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Analytical Study of the Physicochemical Parameters and Skin Behavior of a Soap Synthesized from Shea Butter (*Butyrospermum parkii*) and Derivatives of a Naphthalene Fragrance

Adam Bouraima*, Crislain Bissielou, Albert Novy Messi Me Ndong, Phil Lewis Mpampoungou Langama, Grace Christophe Mackaya, Jean Jacques Anguile

Laboratoire de Chimie des Matériaux Inorganiques, Département de Chimie, Faculté des Sciences, Université des Sciences et Techniques de Masuku, Franceville, Gabon
Email: *abourae@yahoo.fr

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Abstract

This study examines the physicochemical properties and effects on the skin of a soap synthesized from shea butter (*Butyrospermum parkii*) and a naphthalene fragrance. This soap is composed of fatty acids derived from fats, extracted by melting at 35˚C in the form of shea butter oil, which consists mainly of oleic and stearic acids forming its lipophilic phase, to which sodium hydroxide (NaOH) is added to form its hydrophilic phase. The combination of shea oil and lye enabled a cold saponification reaction, with a calculated saponification index (SI) of 119 mg/g, in accordance with ISO 3657. Based on this index, a 7% superfat was added to 3.3 mL of water to impart moisturizing, nourishing, and protective properties to the final product. The addition of the naphthalene fragrance served, on the one hand, to mask the strong odor of shea butter and, on the other hand, to improve the product's stability by preserving its antioxidant properties, as evidenced by the results regarding its quality (odor, appearance, color) and its physicochemical parameters (moisture content, pH, yield, density, etc.) in this study.

Keywords

Fragrance, Naphthalene Derivatives, Shea Butter, Lipophilic, Hydrophilic, Superfatting, Antioxidant

1. Introduction

In our daily lives, soaps hold a prominent place among cosmetic products, as their use dates back several millennia and their application, both for skin care and household purposes, remains very widespread [1]. Chemically speaking, soap is a salt resulting from the combination of a fatty acid or, more generally, a mixture of fatty acids, with a strong base such as sodium or potassium hydroxide. This process is known as saponification. Fatty acids, which are components of fats and oils, are converted in the presence of a base into soap and glycerin, the latter being produced as a byproduct. Over time, soap has evolved to meet the needs and expectations of modern consumers. Technological advances have made it possible to develop soaps that are gentler on the skin, enriched with moisturizing agents and natural ingredients. The coronavirus pandemic has also highlighted the importance of soap as part of daily hygiene. Innovations in ingredients and manufacturing processes have led to a wide variety of soaps suited for different uses: antibacterial, moisturizing, for sensitive skin, and more. The purpose of this study is to highlight one of these ingredients, namely shea butter (*Butyrospermum parkii*), which consists of triglycerides containing the following fatty acids: oleic, stearic, linoleic, and palmitic acids. This fat fraction accounts for between 40 and 55 percent of the dry weight of ripe fruits [2]. The use of this ingredient as a raw material, combined with the incorporation of naphthalene fragrance derivatives, gives the soap its stability as well as its olfactory properties, which constitutes the originality of the synthesis process for the new product thus obtained. Furthermore, the unsaponifiable fraction of shea butter appears to be particularly significant compared to other fats, leading some researchers to assert that this fraction, which possesses anti-inflammatory and antioxidant properties, can be leveraged in the field of skincare [3]-[5], particularly due to its well-established moisturizing and emollient properties [6]. Given all the remarkable properties of shea butter, it has become a favorite ingredient in cold-process soap making. Its high content of fatty acids and unsaponifiables gives it the ability to impart firmness, softness, and nourishing properties to soaps. Furthermore, cold process soap-making using raw shea butter produces a superfatted soap that is particularly rich in active ingredients and perfectly suited for sensitive skin.

2. Materials and Methods

2.1. Materials

For the purposes of our study, the materials used fall into two main categories: products and measuring devices. The products used include a fragrance derivative, specifically 2-methoxynaphthalene (C11H10O), which is supplied by Merck in the form of white crystals with a purity of 99%, as well as shea butter, 50% CHARLAU brand extra-pure caustic soda, and distilled water. As for the equipment, we used a CE-brand precision pH meter, a DB-1A-type precision hot plate with a maximum temperature of 400˚C, and an S.METTER-brand precision ana-

lytical balance with a maximum capacity of 500 g. In addition, an agate mortar for grinding the fragrance, a spatula, and Pyrex beakers were also used throughout our work.

