**Journal of Animal, Food and Environmental Sciences (JAFES)**
Vol.1, No.1, 2026: Month: 78-88, E-ISSN: XXXX-XXXX
https://jafes.org/index.php/journal/index

# Optimization of Liquid Soap Formulation Through Saponification: Evaluation of Emulsion Stability and Factors Affecting Product Homogeneity

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Submission Track:
Received: 01-01-2026, Final Revision: 27-04-2026, Available Online: 01-05-2026


**ABSTRACT**
Drying is one of the most widely applied food preservation techniques for extending shelf life by reducing moisture content and water activity while maintaining product quality. This study aimed to compare the effectiveness of natural sun drying and controlled oven drying in preserving selected agricultural commodities, including banana, corn, and apple, through the evaluation of drying performance, product yield, and organoleptic characteristics. Fresh samples were pretreated with a 1% ascorbic acid solution to minimize enzymatic browning before being subjected to either sun drying for approximately 72 h or oven drying at 60°C for 6–8 h. Initial and final sample weights were recorded to determine product yield and moisture loss, while qualitative observations of color, texture, aroma, taste, and drying uniformity were conducted after dehydration. Sun drying effectively reduced sample moisture in all commodities but required substantially longer processing time and produced greater variability in drying performance due to environmental conditions. Oven drying generated more uniform dehydration, superior color retention, improved texture, and greater processing efficiency. However, quantitative measurements for oven-dried banana and apple samples contained inconsistencies, indicating experimental or recording errors that limited direct quantitative comparisons. Despite these limitations, the qualitative findings agreed with established drying principles, demonstrating that controlled thermal drying generally provides higher process efficiency and more consistent product quality than traditional sun drying. These findings reinforce the importance of appropriate drying technology in food preservation and emphasize the need for accurate experimental measurements to improve the reliability of laboratory-based drying studies.

**Keywords***: food preservation; drying technology; oven drying; sun drying; moisture reduction.*

## INTRODUCTION

Liquid soap has become one of the most widely used personal and household hygiene products due to its effectiveness in removing dirt, oils, and microorganisms from various surfaces. The increasing awareness of sanitation and disease prevention has further elevated the importance of soap as an essential public health commodity. Soap functions by reducing the surface tension of water and forming micelles that encapsulate hydrophobic contaminants, thereby facilitating their removal during rinsing. This cleaning mechanism makes soap highly effective against both visible impurities and many pathogenic microorganisms, contributing significantly to improved personal hygiene and environmental cleanliness (Winarno, 2004). The manufacture of soap is fundamentally based on the saponification reaction, in which triglycerides contained in vegetable oils or animal fats react with strong alkalis to produce fatty acid salts (soap) and glycerol as a by-product (Ketaren, 2016). Advances in soap technology have shifted industrial and academic attention toward optimizing formulations that not only exhibit superior cleansing efficiency but also possess desirable physicochemical characteristics such as suitable viscosity, pH, foam stability, moisturizing properties, and long-term storage stability. Recent developments in surfactant chemistry and emulsion science have further emphasized the importance of controlling formulation variables and processing conditions to improve the quality and functionality of liquid soap products. Consequently, understanding the scientific principles governing soap formulation remains highly relevant for both educational purposes and industrial applications (Hambali et al., 2020; Suryani et al., 2019).

The significance of studying liquid soap production extends beyond the acquisition of laboratory skills, as it provides fundamental knowledge of chemical reactions, emulsion systems, and quality control in consumer product manufacturing. Unlike solid soap, liquid soap is generally preferred because of its convenience, hygienic packaging, ease of application, and reduced risk of microbial contamination during use. These advantages have led to its widespread utilization in households, healthcare facilities, food processing industries, and public institutions. However, consumer acceptance depends not only on cleaning performance but also on product stability, appearance, safety, and skin compatibility. Physicochemical properties such as pH, viscosity, foam stability, moisture content, color, and aroma directly influence product quality and user satisfaction (Hambali et al., 2020). Maintaining an appropriate pH is particularly important because excessively alkaline soap may cause skin irritation and dryness, whereas inappropriate water content or unstable emulsions may reduce shelf life and product performance (Suryani et al., 2019). Therefore, practical studies on soap manufacturing provide valuable opportunities for students to understand the relationship between raw material selection, processing variables, and final product characteristics while simultaneously introducing the principles of industrial quality assurance.

