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Research Article

The application of seaweed *Gracilaria verrucosa* in Karawang, Indonesia, as an enrichment material for antibacterial soap production

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Abstract

Seaweed *Gracilaria verrucosa* is one of the potential marine natural resource commodities in Karawang Regency, Indonesia. Solid soap is one of the added value products that can be developed from seaweed since it has a potential antibacterial function for human skin. The solid soap with seaweed enrichment sale could increase the seaweed farmers and coastal community income. This study aims to produce solid soap with the addition of different seaweed *G. verrucosa* formulations and examine the sensory, physicochemical parameters, and antibacterial activity of the soap. This study applied five variants: solid soap with the addition of 0.025%, 0.050%, and 0.075% seaweed water extract (W250, W500, and W750), 0.075% seaweed ethanol extract (E750), and seaweed pulp (SWP). The variant W500 and SWP have the highest attributes according to the sensory (aroma, color, amount of foam, and power of detergency) and physicochemical (pH, foam stability, and unsaponifiable fat content) parameters, respectively. The variant SWP and W500 also have a strong antibacterial activity. From the results, the variant SWP and W500 can be the candidates for further product development.

Keywords: Antibacterial activity, Indonesia, Seaweed, Sensory parameters, Physicochemical parameters

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Introduction

Seaweed *Gracilaria verrucosa* is one of the prospective marine natural resource commodities in Karawang Regency, Indonesia (Waluyo *et al*., 2019). According to BPS-Statistics of Karawang Regency (2022), the productivity of seaweed cultivation in Karawang Regency was 757.54 metric tons in 2021. Usually, the harvested seaweeds are sold as dried products to the small traders and industries around Karawang. However, the price of dried seaweed is low, approximately 0.50 USD/kg (Setyaningsih *et al*., 2012; Deswati and Luhur, 2014; Waluyo *et al*., 2019).

On the other hand, seaweeds contain bioactive metabolites such as polyphenols, alkaloids, and carotenoids (De Almeida *et al*., 2011; Gouda *et al*., 2013; Kim *et al*., 2015). The bioactive compounds from various seaweeds may promote antibacterial activity on the skin, e.g., *Aeromonas hydrophila* and *Pseudomonas putida* (Maftuch *et al*., 2016). Due to the bioactive compounds content, previous studies have applied seaweeds *Eucheuma cottonii* and *Sargassum sp.* to produce antibacterial soap (Rahayu, 2015; Prasedya *et al*., 2018; Baehaki *et al*., 2019). Hence, those findings become the foundation of this study in applying seaweed *G. verrucosa* as an additional material to produce antibacterial solid soap.

The development of antibacterial soap with *G. verrucosa* produced in Karawang Regency could provide more local product and souvenir to Karawang Regency. Moreover, seaweed-enriched solid soap can be sold at a higher price than dried seaweed. As a reference, the price of solid soap enriched with natural material (e.g., *Cymbopogon citratus*) was approximately 10 USD/kg (Mahyati *et al*., 2018). Therefore, the seaweed farmers and coastal communities in Karawang Regency could gain more income from the sale of seaweed-enriched soap.

However, the study of solid soap with seaweed *G. verrucosa* enrichment is emerging compared to other seaweed species. Before this information can be passed to the public, preliminary studies regarding the formulation and quality of solid soap with seaweed *G. verrucosa* enrichment must be conducted. The quality of the solid soap must also meet the standard requirement (NSAI, 2016). Hence, this study aims to produce solid soap with different seaweed *G. verrucosa* formulations and examine its sensory, physicochemical parameters and antibacterial activity.

Materials and methods

Sample collection

Seaweed *G. verrucosa* samples were collected from Tirtajaya District, Karawang Regency (6°00'21"S 107°14'02"E), and West Java, Indonesia (Fig. 1). The seaweed samples were cleaned through immersing in clean water and then dried at room temperature for 24 hours (Wang *et al*., 2008).

Seaweed pulp preparation

Seaweed pulp was prepared by modifying the method of Hwang *et al*.

(2010) and Tanjung *et al*. (2020). Seaweed samples (100 g) were immersed in 1 L of distilled water (1:10 w/v) and boiled (100°C) for 30 minutes. The water-immersed seaweed was then cooled at room temperature and refined to seaweed pulp using a blender.

