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Formulation and Evaluation of Dishwashing Soap Based on *Eichhornia crassipes* Activated Carbon as an Environmentally Friendly Cleanser

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Abstract
Eichhornia crassipes is an invasive aquatic plant found in tropical and subtropical waters that has high cellulose, lignin, and hemicellulose content, making it a potential raw material for activated carbon. The use of activated carbon in dishwashing soap can enhance cleaning power by absorbing oil, odors, and microscopic dirt. This study aims to formulate and evaluate a liquid dishwashing soap product containing carbon from water hyacinth as a natural cleaning agent. The water hyacinth samples used were dried stems, collected from local water bodies, and prepared by drying under sunlight to reduce moisture content. The stems were then subjected to carbonation at 600 °C for 60 minutes to produce biochar, followed by a comminution process using ball milling to produce fine activated carbon powder. The resulting carbon was formulated into a dishwashing soap base at a ratio of 1 mg per 100 mL of product. Product evaluations were conducted based on Indonesian National Standards (SNI) and yielded the following results: a pH value of 9.78 (SNI 8–10.8), foam stability of 90% (SNI 60–100%), viscosity of 206.11 cP (SNI 400–4000 cP), free alkali content of 0.104% (SNI <0.14%), and specific gravity of 1.045 g/mL (SNI 1.01–1.1 g/mL). The novelty of this study lies in the utilization of activated carbon derived from *Eichhornia crassipes*, which is formulated into liquid dishwashing soap and comprehensively evaluated based on national quality standards (SNI). This approach has rarely been reported in similar studies. The results demonstrate the potential of water hyacinth as an alternative active ingredient in the development of sustainable household cleaning products.

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INTRODUCTION

Environmental pollution caused by domestic waste, particularly synthetic chemical detergents, has emerged as a growing global concern due to its persistent impact on water quality and the disruption of aquatic ecosystems (Hendrasarie & Redina, 2023). As a response, there has been increasing interest in the development of natural, biodegradable alternatives to synthetic cleaning agents. One promising material in this regard is activated carbon derived from *Eichhornia crassipes* (water hyacinth), an invasive aquatic weed that is abundant in tropical waters (Nababan et al., 2024). Due to its high porosity and pollutant-absorbing capacity, water hyacinth-based activated carbon represents a sustainable and cost-effective raw material for environmentally friendly cleaning products (Ananpreechakorn & Seetawan, 2021).

Recent advances in formulation science have highlighted the potential of natural-based dishwashing soaps that utilize plant-derived surfactants and additives, such as saponins and essential oils, to enhance cleaning performance with reduced toxicity and environmental

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impact (Do et al., 2019); (Nisa et al., 2025). Among natural additives, activated carbon offers superior adsorption of oils and organic residues due to its microporous structure (Masakul et al., 2023). Activated carbon made from biomass such as *E. crassipes* has been shown to perform effectively in water filtration, pollutant removal, and even as a fat-binding component in cleaning products (Maulina et al., 2019).

Despite these promising characteristics, previous research has primarily focused on the use of *E. crassipes*-based activated carbon in areas such as wastewater treatment and energy storage, with limited exploration of its formulation into dishwashing soap (Morales S et al., 2021). Moreover, no studies have comprehensively evaluated its effectiveness in removing greasy residues from kitchen utensils when incorporated into liquid soap formulations (Ananpreechakorn & Seetawan, 2021). Many commercial "natural" soaps still rely partially on synthetic surfactants, which undermines their ecological benefits (Lakshmipurada et al., 2021). This identifies a clear scientific novelty: the formulation and testing of *E. crassipes* based activated carbon as a core cleaning agent in biodegradable dishwashing soaps.

To fill this gap, this study poses two main research questions (1) What are the physical and chemical characteristics of a dish soap formulation using activated carbon from water hyacinth (2) Does the resulting formulation meet the Indonesian National Standard (SNI) criteria for dishwashing products.

The objective of this study is to develop a liquid dishwashing soap formulation based on activated carbon from *Eichhornia crassipes* and to evaluate its quality and cleaning performance according to SNI standards. In addition, this research aims to explore the environmental sustainability potential of repurposing water hyacinth biomass typically considered ecologically harmful and economically worthless into a high-value, eco-friendly household product.

METHOD

A series of processes starting from raw material processing, soap production, to product quality testing.