2.2. Synthesis Method

The new soap that is the subject of this study was produced using the cold saponification method. First, 10 g of shea butter was weighed out and heated to 35˚C to extract the fatty acids it contains. Next, 3.3 mL of distilled water was mixed with 1.19 g of NaOH that had been weighed out beforehand, resulting in a lye solution. This solution was then added to the shea butter, and the mixture was homogenized using a wooden spatula until a high-density solution was obtained. Next, 0.4 g of fragrance derivative was added to the mixture, which was stirred until a homogeneous preparation was obtained. The reaction mixture was finally poured into a mold and then dried, resulting in a pale yellow soap.

2.3. Qualitative Analysis of the Soap

The new soap developed during this study is pale yellow in color and has a solid texture (see Figure 1), while also offering remarkable lathering power and a pleasant fragrance.



Figure 1. Pale yellow soap.

2.4. Study of pH Variation in Soap

As part of the pH variation tests, three trials were conducted: the first during the first week of curing, the second two weeks later, and the third after 27 days of curing. For each of these tests, conducted at room temperature, samples weighing 0.5 g, 0.8 g, and 1 g were successively dissolved, during the specified time periods, in 100 mL of distilled water contained in a volumetric flask, before the pH meter electrode which had been previously calibrated was inserted into the flask. The values obtained are recorded in Table 1.

The pH value obtained after 27 days was 9.52, confirming the completion of the

curing phase, since, in accordance with ISO 4316, a soap of satisfactory quality has a pH that stabilizes between 9 and 10.5. In addition, each test was repeated more than ten times at different intervals with varying concentrations. The results recorded in Table 1 were confirmed. Variations in concentration and curing time may explain the observed differences in pH values.

Table 1. pH values obtained.

	The week of waiting essay	Test after a 2-week treatment	After a 27-day treatment
pH	11.03	9.97	9.52

2.5. Foaming Test

To evaluate foaming ability, 1 g of soap with a pH of 9.52 was added to a 250-mL graduated cylinder containing 250 mL of distilled water; the mixture was then shaken vigorously for approximately 2 minutes to generate foam. After agitation, the height of the foam was measured, and the sample was then allowed to stand for 5 minutes to observe the foam's stability [7].

2.6. Determination of Moisture Content

To determine the water content of the soap studied in this work, a 5-gram sample was taken and weighed using a crucible and a previously calibrated analytical balance, and then heated to 100˚C until a constant mass was obtained [8]. The moisture content (H) was then calculated using the following formula [9]:

$$H(\%) = \frac{W_2 - W_1}{W} \times 100 . \quad (1)$$

where:

W_2 = mass of the dry crucible + soap sample;

W_1 = mass of the dry crucible + dry soap;

W = mass of the soap used.

2.7. Determination of the Saponification Index

To determine the saponification index, we followed ISO 3657 to establish the saponification index of the soap under study. To this end, we performed an acid-base titration. First, we prepared a 0.5 mol/L hydrochloric acid solution, then calculated the mass of NaOH (1.19 g) required to saponify 10 g of shea butter. During the titration, phenolphthalein was used as a color indicator. The saponification index was then calculated using the formula shown below.

$$I_S = \frac{(V_a - V_b) \times 40 \times 0.5}{10} . \quad (2)$$

where:

V_a is the volume in mL of HCl for the blank titration;

V_b is the volume in mL of HCl for the titration of our sample;

C: concentration of HCl;

m: mass in g of our shea butter.

3. Results and Discussion

The values of the various physicochemical parameters obtained from the analysis of the soap studied in this work are presented in Table 2.

Table 2. Physicochemical properties of soap formulated with shea butter and a fragrance agent.

	pH	H(%)	I_S
Savon	9.52	12.58	119 mg/g

In addition to the pH and saponification index values determined experimentally, the moisture content shown in Table 2 was calculated using the formula proposed by Owoicho I. (2021). To this end, a mass ratio was established in accordance with Equation 1. The result obtained, 12.58%, is consistent with the requirements of ISO 672, which does not define a threshold value but specifies the measurement method, as well as with data from the literature, which indicate that the residual moisture content of a cold-processed solid soap, after its curing period, generally ranges between 10% and 15%.