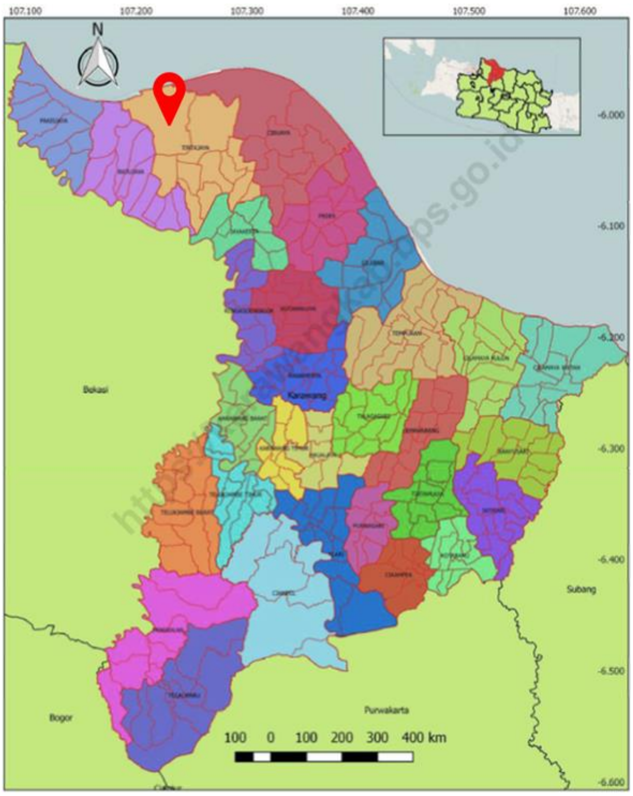

Figure 1: Map of Karawang Regency, West Java, Indonesia (BPS-Statistics of Karawang Regency, 2022). The red pin indicates the sampling location.

Seaweed extraction

The extraction of seaweed was carried out by a maceration method (Hwang *et al*., 2010; Widyasanti *et al*., 2016; Baehaki *et al*., 2019). The extraction applied two different solvents, distilled water and ethanol 70%. The weight of seaweed samples extracted for each variable is shown in Table 1, based on the total weight of oil used to produce solid soap (500 g). The seaweed samples were immersed in each solvent and then heated for 30 minutes at 100°C for water solvent and 60-70°C for ethanol 70% solvent. The resulting filtrate solution was then separated from the solid cakes using a filter paper.

Table 1: The weight of seaweed samples and solvent used for the extraction.

Extraction components	W250	W500	W750	E750
Seaweed sample (g)	0.125*	0.250**	0.375***	0.375***
Distilled water (g)	171	171	171	-
Ethanol 70% (g)	-	-	-	171

*0.125 g/500 g = 2.5 x 10-4 = 250 ppm or 0.025%
**0.250 g/500 g = 5.0 x 10-4 = 500 ppm or 0.050%
***0.375 g/500 g = 7.5 x 10-4 = 750 ppm or 0.075%

Solid soap variants

The present study applied five variables and two controls. The variants were solid soap with 0.025%, 0.050%, 0.075% of seaweed water extract (W250, W500, and W750), 0.075% of seaweed ethanol extract (E750), and seaweed pulp (SWP). The controls were solid soap without any addition (C1) and commercial antiseptic solid soap (C2). In the next part, each variant and control will be mentioned by its code.

Formulation of solid soap with seaweed enrichment

The formulation of seaweed-enriched solid soap was adapted from Baehaki *et al*. (2019) and is shown in Table 2. The formulation was based on the cold process method and supported by the soap formulation application "Lye Calculator" (Bramble Berry Inc., 2019; MFL, 2019). The soap production began with the mixing of palm and coconut oil. At the same time, a NaOH solution was prepared by dissolving NaOH crumbles in distilled water. The oil mixture was then mixed with the NaOH solution using a blender for ±5-10 seconds to achieve the trace phase, a condition where the oil and NaOH solution is entirely mixed and indicated by a viscous and whitish mixture.

Table 2: The formulation of seaweed-enriched solid soap.

Soap composition	Variants					
	C1	W250	W500	W750	E750	SWP
Palm oil (g)	250	250	250	250	250	250
Coconut oil (g)	250	250	250	250	250	250
Distilled water (g)	171.01	-	-	-	171.01	171.01
NaOH crumbles (g)	76.47	76.47	76.47	76.47	76.47	76.47
Seaweed pulp (g)	-	-	-	-	-	50*
Seaweed extract W250 (g)	-	171.01	-	-	-	-
Seaweed extract W500 (g)	-	-	171.01	-	-	-
Seaweed extract W750 (g)	-	-	-	171.01	-	-
Seaweed extract E750 (g)	-	-	-	-	171.01	-
Essential oil** (g)	-	5	5	5	5	5

Notes: The solid soap formulation is based on 500 g of the oil mixture
*The seaweed pulp's weight is 10% of the oil mixture (Baehaki *et al*., 2019)
**The essential oil's weight is 1% of the oil mixture

During the production of solid soap with seaweed pulp enrichment, seaweed pulp and essential oil were added to the soap right after the trace phase was reached. The seaweed pulp, essential oil, and soap were mixed using a blender for ±3-5 seconds. As for the production of solid soap with seaweed extract enrichment, the NaOH solution was prepared by dissolving the NaOH crumbles in seaweed extract solution. The essential oil was added to the soap just after the trace phase was achieved.

