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Research Article

Physicochemical and biological properties of eco-friendly soap from used cooking oil infused with colloidal oatmeal and thiourea derivative

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Abstract

Escalating environmental concerns and the need for sustainable solutions have led to the exploration of innovative methods to repurpose waste materials. The culinary world generates vast amounts of used cooking oil (UCO), often seen as a disposable waste product. Repurposing UCO into soap is a sustainable waste management solution. This study aims to produce eco-friendly soap using UCO infused with colloidal oatmeal, which is renowned for its soothing and moisturizing properties. The research investigated the feasibility of utilizing readily available and inexpensive ingredients to create a functional cleansing product while minimizing environmental impact. The process involved the saponification of UCO with sodium hydroxide, followed by the incorporation of colloidal oatmeal and a thiourea derivative. The resulting soap was assessed for its physicochemical, antioxidant, antifungal, and antibacterial properties. The final product is anticipated to offer effective cleansing while being gentle and suitable for individuals with sensitive skin conditions. Overall, the production of this eco-friendly soap is expected to have a positive impact on individual's well-being and address skincare needs while fostering environmental stewardship.

Keywords: eco-friendly soap, used cooking oil, oatmeal, thiourea, waste management

Introduction

Used cooking oil (UCO), a by-product of household and commercial cooking, poses health and environmental risks due to its chemical composition and potential for oxidation. Malaysia approximately produced 50,000 tons of UCO per year from vegetable oils and animal fats, which were disposed of without proper treatment [1]. UCO contains carcinogenic compounds and can lead to various health issues, including increased cholesterol, blood sugar, and uric acid levels [2]. Nevertheless, despite the aftereffects, UCO can be repurposed for homemade soap making, which can help raise awareness about its potential reuse [3]. Homemade soap offers an eco-friendly alternative to commercial products by promoting waste reduction and natural ingredient use. Repurposing UCO into soap combines sustainable waste management with the benefits of supporting both environmental and personal care goals.

Oatmeal has been recognized for its nutritional and therapeutic benefits, including its use in skincare products. It has been traditionally used to alleviate skin dryness, reduce acne, and soothe rashes, making it a popular choice in skincare products [4]. Oat extracts have been reported to exert beneficial effects in the treatment of various conditions, including hypertension, celiac disease, and dermatosis [5]. The combination of oatmeal with other natural ingredients, such as coconut oil and palm oil, can enhance the characteristics of soap bars, making them suitable for commercial use [6].

Thiourea and its derivatives are an important class of chemicals known for their diverse range of biological activities, particularly their antibacterial and antifungal properties. Their potential uses in treating illnesses brought on by resistant bacterial and fungal strains have increased their significance. Studies have highlighted how structure affects the biological activity of thiourea derivatives, showing that some changes can increase their potency against infections [7].

Addressing these challenges requires innovative and sustainable solutions that can provide effective skincare without imposing financial burdens. Hence, one promising approach is the development of eco-friendly homemade soap made from UCO and colloidal oatmeal with the addition of thiourea as the active compound. This study focused on the physicochemical and biological properties of oatmeal soap. The soap not only utilizes waste materials and promotes environmental sustainability but also offers a cost-effective alternative to conventional skincare products.

Materials and Methods

Preparation of homemade soap infused with colloidal oatmeal

The preparation of soap from UCO and colloidal oatmeal involved several key steps. Approximately 500 g of UCO was filtered to remove impurities. Next, a lye solution was prepared by gradually adding 67 g of sodium hydroxide to 135 mL of distilled water and allowing it to cool. The lye solution was then mixed into the filtered oil and blended continuously until the mixture reached a pudding-like consistency, known as the trace. Next, 50 g of colloidal oatmeal was added and thoroughly mixed. The soap mixture was then poured into molds, tapped to release air bubbles, and insulated for 48 hours. After this period, the soap was unmolded, cut into bars, and left to cure in a well-ventilated area for two weeks to ensure complete saponification and hardness. The steps were repeated using commercial oil instead of UCO, without oatmeal, for comparison.

