International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal

Mark Swen S. Morano
Tetuan, Zamboanga city, Philippines
Email address: morano.markswen@gmail.com

I. INTRODUCTION

1.1 Background of the Study

The production of cleaning products like soap has been a long-standing human practice that has progressed from basic mixtures of plant ashes and animal fats to highly marketed, chemically manufactured goods. The global soap market was estimated to be worth 43.8 billion US Dollar in 2022 and is expected to continue growing steadily as a result of rising hygiene awareness. Today, soaps and detergents are widely used as household necessities (Grand View Research, 2023). The production of agricultural waste in the Philippines, where agriculture is still the main industry, presents an opportunity to explore natural, renewable and cost effective materials for soap production.

In the past, plant ashes were used as an alkali source for the saponification process in traditional soapmaking. When burned, banana peels in particular, produce potassium carbonate, a substance that effectively reacts with oils to create soap (Onyegbado et al., 2019). Large amounts of peel waste are produced every year because bananas are one of the most popular fruits in the world and the Philippines is one of the top five banana-producing countries in the world (Food and Agriculture Organization, 2021). Utilizing this waste promotes sustainable waste management in addition to offering an alternate source of alkali.

Consumer behavior trends indicate a growing demand for eco-friendly and biodegradable household products. Despite their effectiveness, many commercial soaps contain artificial chemicals that can pollute water and endanger aquatic ecosystems and human health (Olabisi et al., 2020. This concern necessitates the development of safe, efficient, and environmentally friendly natural soap alternative. Additionally, removing stains remains a problem for household cleaning, especially when it comes to rust stains that are frequently encountered on furniture and fixtures in households. An innovative, environmentally friendly solution to this issue is the use of coconut oil and alkali derived from banana ash in the manufacturing of laundry soap.

1.2 Statement of the Problem

Commercial laundry soaps available in the market often rely on synthetic alkalis and chemical additives that, while effective, may contribute to environmental pollution and pose potential health risks (Olabisi et al., 2020). At the same time, agricultural wastes such as banana peels are often discarded despite their potential as a sustainable source of alkali for soap production (Onyegbado et al., 2019). Likewise, the Philippines has abundant coconut oil, a resource well-suited for producing effective cleansing agents. However, the potential of combining banana ash-derived alkali and coconut oil in formulating laundry soap specifically targeted at removing rust ink stain remains underexplored. This gap highlights the need to investigate whether such a formulation can provide an eco-friendly, cost-effective, and efficient alternative to rust stain removers.

1.3 Objectives of the Study

This study aims to formulate laundry soap produced from banana ash-derived alkali and coconut oil for the removal of rust stains. Specifically, it seeks to:

1. Formulate three (3) soap variants with mixture of different lye solution concentrations and coconut oil:
   a) Soap Formulation 1: 25:75 (Lye Solution: Coconut Oil)
   b) Soap Formulation 2: 30:70 (Lye Solution: Coconut Oil)
   c) Soap Formulation 3: 35:65 (Lye Solution: Coconut Oil)
2. Rank the most desirable soap formulation based on the following mixture through their physicochemical properties measured in terms of:
   a) pH
   b) Stain removal cleaning efficiency
3. Compare the stain removal effectiveness of formulated soap against rust stains with that of a commercial soap.

1.4 Significance of the Study

This study examines the potential of producing affordable and environmentally friendly laundry soaps by using locally abundant coconut oil and valuing banana peel waste directly centring rust stain removal, besides it can cause fabric blemishes, it also pollutes water. By such, concentrating on the combined use of coconut oil and an alkali derived from banana ash optimizes formulations for sustainability, usage of saponification process of a small number of non-polluting chemicals such as agricultural waste to remove rust stains. It still leaves area with little prior research filling gaps in the body of existing literature. Furthermore, the results can be

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

used as a foundation for future studies on production scaling, cleaning product diversification based on agro-waste, and assessing long-term environmental effects.

1.5 Scope and Limitation

This study is limited to the small-scale formulation of laundry soap from banana ash-derived alkali and coconut oil, focusing specifically on its effectiveness in removing rust stains, with raw material sources obtained in Zamboanga City. It covered alkali extraction from cardava banana peel ash, soap formulation under controlled ratios, and examination of physicochemical properties such as pH, and stain removal effectiveness, with compared to the commercial bar soap "Perla', as the benchmark. This study solely utilized the use of cotton fabric and synthetic rust stain solution. The physicochemical testing parameters were tested once per batch with three trials conducted for each sample. All tests were conducted using a Do-It-Yourself (DIY) manner, which are prepared and tested at the College of Engineering (COE)-Western Mindanao State University and in the researcher's residence located at Luyahan, Zamboanga City, the research did not include large-scale manufacturing, the use of other oils or agricultural wastes, or testing against stains other than rust stains

II. METHODOLOGY

This chapter presents the saponification preparation process, experimental procedures and testing methods. Three formulations utilizing banana peel ash-derived alkali and coconut oil will be evaluated, with each formulation subjected to three trials to determine pH levels and stain removal efficiency.

2.1 Data Gathering

This study on the titration-based saponification of coconut oil and banana peel ash-derived alkali utilized both primary and secondary data.

Primary data were obtained through laboratory experimentation, which included the preparation and titration of banana peel ash-derived alkali, formulation of soap using coconut oil and the titrated lye solution, and the subsequent evaluation of the soap's physicochemical properties and rust stain removal efficiency. Data were generated from direct tests such as pH determination and cleansing efficiency on rust stains.

Secondary data were gathered through a comprehensive review of existing literature related to saponification, soap formulation from agro-waste, eco-friendly soaps, and natural alkali sources. Sources included academic journals, published theses, books, and online databases such as Google Scholar, ScienceDirect, and ResearchGate. These sources provided scientific and contextual support for the methodology, standard procedures, and interpretation of results.