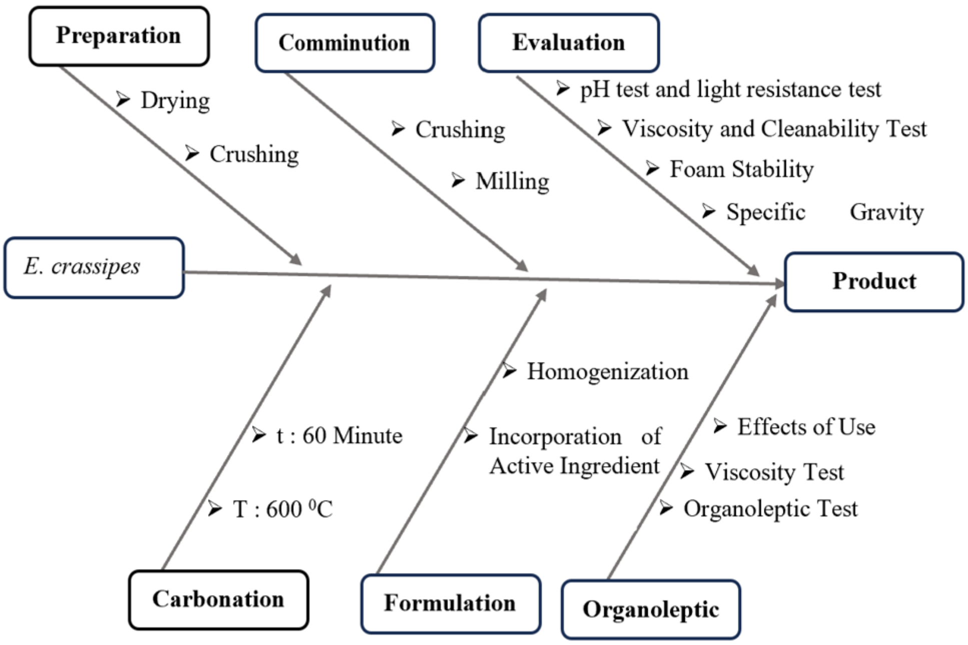

Figure 1. Process flow of the research on the production and testing of dishwashing soap made from activated carbon derived from *Eichhornia crassipes*.

Materials and Tools

The tools used in this study include knives or scissors, washing containers, drying mat, ovens, blenders, electric stoves, mortars and pestles, 200-mesh sieves, mild tools, measuring cups, beaker glasses, 250 mL Erlenmeyer flasks, test tubes, droppers, burettes, water baths, stopwatches, marbles, pycnometers, cooler, and a digital pH meter. The materials used include *Eichhornia crassipes* stems, 120 g of Texapon, 35 g of sodium sulfate, 100 mg of carbon from carbonization, approximately 800 mL of water, 20 g of Camperlan, 20 g of sodium chloride, 10 g of foam booster C-KD, 1 g of EDTA, glycerin 1 mL, and perfume 3 mL, phenolphthalein indicator, 96% alcohol, 0.1 N HCl solution, sodium carbonate (Na_2CO_3) 50 mg, methyl red indicator, boiling stones, and CO_2-free distilled water.

Carbonization Process

E. crassipes stems were obtained from ponds around FKIP Mulawarman University and washed thoroughly using running water to remove dirt. E. crassipes stems were cut into small pieces and dried under direct sunlight for 3 days. After drying in the oven for 30 minutes and blended to powder form. The powder was carbonized in an electric furnace for 1 hour at 600°C. The resulting carbon is pulverized using a mortar and pestle and then filtered using a 200 mesh sieve. Reduced particle size with a mild tool for 2 hours (Nurhadi et al., 2019).

Evaluation of Dishwashing Soap Production

The evaluation of dishwashing soap preparations was conducted through a series of tests, including organoleptic tests (color, texture, and odor), viscosity tests, acidity tests (pH), free alkali content tests, foam stability tests, and specific gravity tests.

Organoleptic Test

Prepare dishwashing soap samples containing activated carbon based on the formula obtained, ensuring they are stored in appropriate conditions (transparent containers). Prepare observation sheets or organoleptic test forms for the test parameters.

Odor Test

Samples were stored in closed, transparent containers to preserve their volatile components. During testing, the containers were opened briefly, and panelists were asked to smell the samples for 3–5 seconds. Each panelist then recorded the soap’s scent intensity and acceptability based on a predetermined rubric. This method follows practices used in recent studies of plant-based liquid soap, which assess the aroma for natural extract consistency and consumer preference (Fatkhurrachman et al., 2023); (Diana et al., 2024).

Color Test

Samples were placed in transparent containers under uniform lighting to prevent distortion from shadows or reflections. Panelists observed and recorded the color, noting any changes or inconsistencies. Color differences among liquid soap formulations have been similarly documented in recent formulations involving natural extracts, where concentration and ingredient interactions influence product hue (Nurhayati et al., 2023).