Physicochemical properties of the soap

Approximately 10 mL of distilled water and 1 g of soap were added to a beaker. The mixture was then stirred until the soap was completely dissolved. The moisture content of the solution was measured using a digital moisture analyzer (Sartorius MA 150), while the pH was determined with a universal test paper (HmbG). The physicochemical properties of the UCO-oatmeal soap were compared to UCO soap without oatmeal, commercial oil-oatmeal soap, and commercial oatmeal soap (store-bought).

Antioxidant assay

The 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay was carried out according to the method described by a previous study with slight modifications [8]. The assay was performed in 96-well microplates. A concentration of 0.1 mM DPPH solution was prepared by dissolving 3.8 mg of DPPH in 100 mL of methanol. The tested soaps were prepared using methanol at different concentrations using serial dilution (0–10000 µg/mL). Methanol was used as a control, and ascorbic acid was used as an antioxidant standard. The analysis was performed in triplicate. The samples were incubated in the dark for 30 minutes. The absorbance of the reaction mixture was measured at 517 nm using a microplate reader (Multiskan Go, Thermo Fisher). DPPH radical scavenging activities of the sample extracts were expressed as IC_{50} values. The percentage of inhibition was calculated using the formula:

$$\text{Percentage inhibition of DPPH activity} = (A-B)/A \times 100\%$$

A = Absorbance of reagent blank
B = Absorbance of test sample

Antifungal and antibacterial assays

Candida albicans and selected Gram-positive (*Staphylococcus aureus* [ATCC 25923]) and Gram-negative (*Escherichia coli* [ATCC 25922]) bacteria were used in the antifungal and antibacterial assays in this study. The fungal and bacterial strains were prepared from an overnight broth culture and diluted to an inoculum size of about 108 colony-forming units per milliliter (CFU/mL). The bacterial suspension density of the culture was standardized turbidimetrically to 500,000–1,000,000 CFU/mL at a wavelength of 600 nm. The bacterial suspension containing 108 CFU/mL of bacteria was spread on nutrient agar.

The well-agar diffusion assay was done with slight modification. The tested soaps were dissolved in sterile water and diluted to 2500 µg/mL. Then, wells were cut with a sterile borer (5 mm in diameter), and the tested soaps were placed into the wells. Sterile water was used as the negative control, while nystatin (antifungal) and streptomycin (antibiotic) were used as positive controls to determine the sensitivity of each bacterial species tested. Additionally, an antibacterial agent (thiourea derivative) obtained from Universiti Sultan Zainal Abidin (UniSZA), Malaysia, was infused with the soap as a reference. The analysis was performed in triplicate.

The inoculation plates were incubated at 37 °C for 48 (antifungal assay) and 24 (antibacterial assay) hours. The antifungal and antibacterial activities were assessed by measuring the clear zone of inhibition (in mm diameter) surrounding the well against the tested organisms.

Results and Discussion

The soap was prepared by mixing UCO and lye until a trace was formed. The mixture was then allowed to develop for two weeks at room temperature. To get the best consistency, sodium hydroxide was utilized as a strong base, which combined with glycerides to

provide additional neutralizing activity. The saponification process of the soap is depicted in **Figure 1**.

Physicochemical analysis

The physicochemical properties of the homemade soap, including moisture content and pH, were analyzed. The analysis of UCO-oatmeal soap (UCTO) was compared to three other types of soaps: UCO soap without oatmeal (UCOP), commercial oil-oatmeal soap (COTO), and commercial oatmeal soap (readily available in the market, ST). The results obtained are summarized in **Table 1**.

UCTO exhibited the highest moisture content among the other tested solid soaps. The hardness of the soap is dependent on its total moisture content. The lye solution and water generated throughout the neutralization procedure serve as the water sources. Less than 5% of water added usually results in soap that is excessively hard and tends to crystallize [9]. The addition of colloidal oatmeal in the preparation of the homemade soap has increased the moisture content of UCTO, resulting in a softer soap.