The viscous soap mixture was put in a soap mold. The soap mixture was then homogenized to release air bubbles that could create holes in the final product. After two days of storage, the solid soap was solidified under open conditions at room temperature.

Sensory parameters analysis

The sensory parameters were analyzed based on the hedonic test. The test was adapted from Ismanto *et al*. (2016) and Widyasanti *et al*. (2016). The test involved 11 untrained panelists evaluating the soap texture, aroma, color, amount of foam, and power of detergency. The mentioned parameters were scored between 1 (more unpreferable), 2 (unpreferable), 3 (preferable), and 4 (more preferable). The data were then processed based on the percentage of scores 3 and 4 (Equation 1):

$$Hedonic\ value\ (\%) = \frac{amount\ of\ score\ 3\ \&\ 4\ in\ a\ parameter}{total\ panelists\ number} \times 100 \quad (1)$$

Irritation assessment

The irritation parameter was scored between 0 (non-irritant) and 1 (irritant), involving 11 untrained panelists. The data were then processed based on the percentage of scores 1 as shown in Equation 2 (Ismanto *et al*., 2016):

$$Irritation\ value\ (\%) = \frac{amount\ of\ score\ 1}{total\ panelists\ number} \times 100 \quad (2)$$

Physicochemical parameters analysis

The physicochemical parameters analysis constituted total fat, unsaponifiable fat, pH, and stability of the foam. The total fat and unsaponifiable fat were analyzed at the laboratory of PT. Saraswanti Indo Genetech, Bogor, Indonesia. The analysis was conducted based on the Indonesian National Standard SNI 3532:2016 for solid soap (NSAI, 2016).

The pH of the soap was measured according to Baehaki *et al*. (2019). Solid soap samples (5 g) were dissolved in 10 ml of distilled water, and then the pH was measured using a Universal pH indicator strip (Merck, Germany). The solid soap foam stability was measured based on Baehaki *et al*. (2019), where 0.5 g of solid soap was dissolved in 4.5 mL of distilled water (1:9 w/v) in a test tube. The sample was then mixed for 1 minute and left for 15 minutes. The stability of foam was then measured according to Equation 3:

$$The\ stability\ of\ foam\ (\%) = \frac{b}{a} \times 100 \quad (3)$$

Where “a” is the height of foam after the mixing (cm) and “b” is the height of foam after 15 minutes. All physicochemical parameters were analyzed in duplicates and reported as mean±standard deviation.

Antibacterial activity analysis

The antibacterial activity was analyzed according to Razarinah *et al*. (2018) and Baehaki *et al*. (2019). This analysis was performed at the laboratory of Aquaculture Production Business

Service Center (*Balai Layanan Usaha Produksi Perikanan Budidaya*), Karawang, Indonesia. The antibacterial activity of the sample was tested against a Gram-positive bacterium, *Staphylococcus aureus* ATCC.

The antibacterial activity was indicated by the inhibition of bacterial growth, which is measured by the Kirby Bauer disc diffusion method. Agar media (15 mL) was poured into a sterile petri dish, and liquid bacteria culture (10 μL) was spread on agar media. Furthermore, disc papers were immersed separately in sample solutions for 2 minutes each. The disc papers were then put on the agar media that contained the testing bacteria in petri dish. The petri dish was incubated for 24 hours at 37°C. The antibacterial activity was then measured according to the resulting inhibition/clear zone diameter in mm. The antibacterial activity was analyzed in duplicates and reported as mean±standard deviation.

Results

Solid soap variants

The solid soap variants produced in this study are shown in Figure 2.