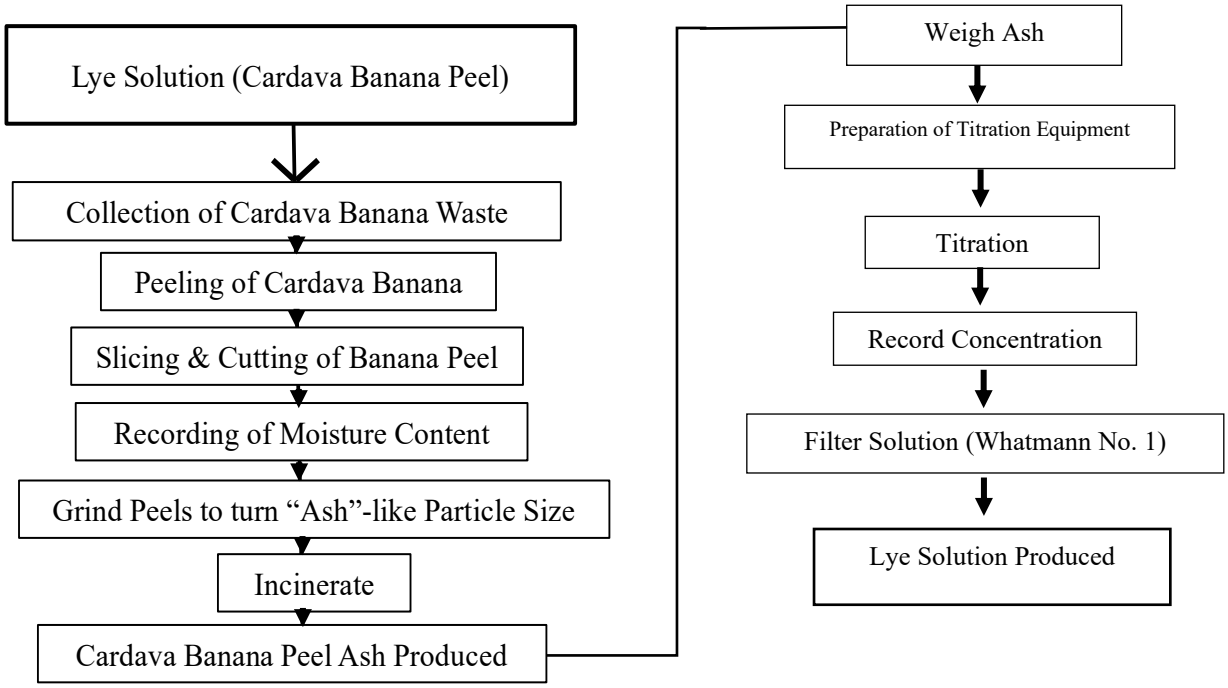

Figure 2.1. Flowchart of the formulation of lye solution from cardava banana peel ash

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

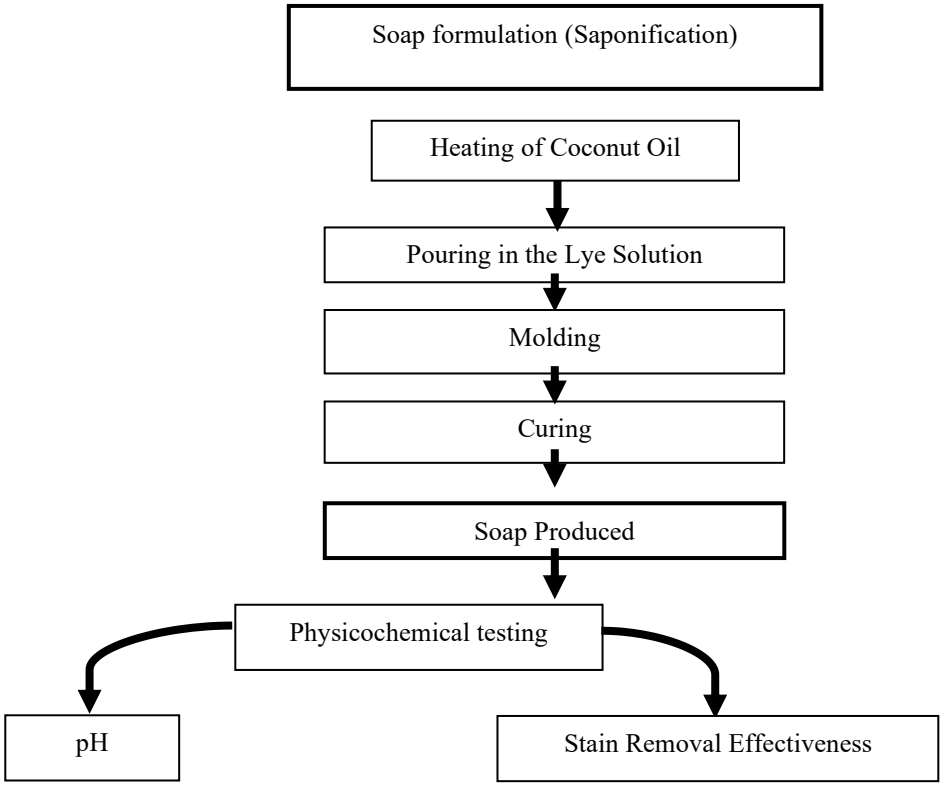

Figure 2.2. Saponification process of lye solution and coconut oil

2.2 Location of the Experiment and Research Area

The experimental phase of the study was conducted at the researcher's residence at Luyahan Zamboanga City and at the College of Engineering (COE) of Western Mindanao State University. The available space was modified into a functional laboratory area suitable for small-scale soap production and testing. This controlled setting helped ensure the accuracy, safety, and reliability of the experimental procedures.

2.3 Research Design

This study employed an experimental laboratory design to investigate the formulation and evaluation of laundry soap produced through titration-based saponification of coconut oil using banana peel ash-derived alkali. The soap formulations were evaluated based on their physicochemical properties and their effectiveness in removing rust stains from fabric.

2.4 Saponification Process

The methodology revolves mainly around the saponification process through mixing titrated ash-derived alkali from Cardava banana peel to coconut oil. But getting the extracted cardava banana peel ash lye solution is a must for saponification process to occur. Hence, figure 2.1 shows the flowchart of the formulation of lye solution from cardava banana peel ash. For saponification process see figure 2.2.

2.4.1 Collection of Raw Materials

A total of 1,010 grams of raw Cardava banana peels and 2 liters of coconut oil were obtained from a common source, Zamboanga City Public Market, located in the City Proper of Zamboanga City.

2.4.2 Cardava Banana (Musa acuminata)

Shown in Figure 2.3 are the thick, medium-sized Cardava banana peels waste weighing 1010 grams, placed in a stainless-steel container. Researcher thoroughly soaked-clean it in a steel container with one liter of water piece by piece to remove dirt, adhering soil, and other contaminants. The washing process reduced impurities that could interfere with ash quality.

Figure 2.3. *Recorded mass of collected cardava banana peel wastes*

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

Figure 2.4. *Cardava banana peels cut into cubes*

2.4.2.1 Cutting of Banana Peel

The cleaned banana peels were first cut into strips approximately 0.5 cm by 10 cm, and then each strip was further cut into small cube-shaped 0.5 cm by 0.5 cm pieces. This cutting process increased the surface area of the peels, which facilitated faster drying. Figure 2.4 shows the Cardava Banana peels cut into cubes.

2.4.2.2 Drying of Peels

As adapted from ChemTalk (2023), the banana peels were air-dried (See Figure 2.5), enough to ensure the removal of excess moisture that could interfere with subsequent ash production. All thinly sliced peels were evenly spread in a single layer under direct sunlight and air-dried for two (2) days. During this period, the peels were monitored periodically to prevent spoilage or mold growth and to confirm that moisture content remained stable, resulting in a uniform and fully dried material suitable for incineration.

Figure 2.5. *Air-drying of the cube-sliced cardava banana peels*

A total of 1010 grams Cardava banana peels were collected for moisture content determination. The sample were weighed at six-hour intervals to monitor the reduction in moisture over 24 hour period. The corresponding weights and moisture loss at each interval are presented in Table 2.1.

Monitoring moisture help identify water content of the peels preventing incomplete combustion during incineration and maintaining consistency in alkali yield (Ademiluyi & Adebayo, 2020).