The pH of the samples was also studied. All solid soaps were found to be alkaline due to the usage of lye, which has raised the pH. UCTO with infused colloidal oatmeal has a similar pH (9) to UCOP, while COTO has a higher pH of 10. Soaps with a pH range of 8 to 10 can solidify and cleanse [10]. Higher pH obtained using commercial oil may lead to skin irritation and dehydration and can alter the bacterial flora of the skin [11]. In contrast, ST gave the lowest pH, which is in the acidic range. A soap with a pH lower than 8 will have reduced cleansing power [10].

Antioxidant properties

The antioxidant activity of all samples (UCOP, UCTO, COTO, and ST) was assessed using a DPPH assay. **Table 2** displays the percentage of DPPH radical scavenging against the concentration of samples, including ascorbic acid (AA) as a standard. The findings revealed that all samples were inactive as antioxidants, with IC_{50} values exceeding 2500 ppm, compared to ascorbic acid (IC_{50}: 67.28 ppm). This could be due to the ingredients of the soap, such as lye and oils, which might interact with antioxidant compounds, potentially neutralizing their activity and altering their efficacy [12].

Antifungal properties

Due to the ineffectiveness of the samples as antioxidants, the antifungal properties of the samples were evaluated against *C. albicans*, which is an opportunistic pathogen that can cause skin infections under conducive conditions, making it an important organism to understand in the context of dermatology and infectious diseases [13]. The findings are tabulated in **Table 3**.

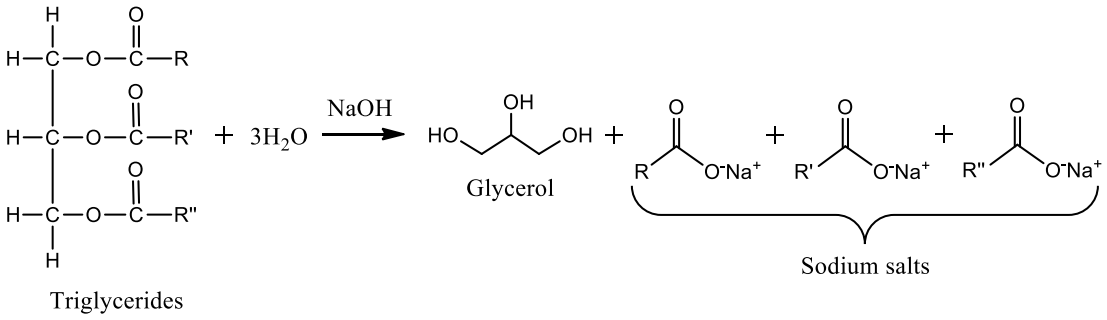

Figure 1. The saponification process of soap

Table 1. Physicochemical properties of soap

Sample	Physical properties	Moisture content %	pH
UCOP	Solid	2.20	9
UCTO	Solid	4.60	9
COTO	Solid	3.01	10
ST	Liquid	79.40	5

Table 2. Percentage of DPPH radical scavenging of soap samples and ascorbic acid at different concentrations

Concentration (ppm)	Percentage of DPPH Radical Scavenging (%)			
	UCOP	UCTO	COTO	ST
2500	ND	ND	12.63	15.68
1250	ND	ND	12.66	15.30
625	ND	ND	12.80	15.13
312.5	ND	ND	12.92	14.70
156.25	ND	ND	12.63	14.36
78.125	ND	ND	13.21	14.53
39.0625	ND	ND	13.11	15.92
19.53125	ND	ND	1.00	0.31
9.765625	ND	ND	ND	ND
0	0	0	0	0

Note: ND = Not detected

Table 3. Inhibition zones of soap samples against *C. albicans*

Samples	Zone of Inhibition (mm)
UCOP	-
UCTO	-
COTO	-
ST	-
Nystatin	-
Sterile Water	-

Note: (-) = No activity

The results showed that all samples, including nystatin, did not inhibit the growth of *C. albicans*. It has been reported that *C. albicans* can form biofilms on surfaces, which are complex structures that protect the yeast cells from antifungal agents [14]. This biofilm formation can hinder the effectiveness of antifungal compounds released from the soap samples in the well diffusion assay. Moreover, the cell wall of *C. albicans* is composed of polysaccharides, such as glucans, mannans, and chitin, which provide structural integrity and protection [15]. These components act as barriers for the antifungal agents in the soap, preventing them from penetrating and effectively inhibiting fungal growth in the assay.

