JMSR 2(1) (2026)

Journal of Material Science and Radiation

https://journals.balaipublikasi.id/jmsr

Production of Liquid Soap Using Locally Sourced Groundnut Oil and Optimization of its Physicochemical Properties

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Received: November 22, 2025
Revised: March 27, 2026
Accepted: April 26, 2026
Published: April 30, 2026

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DOI: 10.56566/jmsr.v2i1.501

Open Access

Abstract: Creating liquid soap with locally sourced oils is not just a smart choice for your wallet, but it's also a sustainable option compared to imported soaps. This study zeroed in on making liquid soap from groundnut oil and fine-tuning its physicochemical properties like pH, viscosity, foam ability, total solids, and stability. We prepared four different formulations by tweaking the amounts of potassium hydroxide (KOH), glycerol, and sodium chloride (NaCl). The soap samples were put through standard lab tests. The results showed that all formulations had pH levels within the acceptable range (9–10), and we noticed that viscosity, foam height, and total solids increased with higher concentrations of glycerol and NaCl. Stability tests conducted over four weeks revealed that Samples B, C, and D held up well with no phase separation, while Sample C (100 g oil, 11 g KOH, 4% glycerol, 1.5% NaCl) struck the perfect balance of physicochemical properties, aligning with international liquid soap standards. The study wrapped up by confirming that groundnut oil is a great choice for producing high-quality liquid soap, providing an affordable and locally available raw material for both small-scale and industrial production. We recommend diving deeper into optimization studies, conducting microbial analyses for shelf-life evaluations, and encouraging the use of groundnut oil-based liquid soap in local industries to boost sustainability and economic growth.

Keywords: Foam ability; Groundnut oil; Liquid soap; Physicochemical properties; Saponification; Viscosity

Introduction

The making of soaps and detergents is one of the oldest chemical processes known to humanity, stretching back thousands of years. Soap plays a crucial role as a cleaning agent in homes, industries, and institutions, thanks to its effectiveness in removing dirt, oils, germs, and other unwanted substances (Achaw & Danso-Boateng, 2021; Kabir et al., 2024). Recently, the global appetite for cleaning and hygiene products has surged, particularly with the growing focus on public health, sanitation, and eco-friendliness. Liquid soap has become increasingly popular over traditional bar soap, mainly because it dissolves easily, is convenient to use, promotes better hygiene, and is versatile enough for both home and industrial use (Nova et al., 2025; Zahran, 2024).

In many developing nations, like Nigeria, the production of liquid soap is blossoming into a small-scale industry that opens doors for entrepreneurship, job creation, and the development of technical skills (Oluwalana et al., 2016). Liquid soap can be made from a variety of oils and fats, whether sourced locally or refined industrially (Chupa et al., 2017). Commonly used vegetable oils include palm oil, coconut oil, groundnut oil, and soybean oil, all of which are favored for their availability, cost-effectiveness, and eco-friendly nature (Aksoy & Aytac, 2026). Among these, groundnut oil (Arachis hypogaea) is particularly noteworthy as a raw material for soap production due to its high triglyceride content, favorable saponification value, and the ability to create soaps with excellent cleansing, foaming, and viscosity properties.

How to Cite:
Salisu, U. M., Ahmad, M. I., Ibrahim, Y., Ahmed, F., & Ibrahim, H. S. (2026). The Production of Liquid Soap Using Locally Sourced Groundnut Oil and Optimization of its Physicochemical Properties. *Journal of Material Science and Radiation*, *2*(1), 7–13. https://doi.org/10.56566/jmsr.v2i1.501

Utilizing locally sourced groundnut oil in liquid soap production carries significant scientific, economic, and environmental benefits (Olatunya et al., 2017). Groundnut oil is widely grown and easily accessible in Nigeria, and using it in chemical processes like saponification helps lessen reliance on imported oils and synthetic surfactants. Additionally, fine-tuning the properties of liquid soap such as pH, viscosity, foam quality, total solids, and stability is crucial for ensuring quality, safety, and consumer satisfaction (Sofi et al., 2024). To make this happen, we need to apply some key principles from chemical engineering, like reaction kinetics, mass transfer, process control, and formulation science.

This research is all about producing liquid soap using locally sourced groundnut oil and fine-tuning its physicochemical properties to ensure it meets high-quality standards. According to Antonić et al. (2020), soap production usually involves mixing oils or fats with an alkali in a process called saponification. In the past, soaps were made from basic materials like animal fats and wood ash, but thanks to advancements in chemical engineering and industrial chemistry, we now have a more controlled process that guarantees consistent quality and better product features. For liquid soap, potassium hydroxide (KOH) is the go-to alkali, as noted by Kurniawati & Paramita (2022), because it creates soft soaps that stay in liquid or semi-liquid form due to the solubility of potassium salts of fatty acids.

