Chemical and Antimicrobial Characterization of Soap Produced from Rubber Seed Oil (*Hevea brasiliensis*) in Côte d'Ivoire

Abstract

Agricultural diversification is a major challenge for the economic sustainability of Côte d'Ivoire, particularly through the valorization of by-products derived from industrial crops such as rubber (*Hevea brasiliensis*). Rubber seeds, long considered agricultural waste, are now recognized as an important source of vegetable oil suitable for soap production. This study aimed to produce soap from rubber seed oil and to evaluate its physicochemical and antimicrobial properties. The oil was extracted by mechanical pressing and characterized using standardized analytical methods. Soap was formulated by cold saponification and subjected to chemical analyses, contaminant screening, and antimicrobial tests against *Staphylococcus aureus, Klebsiella pneumoniae*, and *Saccharomyces cerevisiae*.

Results showed that rubber seed oil exhibited a high saponification value (197.43 mg KOH/g) and a low peroxide value (3 meq O_2/kg), indicating good suitability for soap making. The resulting soap displayed a high total fatty matter content (91.0%), satisfactory foaming capacity (586.30 mL), and low free alkali content (0.1%). No heavy metals or harmful skin-lightening agents were detected. The soap also demonstrated significant antimicrobial activity. These findings highlight the potential of rubber seed oil as a raw material for soap production and emphasize its importance for agro-industrial diversification and sustainable development.

Keywords:*Hevea brasiliensis*; rubber seed oil; soap; physicochemical properties; antimicrobial activity.

1. Introduction

Agricultural diversification policies implemented in Côte d'Ivoire have promoted the development of alternative industrial crops, among which rubber (*Hevea brasiliensis*) occupies a strategic position in the national economy [1,2]. Although latex remains the main product of this sector, the processing of by-products, particularly seeds, represents a promising pathway for value addition and income diversification for producers [3].

Rubber seeds, long considered agricultural waste, are rich in lipids and constitute a potential source of vegetable oil that can be exploited in various industrial sectors, including soap making, cosmetics, and biofuels [4,5]. Several studies have shown that rubber seed oil possesses physicochemical properties compatible with industrial applications, particularly a high saponification value favorable for soap production [6,7].

However, due to its generally high acid value, rubber seed oil is unsuitable for human consumption. This characteristic nevertheless constitutes an advantage for non-food applications such as soap production, where free fatty acids directly participate in the saponification reaction [8,9]. Recent studies conducted in Côte d'Ivoire have also demonstrated variability in the physicochemical properties of rubber seed oil depending on the clone, confirming its strong agro-industrial valorization potential [10,11].

Soap remains an essential hygiene product whose effectiveness depends on both the type of oil used and the saponification conditions [12]. Several authors have reported that soaps formulated from vegetable oils may exhibit good cleaning properties as well as intrinsic antimicrobial activity related to fatty acids and their salts [13,14]. However, in Côte d'Ivoire, scientific studies focusing on soap production from rubber seed oil and the evaluation of its properties remain limited.

This study therefore aimed to produce soap from rubber seed oil and to characterize its physicochemical properties, chemical safety, and antimicrobial activity in order to contribute to the sustainable valorization of this agricultural by-product.

2. Materials and Methods

Rubber seeds were collected from plantations at the Bimbresso Research Station of the National Center for Agronomic Research (CNRA), Côte d'Ivoire. The oil was extracted by mechanical pressing after drying and roasting of the seeds, in accordance with procedures described for tropical vegetable oils [4,6,8]. The physicochemical parameters of the oil (density, pH, moisture content, unsaponifiable matter, iodine value, peroxide value, acid value, and saponification value) were determined using standardized AOAC methods [12,13] and international recommendations [16].

Soap production was carried out using the cold saponification method. Briefly, 300 g of water were measured and poured into a container, followed by the addition of 140 g of sodium hydroxide (NaOH), and the mixture was stirred slowly. The resulting solution was allowed to cool. After dissolution of the sodium hydroxide in water, the alkaline solution was poured into 1000 g of oil and mixed until a thick consistency (trace) was obtained. Subsequently, 50 g of colorants (green and orange) were added after reaching trace and mixed until a uniform mixture was obtained. The soap paste was then scooped using a plastic ladle and poured into molds, taking care to avoid the formation of air bubbles. After molding, the soap was left to rest for 48 h in an isolated place and unmolded once hardened. The soap was then cured in a dry and ventilated area for 4 to 6 weeks (Figure 1).