Antibacterial properties

The samples were further investigated for antibacterial activity against Gram-positive *S. aureus* (ATCC 25923) and Gram-negative *E. coli* (ATCC 25922). *S. aureus* is a major cause of various infections, including skin and respiratory infections, as well as food poisoning [16]. On the contrary, *E. coli* is a common cause of urinary tract infections and is often associated with severe foodborne illness [17]. The prevalence of resistant bacterial strains makes it a significant concern in both community and healthcare settings. The results obtained are presented in **Table 4**.

All UCOP, UCTO, COTO, and ST soap samples demonstrated similar antibacterial activity against *S. aureus*, with inhibition zones measuring approximately 5.5 mm at a concentration of 2500 µg/mL. UCO with oatmeal (UCTO) exhibited similar activity compared to the standard antibiotic, streptomycin. In contrast, the effectiveness against *E. coli* varied. UCOP and UCTO showed notable inhibition, with zones measuring 5.5 mm and 6.0 ± 1 mm, respectively, while the standard commercialized soap (ST) did not exhibit any inhibition against *E. coli*. This result indicated that UCO formulations, especially with oatmeal, are more effective against *E. coli* than standard commercial soap. Oats are capable of inhibiting microbial growth due to their various bioactive compounds, including avenanthramides [18]. Avenanthramides, classified as N-cinnamoylanthranilic acids, represent a class of phenolic alkaloid compounds synthesized by oat plants as phytoalexins, which contribute to their inhibitory effect [19].

Table 4. Diameter of inhibition zones of homemade soap samples against *S. aureus* and *E. coli*

Samples	Zone of Inhibition (mm)	
	S. aureus	***E. coli***
UCOP	5.33	5.67
UCTO	5.50	6.00
COTO	5.33	5.17
ST	5.60	-
UCTO + Compound A	8.00	5.67
Streptomycin	5.50	9.00
Sterile water	-	-

Note: (-) = No activity

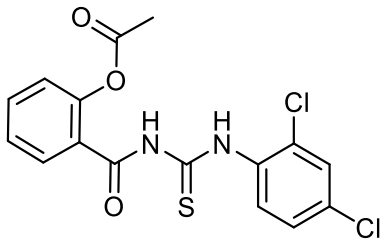

Figure 2. The molecular structure of 2-(((2,4-dichlorophenyl)carbamothioyl)carbamoyl)phenyl acetate (Compound A)

Additionally, a thiourea derivative, Compound A (**Figure 2**), obtained from UniSZA was added to the UCTO mixture to determine the antibacterial activity. The combination of UCTO and Compound A synergistically enhanced antibacterial activity against *S. aureus*, surpassing the efficacy of the standard antibiotic. This increased activity is attributed to the C=O, C=S, and NH groups in the molecular structure of Compound A, which interact with carboxyl and phosphate groups on the bacterial membrane surface [20]. Additionally, the presence of phenyl groups increases the compound's lipophilicity, facilitating more efficient permeation through the microbial membranes [21]. This finding implies that the addition of a thiourea-based compound can enhance the antibacterial activity of homemade soap.

Conclusion

In conclusion, the physicochemical and antibacterial properties of the UCO soap infused with colloidal oatmeal demonstrate potential as an effective cleaning agent. The presence of oatmeal in the UCO soap formulation has effectively inhibited the growth of *S. aureus* and *E. coli*. Additionally, the incorporation of thiourea as an active compound significantly enhanced its antibacterial activity. This homemade soap holds commercial potential and can be further explored in clinical studies, particularly by incorporating antibacterial agents such as thiourea derivatives.

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