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Research Article

Formulation and Antibacterial Evaluation of a Glycerin Soap Incorporated with *Cymbopogon citratus* Essential Oil

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Abstract

Soap remains one of the most widely used hygiene products for reducing microbial contamination of the skin. In recent years, interest has increased in the development of natural antimicrobial agents as alternatives to synthetic antiseptics. The present study aimed to formulate a glycerin-based soap incorporating *Cymbopogon citratus* essential oil and to evaluate its physicochemical properties and antibacterial activity.

Different soap formulations were prepared using coconut oil, sodium hydroxide, glycerin, ethanol, sugar and distilled water. Increasing concentrations of *Cymbopogon citratus* essential oil (0.5–2.5%) were incorporated to obtain formulations S1–S5, while S0 served as the reference formulation without essential oil. The physicochemical properties of the soaps were evaluated by determining pH and foaming capacity. Antibacterial activity was assessed using an experimental contamination model involving sterile gloves inoculated with *Escherichia coli*, followed by washing and microbiological analysis.

The results showed that the formulated soaps exhibited pH values ranging from 9.0 to 12.1. Foaming tests demonstrated satisfactory foaming ability, with the highest foam height observed for formulation S2. Antibacterial evaluation revealed that formulations containing higher concentrations of essential oil (S4 and S5) showed complete inhibition of bacterial growth after washing, comparable to commercial antiseptic soaps.

These findings suggest that incorporation of *Cymbopogon citratus* essential oil into glycerin-based soap may represent a promising approach for developing natural antibacterial cleansing products. Further studies involving additional microorganisms and dermatological tolerance evaluations are recommended.

Keywords: Soap formulation; Glycerin soap; *Cymbopogon citratus*; Essential oil; Antibacterial activity; Natural antiseptic

INTRODUCTION

Soap has been used for centuries as an essential product for personal hygiene. Its action is mainly based on the mechanical removal of dirt and microorganisms present on the skin surface through the action of surfactants formed during the saponification of fatty acids. These surfactants possess an amphiphilic structure that allows the emulsification of lipophilic substances and facilitates their removal during rinsing. This mechanism contributes to reducing the bacterial load on the skin and limiting the transmission of certain pathogenic agents ^{1,2}.

To improve this effectiveness, the incorporation of antiseptic or antimicrobial agents into soap formulations is frequently explored. Among the different galenic

forms, glycerin soaps constitute a particular category characterized by a high glycerin content, either naturally produced during the saponification reaction or added during formulation. Glycerin is a hygroscopic polyol known for its humectant properties, enabling it to attract and retain water within the stratum corneum. This property helps maintain skin hydration and reduce the drying effect often associated with traditional soaps ³. Because of this improved skin tolerance, glycerin soaps are widely used in dermocosmetic formulations intended for frequent use.

Furthermore, the foaming and cleansing properties of soaps depend largely on the nature of the fatty acids present in the oils used. Coconut oil, which is rich in

lauric acid, is particularly appreciated in soap manufacturing because of its ability to produce abundant and stable foam as well as good cleansing properties ⁴.

In the context of the search for natural alternatives to synthetic antiseptics such as triclosan or chlorhexidine, the incorporation of essential oils with antibacterial activity into soap formulations appears to be a promising approach ⁵. Essential oils are generally obtained through physical processes such as steam distillation or hydrodistillation, which allow the extraction of volatile aromatic compounds without the use of organic solvents ⁶. Among these natural substances, the essential oil of *Cymbopogon citratus* (lemongrass) has been widely studied due to its high citral content, mainly composed of geranial and neral, compounds responsible for antibacterial activity against various pathogenic bacteria ⁷.

Objective

The objective of the present study was to formulate a glycerin-based soap incorporating *Cymbopogon citratus* essential oil and to evaluate its physicochemical properties as well as its antibacterial activity.

MATERIALS AND METHODS

Materials

The equipment used for the preparation and evaluation of the formulations included a precision balance, 100 mL and 200 mL beakers, a 50 mL graduated cylinder, 100 mL and 250 mL Erlenmeyer flasks, a 100 mL graduated burette, graduated pipettes, a thermometer, and a pH meter.

Reagents and Raw Materials

The reagents used in this study included sodium hydroxide (lot KZ2334), ethanol (lot 90 Valda), glycerin (lot 77YH, Valdafrique), food-grade sugar (lot: not applicable), and distilled water. The distilled water used for the different preparations was provided by the Toxicology Laboratory of the Faculty of Medicine, Pharmacy and Odontology (FMPO), Cheikh Anta Diop University, Dakar.