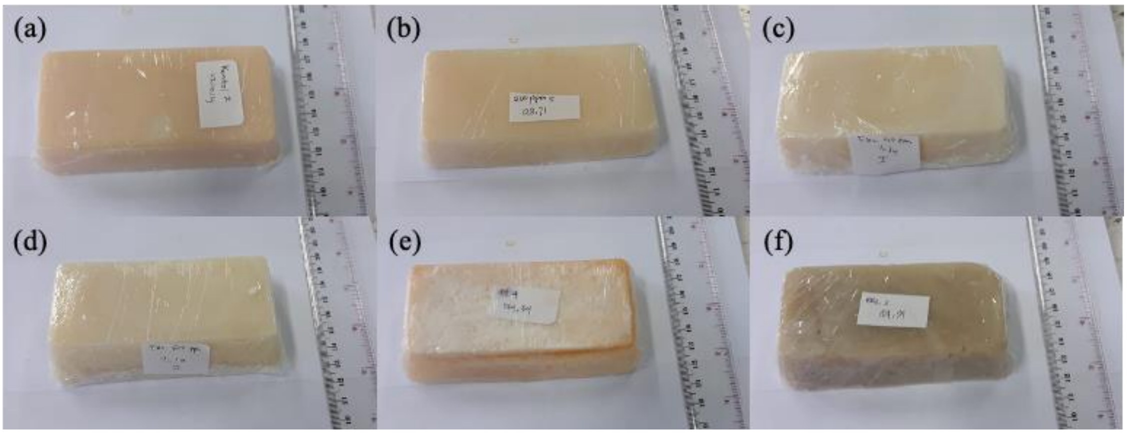

Figure 2: Solid soap variants: (a) C1. (b) W250. (c) W500. (d) W750. (e) E750. (f) SWP .

Sensory parameters

The hedonic values of the soap variants are shown in Figure 3. As can be seen in Figure 3, the most preferred texture is soap of variant E750 (72.7%), followed by W500 (63.6%), W250 and W750 (54.5%), and SWP (27.3%). However, the control soap (C1) has more texture preference (81.8%) than E750. Additionally, the commercial antiseptic soap (C2) has the same texture preference as W250 and W750. Soap with the most preferred aroma is variant W500 (81.8%), followed by W250 (72.7%), W750 (54.5%), and E750 (45.5%). The least preferred aroma is variant SWP (27.3%). For comparison, the control soap (C1) has 0% aroma preference, while the commercial antiseptic soap (C2) has 90.9% preference, higher than the seaweed-enriched soaps.

The variant W250, W500, and W750 have the same color preference (72.7%), followed by E750 (45.5%) and SWP

(36.4%). On the other hand, the control soaps (C1) and the commercial antiseptic soap (C2) have 81.8% color preference. C1 and C2 color preference are higher than the soaps with seaweed enrichment.

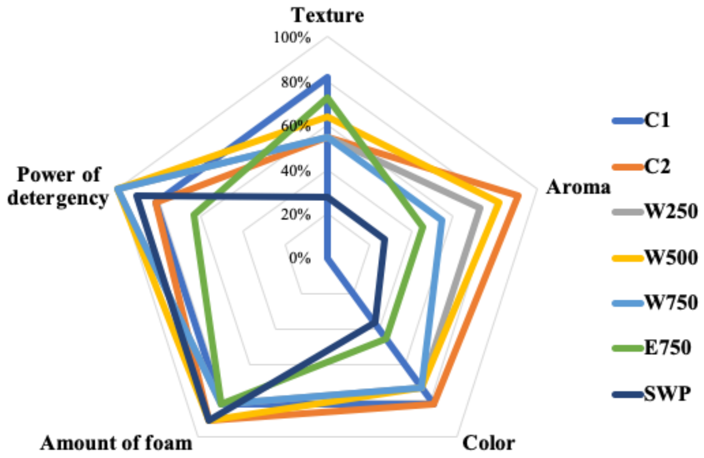

Figure 3: The hedonic value of texture, aroma, color, amount of foam, and power of detergency from different soap variants.

For the amount of foam parameter, variant W500 and SWP have the highest preference value (90.9%). Variant W250, W750, and E750 followed with the preference value of 81.8%. The preference value of soaps with seaweed enrichment is comparable with the control (C1) and commercial antiseptic (C2) soap, which is 81.8% and 90.9%, respectively.

As for the power of detergency parameter, variant W250, W500, and W750 have the preference value of 100%. Variant SWP (90.9%) and E750 followed with the preference value of 63.6%. The control (C1) and commercial antiseptic (C2) soap have the same preference value, 81.8%.

Irritation assessment

The irritation value of soap variants is shown in Table 3. The panelists regarded variant W250 as non-irritant (0%). The irritation value then is followed by variant W500 and SWP (9%), E750 (27%), and W750 (36%). Likewise, the control (C1) and commercial antiseptic (C2) soap were also regarded as non-irritant (0%).

Table 3: The irritation value of different soap variants.

Solid soap variants	Irritation value (%)
C1	0
C2	0
W250	0
W500	9
W750	36
E750	27
SWP	9

Physicochemical parameters

The soap variants' pH, foam stability, total fat, and unsaponifiable fat content are shown in Figures 4-7, respectively.

