J Biochem Technol (2024) 15(1): 6-11
https://doi.org/10.51847/phjK0zhlEe
ISSN: 0974-2328

Synthesis, Preparation, and Characterization of Natural Soaps from Some Selected Plant Extracts

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Received: 23 October 2023 / Received in revised form: 24 February 2024, Accepted: 28 February 2024, Published online: 15 March 2024

Abstract

Natural and sustainable alternatives are becoming more and more popular as people become more conscious of the negative impacts that synthetic chemicals have on their health and the environment. Making soap from plant extracts became more popular in these circumstances. The current study aims to characterise and investigate the physico-chemical and antimicrobial properties of synthesized natural soaps. The properties such as pH, volatile matter, total fatty matter, and antibacterial activity of the soaps were measured and compared to those of commercial soaps that are available in the market. The agar-disc diffusion method was used to evaluate the antimicrobial efficacy of these natural soaps against certain microorganisms. According to results, soap types such as neem and beetroot (NB) soap, sandal and turmeric (ST) soap, commercial soap 1 (CS1), commercial soap 2 (CS2), and commercial soap 3 (CS3) had shown significant zones of inhibition. Some soap types did not exhibit any inhibitory zone against certain microorganisms. As per the results, it was concluded that the soaps made from neem and beetroot (NB) and sandal and turmeric (ST) had high antimicrobial qualities, effective alkaline pH (9.3), less volatile matter (6%), low alkaline content (3.5), and grade 1 total fatty matter (77%). As a result, both soaps are amenable to industrial production.

Keywords: Natural soaps, Plant extracts, Saponification, Characterization, Antimicrobial activity

Introduction

Conventional soaps typically include harsh chemicals and artificial additions that can be harmful to the environment and human health. However, natural soaps offer a skin and environmentally-friendly substitute. In small to medium-sized handmade soap businesses, there is a growing demand for natural ingredients in cosmetic and personal skin care products (Prieto Vidal *et al*., 2018). According to Chirani *et al*. (2021) soaps and detergents dissolve surface impurities on the skin, eliminate the lipid bilayer membrane enclosing the microorganisms, and render them inactive. To preserve cleanliness and aesthetic appeal, soaps are used to remove dirt, stains, bacteria, and odours (Kegbunam *et al*., 2013). Large amounts of chemical components enter the environment as a result of the increased use of synthetic detergents and soaps, particularly during the pandemic (Kalbusch *et al*., 2020). For the safety of the environment and people, it is therefore necessary to make eco-friendly soaps and detergents using natural, biodegradable, and sustainable chemicals. Natural soaps are more in line with nature since they don't generate any hazardous waste or by-products and use less energy during production (Maotsela *et al*., 2019). For this reason, using natural plant-based components is essential when making handmade or natural soaps.

The human skin is the largest organ in the body and covers the outside of the body to prevent infections in the interior organs. By creating a physical barrier against water, it prevents the growth of bacteria, fungi, viruses, and parasites (Grice *et al*., 2008). Washing the skin's surface with antiseptic soap promotes wound healing and the restoration of skin continuity by warding off pathogenic microorganisms such as *Pseudomonas aeruginosa*, *Escherichia coli*, and *Staphylococcus aureus* (Teniola *et al*., 2019). Certain plant or herb extracts have been used in various forms for human usage because of their excellent anti-inflammatory, antibacterial, antioxidant, and antifungal capabilities (Masdar *et al*., 2020; Thirunavukkarasu *et al*., 2020). Around 65 to 85% of organisms can be eliminated from the human body or skin with antimicrobial soaps. Many environmental microorganisms, such as *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, and *Pseudomonas aeruginosa*, are deposited on the skin's surface and can cause infections (Mariani & Galvan, 2023; Zegadło *et al*., 2023). The use of soaps with antimicrobial properties can stop the spread of infections brought on by these bacteria. Natural soap can be used regularly in addition to being utilised to cure bacterial illnesses (Nisha & Kumar, 2021). A variety of illnesses and disorders have been treated with extracts made from medicinal plants. The active ingredients that have such therapeutic benefits are applied topicall y in the form of soaps, oils, lotions, and ointments to treat skin conditions for both antimicrobial and