Texture Test

To evaluate tactile quality, panelists first cleaned their hands, then applied a small amount of the soap and rubbed it between their fingers. They assessed the sample’s slipperiness, consistency, and smoothness, noting whether the soap left a residue or had an uneven feel. The texture was then rated using a qualitative scoring sheet. This method is consistent with protocols in studies evaluating the physical feel of herbal-based liquid soaps (Isnawati, 2020).

pH Test

The test was conducted using a pH meter. Before testing, the pH meter was calibrated using pH 4.7 and 10 buffer solutions. After that, the electrode was cleaned with distilled water and dried. Then, the electrode was inserted into the soap sample. Next, the pH meter was left for several minutes until the value on the pH monitor stabilized, then the value on the monitor was recorded as the pH of the sample (Arrazi et al., 2021).

Foam Stability Test

A total of 10 mL of liquid soap was dissolved in 10 mL of distilled water. Next, it was placed in a test tube and the tube was shaken for 30 seconds. The height of the foam formed was measured after the tube was left to stand for 6 minutes (Sriwening & Susanti, 2022).

Free Alkali Test

Qualitative Examination

Take sufficient samples of dishwashing soap and place them in a test tube. Next, add a few drops of phenolphthalein indicator. If a red color forms, it indicates the presence of free alkali.

Quantitative Examination

Standardization of 0.1 N HCl with Na_2CO_3

Weigh 50 mg of sodium carbonate that has been dried at 70°C for 1 hour. Next, place it in an Erlenmeyer flask, then add 10 mL of CO_2-free distilled water and stir until homogeneous. Then add 2 drops of methyl red indicator. After that, titrate the solution with 0.1 N HCl until the red color disappears completely.

Determination of free alkali content in dishwashing soap

Weigh 2.5 grams of dishwashing soap samples, then place each soap sample into a 250 mL Erlenmeyer flask. Add 100 mL of 96% alcohol, a few drops of phenolphthalein, and boiling stones. Place the flask on a water bath until it boils, then let it sit until the sample dissolves. Titrate with 0.1 N HCl solution using a buret until the color changes to clear (Dipaningrum et al., 2021).

Viscosity test

Pour samples of dishwashing soap into 50 mL measuring cups. Measure the viscosity of the soap by dropping a marble into the measuring cup containing the sample, then measuring the time it takes for the marble to fall using a stopwatch. Repeat this process five times to obtain accurate results (Laksana et al., 2017).

Specific gravity test

The pycnometer along with its cap, which had been cleaned and dried, was weighed (a). Next, distilled water and dishwashing liquid were added into separate pycnometers using a dropper. The pycnometers were sealed and placed in a cooler until the temperature reached 25°C. Then, the weight of the pycnometer containing water (b) and the pycnometer containing dishwashing liquid (c) was measured (Sianiar et al., 2021).

RESULTS AND DISCUSSION

Soap Making Formulation

The dishwashing soap formulation developed in this study combines synthetic and natural active ingredients to produce an effective yet environmentally friendly cleaning product. The main ingredient used is Texapon (sodium lauryl ether sulfate or SLES), at a concentration of

120 grams, functioning as the primary anionic surfactant. It serves to reduce surface tension and generate abundant foam, thereby enhancing the emulsification of grease and dirt on kitchenware. The widespread application of SLES in liquid detergent formulations has been supported by its strong performance characteristics, especially when paired with co-surfactants such as cocamidopropyl betaine (CAPB) (Wu et al., 2019).

Table 1. Dishwashing Soap Formula

Ingredients	**Composition**
Texapon	120 g
Sodium sulfate	35 g
Activated carbon	10 mg
Camperlan	20 g
Sodium chloride	20 g
Water	1000 mL
Foam booster C-KD	10 g
EDTA	1 g
Glycerin	1 mL

Camperlan (CAPB), at a concentration of 20 grams, acts as a nonionic co-surfactant and foam stabilizer, contributing to improved lather richness and product mildness on the skin. The synergy between SLES and CAPB has been proven to enhance cleansing performance across a range of water conditions and temperatures, making it a reliable base for household cleaning formulations (Maysarah et al., 2023).

Activated carbon derived from biomass in this study, water hyacinth was added in the amount of 10 mg as a natural adsorbent. Despite the small concentration, this ingredient aids in the absorption of residual oils and organic matter from dishes. The use of plant-based carbon aligns with circular economy principles and addresses biomass waste management, while also contributing to the environmental sustainability of the product (Rofikoh et al., 2023). Studies have confirmed that activated carbon sourced from agricultural waste materials retains high porosity and adsorption capacity, making it a viable additive in cleaning formulations (Maysarah et al., 2023).

