

Development and Performance Evaluation of Bio-Based Detergents Derived from *Morus alba* Leaf Extract.

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ABSTRACT

The growing environmental concern over synthetic detergents has prompted the development of biodegradable and eco-friendly cleaning solutions produced from natural resources. In the current work, herbal detergent was developed with Morus alba (mulberry) leaf extract as the principal source of natural surfactants (saponins). Mulberry leaves contain about 11.3% saponins, which have powerful cleansing, emulsifying, and antibacterial capabilities. Saponins were extracted by soaking mulberry leaves in water for 3-4 days and then filtering them. Additional natural ingredients such as neem extract, citrus juices (Citrus limon and Citrus sinensis), aloe vera gel, and liquid Castile soap were added to improve antibacterial activity, aroma, and cleaning performance. The designed detergent was tested for stability, pH, and stain removal efficacy on cotton fabrics. The results showed that the detergent kept its color and odor throughout storage and effectively removed typical stains including coffee, mud, turmeric, and ink. The detergent's measured pH was 8, indicating mild alkalinity ideal for fabric washing while being gentle on the skin. The findings show that mulberry leaf-based detergent can be a sustainable and environmentally friendly alternative to traditional synthetic detergents.

Keywords: Morus alba, Herbal detergent, Saponins, Natural surfactants, Eco-friendly cleaning agents, Antimicrobial activity, Green chemistry.

1. INTRODUCTION

Environmental pollution is a burning problem confronting the current world which occurs due to the high accumulation of hydrocarbons, chemicals, solvents, heavy metals etc. These pollutants have serious harmful effects on living organisms and also can hamper the economic growth in developing countries especially by polluting the aquatic environment[1]. Green surfactants are amphiphilic molecules derived from natural sources or synthesised from renewable raw materials. Triglycerides, carbohydrate sources, and organic acids obtained through fermentation are commonly used as raw materials for synthesising surfactants[4]. Saponins are a large family of structurally related compounds of steroid or triterpenoid aglycone (sapogenin) linked to one or more oligosaccharide moieties by glycosidic linkage. The carbohydrate moiety consists of pentoses, hexoses, or uronic acids. The presence of both polar (sugar) and nonpolar (steroid or triterpene) groups provide saponins with strong surface-active property. *Sapindus mukorossi* Gaertn (Sapindaceae) which generally grows in tropical and sub-tropical regions of Asia is a economically important agricultural plant as a source of natural surfactants. The major active ingredients of *S. mukorossi* Gaertn are saponins[5]. A stain is a chemical reaction between the staining agent and the fibers and finishes of a fabric. There is no single product or method for removing all stains, because the chemical makeup of each stain and agent is unique. Stain removal is the process of removing a mark or spot left by one substance on a specific surface like fabric. A solvent or detergent is generally used to conduct stain removal & many of these are available over another. Many stains may be removed from clothing and household furnishings, increasing their quality and prolonging their useful life[6]. Detergents are usually used to remove stains, while removing stains may not necessarily kill harmful bacteria. The active ingredients commonly used in detergents are Linear Alkylbenzene Sulfonate (LAS) surfactants. Surfactants are compounds that have two hydrophobic (lipophilic) and hydrophilic(lipophobic) groups, as foam-forming and detergency properties. Hibiscus leaves contain phytochemical compounds such as saponins, flavonoids, polyphenols, and tannins. Derivatives of polyphenolic compounds are known to have antibacterial effects[7]. The current commercially available natural detergents are plant-extracted surfactants including seed saponins, fibres and carbohydrates, or fatty alcohols based on natural fats and oils such as coconut palm oil-derived surfactants. Other biological eco-friendly detergents such as enzymatic detergents like protease or lipase are quite effective in removing protein and lipid-based stains[8]. Detergents are synthetic products derived from petroleum that are produced by chemical means and leave residues that can pollute rivers and other environments. Over the years, there has been an increase in the use of biodegradable detergents, which do not have these shortcomings and are made up of linear chain (unbranched) organic compounds that allow organisms to degrade them effectively[9]. A surfactant is a substance which reduces the surface tension of water and the interfacial tension between oil and water. Structurally, surfactants contain both hydrophobic and hydrophilic groups called amphipathic molecules [10]. A special polymer has been synthesized based on sorbitol, polyethylene glycol (400) and maleic anhydride. A slightly higher amount of maleic anhydride has been used as this gives higher cleaning and stain removing efficiency[11,12]. The bio-based detergent demonstrated an acceptable shelf life and efficiency comparable to commercial synthetic detergents, indicating the potential of utilizing liquid waste and residues as feedstock for cleaning product production[13].

