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# Production and Process Optimization of an Emulsifier as a Tradition Food Salt (*Nikki*) from *Musa paradisiaca* (Plantain) Waste Peels Enriched with *Ficus Waste* Peels Ash and Evaluation of Its Effect on the Emulsification, Stabilisation and Sensory Properties of Yellow Achu-Soup

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## Abstract

Yellow achu-soup, an emulsion of red palm oil and water is a traditional delicacy in the grass field of Cameroon, which faces a problem of its stability due to the quality of the emulsifier used to emulsify and stabilize it. This study was designed for the optimization of the production of an emulsifier (*Nikki*) from *Musa paradisiaca* (Plantain) Peels enriched with *Ficus* Peels as a traditional food salt for the emulsification and stabilisation of yellow achu-soup. A factorial design with three factors (combustion time and temperature and the ash extraction temperature) and a mixture design were used to evaluated the effect of the combustion process and emulsifier mixture ratios on the physico-chemical and functional properties of the emulsifiers and the yellow achu-soup respectively, including the Ash Yield (%), pH, Alkaline Content (%), Non-alkaline content (%) Potash Content (%), Foam Capacity (%), $EI_{24}$ and $EI_{48}$, (%), Foam stability (%). The sensory properties of the resulting soup were evaluated for its acceptability using the 9 point hedonic scale. From these studies, the highest alkalinity of 12.91 ± 0.01 for the mixture was obtained at a mixture ratio of 85:15 (S239). There enriched salts had significantly higher form capacity and stability of 35.4 compared to the un-enriched salts with highest foam stability of 29.77 for plantain and 31.01 for *Ficus*. Salt mixtures of sample S339 with plantain to *Ficus* ash ratios of 85:15, 70:30, 55:45, and 35:65 had the highest foaming capacity and stability. Highest $EI_{24}$ of 41.5% ± 0.10% (S3.66a) and 46.2% ± 0.10% (S3.66b) for plantain and *Ficus* peels ash extract. All samples showed a decrease in emulsification index after 48 hours with enrichment. Burning time and temperature had a significant positive ($P < 0.05$) effect on the ash yield and alkaline content while the burning time and extraction temperature had a significant effect on the alkaline content. Maximum alkaline content of 79.06% for plantain and 91.58% for *Ficus* was obtained at 250˚C and 30 mins with maximum extraction temperature of 90˚C. Maximum $EI_{24}$ of 35.80% for plantain and 32.47% for *Ficus* and $EI_{48}$ of 35.15% for plantain and 32.13% for *Ficus* were obtained at 250˚C and 30 mins with a maximum extraction temperature of 30˚C and at 250˚C and 30 mins with a maximum extraction temperature of 30˚C respectively. Out of the thirty panelist involved in the sensory evaluation, 53.3% generally accepted sample S393c and 40% accepted sample S239c. From the results, it was concluded that the addition of *Ficus* peel ash solution at a percentage of 30% and above to plantain emulsifier enhanced the stability of achu soup even after 48 hours, with acceptable sensory properties.

## Subject Areas

Biochemistry, Bioengineering, Plant Science

## Keywords

Food Waste, *Musa paradisiaca*, *Ficus*, Emulsifier, Optimization, Yellow Achu-Soup, Stability

## 1. Introduction

Salt has been used in food preparation since pre-history and is still routinely added in modern food manufacturing processes. Salt is made up of sodium and chloride, with up to 40% of the molecule being sodium. Common edible salt, a natural evaporite that can be obtained from the sea, underground ore or natural brine, and contains at least 97% of sodium chloride (NaCl), is the main salt used in food preparations, with objectives to improve food taste, color, flavor and aroma [1] [2] Out of that, other specific salts that have been reported to be used in food preparations are Lakes' deposits [3], plant-based ashes their filtrates, and evaporites of these filtrates [4] [5]. Their chemical composition shows they are a mixture of salts and thus, made of cations and anions, with major cation being generally sodium or potassium whereas major anions are generally carbonates, bicarbonates, sulfates and chlorides [6] [7]. Their usage have mostly been reported in African countries like; Cameroon, Nigeria, Niger, Chad, Ghana, Kenya, Burkina Faso, Uganda, Tanzania, Sudan, Central and East African countries [8] [9] [10].

