

Effect of *Ulva* sp. Incorporation on the Physical and Sensory Properties of *Lemuru* (*Sardinella lemuru*) Fish Crackers

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ABSTRACT

Fish crackers are a widely consumed ready-to-eat snacks in Southeast Asian. They are rich in carbohydrates and protein, but low levels of dietary fiber and minerals. Recently, *Ulva* sp. has received increasing attention as a new sustainable food resource due to its high dietary fiber and nutritional value. Its incorporation into food products may enhance food diversification and quality. This study aimed to evaluate the effects of *Ulva* sp. incorporation on the physical characteristics and sensory properties of *lemuru* (*Sardinella lemuru*) fish crackers, as well as to determine the most acceptable formulation for product quality. Results revealed that *Ulva* sp. supplementation significantly increased product yield ($p < 0.05$), while linear expansion and oil absorption decreased with increasing concentration. After deep-frying, crackers with 2% *Ulva* sp. showed the highest linear expansion ($82.24 \pm 3.68\%$) and oil absorption ($12.62 \pm 0.90\%$, $p < 0.05$), whereas those with 10% *Ulva* sp. showed the lowest levels, at $51.06 \pm 7.53\%$ for linear expansion ($p < 0.05$) and $8.38 \pm 0.76\%$ for oil absorption ($p < 0.05$). Sensory evaluation indicated that the addition of 10% *Ulva* sp. significantly ($p < 0.05$) reduced the consumer acceptance of the appearance attribute, while odor, taste and texture were not significantly altered. Based on overall attribute, *lemuru* cracker with 5% *Ulva* sp. was identified as the optimal formulation. This study contributes to use of *Ulva* sp. as a functional ingredient in resulting food products with acceptable product quality.

KEYWORDS

Diversification; Hedonic; Linear expansion; Oil absorption; Seaweed

1. INTRODUCTION

Fish has been recognized as an important source of protein, essential amino acids, minerals such as calcium and phosphorus, and omega-3 fatty acids, often at higher than those found in terrestrial meat [1], [2]. However, due to its nutritional composition, fish is highly perishable and has a relatively short shelf life if not handled promptly and properly. Product diversification represents an effective strategy to extend the shelf life of fish while simultaneously enhancing its economic value. One of the most popular processed fish products is fish crackers. Fish crackers are considered ready-to-eat snack foods with high consumer demand, particularly in Southeast Asian countries [3].

Fish crackers are typically produced from a mixture of minced fish meat, starch flour, water, and seasonings. The dough is shaped into various forms, such as round, oblique, stick, or elongated shapes, and subsequently gelatinized through boiling or steaming to obtain a cooked dough. The product is then cooled, sliced, dried, and finally fried prior to consumption [4]. Fish crackers are categorized as protein-rich and shelf-stable products at room temperature. Nevertheless, despite their protein content, fish crackers are

generally high in carbohydrates, fats, and calories, while being relatively low in dietary fiber and certain minerals.

Lemuru (*Sardinella lemuru*) is an abundant fish species harvested from the Bali Strait fishing grounds. The peak fishing season for *lemuru* typically occurs from September to December and in April [5]. During peak seasons, the price of fresh *lemuru* can be as low as IDR 5,000–7,000 per kilogram. Despite its low price, *lemuru* possesses high nutritional value, including substantial levels of protein, minerals, vitamins, and omega-3 fatty acids [6], [7]. Various food products derived from or incorporating *lemuru* have been developed to increase its market value, including canned fish [8], *pedetan* [9], biscuit and chips [10], frozen food [11], [12], as well as fish oil and fat products [13]. Nevertheless, due to its abundant landings, low market price, and high nutritional quality, *lemuru* remains a promising raw material for further diversification into value-added food products.

Recently, *Ulva* sp. has attracted considerable global attention as a potential ingredient in innovative food products. It contains approximately 8–13% of moisture, 25–33% of ash, 9–22% of protein, 0.22–0.59% of fat, and 40–62% of carbohydrate [14], [15]. Bikker, et al. (2016) [16] reported that the protein content of *Ulva* sp. is comparable in both quantity and quality to that of soy and certain animal products, while its dietary fiber content can reach up to 40%. Many studies have also widely investigated the functional activities and bioactivities of *Ulva* sp., such as antioxidant [17], ACE-inhibition [18], anticancer [19], anti-inflammatory [20], and metabolic syndrome management activities [21]. The use of *Ulva* sp. as a functional ingredient has been applied in various food products, including bread [22], nutri-bars [23], noodles [24], cookies [25], surimi products [26], patty [27], [28] and sausages [29]. Furthermore, previous studies have demonstrated that seaweed incorporation can improve the physical and sensory properties of crackers [30], [31]. Seaweeds used in these previous studies were *Gracilaria tenuistipitata*, *Kappaphycuss alvarezii* and *Eucheuma* sp., where have been widely cultured and often used in food industries.