3.1. pH of the Soap Synthesized from Shea Butter and Derivatives of a Naphthalene Fragrance

The pH value measured after 27 days of curing was 9.52. This soap, made from shea oil, has a basic pH resulting from hydrolysis in an aqueous medium between the salt of a weak acid (fatty acid) and a strong base, in this case NaOH. This pH value is higher than those reported by MakMensah and Firempong (2011) [10] for toilet soaps made from neem seed oil, which ranged from 5.5 to 8.0. Numerous authors have reported basic pH values similar to those obtained in the present study [11] [12]. Although basicity enhances cleansing power, a basic pH leads to the neutralization of the skin's protective hydrolipid film [13].

3.2. Moisture Content of Soap Synthesized from Shea Butter and Naphthalene Fragrance Derivatives

Water content has a significant influence on a soap's hardness as well as its shelf life. Indeed, a high moisture content in soap can cause the unsaponified triglycerides to undergo hydrolysis due to excess water, leading to the formation of free fatty acids and glycerol during storage [8]. The moisture content value obtained for the soap studied here is consistent with those reported by several authors (Kuntom *et al.*, 1999; Oyekunle *et al.*, 2021; Osuji *et al.*, 2013; Habib *et al.*, 2016; Mahesar *et al.*, 2019) [14]-[18]. The content of 12.58% obtained in this study remains lower than that reported by Habib *et al.* (2016), who recorded a value of approximately 21.06% for a soap from Bangladesh. This content is nevertheless significantly lower than that reported by Ogunsuyi and Akinnawo (2012), who

obtained a value of 29.05% for a soap made from coconut oil saponified using palm frond ash lye; this difference can be explained by the quality of the fatty acids used, the superfat content, and the saponification index.

3.3. Foaming Power of a Synthetic Soap Made from Shea Butter and Naphthalene Fragrance Derivatives

Table 3. Performance of the soap formulated with shea butter and a fragrance.

Foam heigh	60 ml
Foam stability	55 ml

The foam produced by the soap developed in this study was evaluated using a graduated cylinder, in accordance with the protocol defined by ISO 696, which allows for the measurement of both the volume and the stability of the foam produced. The results, shown in **Table 3**, are comparable to those reported by Wara *et al.* (2020).

3.4. Skin Assessment Method

To evaluate the skin properties of the soap under study, a sample of 100 individuals was recruited from the villages of Benguia I, Benguia II, and Mvemgué. Following a week of community outreach about the soap made from shea butter and scented with naphthalene, the individuals contacted volunteered to participate in the evaluation test. Thus, 15 participants were selected in Benguia I, 30 in Benguia II, and 55 in Mvemgué, for a total of 100 people tested, ranging in age from 20 to 55 years. After ten weeks of use, they were given a questionnaire consisting of three questions, in which they were asked to check one of the boxes corresponding to the three trials conducted during the specified period. The questionnaire addressed the following aspects: Does the soap cause itching or skin redness? Are you satisfied with the product? Is the soap hazardous?

3.5. Effect on the Skin of a Synthetic Soap Made from Shea Butter and Naphthalene Fragrance Derivatives

The originality of this study lies in the incorporation of naphthalene fragrance derivatives into the synthesis process of a soap formulated with shea butter. The evaluation of this product, conducted with a panel of 100 participants aged 20 to 55 and carried out over three series of tests, revealed no adverse effects on the skin (see **Figure 2**). Furthermore, to date, no scientific publication identified in the literature addresses this specific issue. However, the work of Ankica Smeh-Skrbin (2007) confirms that naphthalene is used in the treatment of atopic dermatitis, a chronic and recurrent inflammatory skin condition whose prevalence is steadily increasing across all age groups. This research on its use in the treatment of psoriasis has highlighted its anti-inflammatory and antiproliferative properties, as well as a satisfactory and prolonged remission lasting several months in more than 70% of treated patients [19]. In this regard, the incorporation of naphthalene-

based fragrance derivatives into a shea butter-based soap creates a particularly interesting synergy, combining olfactory properties with targeted dermatological and therapeutic effects, including antimicrobial and anti-inflammatory effects conferred by the naphthalene structure, as well as intensive moisturizing protection provided by shea butter, the antibacterial properties of which have yet to be demonstrated. When combined, these components prove effective in reducing redness and alleviating the discomfort characteristic of skin prone to chronic irritation. Active naphthalene derivatives help stabilize keratinization, that is, the process of skin cell renewal, and promote healing. Their beneficial effect on the appearance of thickened or scaly skin, as observed in cases of mild eczema, is also documented in the scientific literature. It should be noted, however, that naphthalene in its pure form is highly toxic and is therefore excluded from cosmetic formulations. On the other hand, its derivatives used in perfumery, such as neroline, which releases notes of orange blossom, or methyl-beta-naphthyl ketone, which adds woody nuances, undergo structural modifications that give them excellent fragrance retention without causing skin irritation, while ensuring a stable and enveloping fragrance capable of masking the sometimes pronounced odor of raw shea butter.