Moisture content (%) equation would then be:

$$Moisture\ Content\ (\%) = \frac{Weight_{initial} - Weight\ d_{ry}}{Weight_{initial}} \text{ x } 100 \quad \text{Equation 3.1}$$

Where $Weight_{initial}$ is the initial weight (1010 g) and $W_{d_{ry}}$ is the final weight.

Table 2.1. *Weight and moisture content after every 6 hours of drying*

Interval	Weight (grams)	Moisture Content (%)
0 hours	1010	100.00
After 6 hours	812	19.60
After 12 hours	563	44.25
After 18 hours	489	51.58
After 24 hours	335	66.83

3.4.3 Production of Ash

The dried banana peels (100 g per batch) were placed in ceramic crucibles and incinerated in a muffle furnace maintained at 500 °C for one hour (Hikal et al., 2022). This temperature ensured the complete decomposition of lignocellulosic material into ash. Figure 2.6 shows the Cardava banana peel ash produced from incineration.

Figure 2.6. *Cardava banana peel ash produced from incineration*

2.4.4 Weighing of Ash

Figure 2.7 shows a 10-gram portion of the bulk ash obtained after incineration was accurately measured using an analytical balance. The use of precise measurement ensured consistency in the ash-to-water ratio during subsequent alkali extraction, which is critical for achieving reproducible concentrations of soluble potassium salts.

Appropriate handling procedures were implemented to handle the ash using clean, dry utensils avoiding contamination or loss of material. The measured portion was transferred into a clean container, and any residual ash remaining on the balance or utensils was collected to maintain mass accuracy. Standardized weighing helped maintain uniformity across all replicates, thereby reducing variability in the chemical composition of the alkali extract. This step was essential to ensure that differences in soap performance could

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

be attributed to treatment variables rather than inconsistencies in alkali concentration.

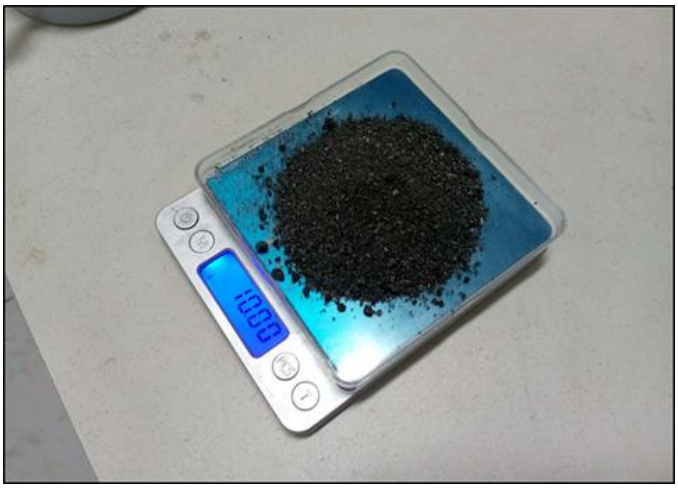

Figure 2.7. *Weighing of cardava banana peel ash*

2.4.5 Extraction of Soluble Alkali

Figure 2.8 shows the 10 grams ash sample dissolved in a 500 millilitres (mL) distilled water in a 1000 mL flask. The suspension was stirred thoroughly with a stirring rod for 5 minutes, then covered and left undisturbed for 24 hours. This soaking period allowed soluble potassium salts to leach into the solution.

2.4.5.1 Filtration of Extract

After 24 hours, the supernatant was filtered using Whatman No. 1 filter paper supported by a plastic funnel into a clean conical flask. The clear alkaline filtrate was collected for titration.

Figure 2.8. Banana ash dissolved in distilled water

2.4.6 Preparation for Titration

Before conducting the titration, all necessary laboratory apparatus and materials were prepared and checked for cleanliness and proper condition. The glassware, including the burette, pipette, and Erlenmeyer flask, was washed and rinsed with distilled water to prevent contamination. The burette was properly mounted on a stand and filled with the titrant solution, ensuring that the tip was free from trapped air and that the liquid level could be read accurately.

A volume of 25 mL of the lye solution was transferred into a clean flask using a beaker. A phenolphthalein indicator for the titration was added to enable detection of the endpoint. The working area was organized so that all required materials were within reach, allowing the titration to be performed smoothly and accurately. Care was taken to ensure that measurements were taken at eye level and that the apparatus remained stable throughout the procedure.

2.4.6.1 Preparation of Reagents

For the standardization of the alkali solution, phenolphthalein served as the indicator during titration, while a 0.1 M hydrochloric acid solution was prepared and used as the titrant to determine the potassium hydroxide (KOH)-equivalent concentration of the banana peel ash extract.

2.4.7 Titration Procedure and Determination of Alkali Concentration

Prior to titration, the burette was filled with the standard Hydrochloric (HCl) solution, ensuring the absence of air bubbles. A measured volume of 25 mL of the ash-derived alkali solution was transferred into an Erlenmeyer flask using a volumetric pipette. Two (2) drops of phenolphthalein indicator were added to the solution.

The lye solution was titrated with HCl while continuously swirling the flask until the endpoint was reached, indicated by the disappearance of the pink color and the solution turning colorless. The final burette reading was recorded. The procedure was repeated for three (3) trials to ensure accuracy and reproducibility of results.

The concentration of the alkali solution was calculated using the titration relationship.

$$M_1V_1 = M_2V_2$$ Equation 3.2

Where:

M_1 = Molarity of HCl (titrant)
V_1 = Volume of HCl used (mL)
M_2 = Molarity of alkali solution (unknown)
V_2 = Volume of alkali solution titrated (mL).

2.4.8 Apparatus and Laboratory Equipment

The experimental work required both basic laboratory glassware and soap-making apparatus. An analytical balance was used to ensure accurate measurement of all raw materials and reagents. Standard laboratory equipment, including beakers, Erlenmeyer flasks, graduated cylinders, burettes, and pipettes, was utilized for mixing, measuring, and conducting titrations. The soap-making process was carried out in a stainless-steel pot with continuous stirring using a stirring rod. Table 2.2 presented the raw materials used in the study, while Table 2.3 listed the reagents utilized in the study, and Table 2.4 showed the apparatus and equipment used in the study.