Although numerous studies have investigated fish crackers, research on fish crackers incorporating seaweed remains limited, particularly with respect to green seaweed (*Ulva* sp.). *Ulva* sp. is often recognized as a nuisance biomass due to its rapid proliferation, leading to green tides (*Ulva* blooms) that negatively impact marine ecosystems and coastal tourism [32]. Many research studies have been explored to valorize *Ulva* sp. into value-added products. However, limited study has focused on the incorporation of *Ulva* sp. into *lemuru*-based fish crackers, particularly in terms of physical and sensory characteristics. Furthermore, the incorporation of *Ulva* sp. may improve the functional properties of fish crackers, attributable to the bioactive compounds present in *Ulva*. Therefore, this study aimed to fill this research gap by evaluating the effects of incorporating *Ulva* sp. on the physical and sensory properties of *lemuru* fish crackers, and to identify the optimal incorporation level for the most acceptable product quality. This research is expected to contribute the enhanced utilization of *Ulva* sp. in food products due to its abundance, as well as to improve the quality characteristic of fish crackers, thereby increasing their market value.

2. MATERIALS AND METHODS

2.1. Materials

The raw materials used in this study included cassava flour, fresh *lemuru* (*Sardinella lemuru*), garlic, flavor enhancer, salt, egg white, sugar, baking powder, palm oil and water. All of which were purchased from local market in Negara, Jembrana district, Bali, Indonesia. Dried *Ulva* sp. seaweed was obtained from an online supplier located in Gunung Kidul, Yogyakarta, Indonesia.

2.2. Preparation of Fish Crackers

The flowchart of the fish crackers preparation process is illustrated in Figure 1, and the formulation of fish crackers enriched with *Ulva* sp. is presented in Table 1. Fresh *lemuru* were gutted, washed, and manually filleted to separate the edible flesh from the head, skin, and bones. The fish flesh was then minced and thoroughly mixed with cassava flour, garlic, flavor enhancer, salt, egg white, baking powder, sugar, and water until a homogeneous dough was formed. Dried *Ulva* sp. was incorporated at levels of 2%, 5%, and 10% (w/w) based on the weight of cassava flour. These proportions were adopted based on the combination on previous studies using *Gracilaria* [30] and *Kappaphycuss* [31] with some modifications.