Traditional functional salts, potash, locally called "*nikkih*", are being produced from *Musa paradisiaca* and *Musa acuminate* peels in many regions in Cameroon, particularly in the North West and West Regions for example. *Nikkih* is produced traditionally by leaching ashes of combusted agro food waste with water to obtain a potassium-carbonate-rich crude bioextract [10] [11]. *Nikkih* is a biobased functional plant extract which is fast replacing "kwang", a common lake salt [12]. From their chemical composition, being a mixture of salts, they are made of cations and anions; with the major cation being generally sodium or potassium whereas the major anions generally as carbonates, bicarbonates, sulfates, and chlorides [3]. *Nikkih* has been found to be cheaper and is now used in the preparation of a variety of foods due to its functional properties since it serves as emulsifier, tenderizer, thickener, seasoning, potentiating adjunct, and preservative [12]. Functionalities of *nikkih* have been attributed to the alkalinity of the aqueous solution [13]. The salt has also been reported to reduce cooking time [4].

In some parts of Africa, plant waste like cassava peels, plantain peels, *Ficus carica* peels, palm branches, and beetroot, are utilised for the production of traditional food salt because of their high alkaline content when given a thermal treatment (Mbawala *et al*., 2015 [9]; Ngwasiri *et al*., 2021 [10]). The local production of potash from these agricultural wastes has been found to be a cheaper alternative source of the much-needed chemical used in the production of soap, fertilizer, plant base salt and other alkalis-based products [11]

One of the major problems faced from some products produced from *nikki*, like yellow achu soup is the stability of the final product as the "Water-Oil" emulsion quickly (Mbawala *et al*., 2015 [9]; Ngwasiri *et al*., 2021 [10]). The problem of stability has been associated with several parameters such as the production method and the raw materials used, which all determine the physico-chemical and functional properties of the *Nikki*. Currently, Nikki is produced principally from *Musa paradisiaca* and *Musa acuminate* peels through combustion and extraction with water under unspecified process conditions. This results in a product with varying properties, which has a consequence on the yellow achu soup. To ameliorate the problem of Achu soup stability, small quantities of certain plant based crude extract with higher emulsification index are being incorporated into the *Nikkih* to form a crude mixture of biosurfactant quickly (Mbawala *et al*., 2015) [9]. The liquid extract of the fruit peel ash of *Ficus carica* is being used in some villages in Bamenda to enriched *Nikkih* with the believe that it enhances the stability and sensory quality of the yellow achu soup. Studies involving plant-based food salts have been focused on their individual chemical composition, effect on the nutritional quality, taste and toxicology. Very few studies have been reported on the effect of processing conditions on the physico-chemical and functional properties of enriched salts.

The aim of this study was the optimization of the production process of an emulsifier (*Nikki*) from *Musa paradisiaca* (Plantain) Peels enriched with *Ficus* Peels as a traditional food salt and evaluation of its effect on the emulsification and stabilization of yellow achu-soup. The effect of the process parameters on the physico-chemical and functional quality properties of the traditional food salt (emulsifier, Nikki) from the plantain peels enriched with *Ficus* peels as an emulsifier were evaluated and optimized. In addition, the stability and sensory properties of yellow achu soup produced from the optimized condition for the emulsifier were further evaluated for its functionality and sensory acceptability.

## 2. Materials and Methods

### 2.1. Materials

**Biological material used**

- Fresh plantain peels
- Fig fruit peels
- Palm oil
- Spices

### 2.2. Methodology

#### 2.2.1. Preparation of Ash

Unripe plantain peels were bought from five people who sell plantain washed, sliced into small sizes, and spread on trays to dry under the sun for 1 week. Dry *Ficus* peels were obtained from Mendakwe village in Bamenda and the same steps for ash preparation of plantain peels was followed. The dried peels were weighed in batches and their respective weights were recorded. The weighed peels were placed in metallic containers and combusted to ash in a furnace at varied temperatures and times. The resulting ash after complete combustion was then collected, weighed and recorded.