Table 2.2. *Raw Materials to be utilized in the study*

Category	Item	Specification / Quantity
Raw Materials	Coconut Oil	2 Liter
	Cardava Banana	2 bunches (~2 kg)
	Banana peel ash	600 g (processed to yield sufficient alkali for 3 formulations)
	Distilled water	3 L (for alkali extraction, dilution, and soap preparation)
	Cotton fabric	63 swatches (5 cm × 5 cm)

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

Table 2.3. *Reagents to be utilized in the study*

Category	Item	Specification / Quantity
Reagents	Phenolphthalein indicator	50 mL (sufficient for all titration trials)
	Hydrochloric acid (HCl)	500 mL of 0.1 M solution (for standardization of alkali extract)

Table 2.4. *Apparatus and equipment to be utilized in the study*

Category	Item	Specification/Quantity
Apparatus and Equipment	Analytical Balance	Sensitivity ±0.001 g, for accurate weighing
	Graduated Cylinder	10 mL
	Erlenmeyer Flask	25 mL, 250 mL
	Burette and pipette	25 mL burette and 10 mL pipette, for titration
	Pitcher container	1000 mL
	Ceramic crucibles	Incineration Container
	Stainless-steel pot	1 L capacity, for soap preparation
	Stirring rod/spoon	Glass or stainless-steel, for continuous mixing
	Filter paper	Whatman No. 1 filter paper, used for filtration
	Plastic Funnel	To channel liquid into containers
	Molds	6 silicone molds, 100 g capacity each (one per variant)
	Drying rack	For curing and storage of soap bars
	Digital food thermometer	Measurement Range: -50 to 250°C

2.4.9 Coconut Oil for Saponification

A corresponding amount of lye solution and coconut oil is essential for every formulation. A 350 mL portion of coconut oil, as shown Figure 2.9, is needed to saponify Formulation 2. Table 2.5 shows the corresponding amount of lye solution and coconut oil for each formulation. Placed in a clean beaker and heated at a temperature of 40 °C for 5 minutes to prepare it for the saponification reaction. The oil was warmed while being stirred gently to ensure temperature distribution and to prevent overheating (See Figure 2.10) Heating was maintained until the oil reached the temperature of 40°C for reaction with the lye solution.

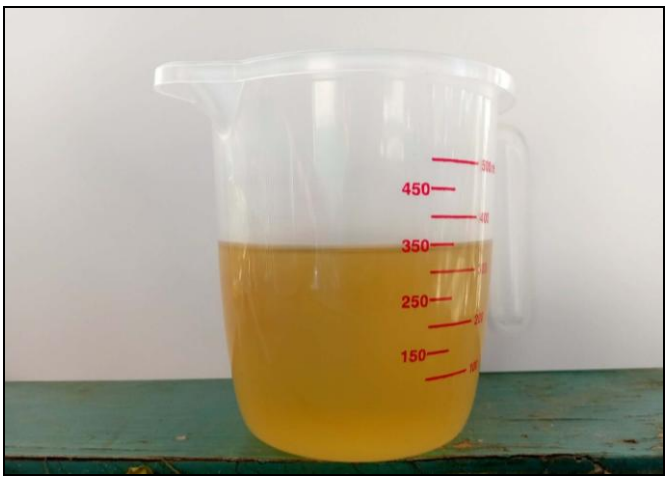

Figure 2.9. Coconut oil to be utilized in the soap-formulation process

Figure 2.10. *Heating of coconut oil*

Table 2.5. *Corresponding amount of lye solution and coconut oil for each formulation*

Formulation	Lye Solution (mL)	Coconut oil (mL)
1	125	375
2	150	350
3	175	325

2.4.9.1 Addition of Lye Solution (Cardava Banana Peel Ash-Derived Alkali)

The amount of lye solution for every soap formulation was slowly added to the equivalent ratio of warmed coconut oil. The addition was performed gradually while the mixture was stirred continuously to promote proper mixing and to avoid sudden localized reactions. Stirring was maintained at entire 5 minutes duration of heating.

Based from the study of Rani (2020) for soap production, the optimal lye concentrations for stable soap formation were identified as 25%, 30%, and 35% (v/v).

Figure 2.11. Appearance of 'trace' after thorough mixing

The procedure formulated three treatment variants using these different lye concentrations (25%, 30%, and 35%) to evaluate their effects on soap performance. A total of three soap variants were prepared using 100% coconut oil and banana-ash-derived alkali standardized through titration and expressed as potassium hydroxide (KOH) equivalent.

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

For every formulation, the lye solution was gradually poured into the heated coconut oil while the mixture was continuously stirred with a glass rod. Gentle stirring was maintained until the mixture reached the "trace" stage, characterized by a thick, pudding-like consistency (See Figure 3.11).

2.4.9.2 Monitoring of Saponification

The reaction mixture was continuously observed during stirring and heating. Progress of saponification was indicated by thickening of the mixture and the formation of a consistent texture commonly referred to as "trace." Heating and stirring were continued until the mixture reached a stable consistency, signifying completion of the saponification process.

2.4.9.3 Molding of Soap Mixture

After "trace" appear, the mixture was left for one (1) minute to cool down, then soap mixture was carefully poured into prepared molds with rectangular cavities measuring 4.5 cm × 7 cm × 2 cm. The molds were gently tapped to release any trapped air bubbles and to ensure even distribution of the mixture. The poured soap was then left undisturbed to allow initial cooling and solidification for 24 hours.

Figure 2.12. *Produced soap formulation 1 (25%:75%)*

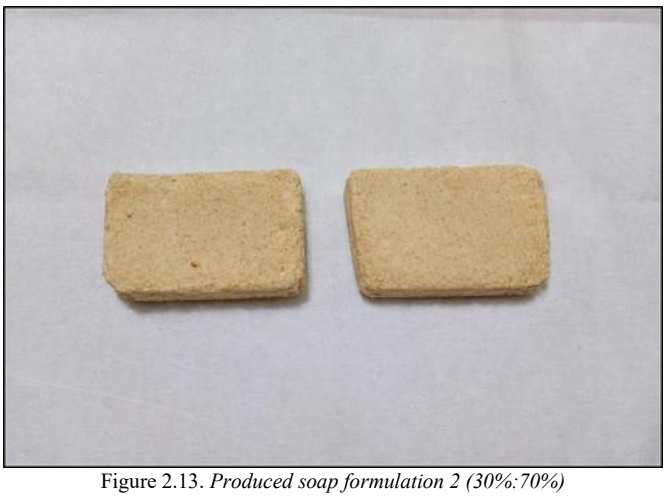

Figure 2.13. *Produced soap formulation 2 (30%:70%)*

2.4.9.4 Curing of Soap Samples

After solidification, the soap samples were removed from the molds and placed in a clean, well-ventilated area for curing. The samples were allowed to dry for a specified curing period of 14 days under ambient storage conditions. This curing stage enabled excess moisture to evaporate and allowed the soap structure to stabilize, resulting in improved hardness, durability, and overall soap quality.

2.4.9.5 Soap Formulation

After curing the three formulations for 14 days they were then readied for the physicochemical testing (ph and stain removal effectiveness). Figure 2.12 shows the soap formulation 1 (25:75) (Lye solution: Coconut Oil), Figure 2.13 shows soap formulation 2 (30:70) produced and Figure 2.14 shows soap formulation 3 (35:65) produced.

Figure 2.14. *Produced soap formulation 3 (35%:65%)*

2.5 Examination of the Properties

The physicochemical properties of the soap formulations produced from coconut oil and Cardava banana peel ash–derived alkali (Lye Solution) through titration-based saponification were evaluated in terms of pH and stain removal efficiency. These tests aimed to determine the safety, effectiveness, and quality of the formulated soaps.

Figure 2.15. *Recorded mass from a portion of formulated soap using the analytical balance*

2.5.1 pH Meter Test

The pH of each soap formulation was determined following the procedure adapted from Ariza (2020). The test

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

was conducted to assess the alkalinity of the soap. For accuracy and reliability, three (3) replicate soap solutions were prepared for each formulation, and each replicate was subjected to pH measurement.