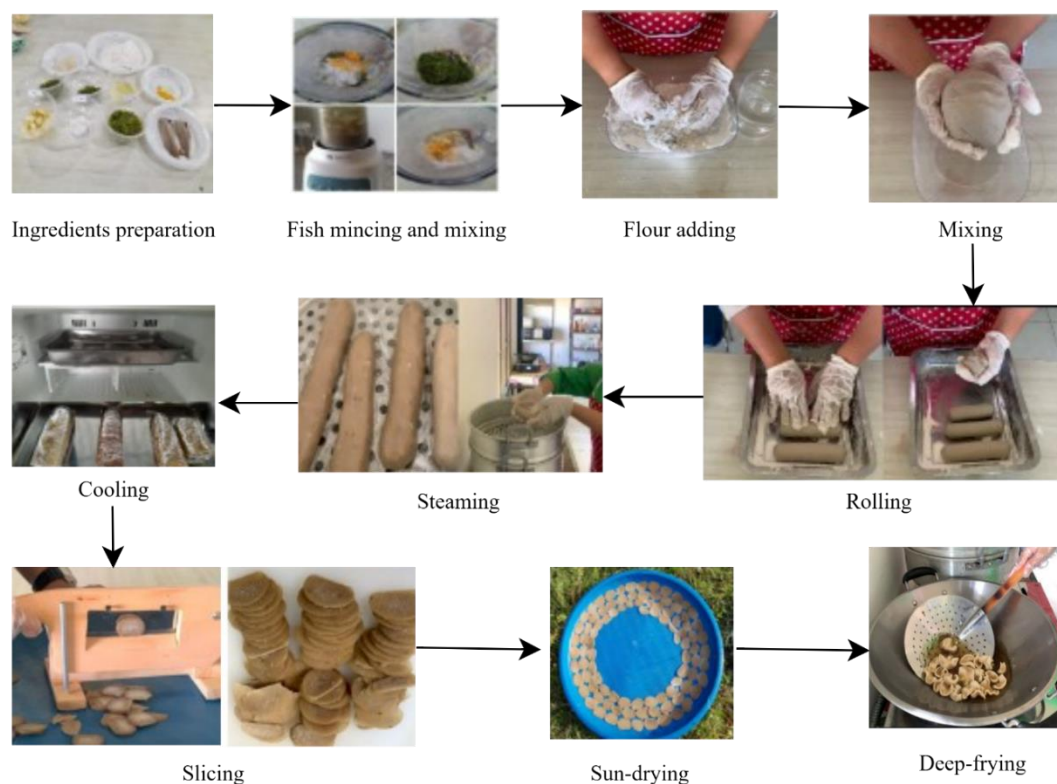


Figure 1. Processing flow diagram for *lemuru* (*Sardinella lemuru*) fish crackers incorporated with *Ulva* sp. at levels of 2%, 5%, and 10%.

The resulting dough was then rolled into a cylinder with a diameter of 3 cm and steamed for 3 hours in boiling water to ensure complete cooking and starch gelatinization. The dough was considered fully cooked when the interior appeared thoroughly cooked upon being cut into two parts. After steaming, the cooked dough was cooled at room temperature for 24 hours to allow firming. The dough was then sliced into thin pieces (approximately 0.1 cm thickness). The slices were sun-dried for 2 days (average daytime temperature 30–32 °C) until completely hardened and reduced to a stable moisture level.

Table 1. Formulation of *lemuru* (*Sardinella lemuru*) fish crackers incorporated with *Ulva* sp.

Ingredients	Fish crackers (g)		
	2% (FC 2%)	5% (FC 5%)	10% (FC 10%)
<i>Lemuru</i> meat	20	20	20
Dried <i>Ulva</i> sp.	2	5	10
Cassava flour	100	100	100
Garlic	25	25	25
Egg white	25	25	25
Salt	3	3	3
Sugar	3	3	3
Flavor enhancer	1	1	1
Baking powder	1	1	1
Water	5	5	5

The dried crackers were deep-fried in palm oil at 170 °C for 10 seconds to induce expansion and develop a crispy texture. After frying, the crackers were drained to remove excess oil and cooled to room

temperature. The final products were packaged in airtight containers and labeled according to the level of *Ulva* sp. incorporation as follows: fish crackers with 2% *Ulva* sp. (FC 2%), fish crackers with 5% *Ulva* sp. (FC 5%), and fish crackers with 10% *Ulva* sp. (FC 10%). In this study, *lemuru* crackers enrich with *Ulva* sp. were produced in triplicate and subjected to further analysis, as illustrated in Figure 2.

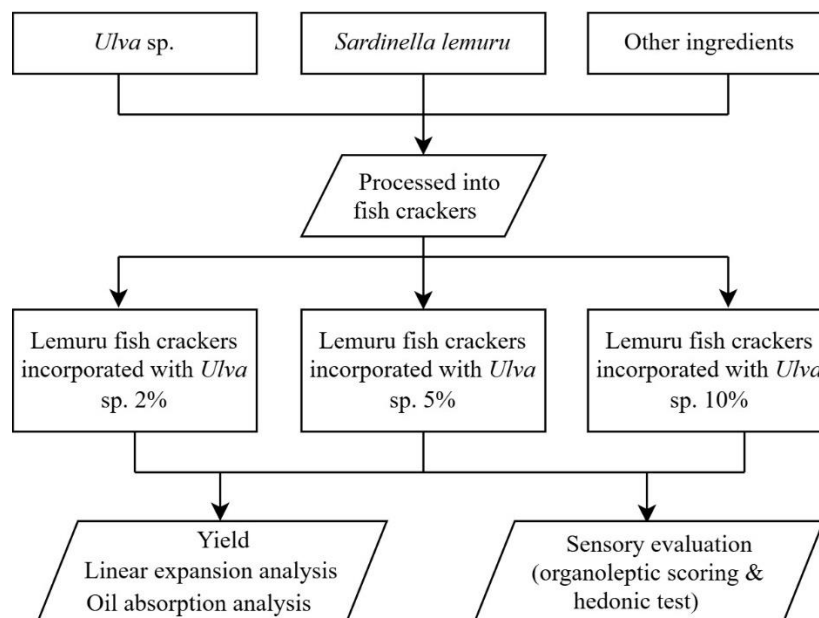


Figure 2. Flow chart of the research methodology.