To enhance the physical and functional properties of the soap, additional ingredients were included: sodium sulfate (35 grams) and sodium chloride (20 grams) as viscosity modifiers and formulation stabilizers; foam booster C-KD (10 grams) to improve foaming height and durability; EDTA (1 gram) to bind heavy metal ions and prevent precipitation of active ingredients; and glycerin (1 mL) as a natural humectant to maintain skin moisture. Water (1000 mL) was used as the primary solvent.

The activated carbon was introduced during the early mixing phase, specifically when SLES and sodium sulfate were combined. This timing allowed for optimal dispersion of carbon particles into the surfactant matrix, reducing the risk of clumping or sedimentation. Previous practical implementations of similar formulations, such as community education programs on liquid soap production using SLES and CAPB, have demonstrated the feasibility of stable, homogeneous products through careful ingredient sequencing (Okkyana et al., 2023).

Soap Product Evaluation

***Product Evaluation Based On Indonesian National Standards* (*SNI*)**

Based on the laboratory evaluation of dishwashing soap formulated with activated carbon derived from water hyacinth, all tested parameters met the requirements of the Indonesian National Standard (SNI), indicating that the product formulation is suitable for use and environmentally safe. The pH value of the product was 9.78, which falls within the ideal range (8–11), suggesting that the soap is sufficiently alkaline to support the cleaning process while remaining safe for users' skin. This finding is consistent with Fernandes et al. (2022), who developed an eco-friendly detergent formulation with a pH below 11 without compromising cleaning efficiency (Fernandes et al., 2022).

Table 2. Product Evaluation based on Indonesian National Standards (SNI)

No	Test Criteria	Test Standards	Results	Explanation
1	Acidity Level (pH)	pH (8-11)	9,78	Compliant SNI
2	Foam Stability	(60-100)%	90%	Compliant SNI
3	Viscosity Test	(400-4000)cP	470,39 cP	Compliant SNI
4	Free Alkali Test	Maks 0,14%	0,104	Compliant SNI
5	Specific Gravity Test	(1,01-1,1)g/mL	1,045	Compliant SNI

Foam stability reached 90%, demonstrating the soap's optimal ability to produce and maintain foam, which is an important sensory factor for consumers. This performance is supported by the presence of activated carbon from water hyacinth, which potentially enhances the effect of surfactants through increased interaction and adsorption of oil and dirt (Atesci & Inan, 2023). Additionally, the viscosity value of 470.39 cP falls within the ideal range for liquid soap (400–4000 cP), ensuring product stability and ease of use. This aligns with findings demonstrating the use of water hyacinth-based activated carbon for the adsorption of heavy metal ions (Nafisyah et al., 2022).

The free alkali content of 0.104% is still below the maximum standard limit of 0.14%, indicating that the soap is non-irritating and safe for regular use. This reinforces the classification of the product as environmentally friendly with low irritation potential, consistent with the importance of using natural materials in wastewater treatment to reduce toxicological risks to users (Galgali et al., 2023). The specific gravity of the soap was recorded at 1.045 g/mL, also within the acceptable range of 1.01–1.1 g/mL, indicating consistent formulation and optimal solubility.

Overall, the data presented in Table 2 demonstrate that activated carbon from water hyacinth functions effectively as a supporting cleaning agent that not only enhances the physicochemical properties of the soap but also contributes positively to environmental sustainability. These findings are further supported by a national study, which reported that activated carbon derived from water hyacinth was capable of reducing color, odor, and COD in food industry wastewater (Ratnani et al., 2022). Therefore, the formulated dishwashing soap meets national quality standards and represents a more sustainable and eco-conscious approach to household product development.

Product Evaluation Based on Organoleptic Testing

Table 3. Organoleptic Testing Results Data

Criteria	Score	Description
Texture	7 out of 7-9	Very Good/Suitable
Color	4.2 out of 5.0	Good/Suitable/Liked
Smell/Aroma	-	No Smell

The results of the organoleptic test indicate that the formulated dishwashing liquid received a very favorable response in terms of texture and color. The texture score was 7 on a scale of 7 to 9, which falls under the “very good” category, reflecting that the product has optimal thickness, softness, and foam dispersion. Good soap texture not only supports comfort during use but also indicates the stability of the emulsion and active ingredients. This is relevant to the characteristics of activated carbon derived from water hyacinth, which has the ability to adsorb impurities and maintain the physical stability of cleaning agents (Ratnani et al., 2022).