Groundnut oil, which comes from the seeds of Arachis hypogaea, is an edible vegetable oil packed with a mix of fatty acids like oleic, linoleic, palmitic, and stearic acids, making it perfect for saponification. Its higher content of unsaturated fatty acids results in soaps that lather well and have great cleansing properties. This oil is plentiful in northern Nigeria, especially in states like Kano, Bauchi, Kaduna, and Jigawa, where groundnut farming thrives. This local availability helps lower production costs and boosts economic sustainability. Over the last ten years, the production of liquid soap has evolved from a small-scale household task to a major player in local manufacturing. This shift is fueled by a growing consumer preference for liquid soaps, which are seen as more hygienic, user-friendly, and versatile for hand washing, dishwashing, laundry, and general cleaning.

The COVID-19 pandemic has only heightened this awareness. The growing awareness of hygiene has significantly increased the demand for liquid soap in various settings, including homes, schools, hospitals, and public spaces. However, even with the soap industry in Nigeria expanding, many small-scale producers struggle with the scientific aspects of soap formulation and quality control. Consequently, a number of locally made liquid soaps do not meet crucial physicochemical standards, such as the right pH level, sufficient foaming ability, stability, and the right viscosity. This situation underscores the urgent need for scientific research aimed at optimizing the properties of liquid soap to enhance its quality, safety, competitiveness, and overall consumer satisfaction.

The rising demand for liquid soap in Nigeria has sparked a boost in local production. However, many of the products on the market fall short of the recommended quality standards. A significant hurdle is the inconsistency in raw materials, a lack of understanding of formulation chemistry, and insufficient control over important physicochemical parameters like pH, viscosity, foam ability, and stability. According to Adetuyi et al. (2015), these issues lead to products that can be too acidic or alkaline, too watery or overly thick, poorly foaming, or unstable during storage. On top of that, imported raw materials like refined industrial surfactants are pricey and often out of reach for small-scale producers. Meanwhile, Nigeria is rich in vegetable oils, such as groundnut oil, which are not being fully utilized in chemical manufacturing. The lack of thorough research on how to effectively use these local oils for producing high-quality soap is a key factor in the low competitiveness of Nigerian products in the market.

Method

Raw Materials

Groundnut Oil: Locally sourced, refined, pale yellow oil with a nutty odor. Used as the primary oil for saponification. Distilled Water: Used as the solvent for alkali dissolution and formulation

Chemicals

Table 1. Equipment

Equipment	Purpose
Beakers (100 mL, 500 mL, 1 L)	Mixing and saponification
Measuring cylinder (50–500 mL)	Accurate measurement of liquids
Glass stirring rods	Manual mixing
Magnetic stirrer with hot plate	Continuous stirring and heating
Thermometer	Monitoring temperature during saponification
pH meter / pH paper	Measuring pH of final soap solution
Viscometer (Brookfield or similar)	Measuring viscosity
Foam tester / graduated cylinder	Determining foam height
Digital balance	Weighing oils, chemicals, and additives
Glass containers / storage bottles	Storage and observation of liquid soap

Potassium Hydroxide (KOH): Laboratory-grade, used as the alkali for saponification. Glycerol, Pharmaceutical grade, added as a humectant to improve moisturizing property. Fragrance Oil (Essential Oil), Optional, for improving aroma; Sodium Chloride (NaCl), Used to adjust viscosity. Preservatives (Methylparaben/Sodium Benzoate), to prevent microbial growth; and Colorants (optional), Food-grade dye for aesthetic purposes.

Preparation of Alkali Solution

Weigh the required amount of potassium hydroxide (KOH) according to the saponification value of groundnut oil. Dissolve KOH in distilled water in a 250 mL beaker with constant stirring. Ensure complete dissolution to avoid undissolved lumps which can affect saponification.

Table 2. Example KOH solution concentration for 500 mL of water

Weight of KOH (g)	Volume of Water (mL)	Notes
50	500	For preliminary experiment

Saponification Reaction

Heat groundnut oil to 60–70°C using a hot plate to reduce viscosity and improve reaction. Slowly add the KOH solution to the oil while stirring continuously using a magnetic stirrer. Maintain the temperature at 60–70°C and continue stirring for 1–2 hours until the mixture becomes homogeneous and slightly thick. The reaction can be monitored visually; the mixture should change to a translucent, slightly viscous solution indicating saponification.