2.3. Yield Determination

The yield of raw crackers enriched with *Ulva* sp. was determined according to the method described by Multazam, et al. (2023) [33] procedure. Yield was calculated as the ratio of the weight of raw crackers after processing (steaming, slicing, and drying) to the initial weight of dough prior to processing using digital scale with the following equation (1).

$$\text{Yield (\%)} = \frac{\text{Weight of raw crackers after processing (g)}}{\text{Weight of dough before processing (g)}} \times 100\% \quad (1)$$

2.4. Linear Expansion Analysis

The linear expansion of crackers after deep-frying was measured in five replicates following the method of Tokarczyk, et al. (2025) [34]. The diameters of dried raw crackers and fried crackers were measured using a Vernier caliper (Deli Group Co., Ltd., China). For each sample, three measurements were taken in random directions and averaged. The percentage of linear expansion was calculated as equation (2).

$$\text{Linear expansion (\%)} = \frac{\text{Length after frying (cm)} - \text{Length before frying (cm)}}{\text{Length before frying (cm)}} \times 100\% \quad (2)$$

2.5. Oil Absorption Analysis

Oil absorption was determined based on the method described by Baishak, et al. (2020) [3]. Samples were weighed before frying and after frying in palm oil, with five replicates for each treatment. The percentage of oil absorption was calculated using the equation (3).

$$\text{Oil adsorption (\%)} = \frac{\text{Weight after frying (g)} - \text{Weight before frying (g)}}{\text{Weight before frying (g)}} \times 100\% \quad (3)$$

2.6. Sensory evaluation

2.6.1. Organoleptic scoring analysis

An organoleptic scoring test was conducted using 30 panelists to evaluate crackers before frying at different *Ulva* sp. incorporation levels (2%, 5%, and 10%). The panelists were students from Marine Product Processing Study Program who have studied the principle of sensory evaluation and been trained to evaluate food products. They assessed the samples based on appearance, odor, taste, texture, and mold presence in accordance with the *Standar Nasional Indonesia* (SNI 8272:2016). The scoring criteria are presented in Table 2.

Table 2. The attributes of fish crackers for organoleptic scoring test based on SNI 8272:2016.

Attributes		Score
1	Appearance	
	- Intact, neat, clean, uniform thickness, bright color	9
	- Intact, neat, clean, non-uniform thickness, bright color	7
	- Intact, neat, less clean, non-uniform thickness, dull color	5
2	Odor	
	- Characteristic fish cracker odor	9
	- Slightly characteristic fish cracker odor	7
	- Non- characteristic fish cracker odor	5
3	Taste	
	- Strong characteristic fish cracker taste	9
	- Strong characteristic fish cracker taste	7
	- Bland	5
4	Texture	
	- Very dry and brittle	9
	- Dry but less brittle	7
	- Less dry, slightly moist, tough/not brittle	5
5	Mold	
	- Absent	9
	- Present	1

The organoleptic score was calculated according to SNI 2346:2015. The minimum acceptable sensory quality was determined using the lower limit of the confidence interval of the organoleptic score. The confidence interval for each parameter was calculated using the equation (4). Where P represents the organoleptic score interval, $\bar{x}$ is the mean quality score, n is the number of panelists, s is the standard deviation, and 1.96 is the standard normal deviation coefficient at the 95% confidence level.

$$P = \left(\bar{x} - 1.96 \times \frac{s}{\sqrt{n}} \right) \leq \mu \leq \left(\bar{x} + 1.96 \times \frac{s}{\sqrt{n}} \right) = 95\% \quad (4)$$

2.6.2. Hedonic analysis

A hedonic test was conducted using 30 panelists, similar to those involved in the organoleptic scoring analysis, to evaluate fried crackers. Panelists assessed appearance, odor, taste, texture, and overall acceptability using a 7-point Likert scale (1 = dislike very much; 7 = like very much). This test was used to determine consumer acceptability of fish crackers incorporated with *Ulva* sp. at different concentrations (2%, 5%, and 10%).

2.7. Statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 22 for Windows (SPSS Inc., Chicago, IL, USA). Data were subjected to one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at a significance level of $p < 0.05$. Results are presented as mean $\pm$ standard deviation (SD).

3. RESULTS AND DISCUSSION

3.1. Yield

The yield of raw crackers enriched with *Ulva* sp. was calculated based on the ratio of the weight of raw crackers after processing (steaming, slicing, and drying) to the initial weight of dough before processing. As shown in Figure 3, increasing the proportion of *Ulva* sp. significantly increased the yield of raw crackers ($p < 0.05$), with values ranging from 62% to 64%. Crackers containing 2% *Ulva* sp. exhibited a yield of $62.09 \pm 0.07\%$, followed by $63.33 \pm 0.12\%$ and $64.08 \pm 0.04\%$ for formulations containing 5% and 10% *Ulva* sp., respectively.