Figure 2.15 shows the scraped soap and weighed using the analytical balance. The solution was dissolved in 100 mL of distilled water and subsequently allowed to cool to room temperature to prevent temperature interference with pH measurement.

2.5.1.1 Calibration of pH Meter

The pH meter was calibrated prior to measurement using standard buffer solutions at pH 4, 6.86, and 9.18 to ensure accuracy. The electrode was rinsed with distilled water and gently blotted with a lint-free tissue before immersion in the soap solution.

2.5.1.2 Measurement of pH

All designated soap were scraped for each soap formulation ratio and poured on to the designated replicate beaker. Each measurement was performed in triplicate for each soap as shown in Figure 2.16. For the pH value recorded from one of the three trials from the formulation see Figure 3.17.

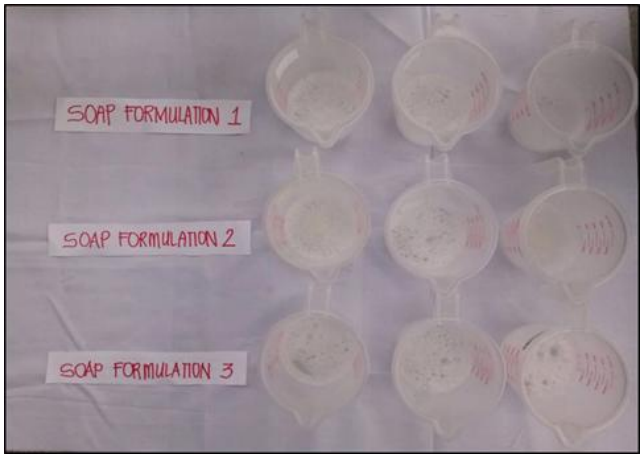

Figure 2.16. *All three (3) soap formulations with its replicates for pH meter testing*

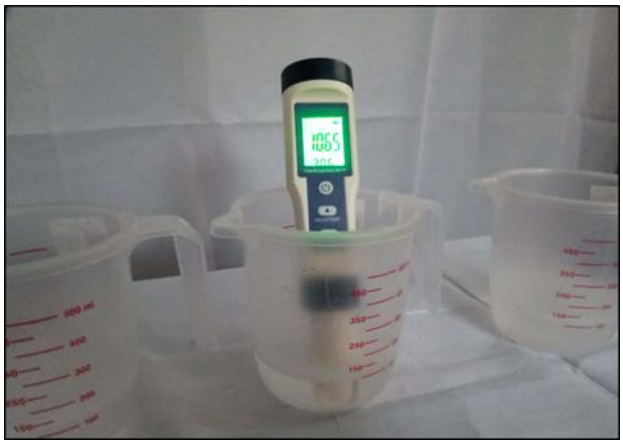

Figure 2.17. *pH value recorded from one of the trials conducted*

2.5.2 Stain Removal Cleansing Efficiency Test

A cotton fabric was used to assess stain removal efficiency. The cotton fabric swatches measures 5 cm × 5 cm with a thickness of less than 1 mm were prepared. The swatches were divided into control and treatment groups; each prepared in triplicate. Control samples included "Unwashed Unstained" swatches representing the original fabric color, "Unwashed Stained" and "Washed Stained" swatches representing the baseline stain intensity. Treatment samples consisted of stained swatches using each soap formulation, while a commercial soap served as a positive control for comparison.

2.5.2.1 Preparation of Soap Solution

To prepare the soap solution, first measure 10 mL of distilled water in a beaker. The one gram of scraped soap sample was then poured into the prepared 10 mL distilled water (See Figure 2.18). Stir the mixture thoroughly until the soap dissolves completely. Which then resulted into a slightly foamy consistency. Once this is achieved, the soap solution is ready for use.

Figure 2.18. Preparation of soap solution using the 1 gram scraped soap

2.6 Swatch Stain Preparation

The cotton fabric swatch was prepared for every soap formulation, having triplicate swatch for each trial. The swatches were applied with two drops of synthetic rust stain solution at the center and allowed to dry for 24 hours (See Figure 2.19). This was recorded as the Unwashed Stained or Before Washing. The "Unwashed" state of fabric was firstly recorded for determination of Color Difference (ΔE).

For the stained fabric swatch, it was immersed into the made Soap Solution (1 gram of dissolved Soap Formulation sample), leaving the fabric swatches for 2 minutes for soap absorption. After immersion to the soap solution for 2 minutes, gentle rubbing was applied to the stained area between the thumb and fingers for 1 minute. After rubbing, the swatches were rinsed under a gentle stream of distilled water for 5 seconds to remove excess soap and detached stain. The swatches were then placed on stainless container, with three readings taken per swatch for each trial soap formulation and mean was recorded afterwards. This fabric was considered as the Washed Stained or After washing the Stained Fabric. Figure 2.19 shows the unwashed stained cotton fabric

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

swatches while Figure 3.20 shows the washed stained cotton fabric swatches.

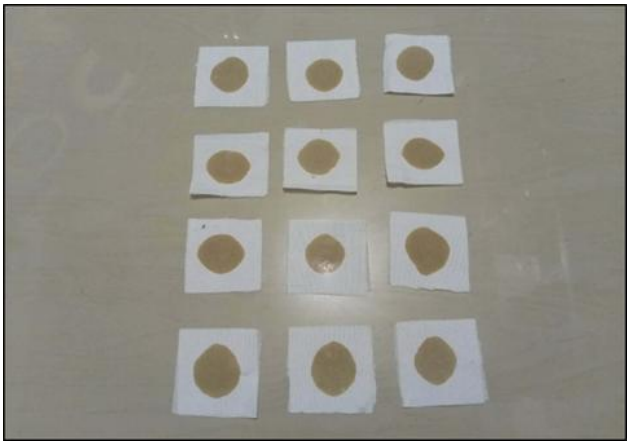

Figure 2.19. *Unwashed stained cotton fabric swatches (before washing)*

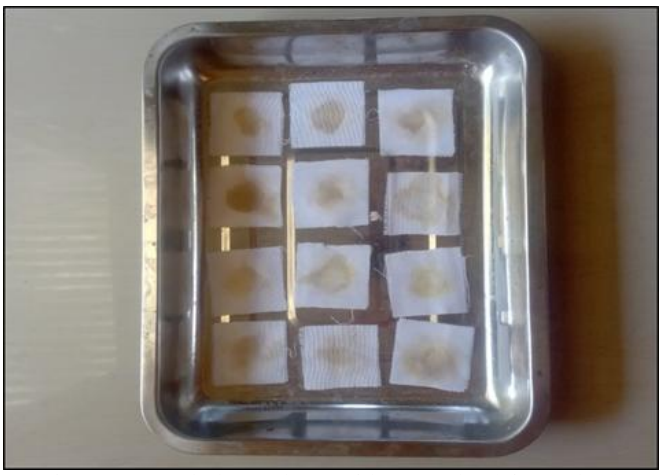

Figure 2.20. *Washed stained cotton fabric swatches (after washing)*

2.6.1 Determination of Color difference (ΔE)

The procedure for the determination of the Color Difference (ΔE) was conducted to examine the stain removal performance of the formulated soap variants against rust stains. Performance was evaluated quantitatively using a spectrocolorimeter to determine the color difference (ΔE*).