2. Materials and Methods

2.1 Materials

Fruits of *Citrus limon* (lemon) and *Citrus sinensis* (orange), Liquid Castile Soap Base, and *Aloe barbadensis* miller (Aloe vera) were obtained from the local market. The juice was extracted from the citrus fruits, and the gel from the Aloe vera leaves. Mulberry leaves were harvested from the nearby region of Udumalaipettai, Tamilnadu, India.



Figure 1. Mulberry leaves.

2.2 Extraction of Saponins from Mulberry Leaves

Mulberry leaves were soaked in water for three to four days, allowing the natural saponins to leach into the water. The extract was then filtered to separate the leaves residue. The saponin-rich filtered liquid was collected and stored in a clean container for future use in the manufacture of the herbal detergent.



Figure 2. Soaked leaves.



Figure 3. Extraction of saponin from Mulberry leaves.

2.3 Preparation of Neem Extract

Neem leaves were obtained from the surrounding region and extensively cleansed to remove dirt and contaminants. The leaves were then dried for a week to minimize moisture content. After the leaves had completely dried, they were powdered, and 10 g of neem powder was mixed with 100 mL of distilled water. The mixture was heated at 60°C for 30 minutes using a heating mantle. After cooling, the solution was filtered using filter paper to obtain the neem extract. The resulting neem leaf powder was then sealed in an airtight container to retain its potency and qualities for later usage.

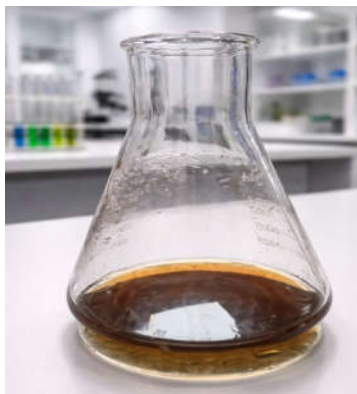


Figure 4. Neem extract.

2.4 Herbal Detergent Formulation

A mixture of 100ml was made by blending 45ml mulberry leaf extract, 15ml lemon juice, 10ml orange juice, 5ml neem extract, 5ml aloe vera gel and 20ml of Liquid Castile Soap Base. The prepared sample was placed in a 100ml glass bottle, shaken vigorously for 15-20 minutes to achieve even mixing, then incubated at 37°C for 24 hours to homogenize the herbal detergent composition.



Figure 5. Formulation of Herbal Detergent.

3. Characterization Process

3.1 Stability test on basis of color and odor

Stability testing of detergents made from mulberry leaves is crucial to ensure their effectiveness, safety, and longevity. Two primary factors to evaluate during this test are color and odor.

Color Stability

Visual inspection at regular intervals (e.g., weekly or monthly) under consistent lighting conditions.

Expected Outcome: This detergent maintained its original color and showed only minimal change when stored at room temperature.



Day 1



Day 7



Day 15

Figure 6. Stability test on basis of color.

Odor Stability:

The detergent is stored in similar to those used in the real world. Conduct sensory evaluations (smelling the detergent) at regular intervals to look for any sour, rotten, or moldy scents. Microbial testing can also be used to check that no microbial contamination has caused odor production.

Expected Outcome: This detergent retained a fresh, herbal fragrance derived from mulberry leaves, without developing undesirable odors.