The majority of soap variants have a pH of 10.0±0.0, except the variant E750 which has a pH of 11.5±0.7 (Fig. 4). As a comparison, the pH of control (C1) and commercial antiseptic (C2) soap is also 10.0±0.0.

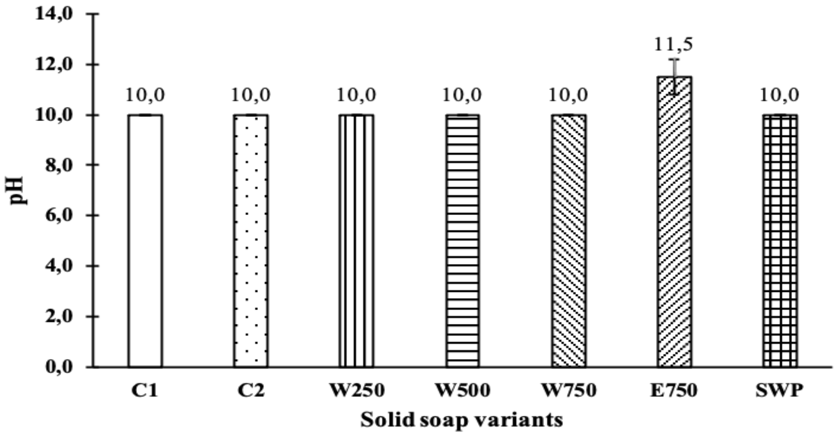

Figure 4: pH of different soap variants.

Figure 5 shows that the foam stability of the soap variants is in the range between 93.7-8.9%. The variant SWP has the highest foam stability (98.9±1.5%), followed by W750 (97.9±3.0%), W500 and E750 (97.4±0.7%), and W250 (93.7±3.0%). As a comparison, the control (C1) and commercial antiseptic soap (C2) have a foam stability of 94.7±0.0% and 100±0.0%, respectively.

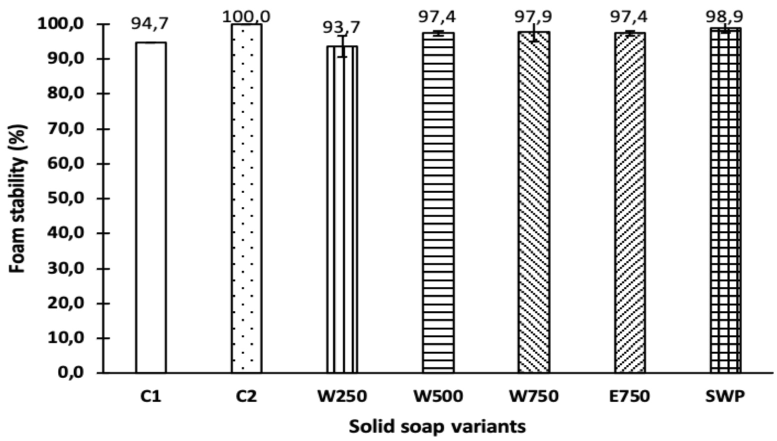

Figure 5: Foam stability of different soap variants.

The highest total fat content is possessed by the variant W250 (62.66±0.28%), followed by W500 (62.59±0.07%), W750 (59.76±0.23%), and E750

(59.61±0.70%) (Fig. 6). The variant SWP has the lowest total fat content, 53.18±0.37%. On the other hand, the control (C1) and commercial antiseptic (C2) soap have a total fat content of 61.22±0.64% and 62.68±0.08%, respectively.

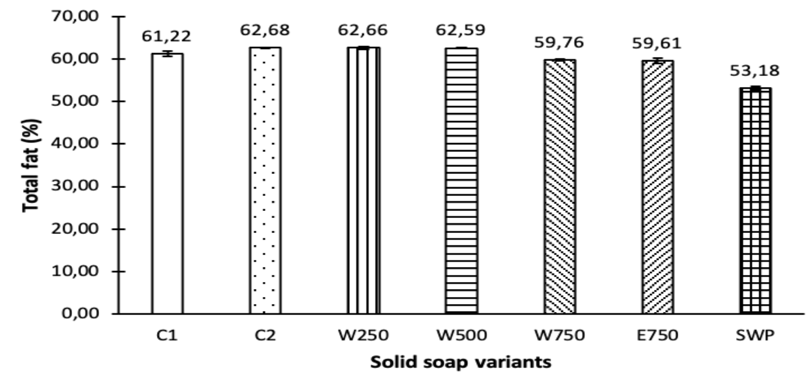

Figure 6: Total fat content of different soap variants.