Regarding color, the average score of 4.2 out of 5.0 reflects a good level of acceptance and was well-liked by respondents. The color of dishwashing soap contributes to the perception of cleanliness and product aesthetics. Although activated carbon sourced from biomass such as water hyacinth may produce a grayish or dark tone, it can still be accepted when combined with a stable formulation that does not interfere with perceived quality (Weerasuk et al., 2024).

In terms of odor or aroma, no unpleasant scent was detected, and the product was categorized as odorless. This supports the goal of producing eco-friendly cleaning agents that contain little to no synthetic fragrance, especially to avoid emission of volatile compounds harmful to indoor environments (Galgali et al., 2023).

Overall, the results presented in Table 3 reinforce that the dishwashing soap formulated with activated carbon from water hyacinth not only meets technical standards but is also well-received in terms of user comfort and consumer acceptance. This confirms the strong potential of plant-based cleaning products as safe, environmentally friendly, and socially preferred alternatives.

The relationship between the formulation components, physicochemical evaluation, and organoleptic testing shows that each ingredient in the dishwashing soap contributes synergistically to the final product quality. Although the amount of activated carbon from water hyacinth used was small (10 mg), it played a crucial functional role in enhancing the soap's ability to adsorb oil and impurities. While it did not significantly influence viscosity, the presence of activated carbon supported cleansing performance, as reflected in the foam stability result (90%) and viscosity value (470.39 cP), both within the optimal SNI range (Hendrasarie & Redina, 2023).

From the organoleptic perspective, the soap's texture was rated very good by panelists (score of 7 on a 7–9 scale), consistent with the viscosity and specific gravity results (1.045 g/mL). This indicates that the balance of surfactants (Texapon and Camperlan), thickener (sodium sulfate), and additives such as glycerin successfully created a comfortable and uniform soap consistency. Color, with a score of 4.2 out of 5.0, was also positively received, despite the grayish tone from natural activated carbon—an aesthetic still acceptable with stable formulation (González-García et al., 2020).

Furthermore, the pH of 9.78 supports both skin compatibility and stability of active ingredients. The neutral aroma (odorless) aligns with the goal of developing environmentally friendly cleaning products without synthetic fragrances. Consistent with (Nababan et al., 2024), the addition of water hyacinth-based extracts improves product acceptability without compromising natural characteristics.

Thus, there is a strong coherence between the formulation approach, laboratory data, and consumer acceptance, highlighting that dishwashing soap with water hyacinth-based activated carbon is not only technically compliant but also well-received in terms of sensory quality and ecological value.

This study still has several limitations, including the use of a very small amount of water hyacinth activated carbon (10 mg), which makes it difficult to specifically evaluate its effect on cleaning performance. In addition, the soap's effectiveness against stains or grease has not been directly tested, and the product has not yet undergone production-scale testing or biodegradability assessments.

Future research can be developed by varying the concentration of activated carbon to optimize its function, along with direct cleaning performance tests and skin safety evaluations. The development of formulations using natural fragrances and the assessment of environmental impact are also important to support comprehensive eco-friendly claims.

CONCLUSION

This study successfully demonstrates the formulation of a liquid dishwashing soap incorporating activated carbon derived from water hyacinth, exhibiting physicochemical and sensory characteristics that comply with the Indonesian National Standard (SNI) for dishwashing products. Product evaluation showed a pH of 9.78, foam stability of 90%, viscosity of 470.39 cP, free alkali content of 0.104%, and specific gravity of 1.045 g/mL, all within acceptable SNI limits. Organoleptic testing further revealed that the soap had excellent texture (scored 7 on a 7–9 scale), a color well-received by panelists (4.2 out of 5.0), and a neutral aroma in line with consumer preferences for fragrance-free and environmentally friendly products. These findings confirm that the soap is safe, physically stable, and functionally effective as a cleaning agent, with strong potential for further development as a sustainable household product. The novelty of this research lies in the incorporation of activated carbon derived from the dried stems of *Eichhornia crassipes* in a low concentration (10 mg per 100 mL) into a dishwashing soap formulation, followed by comprehensive evaluation using national quality standards. This formulation approach has rarely been explored in prior studies, making it a valuable contribution to the advancement of eco-friendly, plant-based cleaning product development.

RECOMMENDATIONS

To maximize the quality of the soap products produced, practitioners and researchers are advised to conduct a soap durability test, to determine the extent to which the product can survive during storage. In addition, testing on various water conditions also needs to be done to evaluate the performance of the soap in different usage situations. At the formulation stage, it is recommended to explore combinations of additional natural ingredients, such as essential oils or plant extracts, to improve aroma, cleaning effectiveness, as well as antibacterial properties, without reducing the eco-friendly characteristics of the developed dish soap products.

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