Color difference (ΔE) Formula:*

$$\Delta E* = \sqrt{[(L*_{\text{stain}} - L*w_{\text{ash}})^2 + (a*_{\text{stain}} - a*w_{\text{ash}})^2 + (b*_{\text{stain}} - b*w_{\text{ash}})^2]}$$

Equation 3.3

Where; L* Lightness (0 = black, 100 = white)
a* Position between green and red
b* Position between blue and yellow

Color measurements of each swatch for "Unwashed Stained" and "Washed Stained" were obtained using a Spectrocolorimeter to record L*, a*, and b* values for color difference analysis relative to the control samples. In addition, the swatches were visually assessed against the commercial soap control using a 5-point grading scale shown in Table 3.6, Cleansing Removal Effectiveness Ranking with its Performance Interpretation.

As adapted from Abouelwafa et al. (2025), applying soap to soiled cotton, followed by scrubbing and rinsing, demonstrated removal of visible dirt and stains. The expected outcome showed stain reduction, with results approaching those of the commercial control. Conducting tests in triplicate and reporting mean values improved statistical reliability.

2.6.2 Post-Wash Measurements

The color difference between the "Unwashed Stained" and "Washed Stained" was calculated using Equation 3.3 Color Difference (ΔE*) Formula.

2. 7 Data Analysis

The data analysis focuses on determining the pH for each soap formulation produced and examining the cleansing efficiency of the Coconut Oil and Cardava Banana peel-ash soap formulation. The tests were carried out in triplicate for each of the three formulations of 25:75, 30:70, and 35:65. Quantitative results for pH were expressed as mean ± standard deviation (SD), while cleansing efficiency was represented as mean grading scores and color difference mean. The performance of the formulated soaps was statistically compared against a commercial soap used as the control.

For rust stain removal, ΔE values were calculated from before and after wash CIELAB measurements of the fabric swatches, with three replicates per swatch. To examine differences among treatments, data were first assessed for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene's test. Afterwards, One-way ANOVA are applied. Statistical analyses were conducted using a public domain online tool, which is the Statistics Kingdom website. A 5% significance level (α = 0.05) was applied, and results were presented as Mean ± Standard Deviation.

For the ranking of the soap formulation proportion results, in terms of pH, the study of Adnan et al. (2020) was adapted, in which soap formulation exhibiting pH value of 11, will be ranked first. While the study of Hatherley (2023) was adapted to determine the highest ranking of whichever soap formulation have the nearest value of 30 color difference.

III. Results and Discussions

This chapter presents the results obtained from the experimental procedures conducted in this study and provides a corresponding discussion of the significance relation of the following soap formulations; Formulation 1 (25:75), Formulation 2 (30:70), and Formulation 3 (35:65). The analysis focuses on evaluating the performance of laundry soaps formulated through titration-based saponification of coconut oil using Cardava banana peel ash-derived alkali. Specifically, this chapter examines the physicochemical property of the formulated soaps in terms of pH, as well as their effectiveness in removing rust stains from fabric as measured through spectrocolorimetric analysis. The results for the three soap formulations with varying lye solution-to-coconut oil ratios are presented and compared to determine differences in alkalinity and cleaning performance. In addition, the stain removal capability of the formulated soaps is compared with that of a commercial soap to assess their relative effectiveness.

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

3.1 Physicochemical Property of the Formulated Soap in Terms of pH

The pH values of the three formulated laundry soaps were measured using a calibrated pH meter. Each formulation was analyzed in triplicate, and the mean and standard deviation were computed to evaluate the alkalinity and consistency of the soap formulations produced from coconut oil and banana peel ash-derived alkali. Results of the pH are shown in the Table 3.1

Table 3.1. *pH values of the formulated soaps (mean ± standard deviation)*

Formulation	Trial 1	Trial 2	Trial 3	Mean pH ± SD
Formulation 1	10.63	10.45	10.60	**10.56 ± 0.10**
Formulation 2	10.65	10.74	10.65	**10.68 ± 0.05**
Formulation 3	10.73	10.86	10.91	**10.83 ± 0.09**

Formulation 1 obtained a mean pH of 10.56 ± 0.10, indicating a moderately alkaline soap solution. Due to having smaller lye solution ratio, the alkalinity level of this formulation resulted the smallest among all formulation. However, according to the study of Alsalhi et al., (2024) this formulation still falls within the typical range of 10-11 pH value. The relatively small standard deviation shows that the pH values across the three trials were consistent, suggesting that the formulation produced stable alkalinity during testing.

A mean pH of 10.68 ± 0.05 falls for Formulation 2, shows slightly higher than Formulation 1 with 5% differential ratio of lye solution this proves that moderate alkalinity would be its resulting pH. For its deviation, it indicates consistency among the trials, implying a stable saponification process.

Moreover, Formulation 3 produced the highest mean pH value of 10.83 ± 0.09 among all formulations. Showcasing high pH value due to the highest proportion of lye solution in the formulation resulting to a stronger alkaline soap mixture.

The pH level of this formulation approaches the upper range reported for natural-based soaps. As reported by Alsalhi et al. (2024), Natural-based soaps produced from ashes can reach pH values close to 10–11, which closely matches the alkalinity observed for all Soap Formulation showing 10± values.

Table 3.2. *Ranking of alkalinity (pH)*

Sample	Result	Ranking
Formulation 3	**10.83 ± 0.09**	1st
Formulation 2	**10.68 ± 0.05**	2nd
Formulation 1	**10.56 ± 0.10**	3rd

Adapting the study of Adnan et al., (2020), pH value approaching 11 are considered desirable because increased alkalinity enhances cleaning performance by facilitating the saponification and repulsion between fabric and stain particles, thereby improving overall stain removal efficiency. Consistent with the findings of the adapted study, Formulation 3 exhibited the highest alkalinity value of 10.83 among the soap formulation and was therefore ranked first in the overall tally, followed by formulation 2 in second place and formulation 1 in last place.

According to Adnan et al. (2020), soap formulation with higher alkalinity, especially those with pH value near 11, exhibit improved stain removal efficiency due to enhanced saponification and emulsification of fats and oils. In this regard, the relatively higher pH of Formulation 3 reflects its stronger alkaline properties, which may result in more effective removal of greasy and organic stains compared to the other formulations.

In relation to the adapted study of Adnan et al. (2020), Formulation 3 is considered the most desirable among the three formulations in terms of alkalinity, as its pH is closest to the upper alkaline range of 11, indicating potentially superior cleaning efficiency. Formulation 2 ranks next, exhibiting moderately high alkalinity, while Formulation 1, with the lowest pH among the three, demonstrates comparatively lower alkaline strength. The results indicate that increasing the proportion of alkali relative to oil in the formulation leads to higher pH levels and may enhance stain removal capability which is consistent with the findings of Adnan et al. (2020).

