World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

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Potassium Hydroxide in Plantain Peels ash and its Uses as a Source of Saponification

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World Journal of Advanced Research and Reviews, 2025, 28(03), 1508-1526

Publication history: Received on 12 November 2025; revised on 20 December 2025; accepted on 23 December 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.28.3.4221

Abstract

The utilization of agricultural waste for value addition presents a significant opportunity for sustainable development in Sierra Leone. This study investigated the potential of plantain peel ash as a local, renewable source of potassium hydroxide (KOH) for saponification. The research aimed to scientifically validate this traditional practice by quantifying the alkali yield from both ripe and unripe plantain peels and demonstrating its efficacy in soap production. The methodology involved collecting, drying, and combusting separate batches of ripe and unripe plantain peels to produce ash. The alkali from each ash type was extracted into a leachate, and the KOH concentration was determined via acid-base titration with a standardized 0.2 M nitric acid solution. A combined alkali solution, mimicking realistic feedstock conditions, was then used to saponify palm oil to produce a final soap product. The study yielded two primary findings. First, a quantitative analysis confirmed that ripe plantain peels produce a significantly higher concentration of potassium hydroxide (12.376 g/dm^3) compared to unripe peels (9.744 g/dm^3), identifying the peel's stage of maturation as a critical factor for optimizing alkali yield. Second, the saponification trial using a combined-source alkali solution was successful, producing a quality soft soap with desirable characteristics, which validates the robustness of the method for practical, small-scale application where feedstock uniformity is not guaranteed. This research concludes that plantain peel ash is a viable and effective alternative to industrial alkali for soap making. It provides a scientific basis for an eco-friendly practice that supports the principles of a circular economy by converting agricultural waste into a valuable commodity. Key recommendations include the standardization of ash production, the development of low-cost methods for testing alkali strength, and the dissemination of best practices to local producers to foster economic empowerment and sustainable enterprise.

Keywords: Saponification; Potassium Hydroxide; Plantain Peel Ash; Waste Valorization; Sustainable Development; Traditional Soap; Circular Economy

1. Introduction

Bananas and plantains rank among the most prolific fruit crops globally. The estimated global production stands at 28 million tons, with Africa contributing approximately 9 million tons of bananas each year [J. Morton and F. M. Julia, 1987]. The substantial production figures indicate the significant amount of kitchen waste that will be generated globally from plantain and banana peels. Potassium is the most prevalent mineral found in plantain peels, with an estimated concentration of 37 g kg-1 in the green peel [K. Addison, 2011, T. Happi Emaga, R. H et al., 2007, IITA, 2009]. This value is increased by a modest amount during the ripening process [W. A. L. Izonfuo and V. O. T. Omuaru et al., 19885]. Numerous researchers have examined the potash, alkali, and metal contents of ashes made from plantain peels [J. O. Babayemi, 2010]. They found that the alkali content of the ash varied from 69 to 81.9%, and the potassium concentration in the peels was as high as 750 mg/kg.

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According to (Wikipedia, 2025), Potassium hydroxide is an inorganic compound with the formula KOH, and is commonly called caustic potash. Potassium hydroxide (KOH), similar to sodium hydroxide (NaOH), is a typical example of a strong base. It has numerous applications both industrially and specifically, primarily owing to its caustic nature and ability to readily react with acids. Its 2005 production was, internationally, estimated at 700,000 to 800,000 tonnes and it has a significant role in the production of most liquid and soft soaps, as well as a range of potassium-related chemicals (Schultz et al., 2005). It comes in a white solid form and is corrosive in nature. Historically, KOH was made by adding potassium carbonate to a strong solution of calcium hydroxide (slaked lime). The salt metathesis reaction results in precipitation of solid calcium carbonate, leaving potassium hydroxide in solution (Aninagyei, D et al., 2023)

$$Ca(OH)_2 + K_2CO_3 \rightarrow CaCO_3 + 2KOH \quad \text{--------------------------------} \textbf{Eq. 1}$$

Filtering off the precipitated calcium carbonate and boiling down the solution gives potassium hydroxide ("calcinated or caustic potash") (Wikipedia, 2025). This method of producing potassium hydroxide remained dominant until the late 19th century, when it was largely replaced by the current method of electrolysis of potassium chloride solutions (Schultz et al, 2005). But before this time, Potash acquired from ashes of tree and other plants were use in the making of soap and other substances. This method of making soap was excessively in use from the time of antiquity to the close of the nineteenth century. (Friends of Schoharie, 2019). It was also sported by the (Sierra Leone Tourism, 2024) for its use in the cooking of Yebeh (A mixture of different Carbohydrate like Cassava, Potatoes and Plantains). Apart from their food values above, the peels are most time considered as agricultural waste (Aurore, G., Parfait, B., & Fahrasmane, L. 2009**)**. These wastes discarded after eating fruits, have been found useful because of their rich content of minerals, especially potassium. Potassium salts, specifically potassium hydroxide (KOH), are common in many industries, such as in saponification a chemical reaction applied in soap production. (Alberto, 2022).

Globally, soap has become prominent to the health and hygiene of man for ages. The earliest known evidence of soap-like products goes back to approximately 2800 BC in ancient Babylon, where a mixture of alkali, water, and cassia oil was utilized for cleansing (Time, 2020). In West Africa for example, Black Soap has been for millennia and is becoming more famous around the world because for its skin-supporting benefits. West Africa women still craft traditional black soap by using local ingredients like plantain skins, cocoa pods, palm leaves, and shea tree bark. They dry these materials under the sun, then burn them into ash, which gives the soap its distinctive black colour (Strausfogel et al, 2016). However, even though the production of Black Soap in Sierra Leone is an old age practice, organization like HEED-SL have started revolutionizing black soap production (Awoko, 2024). Soap therefore is described as a salt of a fatty acid (sometimes other carboxylic acids) used for cleaning and lubricating products as well as other applications.