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cosmetic reasons (Barnes *et al*., 2021). For example, neem is a powerful disinfectant and can treat skin conditions caused by fungi. It also has excellent antifungal and antibacterial qualities. Dried neem (Azadirachta indica) and basil (Ocimum basilicum) leaf extracts are utilised as one of the soap bar's ingredients. Dry neem leaves are utilised as a natural antioxidant remedy for skin conditions (Rudra *et al*., 2019). Dried basil leaf extracts not only moisturise and nourish the skin but also have anti-acne qualities. Pomegranates, or Punica granatum, are frequently included in cosmetic goods, such as antiseptic soaps (Maphetu *et al*., 2022). Pomegranate plant parts, including the fruit, blossoms, leaves, and bark, have been used to cure a variety of illnesses, including arthritis, respiratory conditions, haemorrhage, diarrhoea, and skin conditions.

Several variables, including temperature, pH, volatile matter, kind of oil or fat, total fatty matter (TFM), and fatty acid makeup, affect how well soap performs. According to Rasaretnam and Venujah (2019), components that do not dissolve in soap are considered to be foreign compounds and should be decreased or eliminated to mitigate any negative consequences. Volatile matter is the term used to describe the extremely volatile ingredients found in soap. High-volatile matter soaps are regarded as lower-quality soaps (Shroff *et al*., 2018). Soaps are typically categorised according to their total fatty matter (TFM), which is another important aspect that determines the quality of the soap. Based on TFM content, soaps are divided into three classifications as per the Bureau of Indian Standards. Soap is classified as grade I if its TFM is greater than 76%, grade II if its TFM is greater than 60%, and grade III if its TFM is greater than 50%. To estimate the soap's quality and cleansing activity, all of these parameters must be determined.

This work aimed to use plant extracts with known health benefits to aid in the creation of natural and sustainable soap compositions. We also aimed to develop natural soaps from plant extracts, evaluate the physical and chemical characteristics of natural soaps and compare them to commercial soaps, and ascertain the natural soaps' antimicrobial qualities against bacteria like *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Staphylococcus aureus*, and *Escherichia coli* that are present on the skin's surface.

Materials and Methods

Materials

The following natural ingredients were used to prepare the natural soaps: glycerine, castor oil, neem oil, almond oil, rose essential oil, sandalwood essential oil, honey, coffee powder, dried beetroot powder, turmeric powder, and rose petals soap base.

Sandal and Turmeric Soap Preparation

The soap base was first melted for one minute at 40–55^{0}C using the double boiler method. Afterward, added the sandalwood and turmeric in a 3:1 proportion and then included a few drops of sandalwood essential oil, one vitamin E capsule, and five to ten drops of rose water, glycerin, and castor oil. Ensure that all the components are thoroughly mixed and no lumps formation occurs. Once the liquid mixture thickens after five minutes, turn off the heat and pour the mixture into moulds. Let the soap harden for four to five hours.

Neem and Beetroot Soap Preparation

Beetroots were gathered at the Guntur local market, and fresh neem leaves were gathered from the Vignan University grounds in Vadlamudi. After three washes, the beetroot and neem leaves were sun-dried for six to seven days, and then they were pulverised with a mill and pestle into a fine powder. Subsequently, the soap base was melted for one minute at 40–55^{0}C using the double boiler method. And then mixed in equal parts neem and beetroot powders. Next, add neem oil, glycerol, a few drops of almond oil, and one vitamin E tablet. After thoroughly mixing all the components, transfer the liquid mixture into moulds to solidify the soap.

Rose Soap Preparation

We bought fresh roses from the nearby flower market in Guntur. Dried the petals in the sun for two to three days after giving the flowers two thorough washes with fresh water. Using a mortar and pestle, grind them into a fine powder after they have dried. The soap base was melted for one minute at 40–55^{0}C using the double boiler method. Add the necessary amount of rose powder gradually, then stir in glycerin, essential oils, five to ten drops of rose water, and one vitamin E capsule. When the soap mixture thickens, pour it into moulds and let it harden for four to five hours.