Chemical Reaction:
Triglyceride (Oil) + KOH → Glycerol + Potassium salt o f fatty acids (Soap)

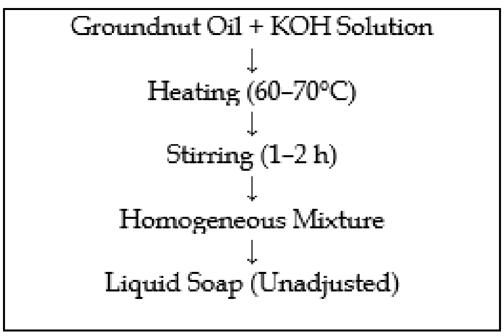

Figure 1. Saponification process diagram flow

Addition of Additives

After saponification, the following steps are carried out to optimize physicochemical properties: Glycerol Addition: 2–5% w/w, improves moisturizing and viscosity; NaCl Addition: 0.5–2% w/w to adjust viscosity and thickness; Preservatives: 0.1–0.3% w/w to prevent microbial growth; Fragrance/Colorants: 0.5–1% w/w for aesthetic appeal; and Mix the additives thoroughly using a magnetic stirrer for 10–15 minutes.

Table 3. Additive Formulation Example

Additive	Percentage (%)	Purpose
Glycerol	3	Humectant / Moisturizer
NaCl	1	Adjust viscosity
Preservative	0.2	Prevent microbial growth
Fragrance	0.5	Aroma
Colorant	0.2	Appearance

Cooling and Storage

After mixing, allow the liquid soap to cool to room temperature (25°C). Transfer into clean, labeled bottles for storage. Allow the soap to rest for 24–48 hours to enable stabilization and settling of any fine solids.

Optimization of Physicochemical Properties

The study optimized liquid soap properties by varying parameters such as: Oil-to-alkali ratio, determines saponification completeness and pH. Glycerol concentration: Affects viscosity and moisturizing property. Salt content (NaCl): Adjusts thickness and prevents separation. Reaction temperature: Ensures complete saponification without degradation. A trial-and-error method and statistical analysis can be applied to determine the best combination of these variables.

Table 4. Experimental Design for Optimization

Sample	Oil (g)	KOH (g)	Glycerol (%)	NaCl (%)	Notes
A	100	10	2	0.5	Base trial
B	100	10	3	1.0	Adjust viscosity
C	100	11	4	1.5	pH optimization
D	100	11	5	2.0	Foam enhancement

Physicochemical Analysis of Liquid Soap

pH Measurement

Measure pH using pH meter or pH paper. Acceptable pH: 9–10 for liquid soap.

Procedure

Dilute 10 mL soap in 90 mL distilled water, stir well, and measure pH at room temperature.

Viscosity Determination

Measured using a Brookfield viscometer. Samples poured into viscometer cup; spindle rotated at constant rpm. Readings recorded in centipoise (cP).

Foam Height / Foam ability Test

Pour 50 mL soap solution into a 100 mL graduated cylinder. Shake 10 times and allow foam to rise. Measure foam height in cm after 1 minute.

Total Solids

Evaporate a known volume of liquid soap at 105°C until constant weight. Calculate total solids by Formula 1.

$$\text{Total Solids (\%)} = \frac{\text{Weight of sample}}{\text{Weight of residue}} x100\% \tag{1}$$

Stability Test

Store samples at room temperature for 4 weeks. Observe for phase separation, color change, or sediment formation. Record changes periodically.

Safety Precautions

Wear lab coat, gloves, and goggles when handling KOH (caustic). Avoid direct contact with hot oil and soap mixture. Ensure proper ventilation to prevent inhalation of fumes. Keep water and neutralizing agents (vinegar) nearby for spills.