Despite the long history of using natural materials like plantain peel ash for soap-making, there is still a significant lack of scientific research to regulate and improve how potassium hydroxide (KOH) is extracted and used from this agricultural waste (Akhtar, N et al., 2017; Efeovbokhan et al., 2016). In many developing countries, such as Sierra Leone, plantain peels are often thrown away, missing out on their potential as a sustainable source of alkali for soap production. This not only contributes to environmental waste but also ignores an opportunity to promote cost-effective and eco-friendly alternatives to commercially produced KOH (Akinnawo, 2014). Therefore, it is crucial to investigate how much potassium hydroxide can be obtained from plantain peel ash and to evaluate its effectiveness and practicality as a source for saponification in modern soap-making.

The enduring traditional practice of making use of plantain peels in the production of black soap in West Africa highlights a deep-rooted indigenous knowledge system that has stood the test of time and delivered practical benefits. These peels, rich in potassium, a critical ingredient in soap making due to its role in saponification, are often discarded as agricultural waste, especially in Sierra Leone (Abulude et al., 2007). This limited usage will continue despite the growing global emphasis on sustainability and circular economies. Modern industrial soap production has increasingly favoured synthetic chemical sources, often imported at high cost and associated with environmental problems like water pollution from surfactants (Olkowska et al., 2014). This shift has not only freeze out traditional practices but has also created dependency on external supply chains, which can be both economically and environmentally unsustainable. Scientific investigation into the potassium hydroxide yield from plantain peel ash presents a unique opportunity. It can legalize and enhance indigenous techniques, establish the chemical viability of this natural alternative, and provide first-hand data to support broader acceptance. Additionally, the process of converting agricultural waste into valuable input for local industries could contribute to rural development, job creation, and a reduction in environmental pollution caused by improper waste disposal.

Therefore, this research is aimed at analyzing the Potassium Hydroxide in Plantain Peel Ash and how it can be used in Saponification and it specific objectives will be (1) To verify the Potassium Hydroxide found in Plantain Peels Ash. (2) To show the process of use in Saponification using Plantain Peels Ash and (3) To identify some challenges and opportunities of using Plantain Peels Ash in the process of saponification and the research will answer the following questions: (1) Is Potassium Hydroxide found in Plantain Peels Ash? (2) What are the processes involved in Saponification while using Plantain Peels ash? And (3) What are the challenges and opportunities involved in using Plantain Peel Ash as a source of Saponification?

2. Data and Methodology

2.1. Study Area

The research was conducted in Sierra Leone, with the primary raw materials for the experiment sourced from Mokonde, a key town within the Kori Chiefdom of Moyamba District in the Southern Province. The geographical context of this area is central to the study, as its environmental and socio-economic characteristics directly influence the availability of plantains, the primary feedstock for this research. The landscape of the Kori Chiefdom is predominantly characterized by flat, low-lying terrain interspersed with extensive swampy areas. This topography, combined with a tropical climate, creates fertile conditions suitable for various forms of agricultural activities. The local economy is heavily reliant on subsistence farming, a practice where families cultivate small plots of land to grow crops primarily for their own consumption. Within this agricultural system, staple food crops such as rice, cassava, and plantains are commonly grown. The prevalence of plantain cultivation as part of this subsistence farming model ensures a consistent and abundant supply of the fruit. Consequently, plantain peels, the specific material required for this study, are generated as a common form of household agricultural waste in the region. This makes Mokonde and its surrounding areas an ideal location for a study focused on the valorization of plantain by-products.