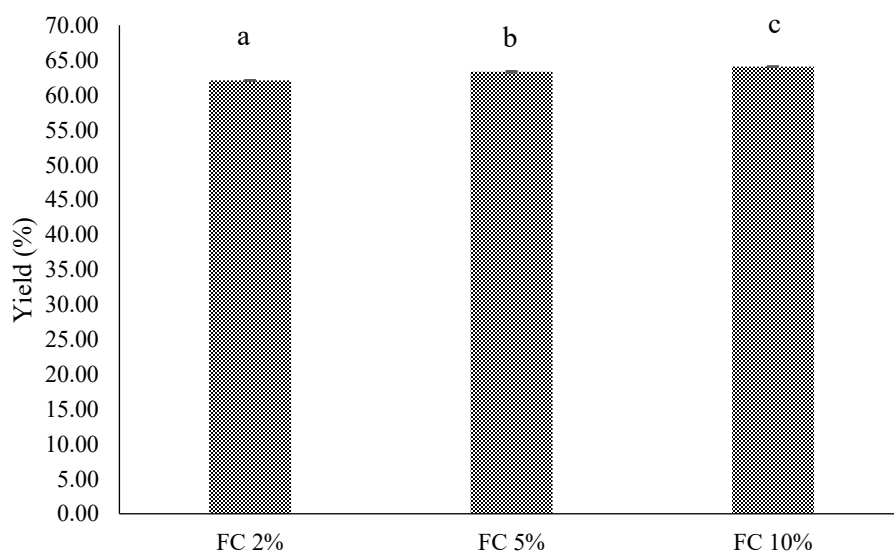


Figure 3. Yield of raw *lemuru* fish crackers enriched with *Ulva* sp. (FC 2%, FC 5%, and FC 10%). Different letters (a,b,c) indicate significant differences at $p < 0.05$.

The increase in yield may be attributed to the high dietary fiber content of *Ulva* sp., which enhances water-binding capacity and solid retention during processing, thereby reducing mass loss. Aganduk, et al. [31] reported that the increase *K. alvarezii* powder in crackers showed improvement in the crude fiber content. Ulvan is a type of water-soluble polysaccharide predominantly found in *Ulva* sp., which contributes to its water retention capacity [35]. Therefore, the incorporation of *Ulva* sp. into fish crackers increases the dietary fiber content, thereby enhancing water retention and leading to higher product yield.

3.2. Linear Expansion

Linear expansion is closely associated with the crispiness of crackers, which is an important sensory attribute [30]. As illustrated in Figure 4, the linear expansion of fried crackers enriched with *Ulva* sp. ranged from 51.06% to 82.24%, which falls within the acceptable range for commercial fish crackers (28–145%) as reported by Huda, et al. (2010) [36]. Crackers formulated with 2% *Ulva* sp. exhibited the highest expansion ($82.24 \pm 3.68\%$), which was not significantly different from those containing 5% *Ulva* sp. However, incorporation of 10% *Ulva* sp. significantly reduced expansion to $51.06 \pm 7.53\%$ ($p < 0.05$). A

similar result was reported in crackers supplemented with *Gracilaria tenuistipitata*, where higher levels of seaweed powder added into crackers reduced the volume expansion [30].