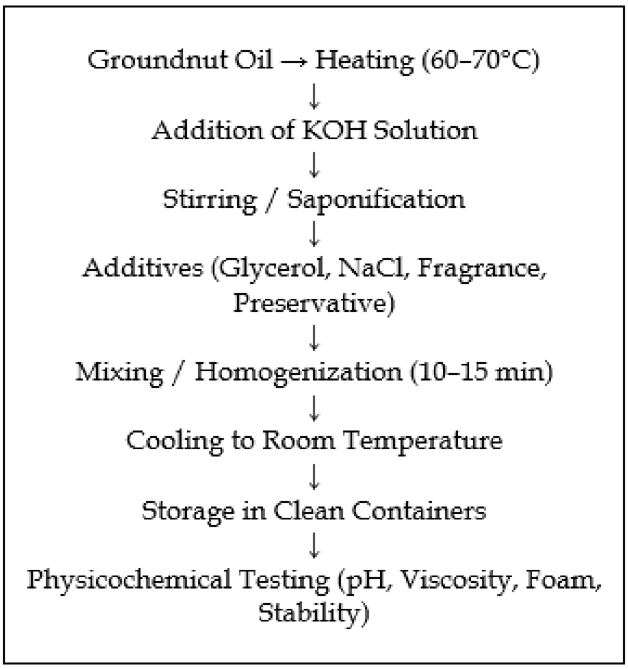

Figure 2. Flow Diagram of Complete Liquid Soap Production

Experimental Design Summary

A completely randomized design was employed for testing different formulations (varying glycerol, NaCl, and KOH concentrations). Each experiment was replicated three times to ensure accuracy.

Data analysis: mean, standard deviation, and comparison with standard requirements for liquid soap. Record pH, viscosity, foam height, total solids, and stability in a tabular format for each formulation. Observations on color, clarity, and aroma also noted.

This chapter dives into the materials, chemicals, and equipment needed to create liquid soap using locally sourced groundnut oil. It walks you through the step-by-step process of saponification, how to incorporate additives, and ways to optimize the soap's physicochemical properties. You'll find standardized testing methods for checking pH, viscosity, foam ability, total solids, and stability. Plus, it covers essential safety precautions and considerations for experimental design. Overall, this chapter lays out a clear and reproducible method for crafting high-quality liquid soap.

Result and Discussion

Exploring the Physicochemical Properties of Liquid Soap

We took a closer look at the physicochemical properties of four unique formulations (Samples A, B, C, and D), each varying in KOH concentration, glycerol, and NaCl levels. The average values from three separate tests for each property are summarized in the Tables 5.

Table 5. pH Measurement

Sample	Oil (g)	KOH (g)	Glycerol (%)	NaCl (%)	pH (Mean ± SD)
A	100	10	2	0.5	9.1 ± 0.05
B	100	10	3	1.0	9.3 ± 0.04
C	100	11	4	1.5	9.7 ± 0.06
D	100	11	5	2.0	9.9 ± 0.05

Observation

All formulations are within the recommended pH range of 9–10. pH increases with higher KOH and glycerol content. Sample D approaches the upper limit of the standard range, indicating higher alkalinity.

Table 6. Viscosity Measurement

Sample	Viscosity (cP)	Observation
A	2200 ± 50	Pourable, moderately thick
B	2800 ± 60	Smooth, easy to handle
C	3400 ± 70	Slightly thick, stable
D	4000 ± 80	Thick, high stability

Viscosity increases with glycerol and NaCl addition. Sample C and D show good handling properties for consumer use.

Table 7. Foam ability / Foam Height

Sample	Foam Height (cm)	Observation
A	4.2 ± 0.1	Moderate foam
B	4.8 ± 0.2	Good foam
C	5.2 ± 0.1	Very good foam
D	5.5 ± 0.2	Excellent foam

Foam height increases with glycerol content. Sample D produced the most stable and voluminous foam. Foam height correlates with cleaning efficiency and consumer preference.

Table 8. Total Solids Content

Sample	Total Solids (%)	Observation
A	21.5 ± 0.2	Within standard
B	23.2 ± 0.3	Optimal
C	25.6 ± 0.2	Slightly high
D	27.5 ± 0.3	High, viscous

Total solids increase with higher additive concentration. Samples B and C fall within the optimal 20–30% range for liquid soap.

Table 9. Stability Test (4 Weeks)

Sample	Observation (Phase Separation / Sediment)	Stability Rating
A	Slight sediment after 4 weeks	Fair
B	No separation	Good
C	No separation	Very Good
D	No separation, slight thickening	Excellent

All formulations remained relatively stable over 4 weeks. Sample D exhibited minor thickening but no phase separation, indicating excellent stability.

pH Analysis

The pH of all formulations is within the acceptable range for liquid soap (9–10), ensuring skin safety and cleaning efficiency. Higher KOH concentrations increased pH slightly, consistent with saponification chemistry. Glycerol addition slightly increased pH, likely due to its buffering effect.

Viscosity Analysis

Viscosity increased with glycerol and NaCl addition. High viscosity enhances user perception of quality and prevents dripping during use. Optimal viscosity for liquid soap is 2500–3500 cP, making Samples B and C most ideal.