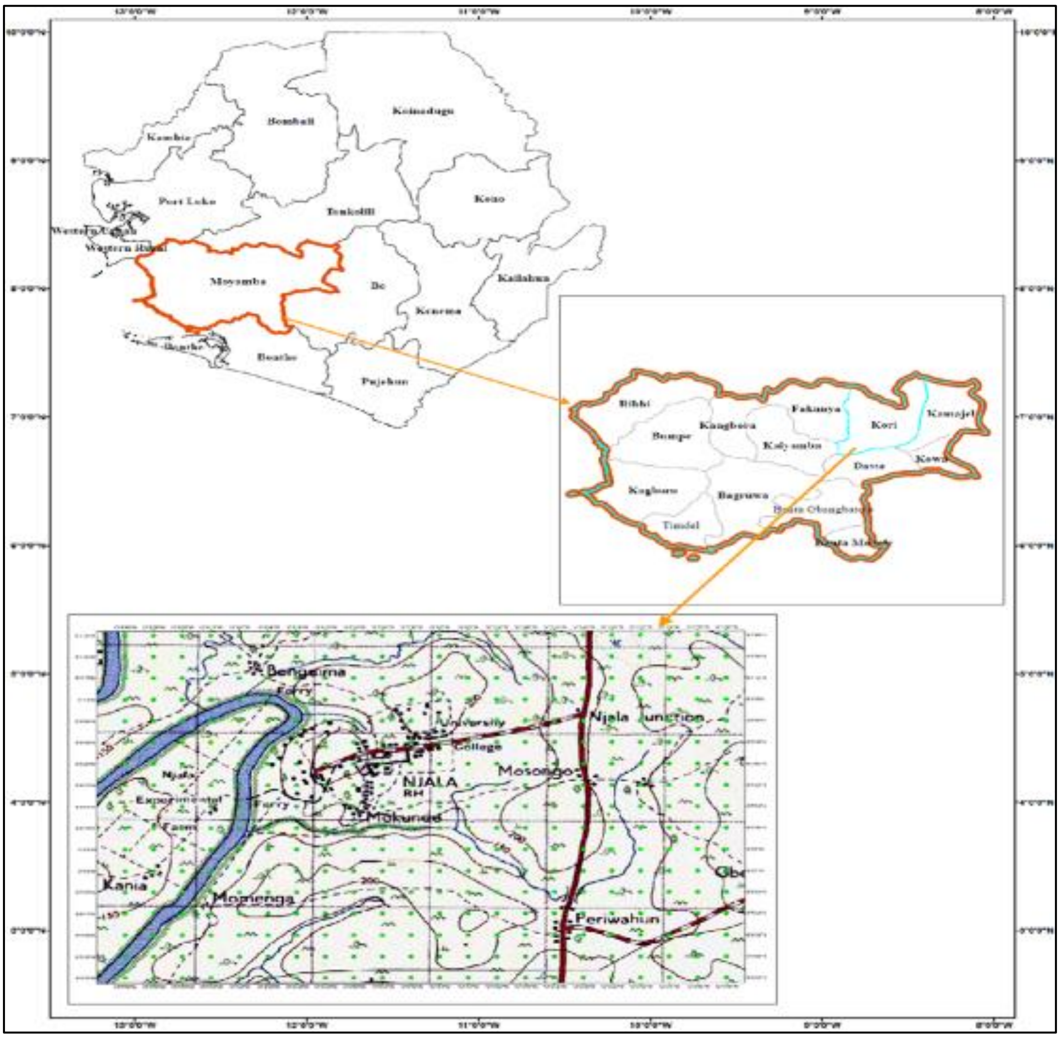

Figure 1 Map of the Study Area. (Source: Author, 2025)

2.2. Materials and Apparatus

2.2.1. Materials

The following materials were utilized for the various experimental stages:

Unripe and ripe plantains (sourced from Mokonde, Kori Chiefdom, Moyamba district, Sierra Leone), Palm oil (Free fatty acid source, sourced from Mokonde Market, Njala Campus), Concentrated Nitric Acid (HNO3, 70% Purity), Methyl Orange indicator, Distilled water, Coal (fuel), Filter paper and Personal Protective Equipment (PPE): gloves, lab coat

2.2.2. Apparatus

The following apparatus were utilized for the various experimental stages:

Beam balance, Stainless steel knife, Drying racks, Evaporating dish, Charcoal-fuelled stove, Volumetric flasks (10 mL, 250 mL, and 500 mL), Measuring cylinder (10 mL, 250 mL), Beakers, Glass rod, Funnel, Burette (50 mL), Pipette (25 mL), Conical flasks, Clamp stand and burette holder, White paper and Wash bottles

2.3. Experimental Procedures

2.3.1. Collection and Drying of Plantain Peels

Plantains (Africa Horn Plantain) were harvested from a farm in Mokonde, Kori Chiefdom, Moyamba district, Sierra Leone. An initial mass of 500 g of green, unripe plantain skin was removed and weighed. The peels were cut into small pieces to accelerate drying. The remaining plantains were stored for 14 days to ripen, after which 500 g of ripe peels were also prepared in the same manner. Both batches of peels underwent a drying process, with their weights recorded daily to monitor moisture loss until a near-constant weight was achieved.

Table 1 Weight of Unripe Plantain Peels During Drying

DATE	TIME	WEIGHT IN (G)
28-02-25	10:20 AM	500.0
	5:00 PM	429.00
01-03-25	10:14 Am	231.00
	5:30 PM	150.00
02-03-25	10:47 AM	98.40
	6:30 PM	92.70
03-03-25	10:00 AM	91.10
	5:30 PM	90.50
04-03-25	10:20 AM	93.10
	5:20 PM	91.40
05-03-25	10:20 AM	93.00
	5:20 PM	91.40
06-03-25	10:40 AM	92.60
	5:20	91.00

Table 2 Weight of Ripe Plantain Peels During Drying

DATE	TIME	WEIGHT IN (G)
14-02-25	10:20 AM	500.0
	5:00 PM	431.20
15-03-25	10:14 Am	240.00
	5:30 PM	163.50
16-03-25	10:47 AM	93.20
	6:30 PM	82.40
17-03-25	10:00 AM	80.40
	5:30 PM	79.33
18-03-25	10:20 AM	81.30
	5:20 PM	79.90
19-03-25	10:20 AM	82.00
	5:20 PM	80.30
20-03-25	10:40 AM	81.00
	5:20	80.00

Figure 2 Drying of smaller Pieces of both Ripe and Unripe Plantain Peels

2.3.2. Ash Production

The dried plantain peels from both ripe and unripe batches were placed in separate evaporating dishes and combusted using a charcoal-fuelled stove. The peels were allowed to burn completely until they formed a fine, grey-black ash.

Figure 3 Burning of Both Ripe and Unripe Plantain Peels

2.3.3. Alkali Extraction from Ash

The ash from each batch was collected and weighed. The ash was then dissolved in a specified volume of distilled water (50g of unripe plantain peel ash in 600 mL of distilled water and 40g of ripe plantain peel in 450 mL of distilled water) to create a stock solution. The mixture was stirred thoroughly to dissolve the soluble alkali components. The resulting solution was then filtered using a funnel and filter paper to remove any insoluble particles, yielding a clear alkali solution (leachate) for each peel type (Nsamba, P., et al., 2022, Femi-Ola T. O et al., 2011).

2.3.4. ***Preparation of a Combined Alkali Solution***

To assess the viability of using a non-uniform feedstock, which simulates a more realistic scenario for small-scale producers who may use plantain peels at various stages of ripeness, the two separate alkali solutions were combined. The entire volume of the leachate from the unripe peel ash (approximately 600 mL) and the entire volume of the leachate from the ripe peel ash (approximately 450 mL) were poured into a single, larger beaker (Adewuyi, G. O et al., 2014). The resulting mixture was stirred thoroughly with a glass rod for two minutes to ensure homogeneity. This final combined solution, representing a mixed-source alkali, was then used for the subsequent saponification trial (Davy H. 1888).

2.3.5. Preparation of 0.2 M Nitric Acid (HNO_3) Standard Solution

A standard solution of 0.2 M nitric acid was prepared for titration. Based on the stock bottle information (Specific Gravity: 1.42, Purity: 70%), the concentration of the stock nitric acid was calculated to be 15.77 M. Using the dilution formula ($C_iV_i = C_fV_f$), it was determined that 6.34 mL of the concentrated acid was required to prepare 500 mL of a 0.2 M solution.