Coffee Soap Preparation

Five grams of coffee powder was added after the soap base had been melted for one minute at 40–55^{0}C using the double boiler method. The mixture was thoroughly mixed to prevent lumps from developing. Add the honey, almond oil, rose water, essential oil, and five to ten drops of glycerin now. Switch off the flame after mixing all the components till the soap thickens. To harden the soap, pour the mixture into moulds and leave them for four to five hours.

Total Fatty Matter (TFM)

A soap sample of 5 g was added to 100 ml water and thoroughly shaken and directly heated for about 20 mins and then added sulfuric acid to separate the fatty acid layer. The resultant mixture was filtered with filter paper and transferred to a Petri dish. The final mixture was evaporated and the residue weighed (Yue *et al*., 2023). The total fatty matter percentage (TFM) is determined as per the following equation (1)

$$Total\ fatty\ matter\ (\%) = (Y - X) \times \frac{100}{weight}\ of\ sample \quad (1)$$

X- weight of empty petri dish and Y-combined petri dish and soap weight after drying.

Volatile Matter

A soap sample of 10 g was weighed and placed in an oven. The temperature was set at 110^{0}C and eventually cooled and weighed. The following equation (2) is used to estimate the volatile matter

$$Volatile\ matter = \frac{m_1 - m_2}{m_1 - m_0} \times 100 \quad (2)$$

m_0= mass of dish in grams, m_1= mass of dish with sample before heating, m_2= mass of dish with sample after heating.

pH

Distilled water (99 ml) was heated up to 70^{0}C and added 1 g soap sample. The solution was stirred well until it dissolved and then cooled to room temperature. The pH was measured by using a pH meter (Tarun *et al*., 2014).

Total Alkali Content

A soap sample of 5 g was added to 100 ml water, dissolved thoroughly, and heated for 30 min. Then 10 ml of soap solution was taken into the titration flask and titrated against HCl which was taken in the burette. Initially two to three drops of phenolphthalein indicator, the color of the soap solution was pale pink and titrated against HCl until the solution changed to colorless. Based on the volume of HCl rundown, the alkali content is present in the soap samples.

Sterile Disc Preparation

Soap samples of 250 mg were dissolved in 1 mL of sterile distilled water. These were used to prepare a disc size of 6 mm. Sterilized discs were soaked in soap solution and then waited for one hour till get full saturation (Serrano-Aroca *et al*., 2022).

Antimicrobial Activity (Disc Diffusion Method)

The antimicrobial activity of soap was determined by using the agar disc diffusion method (Serrano-Aroca *et al*., 2022). The chosen 0.1 ml of test organism was inoculated on nutrient agar plates. The sterile filter paper discs prepared from different soap samples were transferred aseptically onto the surface of agar plates using sterile forceps. The plates were incubated at 37^{0}C for 24 hrs and then observed the zone of inhibition around the disc. The zone of inhibition was measured in millimeters where soap inhibited the growth of organisms.

Statistical Analysis

The experimental data for the antimicrobial activity of synthesized soaps was analyzed using analysis of variance (ANOVA).

Results and Discussion

As seen in **Figure 1**, four natural soaps were made in the current study using plant extracts: sandal and turmeric (ST), neem and beetroot (NB), rose (R), and coffee (C). Four types of commercial soaps were selected at random from the local market in Guntur: commercial soap 1 (CS1), commercial soap 2 (CS2), commercial soap 3 (CS3), and commercial soap 4 (CS4). **Table 1** and **Figure 2** compare the synthesized soaps' attributes, such as pH, TFM, alkali content, and volatile matter, to those of the commercial soaps sold in stores.

Table 1. Characterization of various synthesized and commercial soaps.