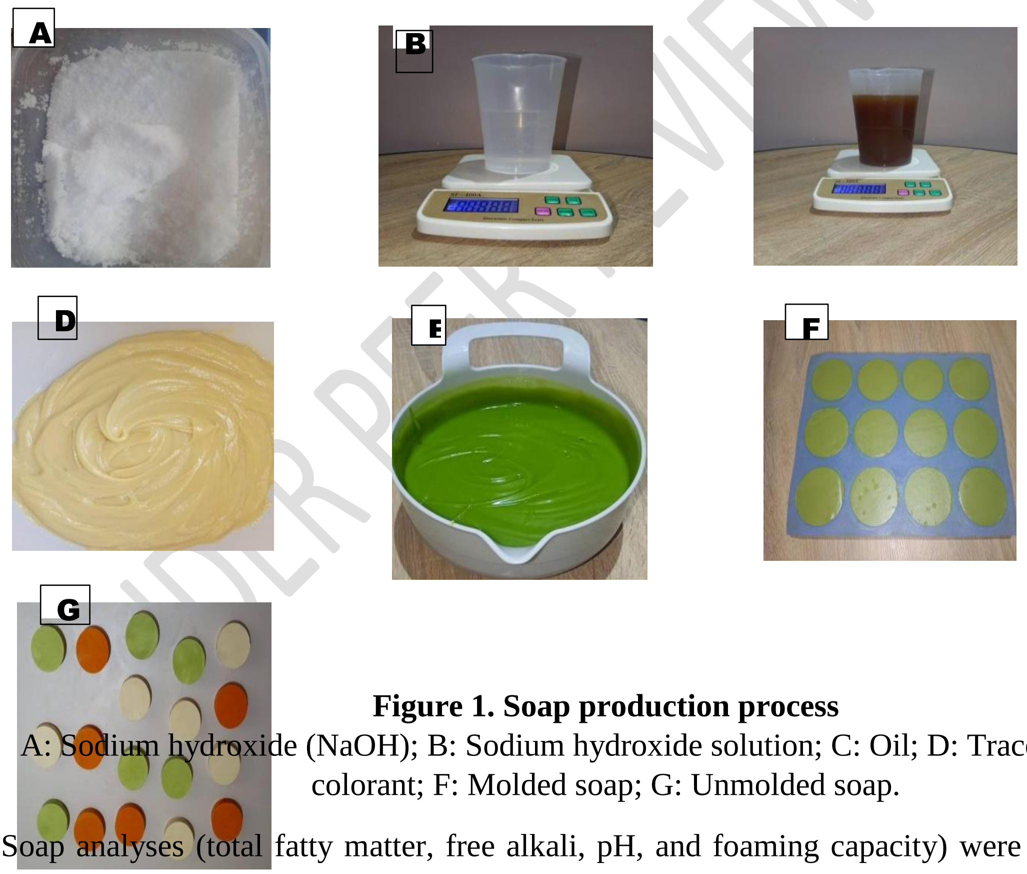

Figure 1. Soap production process

A: Sodium hydroxide (NaOH); B: Sodium hydroxide solution; C: Oil; D: Trace; E: Trace + colorant; F: Molded soap; G: Unmolded soap.

Soap analyses (total fatty matter, free alkali, pH, and foaming capacity) were carried out in accordance with ISO standards [14,15]. Antimicrobial activity was evaluated against *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Saccharomyces cerevisiae* using methods commonly applied for the assessment of hygiene products [10,11,19].

3. Results

3.1. Physicochemical characterization of rubber seed oil

The physical parameters of rubber seed oil are presented in Table I. The analysis showed that rubber seed oil contains 0.45% unsaponifiable matter, a slightly neutral pH of 6.3 at a temperature of 24.3 °C. The observed density was 0.92 at 25 °C, with a moisture and volatile matter content of 0.29%. The refractive index was 1.47.

The chemical parameters of rubber seed oil are presented in Table II. The analysis indicates that rubber seed oil has an iodine value of 171.77 g I_2/100 g, a measured peroxide value of 4.84 meq/kg, a saponification value of 197.43 mg KOH/g, an ester value of 133.65 mg/g, and an acid value estimated at 63.78 mg KOH/g.