To prepare the solution, approximately 200 mL of distilled water was added to a 500 mL volumetric flask. Then, 6.34 mL of concentrated HNO3 was carefully added to the water. The flask was filled with distilled water to the 500 mL mark, stoppered, and inverted several times to ensure thorough mixing (Ogunsuyi, H. O., & Odefunke, O. T. 2018).

Procedure:

- Some necessary safety equipment including gloves, and a laboratory coat were worn.
- 6.34 mL of 15.77 M HNO_3 was measured using a 10 mL measuring cylinder.
- Approximately 200 mL of distilled water was poured into a 500 mL volumetric flask.
- The measured HNO_3 was carefully added to the water in the flask (acid was added to water, not the other way around).
- The solution was stirred gently with a glass rod.
- More distilled water was added gradually until the total volume reached 500 mL.
- The flask was stoppered and the solution was mixed thoroughly.

A clear, colourless solution was obtained. No visible reaction or precipitation was observed during the dilution process.

2.3.6. Titration for Determination of KOH Concentration

The concentration of KOH in the alkali solutions was determined by titration against the standardized 0.2M HNO_3 solution. For each alkali sample, a 25.00 mL volume was pipetted into a conical flask. Two drops of Methyl Orange indicator were added, turning the solution yellow. The 0.2 M HNO_3 was titrated from a burette until the endpoint was reached, indicated by a permanent colour change from yellow to orange-red. The titration was repeated to obtain concordant results (Schultz H et al., 2017).

2.3.7. Saponification

The saponification process was conducted using the combined alkali solution and palm oil. A 50g mass of palm oil was weighed and heated in a beaker for approximately 15 minutes to ensure it was fully liquefied. A 1000g mass of the heated combined alkali solution was measured. The heated palm oil (30g) was then slowly and carefully added to the heated alkali solution while maintaining continuous, vigorous stirring with a glass rod.

The mixture was stirred constantly until it thickened to a consistency where a drizzled trail of the mixture would briefly hold its shape on the surface. This phenomenon, known as "trace," indicates that the saponification reaction has successfully begun and the oil and alkali have emulsified. Once trace was achieved, the thickened mixture was poured into a petri dish to set and solidify. The soap was left to cure for a period of three days before its final characteristics were evaluated (Strausfogel, Sherrie 2015).

2.4. Data Analysis and Calculations

2.4.1. Determination of Moisture Content

The moisture content and percentage for both unripe and ripe plantain peels were calculated based on weight loss during the drying process. The final weight was taken from the last measurement recorded for each batch.

Formulae Used:

Moisture Content = Initial Weight (Wi) - Final Weight (Wf) --**Eq. 2**

$$Moisture\ Percentage = \frac{Moisture\ Content}{Initial\ Weight}\ x\ 100\% \quad \text{--- Eq. 3}$$

- **Unripe Plantain Peel:**

Initial Weight: 500.0 g

Final Dried Weight: 91.00 g

$$Moisture\ Content = Wi - Wf \quad \text{--- Eq. 4}$$

$Where: Wi = initial\ weight\ and\ Wf = final\ weight$

Moisture Content: 500.0g–91.00g = 409.0g

$$Moisture\ Percentage = \frac{Moisture\ Content}{Initial\ Weight}\ x\ 100$$

$$Moisture\ percentage = \frac{409}{500}\ x\ 100 \approx 81.8\%$$

- **Ripe Plantain Peel:**

Initial Weight: 500.0 g

Final Dried Weight: 80.00 g

Moisture Content: 500.0g–80.00g=420.0g

$$Moisture\ percentage = \frac{420}{500}\ x\ 100 \approx 81.8\%$$

2.4.2. Molarity of Concentrated HNO_3

Specific gravity = 1.42 → this means density = 1.42 g/mL

Molar mass = 63.0 g/mol

- **Mass of 1 L of acid**

$1cm \rightarrow 1.42g$

$1000 \rightarrow x$

$$x = 1000\ x\ 1.42,\ x = 1420g$$

- **Mass of Pure**

$70\%\ purity = \frac{70}{100} x1420 \approx 994g$ --**Eq. 5**

- **Moles of HNO_3**

$$Mole\ of\ HNO_3 = \frac{Mass}{Molar\ Mass} = \frac{994}{63.01} \approx 15.775mol$$

- **Molarity (Ci)**

$Molarity = \frac{mole}{volume} = \frac{15.775mol}{1dm^3} \approx 15.775moldm^3$--**Eq. 6**

- **Dilution Calculation**

Using the dilution formula.

$C_iV_i = C_fV_f$ ---**Eq. 7**

Where:

C_i = 15.77 M, V_i = Volume of stock solution used, C_f = 0.2M (desired concentration), V_f = 500mL (final volume)

$15.775\ x\ Vi = 0.2\ x\ 500$

$$Vi = \frac{0.2\ x\ 500}{15.775} \approx 6.34mL$$

Using the dilution formula ($C_iV_i = C_fV_f$), it was determined that 6.34 mL of the concentrated acid was required to prepare 500 mL of 0.2 M solution.

2.4.3. KOH Concentration from Unripe Plantain Peel Ash

Table 3 Titration Readings for Unripe Plantain Peel Ash

Trial No.	Final Burette Reading (mL)	Initial Burette Reading (mL)	Volume of HNO_3 Used (mL)	Remarks
Trial 1	21.80	0.00	21.80	Rough titration
Trial 2	43.50	21.90	21.60	Concordant

- **Average Volume of HNO3 used (VA):**

$Average\ Volume = \frac{21.80+21.60}{2} = \frac{43.4}{2} \approx 21.7cm^3$ --**Eq. 8**

Reaction:

$HNO_3 + KOH \rightarrow KNO_3 + H_2O$

- **Molar Concentration (CB):**

$\frac{C_A V_A}{C_B V_B} = \frac{n_a}{n_b}$ --**Eq. 9**

Where: C_A=0.2M, V_A=21.70mL, V_B=25mL, and n_a=n_b=1.

$$\frac{(0.2)(21.7)}{C_B(25)} = \frac{1}{1}$$

$$C_B = \frac{4.34}{25} = 0.174moldm^{-3}$$

- **Mass Concentration**

$Mass\ Concentration = Mole\ concentration\ x\ Molar\ Mass$

$Molar\ Mass\ \ of\ KOH = 56g$

$Mass\ Concentration = 0.174\ x\ 56 \approx 9.744g/dm^3$

2.4.4. KOH Concentration from Ripe Plantain Peel Ash

- **Titration Data**:

Table 4 Titration Reading for Ripe Plantain Peel.