Despite the well-established principles of soap production, achieving a stable and homogeneous liquid soap formulation remains a technical challenge because numerous variables simultaneously influence the saponification process and emulsion stability. The efficiency of soap formation depends on the complete reaction between triglycerides and alkaline solutions such as sodium hydroxide (NaOH) or potassium hydroxide (KOH), whereas the physical stability of the final product depends on maintaining a stable dispersion of oil and aqueous phases. Incomplete saponification may leave residual free oil, while excessive alkali may produce soap with undesirable alkalinity and reduced safety (Ketaren, 2016). Furthermore, processing parameters including reaction temperature, mixing intensity, reaction time, and alkali concentration significantly affect reaction completeness and product homogeneity (Suryani et al., 2019). The selection of vegetable oils also plays a decisive role because different fatty acid compositions produce soaps with distinct cleansing abilities, foam characteristics, hardness, and storage stability. For example, coconut oil is known for generating abundant foam and excellent cleansing efficiency, whereas palm oil contributes to improved structural stability and durability (Hambali et al., 2020). Consequently, successful liquid soap production requires careful optimization of formulation and processing conditions to minimize phase separation and ensure consistent product quality.

Previous scientific studies have proposed several approaches to improve the stability and quality of liquid soap formulations. Proper control of saponification conditions has been recognized as the primary strategy for maximizing surfactant formation and minimizing residual free oil (Ketaren, 2016). Equally important is the optimization of emulsification conditions, including sufficient mixing intensity and appropriate processing temperatures, which facilitate the formation of uniformly dispersed oil droplets and reduce the likelihood of coalescence. The incorporation of suitable additives such as glycerin has also been widely reported to enhance product quality by functioning as a humectant that improves skin hydration while contributing to viscosity and product texture (Suryani et al., 2019). In addition, the balance between oil, water, alkali, and auxiliary ingredients must be carefully maintained to produce a stable emulsion with acceptable physicochemical properties (Hambali et al., 2020). The amphiphilic nature of soap molecules enables them to stabilize oil–water interfaces by surrounding oil droplets and preventing their aggregation, thereby enhancing emulsion stability (Winarno, 2004). Accordingly, previous literature consistently emphasizes that optimization of formulation, precise control of reaction parameters, and systematic evaluation of quality attributes are essential for producing liquid soap with desirable cleaning efficiency, safety, and storage stability.

Based on these considerations, the present practical study aims to examine the process of liquid soap production through the saponification of vegetable oil using potassium hydroxide and to evaluate the characteristics of the resulting product. Particular attention is given to observing the homogeneity and stability of the liquid soap as indicators of successful emulsification and effective formulation. The working hypothesis of this study is that appropriate control of formulation variables, including the proportion of oil, alkali, water, and glycerin, together with optimized processing conditions such as heating and mixing, will produce a homogeneous and stable liquid soap with satisfactory physicochemical properties. Conversely, deviations from these optimal conditions are expected to result in incomplete saponification, unstable emulsions, and phase separation. The novelty of this laboratory work lies not in the development of a new soap formulation but in integrating theoretical principles of saponification, surfactant chemistry, and emulsion stability with direct experimental observation, thereby enabling students to understand the relationship between chemical reactions, formulation variables, and product quality. The scope of the study is limited to the preparation of liquid soap using vegetable oil and potassium hydroxide, followed by qualitative evaluation of the resulting product based on its physical appearance, homogeneity, and emulsion stability, as fundamental indicators of successful liquid soap production.

## RESEARCH METHOD

The liquid soap was prepared using commercially available vegetable cooking oil (Bimoli®, Indonesia) as the primary lipid source for the saponification reaction. Potassium hydroxide (KOH) was employed as the principal alkali for liquid soap production, while sodium hydroxide (NaOH) and commercial caustic soda were available as supporting alkaline reagents during laboratory practice. Distilled water (aquadest) was used as the solvent throughout the formulation process. Glycerin was incorporated at a concentration of 4% (w/v) as a humectant to improve moisture retention and enhance the physical properties of the final product. A commercial coloring agent was also added to improve the visual appearance of the liquid soap.

### *Equipment*

The laboratory equipment used in this study included glass beakers, Erlenmeyer flasks, graduated cylinders, glass stirring rods, a laboratory thermometer, and a hot plate equipped with a heating function. These instruments were utilized for reagent preparation, volume measurement, temperature monitoring, mixing, and heating during the saponification process.

### *Preparation of Liquid Soap*

The liquid soap was produced through an alkali-catalyzed saponification process. Initially, 100 mL of vegetable oil was heated for approximately 5 min to facilitate the subsequent reaction. After preheating, the oil was gradually mixed with the potassium hydroxide (KOH) solution while continuously stirring until a uniform mixture was obtained. The reaction mixture was subsequently heated for an additional 30 min under continuous stirring to promote complete saponification and improve mixture homogeneity.

Following the formation of a homogeneous soap base, 200 mL of distilled water was slowly incorporated into the mixture while stirring continuously to ensure uniform dilution. Glycerin was then added at a concentration of 4% (w/v) to improve the moisturizing properties and viscosity of the liquid soap formulation. Finally, 2 mL of coloring agent was incorporated into the mixture, followed by gentle stirring until complete dispersion was achieved. After all components had been thoroughly mixed, the liquid soap was allowed to cool naturally to room temperature before being transferred into clean storage containers. The packaged samples were then stored under ambient laboratory conditions for 24 h to allow the formulation to stabilize prior to further observation and evaluation.