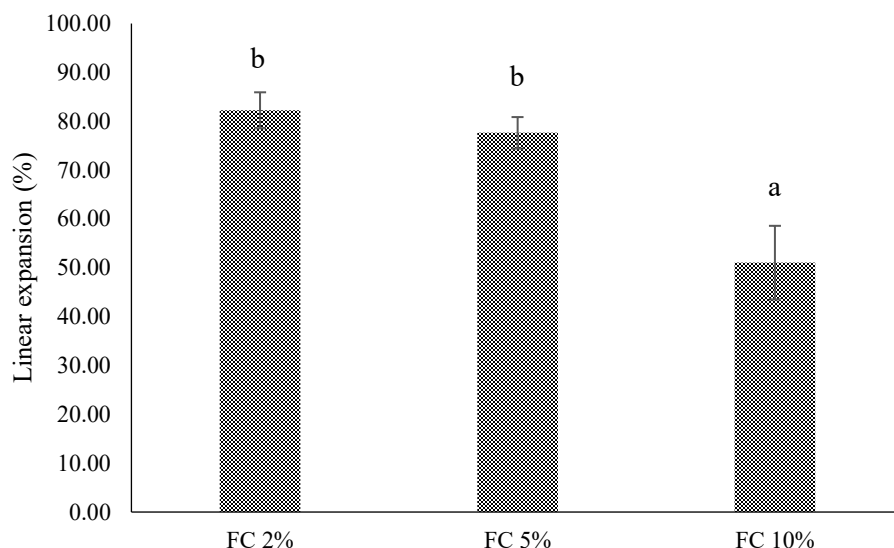


Figure 4. Linear expansion of fried *lemuru* fish crackers enriched with *Ulva* sp. Different letters (a,b) indicate significant differences at $p < 0.05$.

The degree of expansion is influenced by several factors, including starch gelatinization, drying conditions, gel setting, and protein content. Specifically, Tokarczyk, et al. (2025) [34] mentioned that samples with higher protein content showed low level of linear expansion. The increase in *Ulva* sp. concentration likely elevated the protein content of the dough, as *Ulva* sp. contains approximately 15–25% protein (dry weight basis) [37], thereby restricting bubble formation and limiting expansion during frying.

During the fish crackers processing, steaming and cooling process are important in gelatinization and retrogradation in starch that greatly impacts the texture of crackers. However, the presence of high protein in dough can reduce retrogradation of starch [38]. Protein entered starch granule after heating and suppress the retrogradation effect [39]. In addition, protein also inhibited starch swelling and release of amylose from the starch granule during gelatinization [40].

3.3. Oil Absorption

Oil absorption values ranged from 8.38% to 12.62%, as shown in Figure 5. Increasing the concentration of *Ulva* sp. significantly reduced oil absorption ($p < 0.05$). The trend observed in oil absorption corresponded with the linear expansion results. The high value of linear expansion increases the absorption of oil by crackers but decreasing the hardness properties [41].

Samples with higher expansion (e.g., FC 2%) exhibited greater oil absorption ($12.62 \pm 0.90\%$), whereas samples with lower expansion (FC 10%) showed reduced oil uptake ($8.38 \pm 0.76\%$). This finding is consistent with previous studies [41], which reported a positive correlation between linear expansion and oil absorption. Greater expansion promotes the formation of porous structures and air cells during frying, which facilitate oil entrapment. Conversely, reduced expansion limits pore formation and decreases oil retention. In addition, higher protein content in fish crackers may enhance water-binding capacity, thereby reducing moisture loss during frying [38]. Moisture evaporation during deep frying contributes to pore formation, which allows oil to penetrate and adhere to the product surface [42].

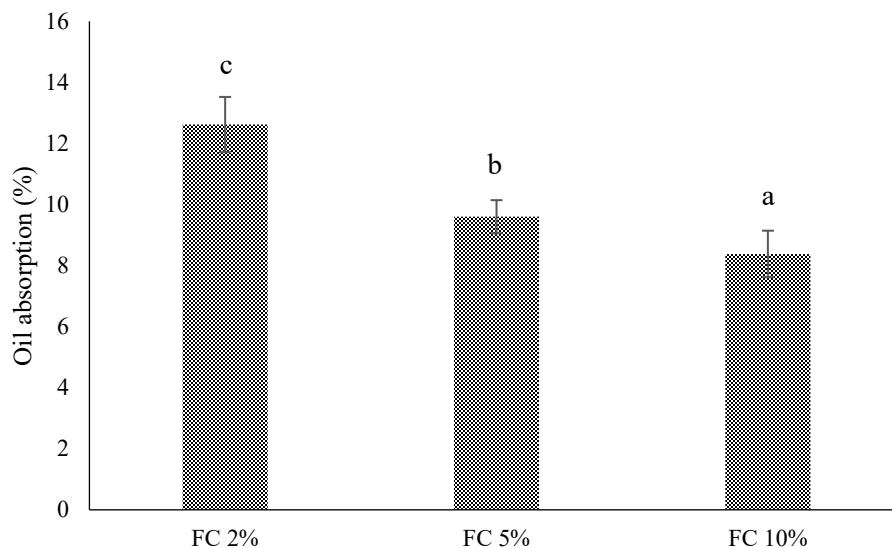


Figure 5. Oil absorption of fried *lemuru* fish crackers enriched with *Ulva* sp. Different letters (a,b,c) indicate significant differences at $p<0.05$.