Table 3.3. *One-way ANOVA results of pH alkalinity*

Source	DF	Sum of Squares	Mean Square	F Statistic	p-value
Between	2	0.1078	0.05388	14.4315	0.005098
Within	6	0.0224	0.003733		
Total	8	0.1302	0.01627		

As shown in Table 3.3, a One-Way ANOVA test was conducted. The test yielded an F-value of 14.4315 with a corresponding p-value of 0.005098 ($p<0.05$), showing that there was a statistically significant difference in the pH values among the three soap formulations which also indicates that the differences in pH values are not due to random variation but are influenced by the formulation type (Adnan et al., 2020).

3.2 Spectrocolorimetric Results of Rust Stain Removal

The rust stain removal efficiency of the formulated soaps was evaluated using spectrocolorimetric analysis based on the CIE Lab color space (Hatherley 2023), utilizing the equipment, Spectrocolorimeter. This system expresses color in terms of lightness (L*) and chromatic components (a* and b*), allowing objective quantification of color change on the fabric surface. Cleaning performance was expressed as the color difference (ΔE) between the "Unwashed Stained" fabric and the "Washed Stained" fabric. Color Difference (ΔE) for commercial soap was also included. Recorded results of color difference (ΔE) values were then gathered (See Table 3.4)

Table 3.4. *Results of recorded color difference (ΔE) of every soap formulation*

Sample	Trial 1 (ΔE)	Trial 2 (ΔE)	Trial 3 (ΔE)	Mean ΔE ± SD
Formulation 1	12.94	16.35	18.06	**15.78 ± 3.09**
Formulation 2	12.58	16.91	18.65	**16.04 ± 3.12**
Formulation 3	19.06	12.82	16.57	**16.15 ± 3.14**
Commercial Soap	18.75	18.19	20.23	**19.03 ± 1.05**

Adapting the study of Hatherly (2023), the Scaling of Cleansing Efficiency is 30:100 (A total of 30 Difference is equals to approximately 100 % cleaning efficiency). Hence, for the Overall or Mean ΔE of every soap formulation, the observed Color Difference shown in Table 3.4 are the

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

following; Formulation 1 showed a ΔE result of 15.78, corresponding to 52.20% rust stain removal. Formulation 2 recorded a ΔE of 16.04, indicating 53.46% rust stain removal, while Formulation 3 obtained a ΔE of 16.15, equivalent to 53.83% rust stain removal. In comparison, the commercial bar soap "Perla" exhibited a ΔE value corresponding to 63.43% rust stain removal, with a total ΔE of 19.03. Overall, the commercial soap demonstrated higher stain removal efficiency than all formulated soaps.

The final calculated mean values of color difference (ΔE) should only have minimal variations among the three soap formulation, indicating that there was no substantial difference in their overall cleaning effectiveness. This suggest that all formulation demonstrated relatively weak cleaning performance. Furthermore, factors such as rubbing frequency and immersion time may have influenced the results, which could explain why even the commercial soap was unable to achieve satisfactory stain removal efficiency.

For the comparison of commercial soap along with its statistical comparison with the other three formulated soap

Table 3.5. *Color difference (ΔE) Shapiro-Wilk Test results*

Formulation	Test Statistic	p-value	Interpretation
Formulation 1	0.9852	0.9999	Normally distributed
Formulation 2	0.9428	0.8301	Normally distributed
Formulation 3	0.9866	1	Normally distributed

The Shapiro-Wilk Test (shown in Table 3.5) confirmed normal distribution for all formulations ($p > 0.05$), validating the use of parametric tests for further analysis. As shown in Table 4.3, all formulations yielded p-values greater than 0.05 (Formulation 1: 0.9999, Formulation 2: 0.8301, Formulation 3: 1.0000). This indicates that there is no significant deviation from normality for any of the datasets. Additionally, the test statistics (W values) for all formulations are close to 1, further supporting that the data closely approximates a normal distribution.

Table 3.6. *Levene's Test results color difference (ΔE)*

Source	DF	Sum of Squares	Mean Square	F Statistic	p-value
Between	2	0.00509	0.0025	0.00064	0.9994
Within	6	23.8657	3.9776		
Total	8	23.8708	2.9838		

As shown in Table 3.6, Levene's Test indicated homogeneity of variance ($p = 0.9994 > 0.05$), satisfying the assumptions for One-Way ANOVA. The very small F-value of 0.00064 further suggests that the variability between groups is minimal compared to the variability within groups. This supports the assumption that the spread of ΔE values is consistent across all formulations.

Table 3.7. *Color difference (ΔE) One-Way ANOVA Test results*

Source	DF	Sum of Squares	Mean Square	F Statistic	p-value
Between	2	0.2145	0.1072	0.01104	0.989
Within	6	58.282	9.7138		
Total	8	58.497	7.3121		

Table 3.7 shows that the one-way ANOVA showed no significant difference in color difference (ΔE) among the three soap formulations with $p = 0.989$. This indicates that the mean rust stain removal efficiency of Formulations 1 to 3 is statistically equivalent under the conditions tested because it demonstrates that the differences in lye concentration contribute minimally to the overall variability of the color difference ΔE values. This confirms the discussions made from the results of Recorded Color Difference (ΔE). The large within-group variation compared to the negligible between-group small variation suggests that differences in ΔE are likely due to almost non-various measurement of Lye Solution ratio (Harkal & Deshmukh, 2024).

Table 3.8. *Shapiro-Wilk Test results of commercial soap color difference (ΔE) in comparison with the other three soap formulation*

Formulation	Test Statistic	p-value	Interpretation
Formulation 1	0.9852	0.9999	Normally distributed
Formulation 2	0.9428	0.8301	Normally distributed
Formulation 3	0.9866	0. 9978	Normally distributed
Commercial Soap	0.9365	0.902	Normally Distributed

As presented in Table 3.8, all samples yielded p-values greater than 0.05 (Formulation 1: 0.9999, Formulation 2: 0.8301, Formulation 3: 0.9978, and Commercial Soap: 0.902), indicating that there is no significant deviation from normality in any group. The test statistics (W values) are also close to 1, further confirming that the datasets approximate a normal distribution. Notably, the commercial soap, which serves as the control or benchmark in this study, also exhibited a normal distribution ($p = 0.902$).

Table 3.9. *Levene's Test results of commercial soap color difference (ΔE)*

Source	DF	Sum of Squares	Mean Square	F Statistic	p-value
Between	3	3.7961	1.2654	0.427	0.7392
Within	8	23.7091	2.9636		
Total	11	27.5052	2.5005		

As shown in Table 3.9, the test produced an F-statistic of 0.427 with a corresponding p-value of 0.7392 ($p>0.05$). This indicates that there is no statistically significant difference in the variances among the groups, confirming that the assumption of homogeneity of variance is satisfied.

Importantly, the inclusion of the commercial soap which serves as the control also meets this assumption. This implies that the variability in Color Difference (ΔE) for the commercial soap is consistent with that of the experimental formulations, allowing for a valid comparison across all samples.