The coconut oil used in the soap formulation was obtained from Rahma Cosmétique, a local company specialized in cosmetic products. The essential oil of lemongrass (*Cymbopogon citratus*) was purchased from a pharmacy

Methods

Soap preparation

The amount of sodium hydroxide required for the saponification of the oil was calculated from the saponification value of coconut oil according to the following equation:

$$m_{NaOH} = \frac{IS \times m_{huile} \times 40}{1000 \times 56,1}$$

where **IS** represents the saponification value of the oil (mg KOH/g) and **m_{oil}** represents the mass of oil used (g).

The base formulation of the glycerin soap consisted of 50 g of coconut oil, 9.5 g of sodium hydroxide, 13 g of glycerin, 31 g of ethanol (95°), 24 g of sugar, and 30 g of distilled water ⁸. Based on this reference formulation (S0), different formulations were prepared by incorporating lemongrass essential oil (*Cymbopogon citratus*) at increasing concentrations of 0.5%, 1%, 1.5%, 2%, and 2.5%, corresponding respectively to formulations S1, S2, S3, S4, and S5.

Determination of pH ⁹

Ten grams of soap were weighed and dissolved in distilled water. The volume was adjusted to 100 mL to obtain a soap solution. The pH of this solution was measured using a pH meter (Hanna Instruments, model HI-211). The pH of soaps generally ranges between 8 and 10. A pH lower than 8 usually corresponds to dermatological bars, whereas a pH higher than 10 may cause irritant or corrosive effects on the skin.

Evaluation of Foam Height Variation ¹⁰

This test was used to evaluate the foaming capacity and foam stability of the soaps. One gram of soap was introduced into 100 mL of distilled water contained in a 250 mL Erlenmeyer flask. The mixture was agitated at 250 rpm at a temperature of 80 °C until complete dissolution.

After dissolution, 10 mL of the resulting solution were transferred into a 100 mL graduated cylinder. The cylinder was manually shaken for 15 seconds to produce foam. Foam height was measured immediately (T0) and again after 15 minutes (T15) in distilled water.

Evaluation of Antibacterial Activity

Principle

The antibacterial activity of the soaps was evaluated using an experimental model of artificial contamination of sterile gloves with *Escherichia coli*, followed by a washing step and microbiological analysis to assess the reduction of bacterial load.

Preparation of the Inoculum

Escherichia coli strains were isolated from pathological samples obtained from the microbiology laboratory of Hôpital Général Idrissa Pouye. The bacteria were cultured on nutrient agar for 24 hours at 37 °C.

A bacterial suspension was then prepared in sterile physiological saline solution (NaCl 0.9%). The turbidity of the suspension was adjusted to the 0.5 McFarland standard, corresponding approximately to 1.5×10^8 CFU/mL ¹¹.

Contamination of Gloves

Three milliliters of the bacterial suspension were applied to sterile gloves by friction in order to simulate hand contamination.

Washing Procedure

The contaminated gloves were washed according to the hygienic handwashing technique recommended by the

World Health Organization (WHO) ¹² using the following products:

- Distilled water alone
- Distilled water + ordinary soap
- Distilled water + NOBACTER soap
- Distilled water + VALDA antiseptic soap
- Distilled water + experimental soaps S0–S5 containing different concentrations of *Cymbopogon citratus* essential oil

Microbiological Analysis

After washing, microbiological samples were taken immediately (T0) and 5 minutes after washing (T+5 min). The samples were inoculated onto nutrient agar and incubated at 37 °C for 24 hours ¹³. The resulting bacterial colonies were counted and expressed as colony-forming units (CFU).

Interpretation

The antibacterial activity of the soaps was evaluated by comparing the reduction in the number of colony-forming units (CFU) observed after washing for each tested formulation.

It should be noted that this study did not include the use of a neutralizing agent intended to inactivate the residual activity of the soap before inoculation. However, the main objective of this work was to compare the relative effect of the different soap formulations, particularly the influence of the incorporation of *Cymbopogon citratus* essential oil, as all experimental conditions were kept identical for all samples analyzed.

Therefore, the absence of a neutralizing agent does not affect the comparison between formulations, since the methodology applied was strictly identical for both the control soaps and the soaps containing essential oil. The antibacterial activity observed can thus be interpreted as a comparative indication of the effectiveness of the different formulations.

RESULTS

Appearance of the soaps

All soap formulations showed a similar macroscopic appearance regardless of the concentration of essential oil incorporated. Figure 1 illustrates the appearance of a representative soap containing 4 g of lemongrass essential oil (*Cymbopogon citratus*).



Figure 1: Appearance of the soap

pH of the soaps

The determination of the pH of the soaps yielded the following results.

Table I : pH Soap

Soap	pH (mean ± SD)
S0	12.1 ± 0.1
S1	10.0 ± 0.1
S2	10.0 ± 0.1
S3	9.8 ± 0.1
S4	9.7 ± 0.1
S5	10.1 ± 0.1
Nobacter	9.0 ± 0.1
Valda	9.3 ± 0.1
Ordinary	10.1 ± 0.1

Foaming capacity

The foaming properties of the soaps according to the concentration of essential oil are presented in Table II.

