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Sustainable solid soap production using recycled cooking oil with ecoenzyme and lemongrass extract

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ABSTRACT

Background: Improper disposal of used cooking oil poses significant environmental challenges, including groundwater contamination and harm to aquatic ecosystems. Recycling used cooking oil into solid soap offers a sustainable solution to reduce waste while creating a valuable, eco-friendly product.

Objective: This study aims to produce solid soap from used cooking oil with the addition of ecoenzyme and lemongrass extract and evaluate its potential as an environmentally friendly and antimicrobial soap.

Method: Used cooking oil was refined using bagasse as an adsorbent to remove impurities. Ecoenzyme was produced by fermenting organic kitchen waste, sugar, and water for three months, while lemongrass extract was prepared by blending and filtering lemongrass stalks. The soap was formulated by saponifying refined used cooking oil with NaOH, ecoenzyme, and lemongrass extract. The physical properties of the soap were assessed.

Results: The resulting soap was solid, creamy in color, and emitted a refreshing lemongrass aroma. Antimicrobial properties are potential due to the organic acids and enzymes in the ecoenzyme, combined with the bioactive compounds in lemongrass extract.

Conclusion: Solid soap made from used cooking oil with ecoenzyme and lemongrass extract offers a sustainable and effective solution for waste recycling while providing natural antimicrobial and cleaning benefits.

Keywords: Antimicrobial activity, eco-enzyme, household organic waste, used cooking oil

Introduction

According to data from the Central Statistics Agency (BPS), the consumption of cooking oil has steadily increased over the years. In 2023, the total demand for cooking oil for household consumption in Indonesia reached 2.66 million tons per year, marking a 2% increase compared to the previous year. This growing consumption of cooking oil inevitably contributes to an increase in cooking oil waste, particularly in the form of used cooking oil [1]. The repeated use of cooking oil results in hydrolysis and oxidation, leading to its deterioration. This degradation is evident from changes in the oil's aroma, which becomes rancid, and its color, which darkens. Used cooking oil contains significantly higher levels of saturated fatty acids than unsaturated fatty acids. These saturated fatty acids pose serious health risks, as they are associated with life-threatening diseases such as heart disease, stroke, and cancer [2].

In addition to health concerns, improper disposal of used cooking oil poses significant environmental challenges. When used cooking oil is carelessly discarded into the environment, it can lead to pollution, particularly in aquatic ecosystems. Disposing of oil into water bodies can increase the Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) levels, as the oil forms a surface layer that prevents sunlight from penetrating the water. This disruption leads to the death of aquatic organisms and ultimately harms the ecosystem [3]. Furthermore, improper disposal of cooking oil in household sewage systems often results in blockages, as the oil solidifies and clogs pipes.

While some studies have shown that used cooking oil can be filtered and refined to restore its appearance, the chemical composition remains compromised, rendering it unsuitable for human consumption. However, refined used cooking oil can be repurposed for other applications, such as the production of laundry soap [4]. Soap production generally involves a saponification process, which combines oils or fats with alkali. Recent studies have demonstrated that bagasse—a byproduct of sugarcane processing—can be used as a filtering agent to purify used cooking oil for soap production. While refined used cooking oil is not safe for consumption, it has shown potential for creating both liquid and solid soap products [5].

This study seeks to explore the use of ecoenzymes as an additive in solid soap made from used cooking oil. Ecoenzymes are produced through the fermentation of organic kitchen waste, such as fruit and vegetable scraps, combined with sugar (e.g., brown sugar or cane sugar) and water. The resulting product is a dark brown liquid with a strong sweet-and-sour aroma that has applications across various sectors, including household cleaning, agriculture, and health [6]. Ecoenzymes, made from organic waste such as orange peels and banana peels, are multipurpose liquids with antimicrobial properties. They are commonly used as natural cleaners, detergents, and sanitizers, as well as for agricultural purposes like cleaning pesticides from produce [7]. Additionally, ecoenzymes have shown potential for health-related applications, such as hand sanitizers and wound care, due to their antimicrobial activity [8].

Despite the versatility of ecoenzymes, there is limited information on their antimicrobial activity when incorporated into solid soap made from used cooking oil. Solid soaps formulated with natural ingredients, such as used cooking oil and ecoenzymes, offer a safer alternative to commercial soaps that often contain synthetic chemicals. Such natural soaps may also benefit skin health and reduce the risk of chemical exposure. This study aims to develop solid soap products made from used cooking oil and enriched with ecoenzymes, evaluating their potential as antiseptic soaps with antimicrobial properties.