3.4. Organoleptic Scoring Analysis

Organoleptic scoring was conducted to assess the quality of raw fish crackers enriched with *Ulva* sp. in accordance with the SNI 8272:2016. The evaluated attributes included appearance, odor, taste, texture, and mold presence. Table 3 showed that incorporation of *Ulva* sp. at 2%, 5%, and 10% did not substantially alter the organoleptic quality of raw crackers. All samples obtained similar rounded organoleptic scores for each attribute. In addition, the incorporation of different concentrations of *Ulva* sp. in raw fish crackers did not significantly influence consumer scores related to fish cracker quality. This finding indicates that the inclusion of *Ulva* sp. at varying concentrations, ranging from 2% to 10%, still met the quality standards of fish crackers. Nevertheless, further studies are required to assess consumer acceptance of fish crackers formulated with more than 10% *Ulva* sp., as higher incorporation levels may affect other quality attributes, especially appearance (Figure 6).

Table 3. Organoleptic scoring evaluation of fish crackers enriched with *Ulva* sp. (2%, 5% and 10%) before deep-frying based on SNI 8272:2016.

Sample	Interval organoleptic score (organoleptic score $\approx$ rounded organoleptic score)				
	Appearance	Odor	Taste	Texture	Mold
FC 2%	$7.13 \leq \mu \leq 8.21$ (7.13 $\approx$ 7)	$8.21 \leq \mu \leq 8.99$ (8.21 $\approx$ 8)	$8.48 \leq \mu \leq 8.99$ (8.48 $\approx$ 8)	$8.23 \leq \mu \leq 8.84$ (8.23 $\approx$ 8)	$8.81 \leq \mu \leq 9.19$ (8.81 $\approx$ 9)
FC 5%	$7.53 \leq \mu \leq 8.47$ (7.53 $\approx$ 7)	$7.75 \leq \mu \leq 8.65$ (7.75 $\approx$ 8)	$8.07 \leq \mu \leq 8.73$ (8.07 $\approx$ 8)	$7.95 \leq \mu \leq 8.72$ (7.95 $\approx$ 8)	$8.81 \leq \mu \leq 9.19$ (8.81 $\approx$ 9)
FC 10%	$6.73 \leq \mu \leq 7.93$ (6.73 $\approx$ 7)	$7.83 \leq \mu \leq 8.57$ (7.83 $\approx$ 8)	$7.83 \leq \mu \leq 8.57$ (7.83 $\approx$ 8)	$7.90 \leq \mu \leq 8.76$ (7.90 $\approx$ 8)	$8.81 \leq \mu \leq 9.19$ (8.81 $\approx$ 9)

For appearance, all treatments received a rounded score of 7, corresponding to the criteria of intact, neat, clean products with non-uniform thickness and bright color. Odor, taste, and texture were rated at level 8 (within the 7–9 interval), indicating good sensory quality. The mold attribute received a score of 9 across all treatments, confirming the absence of mold contamination. Although the products met acceptable standards (scores >5), improvement in appearance is recommended. The relatively lower appearance score

(7) may have been influenced by non-uniform thickness resulting from manual processing. Improvements are needed to achieve higher score for the appearance parameter, particularly in the cutting process to ensure uniform cracker thickness. This can be accomplished by using high-precision calibrated cutting tools and removing improperly cut crackers. In this study, a traditional method commonly used by micro, small and medium enterprises was applied to produce the fish crackers.

3.5. Hedonic Analysis

Hedonic evaluation (Table 4) was conducted on fried crackers using a 7-point Likert scale to assess consumer preference. Representative samples are shown in Figure 6. A 7-point Likert scale (1 = dislike very much; 7 = like very much) was employed by panelists to evaluate appearance, odor, taste, texture, and overall acceptability of fish crackers supplemented with *Ulva* sp. at different concentration.

Table 4. Hedonic evaluation of fish crackers enriched with *Ulva* sp. 2%, 5%, and 10%.

Samples	Appearance	Odor	Taste	Texture	Overall
FC 2%	6.03 ± 0.76 ^b	5.97 ± 0.76 ^a	6.37 ± 0.61 ^a	6.13 ± 0.68 ^a	6.13 ± 0.76 ^b
FC 5%	6.43 ± 0.50 ^c	5.97 ± 0.56 ^a	6.67 ± 0.55 ^a	6.10 ± 0.84 ^a	6.26 ± 0.62 ^b
FC 10%	1.90 ± 0.55 ^a	6.07 ± 0.58 ^a	6.60 ± 0.81 ^a	6.07 ± 0.83 ^a	5.16 ± 0.69 ^a

Data are given as mean ± standard deviation (n = 30). Different letters (a,b,c) within a similar column indicate significant differences (p < 0.05).