Table II. Foam height of the different soap formulations measured immediately after agitation (T0) and after 15 minutes (T15) (mean ± standard deviation, n = 3).

Soap	T0 (cm)	T15 (cm)
S0	2,0 ± 0,1	2,0 ± 0,0
S1	4,0 ± 0,2	3,5 ± 0,1
S2	7,0 ± 0,3	6,0 ± 0,2
S3	3,0 ± 0,1	2,0 ± 0,1
S4	2,5 ± 0,1	2,5 ± 0,1
S5	2,0 ± 0,1	1,5 ± 0,1
Nobacter	5,4 ± 0,2	5,0 ± 0,1
Valda	5,7 ± 0,2	5,0 ± 0,2
Ordinaire	4,5 ± 0,2	4,0 ± 0,1

Determination of the antibacterial activity of the soaps

The antibacterial activity against *Escherichia coli* yielded the results presented below.

Table III. Antibacterial test on contaminated gloves.

Savons	T0	T5
S0	+	+
S1	+	+
S2	+	+
S3	+	+
S4	-	-
S5	-	-
Savon Valda	-	-
Nobacter	-	-
Savon Ordinaire	+	+
Eau distillée	+	+

+ : bacterial growth

- : absence of bacterial growth

DISCUSSION

The results obtained in this study show that the incorporation of *Cymbopogon citratus* essential oil into a glycerin soap matrix makes it possible to obtain formulations exhibiting satisfactory physicochemical properties as well as notable antibacterial activity.

The pH analysis showed that the different formulations presented values ranging from 9.0 to 12.1. Soaps containing essential oil generally exhibited pH values between 9.7 and 10.1, which are consistent with those commonly observed for alkaline soaps produced by the saponification of vegetable oils. These results are consistent with literature data indicating that traditional soaps generally exhibit pH values between 9 and 10 (9). However, formulation S0 showed a higher pH value (12.1), which may be related to the absence of additives capable of modifying the alkaline balance of the soap matrix. High pH values may promote drying or irritating effects on the skin, highlighting the importance of modified formulations aimed at improving skin tolerance¹⁴.

The study of foaming capacity showed that formulations containing essential oil exhibited variable foam heights. Formulation S2 showed the highest foam height (7.0 cm at T0 and 6.0 cm at T15), indicating good foaming ability and satisfactory foam stability. These results may be attributed to the presence of coconut oil rich in lauric acid, a fatty acid known to promote abundant and stable foam formation in soap formulations⁴. The decrease in foam height between T0 and T15 observed for certain formulations reflects the progressive destabilization of foam, a phenomenon commonly observed in surfactant systems.

The evaluation of antibacterial activity showed that certain formulations containing *Cymbopogon citratus* essential oil exhibited notable activity against *Escherichia coli*. Formulations S4 and S5 showed no bacterial growth after washing, similar to the results observed with the commercial antiseptic soaps tested (Valda and Nobacter). In contrast, formulations containing lower concentrations of essential oil (S0 to S3) did not completely inhibit bacterial growth. These results suggest a relationship between the concentration of essential oil incorporated and the antibacterial activity of the soap.

The antibacterial activity observed may be attributed to the presence of citral in *Cymbopogon citratus* essential oil. This compound, mainly composed of geranial and neral, is recognized for its antimicrobial activity against several pathogenic bacteria, particularly Gram-negative bacteria such as *Escherichia coli*^{5,15}. Essential oils generally exert their antimicrobial activity by disrupting the integrity of bacterial cell membranes, leading to increased membrane permeability and inhibition of certain essential enzymatic functions^{16,17}.

These results confirm the potential interest of incorporating essential oils into soap formulations as natural alternatives to synthetic antiseptics. However, certain limitations should be noted. The study was conducted on a single bacterial species and under

simplified experimental conditions. In addition, the absence of a neutralizing agent before inoculation may have influenced the antibacterial activity observed. Nevertheless, since the experimental conditions were identical for all formulations, the relative comparison between the different soaps remains valid.

Overall, this study highlights the potential of *Cymbopogon citratus* essential oil as a natural antibacterial agent in glycerin soaps. Further studies involving other microorganisms, additional physicochemical analyses, and dermatological tolerance evaluations would help confirm and optimize these findings.

CONCLUSION

This study made it possible to formulate a glycerin soap incorporating different concentrations of *Cymbopogon citratus* essential oil and to evaluate its physicochemical properties as well as its antibacterial activity. The results obtained show that certain formulations, particularly S4 and S5, exhibit notable antibacterial activity against *Escherichia coli*, comparable to that observed with commercial antiseptic soaps. The incorporation of lemongrass essential oil therefore appears to be a promising approach for the development of natural antibacterial soaps. Further studies involving additional microorganisms and more extensive dermatological tolerance evaluations are required to confirm these findings.

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