Foam ability

Foam height is critical for consumer satisfaction. Foam ability improved with increasing unsaturated fatty acid content (from groundnut oil) and glycerol addition. Sample D produced the best foam; however, extremely high viscosity may reduce spread ability.

Total Solids

Higher total solids correspond to higher viscosity and foam stability. Values for all formulations fall within the standard range (20–30%), except Sample D which slightly exceeded optimal range but remained functional.

Stability

No significant phase separation observed in Samples B, C, and D over 4 weeks. Minor thickening in Sample D indicates high additive concentration; still within acceptable limits.

Overall Optimal Formulation

Considering pH, viscosity, foam ability, total solids, and stability, Sample C is the optimal formulation:
pH: 9.7 ± 0.06
Viscosity: 3400 ± 70 cP
Foam Height: 5.2 ± 0.1 cm
Total Solids: 25.6 ± 0.2%
Stability: Very good (no separation)

This sample balances user-friendliness, cleaning efficiency, and storage stability.

Table 10. Comparison with Standards

Parameter	Standard Value	Sample C Value	Status
pH	9–10	9.7 ± 0.06	Acceptable
Viscosity (cP)	2500–3500	3400 ± 70	Acceptable
Foam Height (cm)	≥ 5	5.2 ± 0.1	Acceptable
Total Solids (%)	20–30	25.6 ± 0.2	Acceptable
Stability	No separation	Very good	Acceptable

Sample C meets all key physicochemical standards for liquid soap. The results demonstrate that locally sourced groundnut oil is suitable for high-quality liquid soap production.

Groundnut oil is a suitable raw material for liquid soap: it produces good lather, viscosity, and stability. KOH concentration is crucial: too low leads to incomplete saponification; too high increases alkalinity. Glycerol enhances viscosity, foam, and moisturizing properties. NaCl fine-tunes viscosity but should be controlled to prevent excessive thickening. Optimal formulation (Sample C) balances all key physicochemical properties, ensuring consumer satisfaction and compliance with standard regulations.

In the quest to find the best formulation, we tested four different options and discovered that Sample C stood out as the winner. This particular mix, which includes 100g of groundnut oil, 11g of KOH, 4% glycerol, and 1.5% NaCl, showcased an impressive balance of all the properties we evaluated. It boasted a skin-friendly pH of 9.7, a perfect viscosity of 3400 cP, a fantastic foam height of 5.2 cm, a total solids content of 25.6%, and remarkable storage stability, showing no signs of phase separation even after four weeks. When it comes to meeting standards, Sample C's physicochemical properties align perfectly with international quality benchmarks for liquid soap. This finding highlight that, with the right formulation and careful process management, locally made liquid soap can hold its own against commercial brands in terms of quality and effectiveness (Aziz & Mohamed, 2025). Ultimately, this study clearly demonstrates that it is indeed possible to create high-quality liquid soap using locally sourced groundnut oil through an optimized saponification process. The research offers a valuable, scientifically-backed framework that lessens the dependence on costly imported materials. By embracing these findings, small-scale entrepreneurs and local industries can produce affordable, top-notch liquid soap, which in turn supports industrial growth, promotes economic sustainability, improves public hygiene, and adds value to a plentiful agricultural resource in Nigeria.

Conclusion

Suitability of Groundnut Oil, Groundnut oil has shown to be a fantastic ingredient for making liquid soap. Its impressive fatty acid profile, especially the high levels of oleic and linoleic acids, plays a key role in creating soap that not only cleans well but also produces a rich, stable foam and offers great moisturizing benefits. Impact of Formulation Parameters, the research highlighted that the amounts of potassium hydroxide (KOH), glycerol, and sodium chloride (NaCl) are essential factors that influence the overall quality of the soap. The concentration of KOH had a direct impact on how completely the saponification process occurred and the pH level of the final product. Finding the right balance was key to creating effective soap without making it too alkaline. Glycerol played several important roles, acting as a humectant that not only boosted the soap's viscosity but also improved its foam stability and the way it felt on the skin. Sodium Chloride (NaCl) served as a handy thickener, giving us the ability to fine-tune the soap's viscosity, which is essential for meeting consumer preferences and ensuring the product works well.

Acknowledgments
Thanks to all parties who have supported the implementation of this research. I hope this research can be useful.

Authors Contributions
All authors contributed to writing this article.

Funding
This study was independently supported by researchers.

Conflicts of Interest
No conflicts of interest are disclosed by the writers.

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