The variant E750 has the highest unsaponifiable fat content (8.60±0.01%), then followed by W250 (8.04±0.00%), W500 (2.78±0.13%), and W750 (1.98±0.05%) (Fig. 7). The variant SWP has the lowest unsaponifiable fat content (1.84±0.03%). The control (C1) and commercial antiseptic (C2) soap have an unsaponifiable fat content of 9.87±0.02% and 0.97±0.02%, respectively.

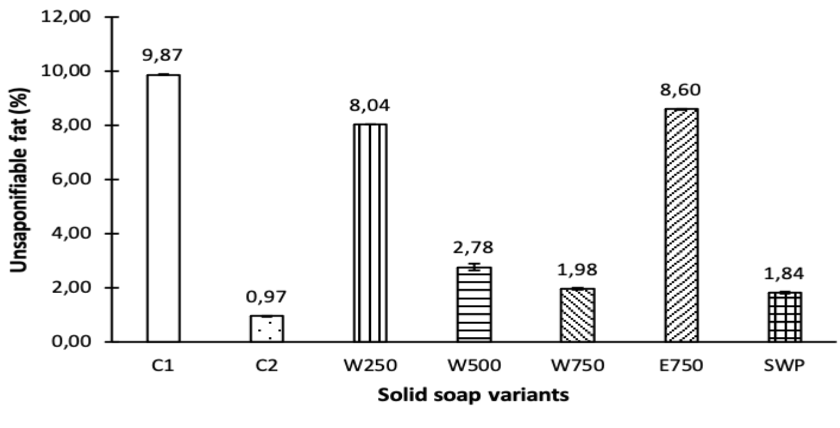

Figure 7: Unsaponifiable fat content of different soap variants.

Antibacterial activity

The inhibition zone of each soap variant can be seen in Figure 8. The variant SWP has the highest inhibition zone (12.33±1.37 mm), followed by W500 (10.17±0.75 mm), E750 (9.17±2.32 mm), W750 (8.83±0.75), and W250 (8.33±1.86 mm). Furthermore, the control soap (C1) has an inhibition zone of 10.33±1.86 mm, while the commercial antiseptic soap (C2) has an inhibition zone of 7.00±0.00 mm.

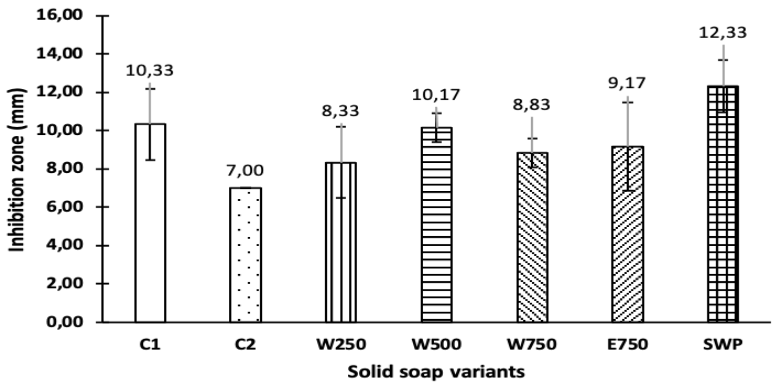

Figure 8: The inhibition zone of different soap variants.

Discussion

Sensory parameters

In this study, the soap with 0.075% of seaweed ethanol extract (E750) has the highest texture preference, possibly due to the effect of the ethanol on soap fatty acid components (Widyasanti *et al*., 2016: Baehaki *et al*., 2019). Contrarily, the soap with seaweed pulp (SWP) has the lowest texture preference. As a comparison, Sany *et al*. (2019) studied solid soaps enriched with different crude *E. cottonii* extract concentrations (0.0, 3.5, 4.0, and 4.5%). The texture preference of their soap tended to increase with higher *E. cottonii* extract concentration (79.22-82.22%). The soap texture became harder with the increase of seaweed extract concentration. The panelists more preferred hard texture soap since softer soap tends to wear off rapidly. The soap texture could be influenced by water; stearic acid, sugar, and oil content (Sany *et al*., 2019).

The low aroma preference value of variant SWP is possibly due to the seaweed high salt content. Sany *et al*. (2019) indicated that soap with more crude seaweed *E. cottonii* extract concentration had lower aroma preference (83.67-67.33%) due to higher seaweed salt content that can produce a fishy aroma. Srilayani *et al*. (2019) reported that high free fatty acids content could also affect aroma negatively since it could lead to lipid oxidation that generates rancid odor. Rahayu (2015) suggested the use of oil with high saturated fatty acids content for soap formulation to prevent rapid lipid oxidation.