#### 2.2.2. Preparation of Liquid Extract from Plantain and *Ficus* Peels Ash

Fifty grams (50 g) of the ashes were weighed and placed in separate bowls. The same volumes of water (100 ml) at different temperatures as per the extraction temperature were measured and poured into the different bowls, to give solutions. The mixtures were stirred thoroughly from time to time while maintaining the various temperatures with the help of an electric cooker and allowed to stand for the required extraction time. Temperature was maintained through double boiling though out the extraction time of 3 hours.

After the extraction time, the clear liquids obtained were carefully poured into clean containers and kept for various analysis.

### 2.3. Experimental Design

Factorial Design was used and the design had 14 experimental runs with three factors; Burning temperature ($X_1$), Burning time ($X_2$) and Extraction temperature ($X_3$) and seven responses; yield ($Y_1$), pH ($Y_2$), Alkaline content ($Y_3$) Non alkaline content ($Y_4$), Potash content ($Y_5$), Foam capacity and Foam stability ($Y_6$), Emulsifying index 24 and Emulsifying index 48 ($Y_7$) as shown on Table 1.

## 2.4. Mixture Design

After obtaining the plant-based ash solution, 100 ml of *nikih* was prepared using different percentages of the two ash solutions (Table 2). The Proportions of *Ficus* peel ash solution added to plantain peel ash solution were varied.

The pH of the 100 ml samples of *nikihs* were obtained and the "*nikih*s" were then preserved in glass containers for other analysis and subsequent use in the preparation of yellow achu soup.

Table 1. Experimental design table for real values.

| Burning Temp (˚C) | Burning Time (mins) | Extraction Temp (˚C) | Ash Yield (%) | pH | Alkaline Content (%) | Non-alkaline content (%) | Potash Content (%) | Foam Capacity (%) | $EI_{24}$ and $EI_{48}$ (%) | Foam stability (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 9.55 | 60 | | | | | | | | |
| 250 | 90 | 30 | | | | | | | | |
| 300 | 60 | 60 | | | | | | | | |
| 300 | 110.45 | 60 | | | | | | | | |
| 300 | 60 | 9.55 | | | | | | | | |
| 350 | 90 | 90 | | | | | | | | |
| 350 | 30 | 90 | | | | | | | | |
| 384.1 | 60 | 60 | | | | | | | | |
| 350 | 90 | 30 | | | | | | | | |
| 250 | 30 | 30 | | | | | | | | |
| 250 | 30 | 90 | | | | | | | | |
| 215.91 | 60 | 60 | | | | | | | | |
| 350 | 30 | 30 | | | | | | | | |
| 350 | 90 | 90 | | | | | | | | |

Table 2. Mixture design.

| Ratio of plantain ash solution to *Ficus* ash solution | Quantity of plantain peel ash solution | quantity of *Ficus* peel ash solution |
|---|---|---|
| 100:0 | 100 ml | 0 ml |
| 0:100 | 0 ml | 100 ml |
| 85:15 | 85 ml | 15 ml |
| 70:30 | 70 ml | 30 ml |
| 55:45 | 55 ml | 45 ml |
| 35:65 | 35 ml | 65 ml |

### 2.5. Preparation of Achu Soup

The soup was prepared using the dry gum method of preparing emulsions. Palm oil was heated in a frying pan for 1 minute after which 20 ml of the oil was measured and poured into separate bowls. Into the bowl was added 10 ml of the emulsifier (*nikih*) and ½ teaspoon of achu spices and 70 ml of hot water (80˚C) was poured into each of the bowls and mixed thoroughly.