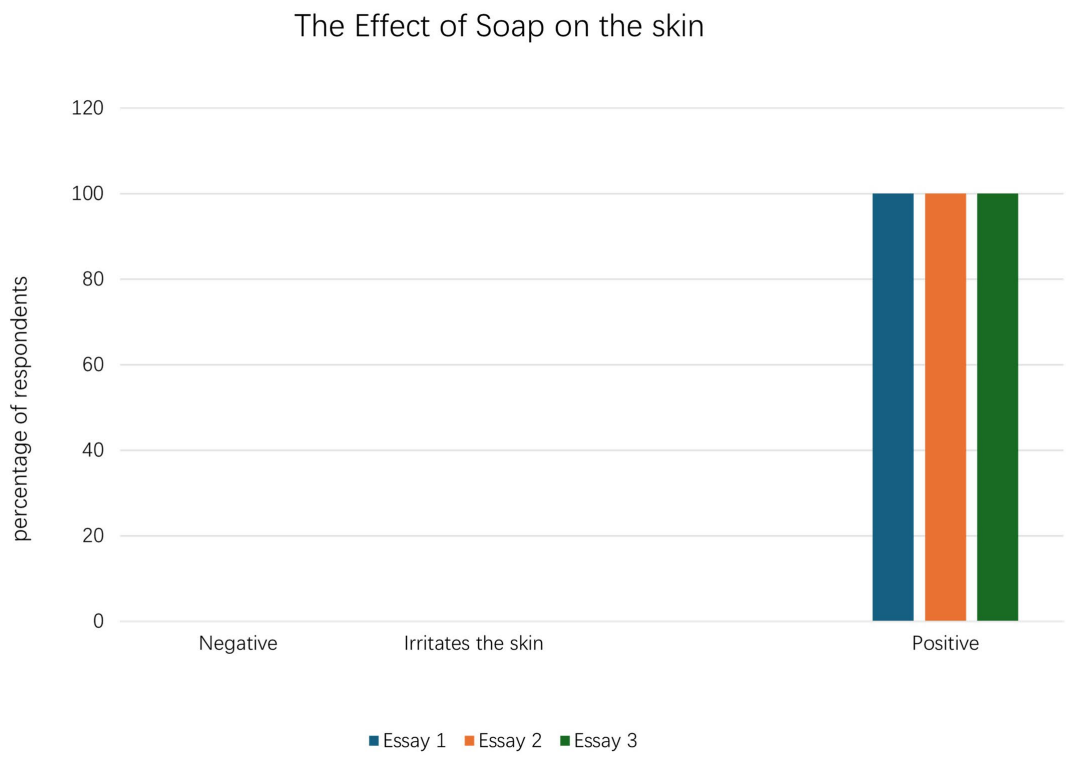

Figure 2. Results of the study on the impact of soap on the skin.

4. Conclusion

The results obtained in this study were compared with data from the scientific literature, leading to the conclusion that the soap synthesized from shea butter

and naphthalene fragrance derivatives exhibits a pH, moisture content, foaming capacity, and saponification index that comply with established scientific standards. The incorporation of fragrance derivatives revealed no adverse effects on the panel of test subjects. The data collected and the methods employed collectively attest to the remarkable quality of this soap.

Author Contributions

Conceptualization, Adam Bouraima. and Grace Christophe Mackaya; methodology, Adam Bouraima; software, Crislain Bissielou; validation, Adam Bouraima, Albert Novy Messi Me Ndong, and Phil Lewis Mpampoungou Langama; formal analysis, Jean Jacques Anguile; investigation, Grace Christophe Mackaya; resources, LACMI; data curation, Grace Christophe Mackaya; writing—original draft preparation, Adam Bouraima; supervision, Jean Jacques Anguile. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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