Table 3.10. *One-Way ANOVA Test results of commercial soap color difference (ΔE) in comparison with the other three soap formulation*

Source	DF	Sum of Squares	Mean Square	F Statistic	p-value
Between	3	21.3285	7.1095	1.0325	0.4285
Within	8	55.0846	6.8854		
Total	11	76.4131	6.9423		

Table 3.10 shows the analysis yielded an F-statistic of 1.0325 with a corresponding p-value of 0.4285 ($p>0.05$). This

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

indicates that there is no statistically significant difference in the mean Color Difference (ΔE) among the groups.

This result suggests that the experimental formulations exhibit comparable color characteristics to one another and to the commercial soap, which serves as the control product. The lack of significant difference implies the need to developed adjustments for formulations to achieve stain removal effectiveness level (Harkal & Deshmukh, 2024).

IV. Conclusion and Recommendations

The study utilizing Cardava banana peel ash-derived alkali and Coconut Oil for Saponification poses potential viable and alternative to Natural-based laundry soap production. Through the systematic evaluation of the three formulated variants, several key conclusions were developed;

4.1 Conclusion

Three soap formulations were developed using varying ratios of lye solution and coconut oil, specifically Formulation 1 (25:75), Formulation 2 (30:70), and Formulation 3 (35:65). The variation in lye concentration allowed for the assessment of its effect on the properties of the resulting soaps. The results demonstrate characteristics of the soap and the determination of its alkalinity and rust stain removal effectiveness undergoes through ranking.

4.1.1 pH Value (Alkalinity)

The ranking of the soap formulations based on alkalinity (pH) showed increasing pH corresponding to higher alkalinity across the samples. Formulation 3 obtained the highest mean pH value of 10.83 ± 0.09, followed by Formulation 2 with 10.68 ± 0.05, and Formulation 1 with 10.56 ± 0.10.

Higher pH values approaching 11 are more associated with improved cleaning performance as stronger alkali holds more emulsification of stains and enhances grip of saponification (Adnan et al., 2020). Thus, Formulation 3 is considered the most favorable in terms of alkalinity, suggesting greater potential for stain removal compared to the other formulations followed by Formulation 2 and Formulation 1, respectively.

4.1.2 Rust Stain Removal Effectiveness

The results of the color difference (ΔE) analysis indicate that all three soap formulations fall within the undesirable range in terms of stain removal effectiveness. Among the samples, Formulation 3 (35:65) obtained the highest mean ΔE value of 16.15 ± 3.14, ranking first in terms of stain removal efficiency performance. This was followed closely by Formulation 2 (30:70), which recorded a mean ΔE value of 16.04 ± 3.12 and ranked second. Meanwhile, Formulation 1 (25:75) produced the lowest mean ΔE value of 15.78 ± 3.09, placing it third in the ranking. Although the differences between the ΔE values of the formulations are relatively small, the trend suggests that Formulation 3 demonstrates marginally better stain removal capability compared to the other two formulations. This slight improvement may be associated with its higher lye content, which potentially contributes to increased alkalinity and enhanced interaction with rust compounds embedded in the fabric fibers (Olabisi et al., 2020).

Despite these variations, all formulations exhibited relative ΔE values, which indicate that the degree of color change observed in the fabrics is not sufficient to be considered acceptable or highly effective in stain removal terms. In practical interpretation, higher ΔE values correspond to greater visible changes in color, which may reflect partial stain removal; however, the values obtained in this study do not reach the threshold typically associated with complete or highly satisfactory cleaning performance. Thus, while some level of stain reduction was achieved across all samples, the overall effectiveness remains limited when compared to established benchmarks.

The overall mean color difference (ΔE) result of 16.15 corresponds to an estimated 53.83% rust stain removal, based on the scale reported in the study of Hatherley. This percentage indicates that slightly more than half of the rust stain content was removed from the fabric, which, while notable, still falls short of optimal cleaning performance. In industrial or practical laundry applications, higher removal efficiencies are generally desired to ensure that fabrics are restored to a near-original appearance without visible staining or discoloration.

In relation to the criteria outlined by Hatherley (2023), effective rust stain removal and acceptable color difference (ΔE) values are expected to fall within the range of approximately 27–30 for ΔE, corresponding to 90%–100% stain removal efficiency. Comparing these benchmark values with the results obtained in this study, it is evident that none of the formulations achieved the required level of performance. The substantial gap between the observed ΔE values (~16) and the suggested acceptable range (27–30) further reinforces the classification of all formulations as undesirable for rust stain removal applications.

Hence, all soap formulations developed in this study demonstrated limited effectiveness in removing rust stains from cotton fabrics. Although Formulation 3 exhibited the highest relative performance among the three variants, it still did not meet the minimum criteria for acceptable stain removal efficiency. The results suggest that while variations in formulation composition particularly the lye-to-oil ratio do influence cleaning performance, the current formulations are insufficient to achieve the level of effectiveness required for practical and reliable rust stain removal. Further optimization of the formulation, as well as potential incorporation of specialized additives or chelating agents, may be necessary to improve performance and achieve results closer to the acceptable standards indicated in related studies.

4.2 Comparison of the Formulated Soaps with Commercial Bar Soap

The commercial laundry bar soap was used as the control for comparison with all formulated soaps in this study. Using Hatherly's (2023) scaling approach, where higher color difference (ΔE) corresponds to better cleaning performance, the results showed that the commercial soap achieved a color difference (ΔE) value of 19.03, indicating the highest cleaning efficiency among all tested samples. In contrast, the natural-based soap formulations recorded lower ΔE values, with

Mark Swen S. Morano, "Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.

Formulation 3 obtaining the highest result at 16.15, followed by Formulation 2 at 16.04, and Formulation 1 at 15.78. Although Formulation 3 performed best among the experimental soaps, it still exhibited a noticeable difference compared to the commercial soap, with 2.88 in ΔE value, which corresponds to approximately 9.6% differential cleaning efficiency. This indicates that even the most effective formulation was not able to match the stain removal capability of the commercial product. Overall, the findings demonstrate that all soap formulations developed in this study were unable to reach the optimal cleaning performance demonstrated by the commercial soap, particularly in terms of rust stain removal effectiveness. This suggests that further optimization of formulation ratios and processing conditions is necessary to improve the performance of the natural-based soap products.

4.3 Recommendations

To further enhance the findings of this study, recommendations of experimental procedure, process and assessment should be with great consideration for better improvement of reproducibility, greater accuracy, and practical application;

1. Use of authentic stain such as coffee, ink, or food dyes can provide a broader assessment of soap cleansing efficiency and practical applicability.
2. Addition of soaking time to the soap solution and rubbing method of fabric swatch is recommended.
3. Use of other fabric types besides cotton.
4. Add more alkali to the formulation, for lye-based formulations to further characterized differences of each Soap Formulation and show significant result in regards to pH and its stain removal efficiency.
5. Further studies and research for storage conditions of natural based-soaps under prolong period of time (after curing) must be taken into consideration.
6. Adding of fragrance or mild essential oils to formulations to increase appeal and make the soap more pleasant to use.

Mark Swen S. Morano, “Titration-Based Saponification of Coconut Oil (Cocos nucifera) and Cardava Banana Peel (Musa acuminata) Ash-Derived Alkali for Rust Stain Removal,” *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 9, Issue 2, pp. 510-522, July 2026.