Trial No.	Final Burette Reading (mL)	Initial Burette Reading (mL)	Volume of HNO_3 Used (mL)	Remarks
Trial 1	27.50	0.00	27.50	Rough titration
Trial 2	27.70	0.00	27.70	Concordant

- **Average Volume of HNO3 used (VA)**

$$Average\ Volume = \frac{27.50 + 27.70}{2} = \frac{55.2}{2} = 27.6cm^3$$

Reaction

$HNO_3 + KOH \rightarrow KNO_3 + H_2O$ --**Eq. 10**

- **Molar Concentration (CB)**:

$\frac{C_A V_A}{C_B V_B} = \frac{n_a}{n_b}$ --**Eq. 11**

Where: C_A= 0.2M, V_A=27.6 mL, V_B = 25mL, and n_a = n_b =1.

$$\frac{(0.2)(27.6)}{C_B(25)} = \frac{1}{1}$$

$$C_B = \frac{5.52}{25} \approx 0.221 moldm^{-3}$$

- **Mass Concentration:**

$Mass\ Concentration = Mole\ concentration\ x\ Molar\ Mass$ --**Eq. 12**

$Molar\ Mass\ \ of\ KOH = 56g$

$Mass\ Concentration = 0.221\ x\ 56 \approx 12.376 g/dm^3$

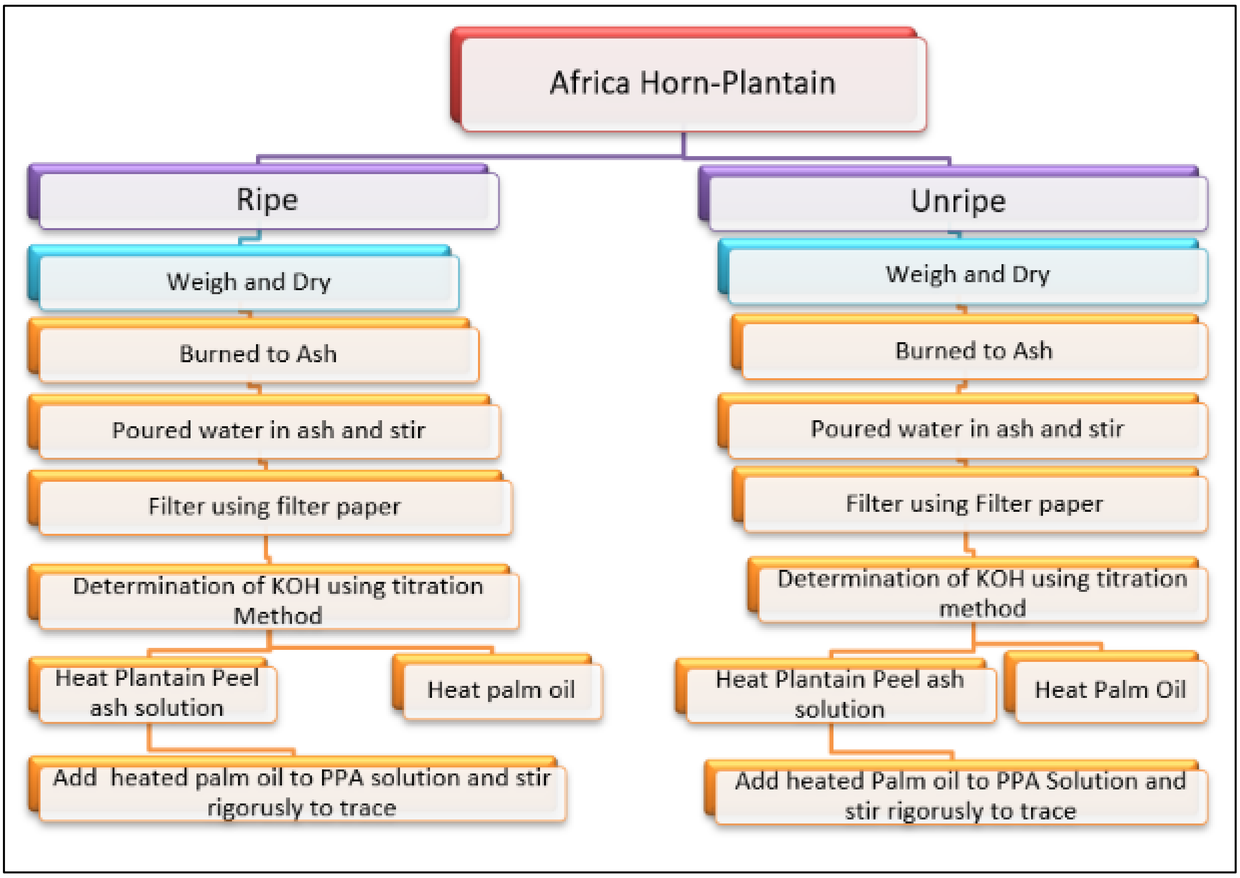

Figure 4 Experimental Framework (Source: Author, 2025)

3. Results

3.1. Presentation of Results

The experimental work yielded quantitative data on moisture content, ash yield, and potassium hydroxide concentration. Qualitative observations were also recorded for the saponification process.