### 2.6. Evaluation of Physiochemical and Functional Properties of *Nikih* from Plantain Peels Enriched with *Ficus* Peels

#### 2.6.1. Determination of pH Value

The pH of the samples was measured using a pH 700 pH meter (APERA instruments). About 20 ml of a sample was put in a small beaker. The electrode of the pH meter was then dipped into the sample and the pH read from the screen and recorded

#### 2.6.2. Determination of Alkaline Content

The alkali content is either potassium carbonate or sodium carbonate. Total alkali may be determined by titration with an appropriate mineral acid:

$$K_2CO_3(aq) + 2HCl(aq) \rightarrow 2KCl(aq) + CO_2(g) + H_2O(l)$$

Or

$$NaCO_3(aq) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

Determination of alkali content of potash obtained from plantain peel, using titrimetric method of analysis (11). Twenty-five (25) ml of the solution was pipetted and titrated against 0.1 M $HCL_{(aq)}$ using phenolphthalein indicator (11). Replicates were obtained, and the average titters were used to calculate the alkali content of the crude potash. Calculation of percentage purity can be used to evaluate the alkali and non-alkali content.

#### 2.6.3. Foaming Capacity and Foam Stability

The foaming capacity and stability of the various samples of yellow achu soup was analysed using a method described by [14], with slight modifications. The protocol for this process is as stated below. Each of the samples (10 ml) was placed into different test tubes. For the determination of foaming capacity, the total height of the mixture was taken note of, the mixture was then whipped for 30 minutes and the total height was noted. The foaming capacity of all the samples was calculated using Equation (1).

$$\text{Foam capacity} = \frac{A - B}{B} \times 100(\%) \quad (1)$$

where:

$A$ = height after whipping (cm)

$B$ = height before whipping (cm)

The foam stability was determined by using the samples obtained in the foam capacity test. The whipped samples were allowed to stand for 3 hrs and the height of the whipped samples was recorded. Foaming stability was calculated using Equation (2):

$$\text{Foam stability} = \frac{C - D}{C} \times 100(\%) \quad (2)$$

where:

$C$ = height after standing (cm)

$D$ = height before whipping (cm)

#### 2.6.4. Calculation of Emulsification Index

The emulsifying activities of the different emulsifying agents at their different proportions used in the preparation of this soup was evaluated using a method described by [15] with slight modifications. 10 ml of the four samples of yellow *achu* soup obtained was placed each in 4 different test tubes, vortexed and allowed to stand. Production of creamy emulsion was observed at time intervals, of 24 hours and 48 hours. All obtained results were recorded in duplicate using the equation 3 below to calculate the Emulsification index (EI):

$$\text{EI} = \frac{\text{height of emulsified layer}}{\text{total height of emulsion}} \times 100 \quad (3)$$

#### 2.6.5. Potash Content

Determination of Potash and Non-potash Content of the Extract. Potash content refers to the water-soluble content of the residue obtained after complete evaporation of the extract solution leached from ashes. The potash content was determined as follows; as described by (12) and (10). A known weight of the peels was completely combusted to ash and a known weight of the ash (W1) was leached with a known volume of water (V) to obtain a solution containing water-soluble inorganic compounds. The resulting potash was obtained in a dry form by evaporating the leachate to complete dryness and drying the residue to constant weight (W2) in an oven at 105˚C. After evaporation of volume V1 of water, the potash content (PCa) (% of ash) was derived using (4) while (5) was used for the non-potash content (NPCa) (% of ash):

$$\text{PCa} = \left[\left(\text{W2}/\text{V1}\right) \times \text{V}\right] \times 1/\text{W1} \times 100, \quad (4)$$

$$\text{NPCa} = 100 - \text{Pca} \quad (5)$$

### 2.7. Evaluation of the Sensory Attributes and Overall Acceptability of Optimized Traditional Food Salt

Thirty untrained sensory panelists were involved, who were required to taste each sample and fill out a questionnaire. A nine-point hedonic scale ranging from dislike extremely (1) to like extremely (9) was used to assess the quality attributes of colour, texture, taste, flavor, thickness, and overall acceptability of the achu soup.