Methods

Lemongrass extraction

Lemongrass (*Cymbopogon citratus*), used for its aromatic and antimicrobial properties, was processed into an extract for this study. A total of 64 grams of lemongrass stalks were soaked in 30 mL of water for 24 hours. After soaking, the stalks were cut into small pieces and blended until smooth for 15 minutes. The resulting pulp was then wrapped in a cloth, immersed in 50 mL of water, and squeezed to extract the lemongrass juice [9].

Refining process of used cooking oil

Used cooking oil was sourced from restaurants, households, and food processing industries and stored in clean, dry containers to prevent contamination. To remove large food particles and debris, the oil was filtered through a fine mesh or filter. The oil was then allowed to settle in a container to separate water and heavier particles that sank to the bottom. Next, the oil was heated to a temperature of 60–70°C to reduce viscosity. A small amount of water or an acid, such as phosphoric acid, was added to the heated oil and thoroughly stirred. The mixture was left to settle, allowing gums and other impurities to separate. Finally, the water phase containing the impurities was removed, leaving the purified oil [10].

Adsorption of used cooking oil using bagasse

Bagasse was used as an adsorbent to further refine the used cooking oil. The bagasse was thoroughly dried to maximize its adsorption capacity and then ground into a fine powder to increase the surface area available for adsorption. The prepared bagasse powder was added to the degummed oil at a ratio of 5–10% by weight of

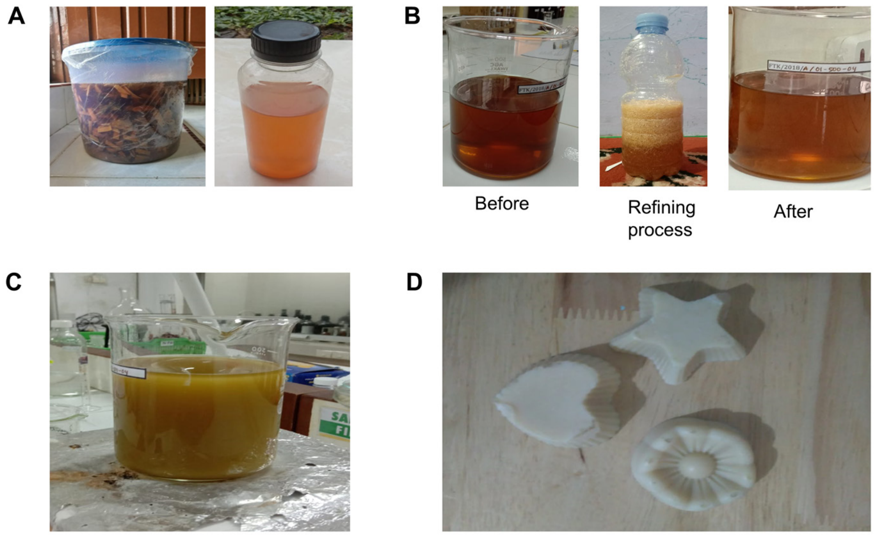

Figure 1. Process of making solid soap with the addition of ecoenzyme. (A) Ecoenzyme production, (B) Refinement of used cooking oil, (C) Soap production process, (D) Final appearance of the solid soap.

the oil. The mixture was heated to 60–70°C and stirred continuously for 30–60 minutes, allowing the bagasse to adsorb impurities such as free fatty acids and oxidized compounds. After stirring, the mixture was left to settle, enabling the bagasse and adsorbed impurities to sink to the bottom. Finally, the oil was filtered through a fine filter or filtration system to remove the bagasse particles and residual impurities, resulting in purified oil [4].

Ecoenzyme production

Organic waste, such as fruit and vegetable scraps, was used to produce ecoenzyme, avoiding meat, dairy, and oily substances to prevent unpleasant odors and slow fermentation. The ingredients were prepared in a ratio of 300 grams of organic waste, 100 grams of brown sugar, and 1000 mL of water. Brown sugar was dissolved in water in a large container, and the organic waste was then added to the sugar-water solution. The container was sealed and stored in a cool, dark place. During the first month, the container was opened every few days to release gases produced during fermentation. The mixture was allowed to ferment for three months, during which the solids settled, and a liquid ecoenzyme formed. After three months, the liquid was filtered to separate it from the solid residue, and the ecoenzyme was stored in clean bottles for various applications [11].

Solid soap production

To produce the soap, 44 grams of NaOH were added to 53 grams of lemongrass extract and 50 grams of ecoenzyme. The mixture was stirred until the NaOH was completely dissolved. After cooling, 300 grams of purified used cooking oil were added, and the mixture was stirred using a magnetic stirrer until it reached a consistency similar to mayonnaise. The resulting mixture was poured into molds and allowed to harden for 24 hours. For optimal performance, the soap was cured for 2 to 4 weeks before use [5].