3.1.1. Moisture Content and Ash Yield

The initial weight of both unripe and ripe plantain peels was 500 g. After a drying period, the final weight was recorded to calculate the moisture content. The drying process showed that unripe peels retained 91.00 g of dry matter from an initial 500.0 g, resulting in a moisture content of 409.0 g (81.8%). Ripe peels had a final dry weight of 80.00 g, indicating 420.0 g (84.0%) moisture. These results align with the literature stating that plantain peels are moisture-rich and require adequate drying before combustion (Onwuka & Onwuka, 2005; Happi Emaga et al., 2007). Dried peels were incinerated completely, resulting in fine, grey-black ash. This suggests optimal combustion, as supported by Vassilev et al. (2010), and confirms the presence of soluble potassium salts.

Table 5 Moisture Content and Ash Yield from Plantain Peels

Peel Type	Initial Weight (g)	Final Dried Weight (g)	Moisture Content (g)	Moisture Percentage (%)	Weight of Ash Produced (g)	Ash Yield (% of Dried Weight)
Unripe	500.0	91.0	409.0	81.8%	50.0	54.9%
Ripe	500.0	80.0	420.0	84.0%	40.0	50.0%

The results indicate that ripe plantain peels had a slightly higher moisture content (84.0%) compared to unripe peels (81.8%). Conversely, the ash yield from the dried weight was higher for unripe peels (54.9%) than for ripe peels (50.0%).

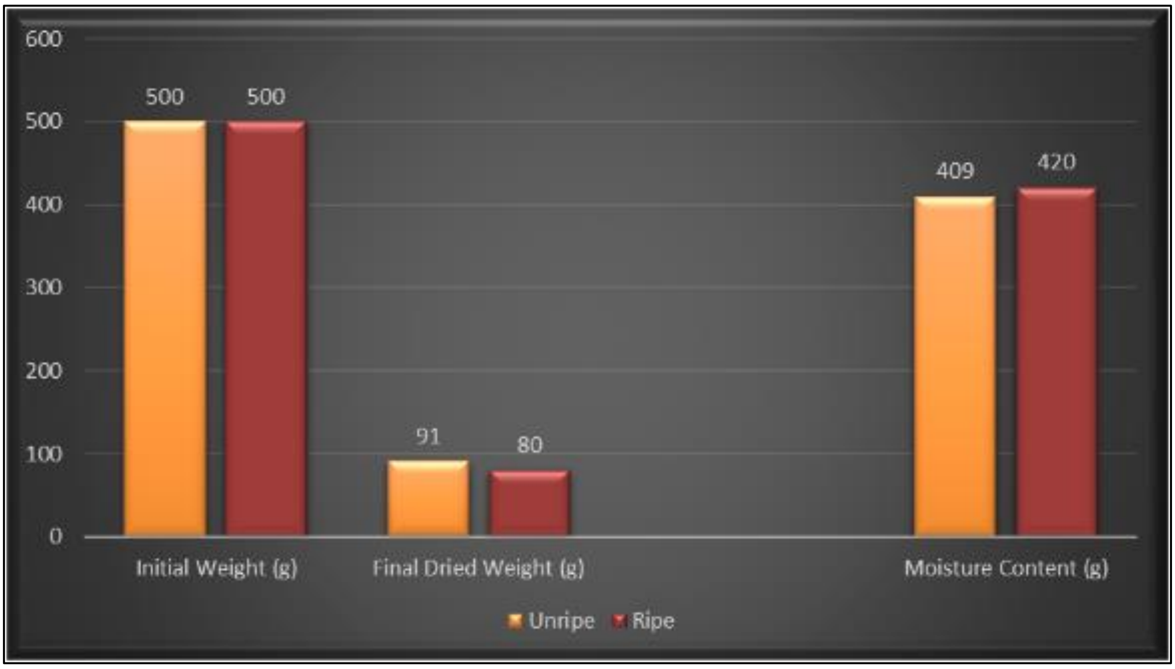

Figure 5 Difference in Moisture content of Ripe and Unripe Plantain peel

3.1.2. Leachate Preparation

Separate leachates were initially prepared from each batch of ash. The ash-to-water ratios were:

- **Unripe peel ash:** 50 g in 600 mL

- **Ripe peel ash:** 40 g in 450 mL

To streamline the process and mimic a more practical field scenario, both leachates were combined before saponification, forming a mixed alkali solution. This combined extract was used in the soap-making stage.

3.1.3. Potassium Hydroxide (KOH) Concentration

The concentration of potassium hydroxide in the alkali solution extracted from the ash of both unripe and ripe plantain peels was determined through titration with a standardized 0.2 M nitric acid (HNO_3) solution.

Table 6 KOH Concentration from Titration Results

Peel Type	Average Volume of HNO_3 Used (mL)	Molar Concentration of KOH (mol/dm^3)	Mass Concentration of KOH (g/dm^3)
Unripe	21.70	0.174	9.744
Ripe	27.60	0.221	12.376

The titration results clearly show that the alkali solution derived from ripe plantain peel ash contained a higher concentration of potassium hydroxide (12.376 g/dm^3) compared to the solution from unripe plantain peel ash (9.744 g/dm^3). These values indicate a sufficient alkali concentration for saponification, validating the ash as a viable source of KOH for soap production (Adekunle et al., 2021; Alberto, 2022).

This visual would effectively highlight the significant difference in KOH yield between the two samples.