### 2.8. Model Validation, Optimization and Statistical Analysis

The responses used for optimization were Ash yield, pH, Alkaline content, Non alkaline content, Potash content, Foam capacity, Foam stability, Emulsifying index 24 and Emulsifying index 48, to maximize all the responses. For each response, the model was a second-order equation with interaction expressed as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{33} X_3^2 \quad (6)$$

where $Y$ is the response variable, while the regression coefficients are $\beta_1$, $\beta_2$, $\beta_3$ (linear), $\beta_{12}$, $\beta_{13}$, $\beta_{23}$ (interaction), and $\beta_{11}$, $\beta_{22}$, $\beta_{23}$ (quadratic). The parameters used in validating the model were the coefficient of determination ($R^2$) and the Root Mean Square Error (RMSE). A model is said to reflect the data when the $R^2$ value is greater than 70%, and the RMSE is less than or equal to 10. Both parameter values were generated using JMP Pro 16 software. The same software was also used in obtaining the response surface curves for the responses, and their corresponding optimum points.

Microsoft Excel was used in calculating the mean and standard deviation for each data set, while JMP Pro 16 software was used in regression analysis, testing the models and obtaining the response surface plots for each of the responses. The results are expressed as mean ± standard deviation (SD), and P values less than 0.05 were considered significant ($P < 0.05$).

## 3. Results and Discussion

### 3.1. Effect of Production Process on the Functional Properties of the Enrich Salt/Emulsifier

From the properties of the non-enriched salt/emulsifier which were determined, a mixture design was generated to produce salts using a combination of both salts. Table 3 shows the effect of the process parameters on the pH, foam capacity, foam stability, emulsification index of the TFS enriched with *Ficus carica*.

#### 3.1.1. Effect of Production Process on the pH of Salts/Emulsifier

It was observed that the pH of the enrich salts/emulsifier was equal to, or slightly different from those of the individual salts. The pH of the mixture varied from 11.11 ± 0.06 to 12.91 ± 0.01. The highest alkalinity of 12.91 ± 0.01 for the mixture was obtained at a mixture ratio of 85:15 (S239). This suggests good alkalinity in the production of a good emulsion base, required for yellow achu soup from palm oil and water. The alkaline pH values obtained are in accordance with other reports on the production of alkaline crude extracts from combusted plant materials [16] [17]. The ashes are usually alkaline (pH > 10) because they are composed primarily of calcium carbonate, potassium chloride, and sodium chloride.

#### 3.1.2. Effect of the Production Process on the Foaming Capacity and Foam Stability of the Soup

It was observed that the values of foaming capacity were higher than those of foaming stability with respect to the raw material as shown in Table 3. The results recorded for the foam capacity and foam stability are shown. The foaming