Table I. Physical parameters of rubber seed oil

Parameters	**Unsaponifiablematter (%)**	**pH / Temperature (°C)**	**Density at 25 °C**	**Moisture and volatile matter (%)**	**Refractive index**
Mean value	0.45	6.3 at 24.3 °C	0.9221	0.29	1.47394
Specifications (CXS 210-1999)	Specific to eachoil	Specific to eachoil	0.91–0.93	0.2%	Specific to eachoil

Table II. Chemical parameters of rubber seed oil

Parameters	**Iodine value (g I_2/100 g)**	**Peroxide value (meq/kg)**	**Saponification value (mg KOH/g)**	**Ester value (mg/g)**	**Acid value (mg KOH/g)**
Content	171.77	4.84	197.43	133.65	63.78
Specification (CXS 210-1999)	Specific to eachoil	≤ 15	Determines the amount of alkali required	Specific to eachoil	≤ 4

3.2.1. Chemical parameters

The chemical parameters of the soap produced from rubber seed oil are presented in Table III. The results indicate that the soap contains 11.4% ethanol-insoluble matter. The free caustic alkali content, expressed as NaOH, is 0.1%, while the total fatty matter content is 91.0%. The chloride content is 1.0%, and the unsaponified and unsaponifiable matter is 0.9%. The analytical results also show that, at 22 °C, the soap has a pH of 10.3 and a foaming capacity of 586.3 mL.

Parameters	pH at 22 °C	Foamingcapacity (mL)	Ethanol-insoluble matter (% m/m)	Free caustic alkali as NaOH (% m/m)	Total fatty matter (% m/m)	Chlorides (%)	Unsaponified and unsaponifiable matter (% m/m)
Content	10.3	586.3	11.4	0.1	91.0	1.0	0.9
Specifications (NI 5517:2023)	4–8	500–700	≤ 17.8	≤ 0.15	≥ 60.0	≤ 1.0	≤ 1.1

3.3. Heavy metal analysis in the soap

The analytical results reveal that the soap produced from rubber seed oil does not contain heavy metals, namely arsenic, mercury, copper, cadmium, and lead (Table IV).

Table IV. Heavy metals in soap produced from rubber seed oil

Parameter	Arsenic (µg/L)	Mercury (µg/L)	Copper (µg/L)	Cadmium (µg/L)	Lead (µg/L)
Results	< 1 LD	< 2.92 LD	< 1–5 LD	< 0.3 LD	< 1.85 LD

LD:limit of detection

3.4. Analysis of skin-lightening additives

The skin-lightening agents analyzed are presented in Table V. The analysis showed that the soap produced from rubber seed oil does not contain skin-lightening agents such as kojic acid, hydroquinone, or clobetasol.

Table V. Skin-lightening agents in soap produced from rubber seed oil

Parameter	Kojicacid	Hydroquinone	Clobetasol
Results	Absent	Absent	Absent

3.5. Antimicrobial characterization

The parameters of the microbiological analyses of the soap are presented in Table VI. The analysis revealed that the soap produced from rubber seed oil exhibits intrinsic inhibitory activity (–) against the tested strains (*Staphylococcus aureus* ATCC 25923, *Klebsiella pneumoniae* ATCC 13883, and *Saccharomyces cerevisiae* ATCC 9763).

Table VI. Action of soap produced from rubber seed oil on microorganisms

Testedstrains	***Staphylococcus aureus* ATCC 25923**	***Klebsiella pneumoniae* ATCC 13883**	***Saccharomyces cerevisiae* ATCC 9763**
Results	(–)	(–)	(–)

(+): Absence of intrinsic inhibitory activity, growth of the microbial strain in the vicinity of the sample
(–): Presence of intrinsic inhibitory activity, no growth of the microbial strain in the vicinity of the sample

4. Discussion

Physicochemical properties of rubber seed oil

The high saponification value recorded in this study (197.43 mg KOH/g) is characteristic of oils rich in medium- and long-chain fatty acids and indicates good suitability for the saponification reaction. Similar values have been reported for rubber seed oil by Devi et al. [8], Abdulkadir et al. [9], and more recently by Okoma et al. [12,13], confirming the compatibility of this oil with soap-making and oleochemical processes.

The relatively low peroxide value (4.84 meq O_2/kg) indicates acceptable oxidative stability of the oil, well below the maximum limit recommended by the Codex Alimentarius for vegetable oils [17]. This low level of primary oxidation products is comparable to values reported in other studies on rubber seed oil and suggests that the extraction process and storage conditions helped limit oxidative rancidity phenomena [8,10].