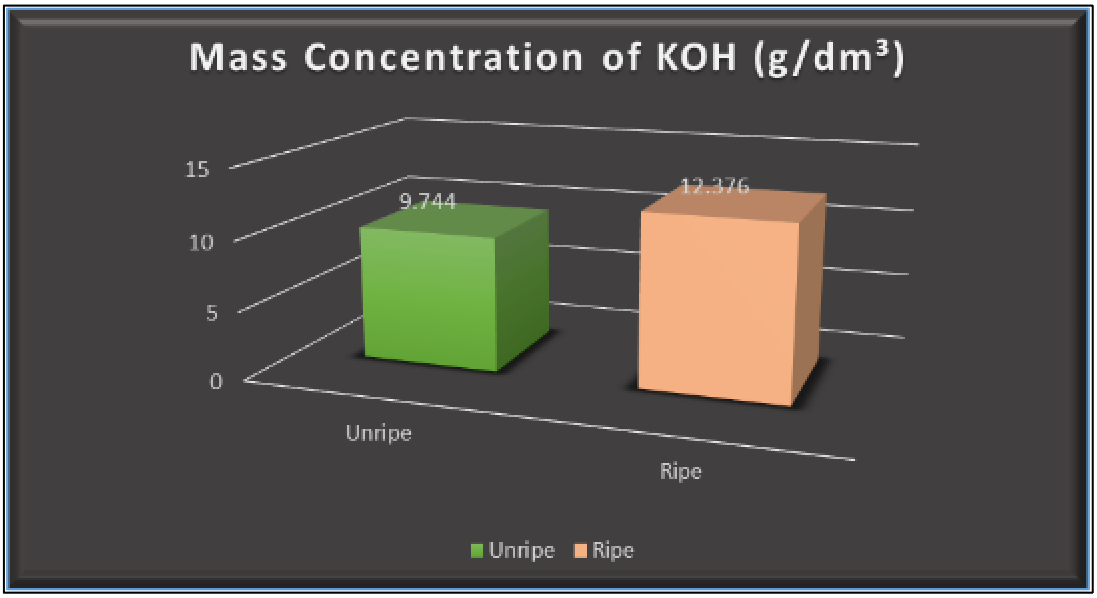

Figure 6 Comparison of KOH Concentration in Ripe vs. Unripe Plantain Peel Ash

3.1.4. Saponification Using the Combined Solution

A 50 g sample of palm oil was heated and combined with a measured volume of the mixed plantain peel alkali solution. The mixture became thickened when continuously stirred, thus the mixture reached trace, indicating the start of saponification. The yielded soap formed was soft, creamy, and lathered easily characteristics typical of potassium-based soaps (Gunam I. B. et al., 2023, Formula Botanica, 2020; Aninagyei et al., 2023). Using a combined solution not only simplified the process but also ensured a more balanced alkali strength. This approach replicates traditional practices where uniform ripeness is rarely guaranteed, suggesting that mixed peel ash can be effectively used without compromising soap quality.

3.1.5. Characteristics of the Final Soap Product

The soap produced from the combined alkali solution was allowed to cure for three days. Qualitative evaluation of the final product yielded the following observations and the solid soap produced have great health impact to human (Okareh, O. T et al., 2015, Sommers, L. E et al., 2014 and Arun, K. B et al., 2015)

Figure 7 The solid Soap Product after Reaction of both filtrate from Ripe and Unripe Plantain Peel and Palm oil

Table 7 Characteristics of Soap Produced from Combined Alkali Solution

Feature	Observation
Texture	The soap was solid but had a soft, smooth consistency, characteristic of potassium-based soaps.
Lathering Ability	It produced a quick, creamy, and stable lather when used with water.
Cleansing Power	The soap was effective in removing oil and dirt from hands.
Scent	It had a mild, natural, earthy aroma with no added artificial fragrance.
Color	The final color was a light brown, likely due to the presence of residual ash particles.

4. Discussion

4.1. Verification and Comparative Yield of Potassium Hydroxide

The first objective of the study was to verify and quantify the presence of potassium hydroxide. The titration results unequivocally confirm that plantain peel ash is a potent source of alkali. The neutralization reaction with nitric acid is indicative of a strong base, which, in the context of lye derived from plant matter, is primarily potassium hydroxide formed from the dissolution of potassium carbonate (K_2CO_3) (Friends of Schoharie, 2019). The key finding from the comparative analysis is that ripe plantain peels yield a significantly higher concentration of KOH. This suggests that as the fruit matures, potassium, a mobile and vital nutrient for metabolic processes, becomes more concentrated in the peel. This insight is a crucial contribution, as it provides a clear, evidence-based recommendation for optimizing the alkali extraction process: using fully ripe peels will maximize the yield of the active ingredient. This aligns with the work of Happi Emaga et al. (2007) on the changing chemical composition of peels during maturation but provides a specific, practical application for saponification.

4.2. Efficacy of a Combined-Source Alkali in Saponification

The second part of the experiment was designed to test a more pragmatic approach. The successful creation of a quality soap using the combined alkali solution is a highly significant finding. It demonstrates that even when peels of varying ripeness are used a highly probable scenario for any small-scale or rural producer the resulting alkali is still effective for saponification. This validates the robustness of the traditional method. The characteristics of the final product are consistent with those of traditional potassium-based soaps, which are known to be softer and more soluble than their sodium-based counterparts (Formula Botanica, 2020). The colour and texture are also in line with descriptions of West African black soap (Aninagyei et al., 2023). This successful outcome proves that a mixed-source alkali can produce a high-quality, effective cleansing product, which is a critical finding for promoting this technology as a reliable enterprise.

4.3. Key Findings

This study was undertaken to scientifically validate and quantify the use of plantain peel ash as a source of potassium hydroxide for saponification. The experimental investigation yielded several key findings:

- **Verification of Plantain Peel Ash as an Alkali Source:** The research confirmed that ash derived from both unripe and ripe plantain peels is a potent source of potassium hydroxide (KOH), capable of inducing saponification in palm oil.
- **Superiority of Ripe Peels for Alkali Yield:** A crucial finding was the significant difference in alkali concentration based on the peel's ripeness. Ripe plantain peels yielded a substantially higher concentration of potassium hydroxide (12.376 g/dm^3) compared to unripe peels (9.744 g/dm^3), indicating that the stage of maturation is a critical factor for optimizing yield.
- **Viability of a Combined-Source Alkali:** The study successfully demonstrated that a combined alkali solution, created by mixing the leachates from both ripe and unripe peels, is highly effective for producing a quality soft soap. The resulting product exhibited desirable characteristics, including a smooth texture and effective lathering ability, confirming the robustness of using a mixed-feedstock approach that mirrors real-world conditions (Ikpoh I. S. et al., 2012).