Soap type	pH	TFM	Total Alkali content (%)	Volatile matter (%)
Sandal and turmeric soap (ST)	9.3	77	3.5	6
Neem and beetroot soap (NB)	8.2	55	4.2	20
Rose soap (S)	9.0	50	4.5	10
Coffee soap (C)	10	64	5.0	30
Commercial soap 1 (CS1)	9.2	63	6.5	23
Commercial soap 2 (CS2)	9.5	55	7.2	44
Commercial soap 3 (CS3)	10.5	76	4.3	8.5
Commercial soap 4 (CS4)	10	68	5.7	58

Skin that is generally healthy has normal bacterial flora and a pH range of 5.4 to 5.9. Applying soap with a high pH raises the pH of the skin, which causes changes in the bacterial flora, irritation, and dehydration impact (Tarun *et al*., 2014). The acidity or alkalinity of a soap is determined by measuring its pH. Determining the pH of bath soap is necessary to determine its suitability for application on the skin. Bath soap typically has a pH of 8 to 10, which is alkaline. A pH of greater than 11 will irritate and be harsh on the skin; a pH of less than 8 will not result in lathering or cleaning action. The moisturising effect alters the cleaning activity. The moisturising impact is low while the washing power is great, and vice versa. For optimal cleaning and moisturising properties, handmade soap and bath water with a pH of 9 are often advised. The aforementioned commercial and synthesized soaps have a pH between 8.2 and 10.5. The pH of these soaps is higher than that of typical skin. Among all soaps, Sandal and turmeric (ST), Rose (S), CS1, and CS2 soaps have a good alkaline pH of 9.0 creating superior moisturising impact and cleansing action, whereas Coffee (C), CS3, and CS4 soaps have a pH of about 10, which also results in excellent cleansing power and lathering, but these are too strong for dry skin. Further, beetroot and neem (NB) soap have a pH of about 8, it is still safe to use on skin and has a considerably lower cleansing and moisturising effect.

a) Sandal & Turmeric soap

b) Coffee soap

c) Neem & Beetroot soap

d) Rose soap

Figure 1. Homemade synthesized natural soaps

Another important feature of soap is TFM, which is widely utilised in soap business operations. It explains the nature and quality of soaps. Higher TFM soaps clean better, last longer, create more lather, don't leave skin feeling dry, and cause less skin damage. Lower TFM soaps draw out all of the moisture from the skin, leaving it dry. When dry skin gets worse, it becomes more prone to breaking down, which can result in infections and rashes (Arasaretnam & Venujah, 2019). Sandal and Turmeric (ST) and CS3 soaps, which fall within grade 1 quality and have the highest TFM of 77% and 76%, respectively, among the chosen soaps, are regarded as effective soaps. The remaining soaps fall under grade 3, which has a very low TFM, whereas coffee, CS1, and CS4 soaps fall under grade 2, which has a TFM above 60%.

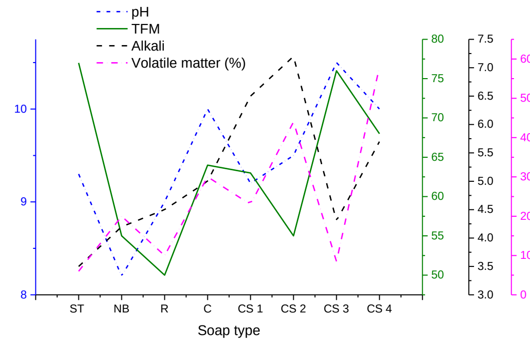

Figure 2. Comparison of synthesized soap properties with various commercial soaps

The soap's total alkali content is a crucial characteristic that ascertains the presence of all the alkaline compounds, including hydroxides, carbonates, and bicarbonates. It gauges how harsh soap is on the skin. While ISO standards specify an alkali level of less than 2%, the Bureau of Indian Standards (BIS) stipulates that high-quality soaps must have a total alkali content of less than 5%. According to BIS and ISO requirements, the investigation found that the alkali level of the remaining soaps is within the usual range, but the alkaline content of CS2, CS1, CS4, and coffee soaps is greater. Sandal and Turmeric (ST) soap has the lowest overall alkali level of any soap. Soap with a low volatile matter content is regarded as superior. Natural and homemade soaps typically have little volatile matter because they don't include colouring, essences, or preservatives. According to standard value, sandal and turmeric (ST), rose (R), and CS3 soaps contain low volatile matter.

Table 2. Zone of inhibition (mm) by different synthesized and commercial soaps on different pathogens using agar disc diffusion method.