**Table 3.** Effect of the production process functional properties of the enriched salt/emulsifier.

| Salts | Salt Mixtures | Burning Temp (˚C) | Burning time (mins) | Extraction temp (˚C) | pH | Foam capacity (%) | Foam stability (%) | Emulsification index 24 hrs (%) | Emulsification index 48 hrs (%) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | S39.6a | 300 | 9.54 | 60 | 12.54 ± 0.01[a] | 16.9 ± 0.06[a] | 3.1 ± 0.10[ab] | 21.5 ± 0.06[bc] | 20 ± 0.00[bc] |
| | S39.6b | 300 | 9.54 | 60 | 11.56 ± 0.00[a] | 23.1 ± 0.01[a] | 10.8 ± 0.06[b] | 23.1 ± 4.35[abc] | 21.5 ± 0.06[abc] |
| | S39.6c | 300 | 9.54 | 60 | 12.34 ± 0.03[a] | 23.1 ± 0.00[a] | 7.7 ± 0.00[ab] | 12.3 ± 0.10[a] | 4.8 ± 0.06[a] |
| | S39.6d | 300 | 9.54 | 60 | 12.32 ± 0.02[a] | 12.3 ± 0.01[a] | 4.6 ± 0.10[ab] | 12.3 ± 0.06[a] | 11.5 ± 0.1[ab] |
| | S39.6e | 300 | 9.54 | 60 | 12.31 ± 0.01[a] | 29.2 ± 0.01[a] | 4.6 ± 0.06[ab] | 9.3 ± 0.15[ab] | 4.8 ± 0.00[abc] |
| | S39.6f | 300 | 9.54 | 60 | 12.15 ± 0.01[a] | 15.4 ± 0.06[a] | 10.8 ± 0.01[b] | 24.6 ± 0.06[c] | 23.1 ± 0.12[c] |
| 2 | S293a | 250 | 90 | 30 | 12.09 ± 0.01[a] | 35.71 ± 0.01[b] | 10.33 ± 0.01[b] | 21.28 ± 0.01[bc] | 20.05 ± 0.01[b] |
| | S293b | 250 | 90 | 30 | 11.96 ± 0.01[a] | 23.1 ± 0.12[ab] | 15.98 ± 0.01[b] | 24.33 ± 0.00[abc] | 23.67 ± 0.01[ab] |
| | S293c | 250 | 90 | 30 | 11.22 ± 0.01[a] | 26.07 ± 0.02[ab] | 5.33 ± 0.01[a] | 15.67 ± 0.02[a] | 14.62 ± 0.01[a] |
| | S293d | 250 | 90 | 30 | 11.13 ± 0.00[a] | 31.0 ± 0.00[b] | 8.34 ± 0.01[ab] | 19 ± 0.01[ab] | 18.34 ± 0.01[ab] |
| | S293e | 250 | 90 | 30 | 11.02 ± 0.01[a] | 31.78 ± 0.01[ab] | 11.99 ± 0.01[b] | 20 ± 0.26[abc] | 19.67 ± 0.01[b] |
| | S293f | 250 | 90 | 30 | 10.81 ± 0.01[a] | 20.0 ± 0.59[a] | 13.87 ± 0.02[b] | 24.8 ± 0.15c | 23.11 ± 0.01[b] |
| 3 | S366a | 300 | 60 | 60 | 12.91 ± 0.01[a] | 40.7 ± 0.01[b] | 24.52 ± 0.00[c] | 15.67 ± 0.01[b] | 15 ± 0.00[a] |
| | S366b | 300 | 60 | 60 | 12.10 ± 0.00[a] | 30.23 ± 0.01[ab] | 28.3 ± 0.01[c] | 20.51 ± 0.01[b] | 19.44 ± 0.01[a] |
| | S366c | 300 | 60 | 60 | 12.34 ± 0.01[ab] | 35.53 ± 0.01[ab] | 22.3 ± 0.01[ab] | 12.41 ± 0.00[a] | 10.82 ± 0.01[b] |
| | S366d | 300 | 60 | 60 | 12.22 ± 0.01[a] | 32.01 ± 0.00[a] | 16.9 ± 0.01[a] | 8.33 ± 0.01[a] | 7.13 ± 0.01[b] |
| | S366f | 300 | 60 | 60 | 12.11 ± 0.00[a] | 29.65 ± 0.01[a] | 23.87 ± 0.00[bc] | 14.67 ± 0.00[ab] | 13.47 ± 0.01[ab] |