Acronyms/Abbreviation

- KOH Potassium Hydroxide
- NaOH Sodium Hydroxide
- $Ca(OH)_2$ Calcium Hydroxide (Slaked Lime)
- $CaCO_3$ Calcium Carbonate
- K_2CO_3 Potassium Carbonate
- M Molar Concentration
- HNO_3 Nitric Acid
- H_2O Water
- PPE Personal Protective Equipment
- NGO Non-Governmental Organization
- Ci Initial Concentration
- Cf Final Concentration
- Vi Initial Volume
- Vf Final Volume
- Wi Initial Weight (Wi) –
- Wf Final Weight

5. Conclusion

The primary objective of this research was to analyze the potassium hydroxide in plantain peel ash and its uses in saponification. Based on the findings, it can be concluded that the study successfully achieved its aims.

First, the presence of potassium hydroxide in plantain peel ash was unequivocally verified and quantified. Second, the process of saponification using this naturally derived alkali was successfully demonstrated, yielding a product with the distinct characteristics of traditional soft soap. Finally, the research identified both the opportunities presented by this sustainable practice and the key challenges, primarily the need for standardization.

Therefore, this study concludes that plantain peel ash is a viable, effective, and sustainable local resource for soap production in Sierra Leone. It validates traditional indigenous knowledge with modern scientific evidence and provides a clear pathway for converting agricultural waste into a valuable commodity. The findings offer a strong foundation for promoting this practice as a means of fostering economic empowerment, environmental sustainability, and greater self-sufficiency within local communities.

Recommendations

Arising from the conclusions of this study, the following recommendations are proposed for future research and for practical implementation.

- **Recommendations for Future Research**

To build upon the findings of this project and address its limitations, future research should focus on:

- **Process Standardization:** Conduct studies to determine the optimal combustion temperature and duration for maximizing the yield and purity of soluble potassium salts from plantain peel ash. This would be a critical step toward standardizing production.
- **Quantitative Soap Analysis:** Perform a detailed chemical analysis of the final soap product. This should include measuring its pH, free alkali content, and glycerin content to ensure it meets established safety and quality standards for cosmetic use.
- **Exploration of Other Biomass:** Investigate the alkali potential of other abundant agricultural waste products in Sierra Leone, such as cocoa pods, palm kernel husks, and rice husks, to identify other viable local resources.
- **Shelf-Life and Stability Studies:** Conduct long-term stability tests on the soap produced to assess its shelf-life, including any changes in color, texture, scent, and performance over time.
- **Broadening the Scope:** Replicate the study using different varieties of plantain and from different geographic regions within Sierra Leone to assess the variability in KOH yield and create a more comprehensive dataset.
- **Recommendations for Practical Application and Stakeholders**

For local entrepreneurs, NGOs, and governmental bodies, the following actions are recommended:

- **Development of Low-Cost Testing Methods:** There is a pressing need to develop and disseminate simple, affordable tools for local soap makers to test the strength of their lye solution. This could include calibrated hydrometers or standardized colour-based pH testing kits to ensure consistent and safe soap production.
- **Dissemination of Best Practices:** NGOs and community leaders should conduct workshops to disseminate the key findings of this research, particularly the recommendation to use fully ripe peels to maximize efficiency and yield.
- **Establishment of a Value Chain:** Government and private sector actors could support the creation of a formal value chain for plantain peels, establishing collection points and processing facilities that can provide a consistent source of quality-assured ash to local soap makers.
- **Safety and Handling Training:** Training programs should emphasize the importance of using personal protective equipment (PPE), such as gloves and eye protection, when handling alkali solutions, regardless of their natural origin.

Compliance with ethical standards

Acknowledgement

With heartfelt gratitude, I thank my Saviour Jesus Christ for enabling me during this period. I am indebted to my primary supervisor, Mr. Alfred Morriba, and co-supervisor, Mr. Sahr Emmanuel Lebbie, for their exemplary guidance and support throughout this dissertation. Special thanks to my lecturers in the Chemistry department, especially Dr. Yahaya Kudush Kawa and Dr. John Paul Kaisam, whose inspiring instruction provided essential knowledge for my research. I am deeply grateful to my mothers, Sia Fanta Fillie, for their unconditional love, and to my family for their unwavering belief in me. Finally, I extend my thanks to the Mahoney family for their spiritual guidance and encouragement during my studies.

Statement of ethical approval

This study involved the chemical analysis of materials and standard soap-making synthesis. No human or animal subjects were used. Therefore, formal ethical approval was not required for this work, in accordance with the policy of Njala University, Sierra Leone. All laboratory safety protocols were strictly followed.

Disclosure of conflict of interest

There is no conflict of interest regarding the publication of the paper, declared the author.

Authors Contribution

- **Tamba Patrick Komba:** Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Visualization, Writing original draft
- **Sahr Emmanuel Lebbie:** Supervision, Validation, Writing – review & editing, Resources, Writing original draft
- **David Conteh:** Funding acquisition, Resources, Supervision
- **Umaru Kanneh:** Funding acquisition, Resources, Supervision
- **Issa Tura:** Funding acquisition, Resources, Supervision
- **Isaac Yongai:** Funding acquisition, Resources.

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	Isaac Yongai, a well profound and deep-rooted science student cultivated from high school, nurtured as an environmental Chemist, Innovative leader, Scientific researcher, Field worker, and an Author in the University. Soon to own a degree of Bachelor of Science in Basic Sciences with Honors in Environmental Chemistry on 20th, December 2025. My desire is to move beyond traditional education and equip myself with practical skills, creative mindset, and unwavering confidence to build my career. I always count it joy when, I find myself in my critical zone (Environmental & Climate stuffs, Innovations, Scientific research and Field work), because it creates for me more learning environment, and executing what, I have learned so far. Always willing and ready to give my all in such environments