Foam Test:

The foaming properties of the detergent were evaluated using a standardized agitation method. A known volume of detergent solution was prepared and transferred into a graduated cylinder, followed by vigorous shaking for a fixed duration. The initial foam height was recorded immediately after shaking to assess foaming capacity. Foam stability was determined by measuring the foam height at regular time intervals (e.g., after 1, 3, and 5 minutes). The reduction in foam height with time indicates foam collapse due to liquid drainage and bubble coalescence. Higher and more stable foam indicates better surface-active properties of the detergent.



Figure 7. Foam Test : (a) 3 minutes, (b) 5 minutes

3.2 Effectiveness of the detergent towards various stains on cloth:

To evaluate the cleaning performance of herbal detergent prepared using mulberry leaves, its effectiveness against common household stains on cotton fabric was tested. The selected stains included turmeric, coffee, ink, oil, and mud, which represent a broad range of stain types -organic, greasy, and particulate.

Method:

The stained cloth samples were allowed to dry for 24 hours before washing. The samples were then washed with the prepared herbal detergent under identical washing conditions. The stain removal efficiency was evaluated visually by comparing the fabric before and after washing.

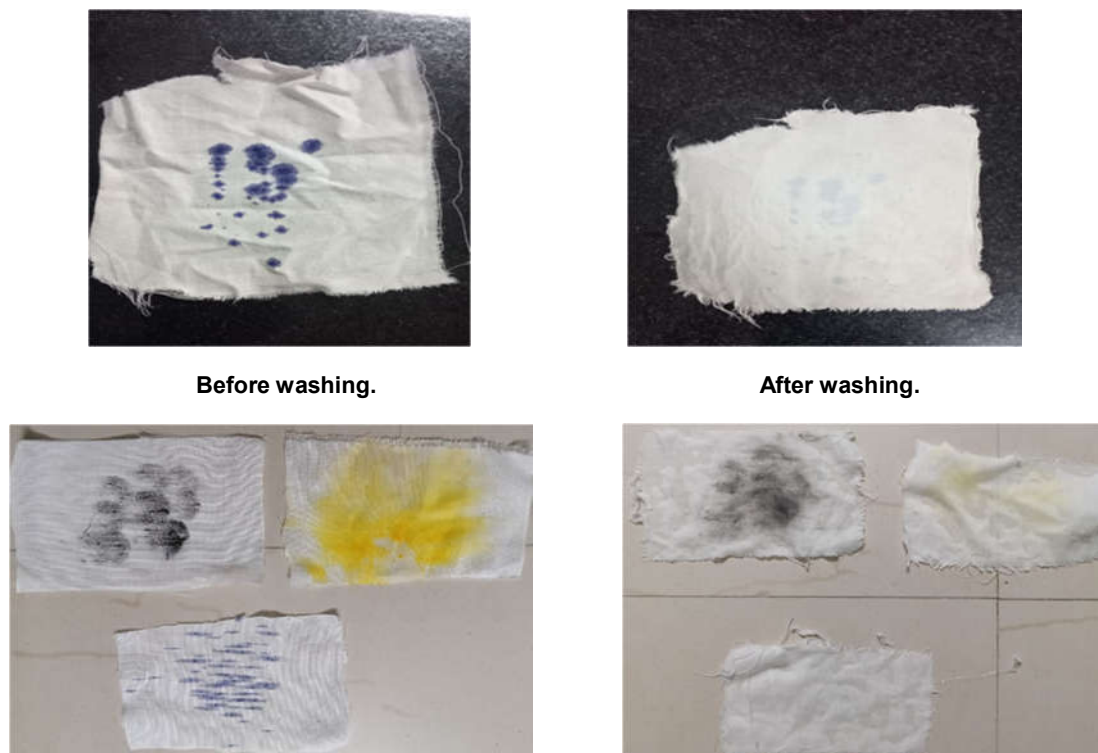


Figure 8. Effectiveness of the detergent towards Cloth.