Results

Ecoenzyme production

In the process of ecoenzyme production, water was added as a growth medium, resulting in a final product characterized by a clear, yellow fermentation liquid. Ecoenzyme is an environmentally friendly product created through the fermentation of organic waste, particularly fruit and vegetable scraps [12]. The concentration and volume of the final product depend on the quantity of raw materials used and the consistency of the fermentation process. Ecoenzyme is typically produced in liquid form and can be diluted for a wide range of applications.

After fermentation, the ecoenzyme was observed to have a low pH of approximately

4.5, attributed to the presence of organic acids. During the fermentation process, the production of enzymes, organic acids, and alcohol occurs [13]. The ecoenzyme exhibited a distinctive sour aroma due to its organic acid content, while its color ranged from golden brown to variations influenced by the specific raw materials used (Figure 1A). Ecoenzyme primarily consists of organic acids (e.g., acetic acid), enzymes, microorganisms, and beneficial minerals. The organic acids provide cleaning efficacy, while the enzymes and microorganisms facilitate the breakdown of organic matter and offer antibacterial properties.

With a low pH level (around 3–4), ecoenzyme functions as an antimicrobial agent. Its acidic nature inhibits the growth of harmful microbes, while its enzymatic and probiotic content helps disrupt biofilms and pathogens. These properties make ecoenzyme an eco-friendly solution for microbial control in cleaning, agriculture, and wastewater management [8]. Furthermore, ecoenzyme production is cost-effective, utilizes natural ingredients, and does not generate hazardous waste, making it accessible and sustainable. The diverse applications of ecoenzyme range from household cleaning to agricultural uses, providing an innovative and environmentally friendly method for transforming organic waste into a valuable resource. Previous studies have demonstrated the utility of ecoenzyme as a detergent additive, showcasing its potential for practical applications [15].

Refining of used cooking oil with bagasse

The physical characteristics of used cooking oil were observed before and after the refining process. Fresh cooking oil is odorless and has a clear yellow appearance. After being used for frying up to four times, the oil exhibited a slightly rancid odor and became cloudy yellow. The purification of this used cooking oil was performed using bagasse as an adsorbent.

The adsorption process with bagasse effectively reduced impurities, improving the oil's clarity and quality. Figure 1B illustrates the refinement process, showing that the color and purity of the oil significantly improved after treatment. The refining method involved heating the oil and mixing it with bagasse, followed by filtration to remove residual impurities. This environmentally friendly and economical technique highlights the dual benefit of reducing oil waste and repurposing bagasse, a byproduct of the sugarcane industry, as an effective adsorbent [4].

Bagasse fibers efficiently absorbed impurities such as free fatty acids and oxidized compounds, leaving behind cleaner oil that can be reused. It demonstrates the efficiency of this process, underscoring its potential as a sustainable method for managing used cooking oil while minimizing waste.

Solid soap from used cooking oil with the addition of eco-enzyme

Soap production from used cooking oil represents an innovative method to recycle waste oil and create a functional product. The process involved filtering and refining the used cooking oil, followed by saponification with NaOH [5]. The soap produced in this study was of sufficient quality for daily use, offering the added benefits of reduced waste and low production costs.

Challenges such as unpleasant odors in the soap can arise if the oil is not adequately refined. This issue was addressed by thorough purification of the oil and the addition of natural fragrances, such as lemongrass extract, to enhance the soap's sensory appeal.

The solid soap produced in this study was observed to be firm, creamy in color, and easy to slice. It also emitted a refreshing lemongrass aroma, which enhanced its appeal (Figure 1D). The soap generated foam, although it did not produce as much lather as commercial soaps containing synthetic surfactants. The addition of natural ingredients, such as essential oils and ecoenzyme, enriched the soap with environmentally friendly and functional properties, making it suitable for household use.

The soap's performance and quality were further enhanced by the incorporation of ecoenzyme and lemongrass extract. Ecoenzyme contributed natural cleaning and antibacterial properties due to its organic acids and enzymes, while lemongrass extract provided additional antimicrobial benefits and a pleasant aroma. Together, these ingredients created a sustainable and multifunctional product with applications for personal hygiene and household cleaning.

This innovative approach of combining waste-based sustainability with natural bioactive additives demonstrates the potential of ecoenzyme-enriched soap as a dual-purpose solution. It addresses environmental concerns by recycling used cooking oil while offering antimicrobial and hygienic benefits. The use of lemongrass extract as a natural fragrance and antimicrobial agent further enhances the soap's functionality and appeal.

Discussion

Improper disposal of used cooking oil poses significant environmental risks, including groundwater contamination and harm to aquatic ecosystems. Transforming used cooking oil into solid soap offers an effective and sustainable solution to reduce waste while creating valuable products. This method not only produces an eco-friendly and economical soap but also raises public awareness about the importance of recycling and sustainability [17].