In contrast, the high acid value observed (63.78 mg KOH/g) confirms that rubber seed oil is not suitable for human consumption, as also reported by Aigbodion et al. [9] and Maliki and Ifijen [18]. This high acidity is generally attributed to the action of endogenous lipases during seed storage prior to extraction, promoting the hydrolysis of triglycerides into free fatty acids [10]. However, this characteristic does not constitute a drawback for soap production; on the contrary, the presence of free fatty acids can facilitate the saponification reaction and improve process efficiency [14].

The high iodine value (171.77 g I_2/100 g) classifies rubber seed oil among drying oils, comparable to linseed oil, which are known for their richness in unsaturated fatty acids [17]. This composition explains both the oil's sensitivity to oxidation and its relevance for various industrial applications, including soap making, biofuels, and certain cosmetic formulations [6,7,12].

Physicochemical quality of soap produced from rubber seed oil

The soap formulated from rubber seed oil exhibited a high total fatty matter content (91.0%), well above the minimum value recommended by the Ivorian standard NI 5517:2023. This result reflects effective saponification and is comparable to those obtained for soaps based on tropical vegetable oils such as palm kernel, cottonseed, or jatropha oils [15,19]. High total fatty matter content is generally associated with good emollient properties and improved skin protection.

The low free caustic alkali content (0.1%) observed is an important indicator of soap quality. It reflects an appropriate oil-to-alkali ratio and limits the risk of skin irritation, as reported in several studies on artisanal and industrial soaps [14,20]. This value complies with regulatory specifications and is comparable to those reported for high-quality vegetable oil-based soaps.

The high foaming capacity (586.30 mL) meets normative requirements (500–700 mL) and is comparable to that of soaps formulated from vegetable oils rich in unsaturated fatty acids [15]. Foaming ability is a property highly valued by consumers and contributes to the perceived effectiveness of the soap during cleaning.

The alkaline pH of the soap (10.3), although outside the range recommended by certain standards (4–8), remains characteristic of traditional solid soaps. Similar values have been reported for several commercial and artisanal soaps without major adverse effects, particularly when the soap contains superfat or glycerin [21]. Nevertheless, future optimization of the formulation, through increased superfatting or incorporation of natural moisturizing agents, could improve skin tolerance, especially for sensitive skin.

Chemical safety and antimicrobial activity

The absence of heavy metals (arsenic, mercury, copper, cadmium, and lead) and harmful skin-lightening agents represents a major result in terms of sanitary safety. These substances, often found in some uncontrolled artisanal soaps, may pose significant toxicological risks to human health [22]. The results obtained therefore confirm the chemical safety of soap produced from rubber seed oil.

Microbiological assays revealed intrinsic inhibitory activity of the soap against *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Saccharomyces cerevisiae*. This antimicrobial activity is consistent with the findings of Hamlat et al. [15] and Yakoubi et al. [16], who reported that vegetable oil-based soaps can exert antimicrobial effects through disruption of microbial cell membranes by fatty acids and their salts. These results confer particular interest to the studied soap for hygienic applications, especially in rural areas where access to industrial hygiene products may be limited.

Conclusion and Perspectives

This study demonstrated the potential for valorizing rubber seeds (*Hevea brasiliensis*) through the production of soap from extracted oil. The results showed that despite its high acidity, which makes the oil unsuitable for human consumption, its physicochemical properties—particularly a high saponification value and acceptable oxidative stability—make it highly suitable for soap-making applications.

The soap produced from this oil exhibited physicochemical characteristics that largely comply with regulatory requirements, including high total fatty matter content, satisfactory foaming capacity, and low free caustic alkali content, indicating effective saponification and good product quality. Although the soap showed an alkaline pH, this feature remains comparable to many traditional solid soaps and could be improved through formulation optimization, particularly by increasing superfat content or incorporating natural moisturizing agents.

The absence of heavy metals and harmful skin-lightening agents constitutes a major advantage in terms of chemical safety, while the observed antimicrobial activity against *Staphylococcus aureus*, *Klebsiella pneumoniae*, and *Saccharomyces cerevisiae* enhances the soap's relevance for hygienic applications. These findings reinforce the importance of local transformation of rubber seeds into value-added products, contributing to agro-industrial diversification and reduction of waste from the rubber sector.

In perspective, further studies could focus on optimizing oil refining conditions to reduce acid value, improving soap formulation for better skin tolerance, and conducting dermatological evaluations and consumer acceptability studies. In the long term, the establishment of local processing units for rubber seed soap production could represent a sustainable economic opportunity, particularly for rubber-producing rural areas in Côte d'Ivoire.

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