Soap type	Zone of Inhibition (mm)			
	Staphylococcus aureus	**Escherichia coli**	**Bacillus subtilis**	**Pseudomonas aeruginosa**
Sandal and turmeric soap (ST)	10 ± 0.5	--	15 ± 0.5	19.5 ± 1.0
Neem and beetroot soap (NB)	18 ± 0	13 ± 2.0	11.0 ± 1.0	25 ± 1.72
Rose soap (S)	8 ± 0.5	--	--	10.5 ± 0.5
Coffee soap (C)	8 ± 0.5	--	--	7.5 ± 0.5
Commercial soap 1 (CS1)	12 ± 1.0	5.0 ± 1.0	9.0 ± 1.5	15 ± 1.0
Commercial soap 2 (CS2)	7.0±0.5	3.5 ± 0.5	8.9 ± 0.5	14.0 ± 0.5

Commercial soap 3 (CS3)	6.5 ± 0.3	7.0 ± 0.5	6.5 ± 0.5	12.0 ± 1.5
Commercial soap 4 (CS4)	---	---	4.5 ± 1.0	---

The agar-disc diffusion method was used to evaluate the antibacterial activity of both commercial and natural soaps against a variety of bacteria, including Staphylococcus aureus, Escherichia coli, Bacillus subtilis, and *Pseudomonas aeruginosa*. These soaps' effectiveness against skin-resident microorganisms is expressed in terms of the zone of inhibition (mm) that forms in various sizes. Four synthesized natural soaps were tested for efficiency using a one-way statistical ANOVA. Statistical analysis for the zone of inhibition demonstrated the variation in antimicrobial activity between the various soap types. After rejecting the null hypothesis and obtaining the most significant model, for which the p-value is 0.000019 (<0.05), it is established that all mean values are different. The investigation's findings showed that all microorganisms exhibited a significant zone of inhibition when exposed to neem and beetroot (NB) soap, sandal and turmeric (ST) soap, commercial soap 1 (CS1), commercial soap 2 (CS2), and commercial soap 3 (CS3). Certain soaps haven't demonstrated any inhibitory zone against certain organisms. The soaps with the highest zone of inhibition against Pseudomonas aeruginosa were neem and beetroot (NB) soap (25±1.72 mm), Sandal and turmeric soap (ST) (19.5±1.0) against Pseudomonas aeruginosa, and neem and beetroot (NB) soap (18±0 mm) against Staphylococcus aureus. Pseudomonas aeruginosa had the highest susceptibility of any organism, with an inhibition zone of 25±1.72 mm against beetroot and neem soap, while Escherichia coli had the lowest susceptibility, with an inhibition zone of 3.5 ± 0.5 mm against commercial soap 2 (CS2). In the end, it was determined that sandal and turmeric (ST) soap had good alkaline pH (9.3), less volatile matter (6%), low alkaline content (3.5), grade 1 total fatty matter (77%) and moderate antimicrobial activity, while neem and beetroot (NB) soap had good antimicrobial properties and moderate soap properties.

These data **(Table 2)** clearly illustrate that when compared to other synthesized and commercial soaps, the neem and beetroot soap had good antimicrobial activity against all pathogens found on the skin's surface. The sandalwood and turmeric soap also showed a good magnitude of inhibition. The best-synthesized soap is sandal and turmeric (ST) soap, which has a low alkali content, good pH, TFM, and volatile matter. Additionally, it contains strong antimicrobial qualities that aid in wound healing, inflammation prevention, and the reduction of psoriasis, eczema, acne, and pimples. At the industrial level, sandal and turmeric (ST) soap can be made on a commercial basis.

Conclusion

The current study outlined the processes for making natural soaps with a few chosen plant extracts. Evaluated several aspects of them, including their physicochemical and antibacterial qualities, and contrasted these qualities with those of commercial soaps that are sold in stores. Good quality soaps are defined as having an alkaline pH, a significant zone of inhibition, a low alkali content, and a high TFM. The sandal and turmeric (ST) soap is classified as grade I quality soap among all synthesized soaps. However, with respect to the zone of inhibition, the neem and beetroot (NB) soap had the strongest growth inhibition. Hence, both soaps can be produced industrially.

Acknowledgments: The authors are grateful to Vignan's Foundation for Science Technology and Research (Deemed to be University) for providing the necessary laboratory facilities to carry out this work.

Conflict of interest: None

Financial support: None

Ethics statement: None

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