Results indicated that FC 10% received the lowest score for appearance (1.90 ± 0.55), significantly lower than FC 2% (6.03 ± 0.76) and FC 5% (6.43 ± 0.50) (p<0.05). The darker green color and denser structure at 10% inclusion likely affected visual acceptability. This finding aligns with the organoleptic scoring results prior to frying. Aganduk, et al. (2024) [31] also reported that addition of *Kappaphycus alvarezii* powder in reduced the color of crackers. Moreover, the structure of FC 10% corresponded to low both linear expansion and oil absorption resulting in dense structure. The presence of *Ulva* in high concentrations led to a cracked appearance in the fish crackers, which may be attributed to its high water-binding capacity reacted with oil at high temperatures during deep frying. In line with these findings, the formulation of fish crackers containing 10% *Ulva* sp. was not recommended, as it does not align with consumer preferences.

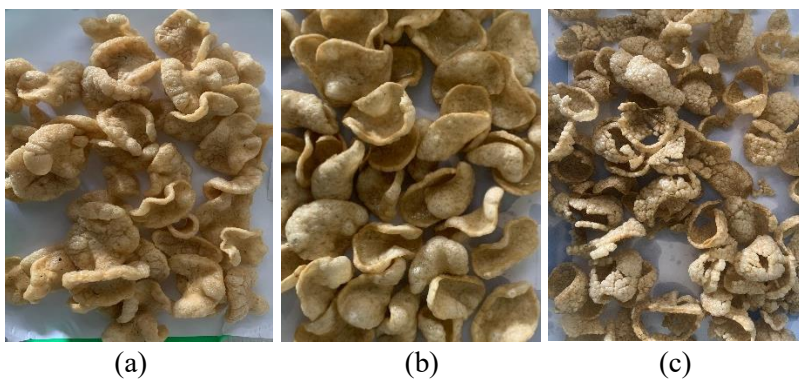


Figure 6. Deep-fried *lemuru* crackers incorporated with *Ulva* sp. at 2% of concentration (a), 5% of concentration (b) and 10% of concentration (c).

For odor, 10% received the highest score (6.07 ± 0.58), suggesting that the incorporation of *Ulva* sp. enhanced aroma acceptability. In addition, *Ulva* sp. is recognized as a source of natural flavors with diversity and distinctive aromas, including pungent sulfur compounds and marine halogenated components but also herbaceous fatty acid derivatives and fruity-floral terpenoids [43]. Furthermore, taste scores ranged from 6.37 to 6.67, indicating that all formulations were generally well accepted. Figueroa, et al. (2023) [44]

reported that *Ulva* sp. contains umami-active compounds, making it suitable ingredient for incorporation into savory culinary food products. Accordingly, the addition of *Ulva* sp. in various concentration enhanced the taste of the fish crackers. For texture, FC 2% achieved the highest score (6.13 ± 0.68), while FC 10% recorded the lowest (6.07 ± 0.83). Texture preference corresponded with linear expansion results, as higher expansion produced crispier products. In terms of overall acceptability, FC 5% showed the highest consumer preference, followed by FC 2%, while FC 10% received comparatively lower overall acceptance.

4. CONCLUSION

This study demonstrates that incorporating up to 5% *Ulva* sp. into *lemuru* fish crackers is a viable strategy, as it maintains desirable physical and sensory properties, while higher concentrations negatively impact appearance and expansion. Sensory evaluation revealed that incorporation up to 5% maintained desirable organoleptic and hedonic characteristics, whereas 10% inclusion negatively affected appearance and overall acceptability. Overall, *lemuru* fish crackers formulated with 5% *Ulva* sp. demonstrated the most favorable balance between physical quality and consumer acceptance, making this formulation the optimal level for product development. The incorporation of *Ulva* sp. may contribute to the development of innovative seaweed-based fish snacks with improved processing characteristics. However, this study did not evaluate nutritional composition; therefore, future research should investigate the nutritional enhancement and shelf-life stability of the developed product.

AUTHOR CONTRIBUTION

All author contributed equally to the main contributor to this paper. All authors read and approved the final paper. **Fenny Crista Anastasia Panjaitan**: Writing (review & editing), writing (original draft), formal analysis, supervision, conceptualization, and funding acquisition. **Amelia Mulya Berliana**: Investigation, formal analysis, and funding acquisition. **Putri Wening Ratrinia**: Writing (review & editing) and funding acquisition. **Raini Panjaitan**: Writing (review & editing) and funding acquisition. **Honey Lyn R. Gomez**: Writing (review & editing) and formal analysis.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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