The variant W250, W500, and W750 have a soft and yellowish-white color (Figs. 2b - d). The variant E750 also has a yellowish with a crystal color part (Fig. 2e), possibly due to the interaction between ethanol and other soap components (Baehaki *et al*., 2019). The variant SWP has a dark color that could be caused by unfiltered seaweed residues (Fig. 2f). Sany *et al*. (2019) reported that soap with a lower seaweed *E. cottonii* extract concentration (0.0 - 4.5%) had a higher color preference (80.78-74.78%). The soap with more seaweed extract content tended to be darker (more brownish). On the contrary, Ismanto *et al*. (2016) indicated that the soap with a higher agarwood (*Aquilaria malaccensis*) oil content and darker color had the highest color preference (33.33 - 66.67%).

The amount of foam is related to the active compounds contained in the soap, such as fatty acids and surfactants (Widyasari, 2010; Karo Karo, 2011). Sany *et al*. (2019) indicated that soap with a higher crude seaweed *E. cottonii* extract had more foam (63.00 - 82.89%). Higher seaweed extract content may indicate higher saponin content, which provides more surfactant characteristic and generates more foam. Ismanto *et al*. (2016) also reported that the soap with higher agarwood oil content tended to have a higher amount of foam (33-80%) due to the higher surfactant feature from the agarwood oil.

Soap molecules have a lipophilic carbon chain that can dissolve oil, fat, and hydrophilic tips that can bind with water molecules. Therefore, soap can bind with impurities, fat, and, oil particles from the skin surface and be rinsed by water. Furthermore, seaweed bioactive compounds, such as saponin, could also promote the soap cleaning performance (Gusviputri *et al*., 2013). Sany *et al*. (2019) reported that soap with a higher crude seaweed *E. cottonii* extract had a higher power of detergency (68.11-80.78%). High unsaponifiable fat or free fatty acid content must be avoided since they may decrease the soap detergency power. Alcohol use in soap must also be noticed since it only binds polar substances, therefore freeing more lipid/fatty acids and decreasing soap detergency power (Srilayani *et al*., 2019).

Irritation assessment

The irritation characteristic of soap can be caused by the remaining caustic soda as free alkali which did not fully react to produce soap (Ismanto *et al*., 2016). The seaweed active compounds can also add alkalinity (increasing pH) to the soap. The curing process, which is storage of soap at room temperature, is usually applied in soap production to evaporate the alkaline compounds and lowering the soap pH (Dyartanti *et al*., 2014). As a comparison, a study by Ismanto *et al*. (2016) showed that all of soap variants had 0% irritation.

Physicochemical parameters

The variant E750 has the highest pH, 11.5±0.7 (Fig. 4). The ethanol in variant E750 may bind more seaweed bioactive compounds, such as phenols, alkaloids, and flavonoids, than water solvent in other variants. These compounds may provide more alkalinity and increase the soap pH (Sany *et al*., 2019). Ethanol has a higher pH compared to water and therefore it possibly provide a higher pH in variant E750. According to a bathing soap standard, SNI 4085:2017, the pH standard of a bathing soap is 4.0-10.0 (NSA, 2017). The majority of soap variants in this study, except variant E750, meet this requirement. On the other studies, soap with different *E. cottonii* extract concentration had a pH “between” 11-12 (Baehaki *et al*., 2019). Soap with *E. spinosum* methanol-based extract addition had a pH of 7 (Akib *et al*., 2019). Also, soap with a combination of *Sargassum* sp. and *Eucheuma* sp. extract had a pH of 8.4 -

9.5 (Sabaani *et al*., 2019). Soap pH correlates with the irritation characteristic, which could be affected by incomplete saponification leaving free alkali (Baehaki *et al*., 2019).

Figure 5 shows an increasing trend of foam stability between the variant W250 (93.7±3.0%), W500 (97.4±0.7%), and W750 (97.9±3.0%). This trend may occur due to the increase of saponin content since it produces foam when in contact with water (Widyasanti *et al*., 2016). Also, the soap variants in this study have a higher foam stability (93.7-98.9%) compared to soap enriched with white tea *Camelia sinensis* extract, which is 36.35-59.36%. (Widyasanti *et al*., 2016). Sany *et al*. (2019), who used crude *E. cottonii* extract, produced soap with a foam stability of 79.63 - 93.39%. Additionally, Baehaki *et al*. (2019), who also used seaweed *E. cottonii* extract, produced soap with foam stability between 42.77-74.41%. The soap foam stability could also be affected by fiber content and fatty acid composition (Baehaki *et al*., 2019; Sany *et al*., 2019). Baehaki *et al*. (2019) also mentioned that soap dominated by unsaturated fatty acids content could make soap foam less stable.