3.3 pH Test

The pH test of the herbal detergent made with mulberry leaves found a pH of 8, indicating an alkaline nature. This pH level is within the permissible range for detergents, and it effectively removes dirt and oil from clothes without damaging cotton fibers. Although slightly alkaline, the detergent is nevertheless suitable for daily domestic use and is generally mild on the skin, particularly when compared to harsher commercial solutions with higher alkalinity. The pH of 8 also contributes to the detergent's cleaning performance while keeping the natural and environmentally friendly nature of the herbal composition.

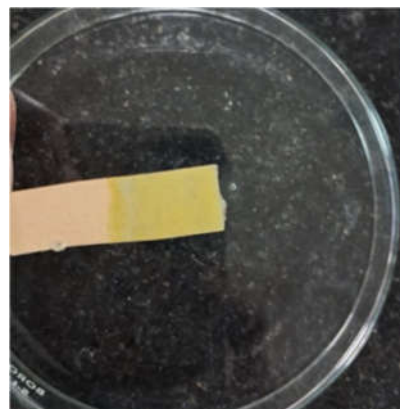


Figure 9. pH Test.

4. Comparison Studies

The developed polyherbal detergent formulation incorporating mulberry leaf extract, neem extract, citrus components (orange and lemon), and aloe vera demonstrated enhanced functional performance compared to previously reported natural detergents. Unlike single-component systems such as soapnut or neem-based formulations, the present study exhibits a synergistic effect, combining effective cleaning, antimicrobial activity, and improved skin compatibility. The inclusion of citrus extracts significantly enhances grease removal, while aloe vera reduces potential irritation, resulting in a balanced, eco-friendly, and low-toxicity detergent suitable for sustainable applications.

Table 1. Comparison Studies for detergent from different research papers.

Reference No.	Material Used	Surfactant Strength	Saponin Content	Cleaning Efficiency	Foam Formation	Stain Removal	Toxicity
[2]	Soapnut	High	10-30%	High	High	Moderate	Moderate
[3]	Neem & Aloe vera	Low	2-5%	Low	Low	Low	Very Low
[14]	Neem	Moderate	0.1-0.5%	Low	Moderate	Moderate	Moderate
[14]	Herbal Plant extract	Moderate	0.2-1%	Moderate	Moderate	Moderate	Low
Present Study	Moras Alba	Moderate	5-10%	High	Moderate	High	Low

5. Results and Discussions

The herbal detergent made from mulberry leaves was put through a variety of tests to determine its efficiency and stability. The stability test revealed that the detergent maintained its original color and odor over time under standard storage settings, showing resistance to physical deterioration and microbiological decomposition. During the efficacy test, the detergent performed well on cotton cloth soiled with ordinary household chemicals. It was especially successful at removing coffee and dirt stains, moderately effective at removing turmeric and ink, and less effective at removing oil stains unless combined with warm water or prolonged soaking. The pH test found a consistent pH of 8, indicating that the detergent is somewhat alkaline, which contributes to its cleaning power while being kind on both fabric and skin. Overall, the herbal detergent performed well in terms of stability, stain removal, and pH balance, indicating its promise as a safe, environmentally friendly alternative to synthetic detergents.

6. Conclusion

The study on eco-friendly detergent made from mulberry leaves emphasizes its potential as a natural and sustainable alternative to chemical cleaning agents. The detergent effectively removed several stains, with remarkable results for coffee and mud and modest effectiveness for turmeric and ink. Although less effective on oily stains, it can be improved with slight formulation or washing condition changes. The product also showed good color and odor stability, indicating that it can be stored without quickly degrading or spoiling. Additionally, the detergent maintained a pH of 8, categorizing it as mildly alkaline - suitable for fabric care and gentle on skin. Its plant-based composition, biodegradability, and absence of harsh chemicals make it an environmentally responsible choice for household cleaning. With further development, mulberry leaf-based detergent can serve as a viable green solution that supports both human health and ecological balance.

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