***Product Observation***

The prepared liquid soap was visually evaluated after the stabilization period to assess its physical characteristics. Observations focused on the homogeneity of the formulation, the presence or absence of phase separation, color appearance, and overall emulsion stability. These qualitative observations were used to determine the effectiveness of the saponification process and the stability of the liquid soap formulation during the initial storage period.

## RESULTS AND DISCUSSION

### *Physical Characteristics of the Produced Liquid Soap*

The physical appearance of the liquid soap was evaluated on the first day after preparation and after 14 days of storage. The observations (Figures 1 and 2) revealed that the liquid soap did not maintain a homogeneous appearance throughout the storage period. Instead, distinct phase separation was observed, indicating that the emulsion system was unstable. The upper layer appeared cloudy white with a relatively higher viscosity, representing the oil-rich phase, whereas the lower layer was clearer with a yellowish appearance, corresponding to the aqueous phase. The persistence of these two separate layers throughout storage suggests that the oil and water phases were not successfully maintained in a stable emulsion.

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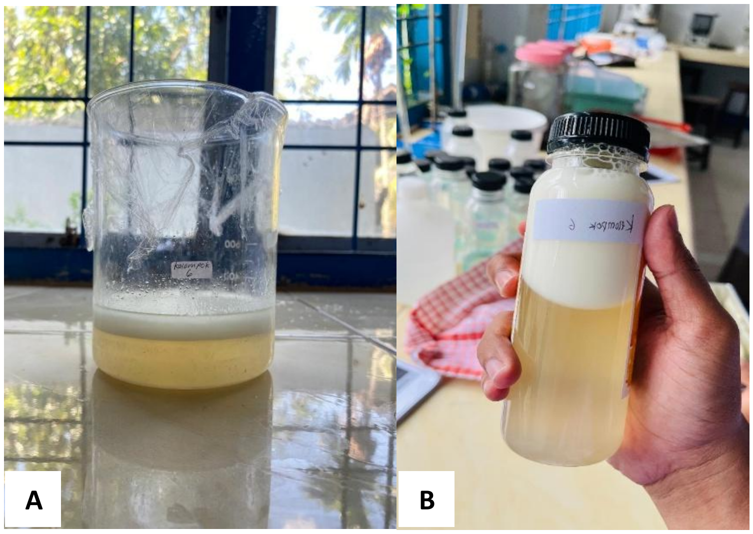


Figure 1. A. Physical appearance of liquid soap on the first day after preparation. B. Physical appearance of liquid soap after 14 days of storage.
(Source: research documentation)

The observed phase separation indicates that the formulated liquid soap failed to achieve sufficient physical stability during storage. In a stable liquid soap formulation, the oil phase should remain uniformly dispersed within the continuous aqueous phase, producing a consistent appearance without visible separation. Therefore, the results demonstrate that the emulsification process was incomplete or that the resulting emulsion was unable to resist destabilization during storage.

***Factors Affecting Emulsion Stability***

Liquid soap is essentially an oil-in-water emulsion in which surfactant molecules generated during saponification stabilize dispersed oil droplets within the aqueous phase. The stability of this emulsion determines the overall quality, appearance, and shelf life of the final product. According to Tian et al. (2022), stable emulsions require the formation of a sufficiently strong interfacial film surrounding oil droplets, preventing them from colliding and coalescing. When this protective layer is weak or insufficient, dispersed droplets gradually merge into larger droplets, ultimately resulting in visible phase separation.

The phase separation observed in this practical study strongly suggests that the surfactant concentration produced during saponification was inadequate to stabilize the entire oil phase. During saponification, triglycerides react with potassium hydroxide (KOH) to produce soap molecules that function as surfactants. If the reaction is incomplete, residual free oil remains within the formulation and gradually migrates toward the surface because of its lower density compared with water. As a consequence, an oil-rich layer develops above the aqueous phase, producing the two-layer system observed in the present study. Similar mechanisms have been described in emulsion systems where insufficient surfactant concentrations accelerate droplet coalescence and subsequent phase separation.

Influence of Processing Conditions on Product Stability

The mixing process represents another important factor affecting emulsion stability. During emulsification, mechanical agitation reduces the oil phase into numerous fine droplets that can be effectively surrounded by surfactant molecules. Smaller droplets possess lower sedimentation or creaming rates and therefore exhibit greater physical stability. Conversely, insufficient mixing intensity or inadequate mixing duration results in larger droplets that are more susceptible to gravitational separation.

