0.4 % salt, 0.5 g oyster sauce, 0.4% pure sesame oil, and 0.2% oil. One hundred grams of soaked seaweeds were mixed with 800 ml water for two minutes. This seaweed slurry was put into a boiling pan and seasoned, then cooked for five minutes to produce a gel product, then mixed using a food processor to make a puree. The cooked seaweed puree was poured into a molding sheet measuring 22 × 30 cm in dimension and then was dried using an oven at 50°C for 10-12 h.

Table 1. Formulation of nori analog.

| Formulation | Gracilaria sp. | Ulva sp. | Caulerpa sp. |
|-------------|---------------|----------|--------------|
| G522        | 50            | 25       | 25           |
| G720        | 75            | 25       | 0            |
| G702        | 75            | 0        | 25           |
| G505        | 50            | 0        | 50           |
| G550        | 50            | 50       | 0            |
| NK          | 0             | 0        | 0            |

Noted: NK Nori Commercial. Total weight one formula 1kg.

2.3. Nutritional analysis
The moisture content of nori was determined by drying the seaweed samples at 105°C to constant weight. Then the moisture content was calculated by subtracting the final weight from the initial weight of the sample. The protein content of nori was analyzed by the Kjeldahl’s method, where a conversion factor of 6.25 has been used to convert total nitrogen into the crude protein. The crude lipid of nori was extracted from the seaweed powder with petroleum ether in a Soxhlet extractor. The crude fiber analysis was determined by filtering with a Fiber Tec system. The crude lipid was estimated using the chloroform-methanol mixture (2:1) by mixing 10 mg of dried powder samples and 5 ml of chloroform-methanol (2:1) in a test tube. The mixture was incubated at room temperature for 24 h in a alu-foil-covered test tube. After the incubation, the mixture was filtered using a filter paper. The filtrate was collected in a 10-ml pre-weighed beaker. The chloroform-methanol mixture was evaporated on a hot plate until a residue was obtained at the bottom of the glass beaker. The dried residue’s weight was...
calculated by substracting the total weight of the glass beaker and the residue and the initial weight of the glass beaker. The ash content was performed based on De Oliveira et al. (2009) using gravimetric method after heating the sample at 550°C for 18 h in a muffle furnace [11]. The proximate composition (moisture, protein, fat, and carbohydrate) of nori was determined according to AOAC10 methods [12]. Carbohydrate analysis was conducted by different. All formulation products were analyzed for microstructure profiles using SEM (Scanning Electron Microscope).

2.4 Statistical analysis
The data were presented as mean ± standard deviation (SD) for the chemical components. Analysis of variance (ANOVA) was run for unpaired values. Value of p < 0.05 was considered statistically significant.

3. Results and Discussion
The characterization of nori based on nutrition contents are shown in Figure 1. The moisture content differed significantly (p>0.05) among formula with nori commercial, except for F550 (p<0.05) from NK.

Nori commercial has high level of protein compared to the other nori analog from this study. The original nori from Porphyra seaweed had a higher protein content than that of Gracilaria seaweed. Sari et al (2019) was reported the Gracilaria sp. protein content of 2.83% [13]. As well as the result by Fransiska at all, 2017 that the commercial nori protein content was 40%, while Loupatty (2014) reported the nori protein content from the P. marcossi was 28% [3,14]. The Nori analog ash levels from this study were also higher than that of commercial nori. The ash content found in F720 was the largest component that used Gracilaria and Ulva mix, which have a high fiber composition, as the main raw material. Raw
materials highly determine the proximate levels of nori products produced. If compared, the nori product protein content of F720 is lower than that from *P. marccosi* (28.60%) [3]. To increase the nutrient composition, such as protein, it is necessary to add ingredients high in protein, such as anchovies, surimi, or protein-rich broth.

Dried nori contains various nutrients, such as dietary fibers, polyunsaturated fatty acids, minerals, and vitamins, and a large amount of proteins (approximately 40% on a dry basis). Lysine is the first limiting amino acid in dried nori. For dried nori, the amino acid score, which represents the protein quality of this product based on humans’ essential amino acid requirements, indicates that nori protein has excellent nutritional value [15]. However, dried nori contains a small amount of lipids (approximately 4% on a dry basis) [16]. The high-fat content obtained in the nori analog, maybe cause by the addition of sesame oil as flavor in the baking process of dried nori.

![SEM analysis of nori analog](image)

**Figure 5.** Results of SEM analysis of nori analog (magnification of 500 times; top from left to right: sample F522, F720, F702; button from left to right: sample F505, F550, NK).

Nori has the form of a snack sheet that is ready for consumption. To determine the quality of the microstructure of the nori products, we used SEM (Scanning Electron Microscope) analysis. The material formulations and process methods used will affect the quality of the microstructure produced. The SEM results of the nori analog structure is shown in Figure 5. The microstructure profile shows that the presence of seaweeds granules are distributed between thin sheets such as film layers. The film layer of the five formulas show a slight difference, where there are an uneven distribution of granular granules. This is possible because of the addition of several food additives ingredients. If compared to commercial nori, the formula F522 was similar to nori commercial according to morphological property. The other nori film layer showed granular granules. Overall the nori analog products that were similar to nori commercial were F720 or F522.

4. Conclusions

The nutrients of nori analog that is considered to be close to commercial nori is the formula F722 (*Gracilaria* and *Ulva* mix). While, the microstructure analysis showed that sheets of film product F522 (mixing *Gracilaria, Ulva*, and *Caulerpa*) were similar to commercial nori. The protein content of commercial nori was the highest amongst all nori formulations. To increase the protein content of substitute nori, it is necessary to add other protein sources.
Author Contributions

ES is the main contributor that conceived and designed the experiments; ES, NH, DF, SH collected the data; ES wrote the manuscript. All authors have reviewed the manuscript.

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