To prepare used cooking oil for soap production, the oil must first be collected and filtered to remove food residues and impurities. Filtering can be achieved using a filter cloth or paper. Further purification is necessary, which involves heating the oil and adding bagasse powder to adsorb residual contaminants and eliminate foul odors. After this step, the oil is filtered again to remove the bagasse and other impurities [4].

Bagasse, the fibrous residue from sugarcane extraction, contains cellulose and lignin fibers, which provide excellent adsorptive capabilities [18]. This agricultural byproduct serves as an effective purifying agent for used cooking oil. Bagasse adsorbs free fatty acids, oxidized compounds, and other impurities, improving the oil's quality for reuse or further processing. Utilizing bagasse not only enhances the efficiency of oil refinement but also promotes environmentally friendly practices by repurposing agricultural waste. Although challenges remain, such as optimizing the adsorption process and ensuring the efficient separation of impurities, bagasse remains an economical and sustainable option for refining used cooking oil.

Ecoenzyme, a fermented liquid produced from fruit and vegetable scraps mixed with sugar and water, offers numerous benefits due to its unique composition. This fermentation process yields organic acids (e.g., acetic acid, lactic acid, citric acid) and enzymes (e.g., protease, amylase, lipase), which contribute to its antimicrobial properties [19]. Ecoenzyme also contains minerals and nutrients derived from the organic materials used during fermentation [6]. These components enable ecoenzyme to effectively inhibit microorganisms by lowering the pH of the microbial environment, disrupting microbial cell walls, and interfering with metabolic processes [8, 19].

The antimicrobial mechanism of ecoenzyme is attributed to its combination of organic acids and enzymes. The acids lower the environmental pH, damaging bacterial and fungal cell walls, while enzymes degrade key components of microorganisms, such as proteins, fats, and carbohydrates, thereby inhibiting their growth and reproduction. Studies have demonstrated that ecoenzyme has antimicrobial efficacy, such as its ability to inhibit *Enterococcus faecalis*, making it a promising addition to cleaning and hygiene products [21]. Furthermore, ecoenzyme is gentle on the skin due to its natural origin and mild composition, making it suitable for use in personal care products like soap.

When incorporated into solid soap, ecoenzyme enhances the soap's cleaning efficacy by breaking down dirt and grease more effectively. Additionally, its antibacterial and antifungal properties make the soap more effective against infection-causing microorganisms. Ecoenzyme also helps reduce unpleasant odors from used cooking oil or other contaminants, though the natural fermentation odor may require additional fragrances to improve sensory appeal.

In this study, lemongrass extract was used as a natural fragrance to complement the ecoenzyme-enriched soap. Lemongrass (*Cymbopogon citratus*) is a versatile plant containing essential oils, flavonoids, and other bioactive compounds with significant health benefits. Known for its antimicrobial, antioxidant, and anti-inflammatory properties, lemongrass is widely used in culinary applications, traditional medicine, and body care products [22].

The addition of lemongrass extract not only enhances the soap's fragrance but also contributes to its antimicrobial properties. Previous studies have demonstrated that lemongrass extract can inhibit the growth of pathogens, such as *Candida albicans*, further supporting its use as a bioactive additive in soap formulations [23]. Incorporating lemongrass into soap provides a natural, eco-friendly alternative to synthetic fragrances while offering additional health benefits.

The production of solid soap enriched with ecoenzyme and lemongrass extract represents an innovative approach to sustainability, combining recycling with environmental and health benefits. This method addresses the dual goals of reducing waste and creating high-quality, eco-friendly products. Recycling used cooking oil not only prevents environmental contamination but also transforms waste into a valuable resource. Adding ecoenzyme enriches the soap with organic acids and enzymes, which improve its cleaning and antimicrobial properties. Meanwhile, lemongrass extract enhances the soap's functionality with its antimicrobial effects and refreshing aroma.

Conclusion

This study highlights the potential of ecoenzyme and lemongrass extract as valuable additives in solid soap production. The combination of these natural bioactive components with recycled used cooking oil creates an innovative product that is both sustainable and functional. This approach not only supports waste reduction and recycling efforts but also provides a natural, antimicrobial soap suitable for personal and household use. Future research could focus on optimizing the formulation and evaluating the long-term stability and efficacy of ecoenzyme-enriched soaps in various applications.

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Author contributions

ZO, YY: Conducted the solid soap-making experiment with the addition of ecoenzyme. ZO, YY, EY: Developed the methodology and contributed to the writing of the manuscript. EY, LU: Performed the literature review and contributed to the experimental design. All authors have read and approved the final version of the manuscript for publication.

Declaration of interest

The authors declare no conflicts of interest with any private, public, or academic entities related to the information presented in this manuscript.

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