The physical characteristics observed in the present study indicate that the emulsification process was likely not sufficiently effective to produce uniformly dispersed oil droplets. According to Biolin Scientific (2025), creaming is among the earliest indicators of emulsion instability and frequently precedes complete phase separation. As larger oil droplets migrate upward due to density differences, repeated droplet collisions promote coalescence, eventually leading to the formation of distinct oil and aqueous layers.

Temperature also plays a fundamental role in determining the efficiency of saponification and the subsequent stability of liquid soap emulsions. Appropriate heating facilitates the chemical reaction between triglycerides and potassium hydroxide, whereas excessively low temperatures may slow reaction kinetics and leave unreacted oil within the formulation. Conversely, excessive heating may alter interfacial properties and reduce the mechanical strength of the surfactant film surrounding oil droplets. Marquez et al. (2018) demonstrated that temperature-induced changes at the oil–water interface accelerate surfactant film disruption, thereby promoting emulsion destabilization. Consequently, maintaining an appropriate processing temperature throughout soap preparation is essential for achieving stable formulations.

***Effect of Formulation Composition***

In addition to processing conditions, the formulation itself strongly influences liquid soap stability. The formulation employed in this practical work consisted of 100 mL vegetable oil, 200 mL distilled water, and 4% glycerin. The balance among these components determines the ability of the surfactant molecules to stabilize dispersed oil droplets. If the proportion of oil exceeds the stabilizing capacity of the generated surfactant, emulsion instability becomes more likely.

Glycerin serves multiple functions in liquid soap formulations, including improving moisture retention, increasing viscosity, and enhancing skin feel. Moderate increases in viscosity generally reduce droplet mobility and improve emulsion stability. However, inappropriate glycerin concentrations may alter the rheological properties of the continuous phase and interfere with uniform droplet dispersion. Therefore, optimization of the oil-to-water ratio together with glycerin concentration is necessary to produce a stable and homogeneous liquid soap formulation.

Another important consideration is the concentration of potassium hydroxide used during saponification. Insufficient KOH limits the conversion of triglycerides into soap molecules, leaving residual free oil within the system. Conversely, excessive KOH may produce highly alkaline formulations that negatively affect product quality and stability. Accurate measurement of alkaline reagents is therefore essential because relatively small deviations in concentration may significantly influence both reaction completion and the physicochemical properties of the final product.

Overall, the present findings demonstrate that the instability of the produced liquid soap most likely resulted from the combined effects of incomplete saponification, insufficient surfactant formation, suboptimal emulsification, imbalanced formulation, and non-optimal processing conditions. These factors collectively promoted droplet aggregation, creaming, and eventual phase separation, resulting in a heterogeneous liquid soap with poor storage stability. The results emphasize the importance of carefully controlling formulation composition and processing parameters to obtain a homogeneous, physically stable, and high-quality liquid soap suitable for practical applications.

## CONCLUSION

The present study demonstrated that the liquid soap produced through the saponification process did not achieve satisfactory physical stability, as evidenced by the clear separation between the oil-rich and aqueous phases during storage. This observation indicates that the emulsion system was unable to maintain a homogeneous dispersion, resulting in a product with suboptimal quality and limited storage stability. The findings suggest that emulsion stability is governed by the combined influence of formulation composition and processing conditions rather than by a single factor. Incomplete saponification, insufficient surfactant formation, inadequate mixing, an imbalanced oil-to-water ratio, and non-optimal processing temperature were identified as the primary factors contributing to emulsion failure and phase separation.

These results reinforce existing knowledge regarding the critical role of surfactant generation, emulsification efficiency, and process optimization in determining the physicochemical quality of liquid soap. The study provides practical evidence that careful control of formulation parameters and manufacturing conditions is essential for producing a homogeneous and stable liquid soap suitable for consumer use. Although conducted as a laboratory-scale practical experiment, the findings contribute to a broader understanding of the relationship between saponification efficiency and emulsion stability in liquid soap formulations. Future studies should incorporate quantitative analyses, including pH, viscosity, foam stability, free alkali content, and long-term storage evaluation, while optimizing oil composition, glycerin concentration, mixing conditions, and alkaline dosage to develop liquid soap formulations with improved stability, safety, and overall product performance.

## AI Declaration

The authors declare that Artificial Intelligence (AI) tools were used only as assistive instruments during the preparation of this manuscript. Specifically, ChatGPT, Grammarly, Quillbot was used to support language clarity, grammar, and formatting. The AI tool did not generate, fabricate, or manipulate research data, analysis, interpretations, or references. All AI-generated outputs were carefully reviewed, verified, and edited by the authors, who take full responsibility for the content of the manuscript. This use of AI complies with the Publication Ethics and Malpractice Statement of the *Journal of Animal, Food and Environmental Sciences (JAFES).*

## Acknowledgments

None.

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