The total fat content in soap variants (Fig. 6) may be mainly acquired from the fatty acids (e.g., lauric, palmitic, and stearic acid) contained in palm and coconut oil (Abast *et al*., 2016). Seaweed bioactive compounds, such as steroids, could also contribute to the soap total fat content (Febrianto *et al*., 2019). However, the soap variants in this study do not meet the total fat standard in SNI 3532:2016 (NSAI, 2016). The total fat standard of solid soap should be more than 65%, whereas the total fat content of the variants in this study is between 53.18 - 62.66%. The lower total fat content indicates that the solid soap will wear off faster (Sany *et al*., 2019). The study of soap with agarwood oil enrichment had a total fat content of 62.43 - 74.92% (Ismanto *et al*., 2016). Another study, which used white tea *C. sinensis* extract, generated soap a total fat content of 34.23 - 38.50% (Widyasanti *et al*., 2016).

The unsaponifiable fat content in the soap variants is still higher than the standard requirement (Fig. 7). According to the solid soap standard SNI 3532:2016, the soap unsaponifiable fat content should be lower than 0.5% (NSAI, 2016). The high soap unsaponifiable fat content indicates that the fatty acids were not fully converted to soap by saponification (Widyasanti *et al*., 2016). A study on soap with seaweed *K. alvarezii* enrichment generated soap with an unsaponifiable fat of 0.16-0.18% by (Srilayani *et al*., 2019). Ismanto *et al*. (2016), who studied soap with agarwood oil addition, generated soap with an unsaponifiable fat between 5.66 - 5.80%. Some lipid-like components, such as sterols and pigments, cannot be saponified into soap and therefore could contribute to the unsaponifiable fat content (Ismanto *et al*., 2016, Widyasanti *et al*., 2016).

Antibacterial activity

The addition of seaweed pulp in soap (SWP) could increase the antibacterial activity against *S. aureus* ATCC since the inhibition zone of SWP is higher than control (C1). The inhibition zone diameter could indicate the soap antibacterial activity. Inhibition zone of less than 5 mm indicates weak, between 5-10 mm indicates moderate, and between 10 - 20 mm indicates strong and more than 20 mm indicates very strong antibacterial activity (Baehaki *et al*., 2019; Bhernama, 2020). The antibacterial activity may come from seaweed metabolites, such as alkaloids, phenols, and flavonoids (Alves *et al*., 2013; Cushnie *et al*., 2014; Xie *et al*., 2015; Bestari, 2018). On the other hand, soaps with the addition of seaweed extract (W250, W500, W750, and E750) have lower antibacterial activity compared to control (C1). This result might occur due to a lower bioactive compounds concentration that was extracted from seaweed to the solvent (water and ethanol).

Another study on soap with an enrichment of *Gracilaria* sp. ethanol extract tested on *S. aureus* ATCC made an inhibition zone between 11.04-11.67 mm (Bhernama, 2020). *Gracilaria* sp. ethanol extract contained secondary metabolites such as flavonoid, saponin, and terpenoid. Flavonoids could denature bacterial cell membrane protein and inhibit bacteria growth (Bhernama, 2020). Baehaki *et al*. (2019) also tested their soap with an *E. cottonii* enrichment on bacteria *S. aureus* ATCC. Their result showed that the soap could generate an inhibition zone of 11.08-17.15 mm. Their seaweed also contained flavonoids that could destroy the bacterial cell membrane. They also reported that other soap materials, such as alcohols and NaOH, could provide antiseptic feature (Baehaki *et al*., 2019).

In conclusion, this study has developed solid soaps with seaweed *G. verrucosa* enrichment by adding seaweed extract (W250, W500, W750, and E750) and seaweed pulp (SWP). According to the sensory parameters (aroma, color, amount of foam, and power of detergency), the variant W500 has the most preference. The variant SWP has the most physicochemical parameters (pH, foam stability, and unsaponifiable fat content) that approach the standard requirement. The variant SWP and W500 have strong antibacterial activity since the resulting inhibition zone was between 10-20 mm. From the results, the variant W500 and SWP can be the candidates for further product development based on the sensory, physicochemical parameters, and especially the antibacterial activity. Product optimization must be performed to improve the quality of soap, such as by adding the seaweed pulp filtering step and testing other extraction solvents/procedures. More complete parameters should also be analyzed in further studies to ensure that the quality of soap meets the standard.

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