| | S366d | 300 | 60 | 60 | 12.01 ± 0.01[a] | 29.21 ± 0.00[a] | 27.45 ± 0.01[c] | 15.11 ± 0.01[ab] | 14.68 ± 0.00[ab] |
| 4 | S316a | 300 | 110.46 | 60 | 12.56 ± 0.00[b] | 26.2 ± 0.02[b] | 15.3 ± 0.10[c] | 16.9 ± 0.01[b] | 13.8 ± 0.00[bc] |
| | S316b | 300 | 110.46 | 60 | 11.70 ± 0.01[ab] | 23.1 ± 0.00[b] | 16.1 ± 0.10[c] | 23.1 ± 0.01[b] | 16.9 ± 0.01[c] |
| | S316c | 300 | 110.46 | 60 | 12.32 ± 0.01[b] | 38.5 ± 0.10[b] | 15.3 ± 0.00[c] | 13.8 ± 0.00[a] | 13.8 ± 0.01[ab] |
| | S316d | 300 | 110.46 | 60 | 12.18 ± 0.01[ab] | 15.4 ± 0.10[ab] | 10.8 ± 0.10[b] | 9.3 ± 0.01[a] | 9.3 ± 0.01[a] |
| | S316e | 300 | 110.46 | 60 | 11.93 ± 0.01[ab] | 23.1 ± 0.00[ab] | 6.2 ± 0.00[a] | 15.3 ± 80.00[ab] | 13.8 ± 0.01[abc] |
| | S316f | 300 | 110.46 | 60 | 11.67 ± 0.00[a] | 7.7 ± 0.10[a] | 6.2 ± 0.01[ab] | 16.9 ± 0.01[ab] | 15.38 ± 0.00[bc] |
| 5 | S369a | 300 | 60 | 9.54 | 12.80 ± 0.01[a] | 12.3 ± 0.14[a] | 4.6 ± 0.00[a] | 16.9 ± 0.06[a] | 15.38 ± 0.01[a] |
| | S369b | 300 | 60 | 9.54 | 11.77 ± 0.01[a] | 9.2 ± 0.00[ab] | 7.7 ± 0.01[ab] | 33.84 ± 0.01[a] | 33.8 ± 0.01[a] |
| | S369c | 300 | 60 | 9.54 | 12.31 ± 0.01[a] | 38.5 ± 0.07[b] | 13.8 ± 0.00[bc] | 13.8 ± 0.06[a] | 13.8 ± 0.01[a] |
| | S369d | 300 | 60 | 9.54 | 12.26 ± 0.01[a] | 13.8 ± 0.07[ab] | 10.8 ± 0.02[ab] | 30.7 ± 0.00[a] | 29.2 ± 0.1[a] |
| | S369e | 300 | 60 | 9.54 | 12.12 ± 0.01[a] | 23.1 ± 0.00[ab] | 7.7 ± 0.02[ab] | 12.3 ± 0.10[a] | 12.3 ± 0.06[a] |
| | S369f | 300 | 60 | 9.54 | 11.91 ± 0.00[a] | 7.7 ± 0.00[a] | 16.9 ± 1.73[c] | 33.8 ± 0.06[a] | 33.8 ± 0.00[a] |
| 6 | S399a | 350 | 90 | 90 | 12.76 ± 0.00[ab] | 12.3 ± 0.06[a] | 4.6 ± 0.06[a] | 40 ± 0.00[a] | 36.9 ± 0.00[b] |
| | S399b | 350 | 90 | 90 | 11.66 ± 0.01[a] | 9.2 ± 0.10[ab] | 7.7 ± 0.10[ab] | 21.5 ± 0.10[a] | 21.5 ± 0.10[ab] |

**Continued**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S399c | 350 | 90 | 90 | 12.13 ± 0.01$^{ab}$ | 38.5 ± 0.06$^{b}$ | 13.8 ± 0.00$^{bc}$ | 32.3 ± 0.06$^{a}$ | 30.7 ± 0.00$^{ab}$ |
| | S399d | 350 | 90 | 90 | 12.65 ± 0.01$^{b}$ | 13.8 ± 0.06$^{ab}$ | 10.8 ± 0.06$^{ab}$ | 27.7 ± 0.10$^{a}$ | 24.6 ± 0.10$^{ab}$ |
| | S399e | 350 | 90 | 90 | 12.15 ± 0.02$^{ab}$ | 23.1 ± 0.00$^{ab}$ | 7.7 ± 0.06$^{ab}$ | 24.6 ± 0.06$^{a}$ | 23.1 ± 0.06$^{a}$ |
| | S399f | 350 | 90 | 90 | 11.72 ± 0.01$^{a}$ | 7.7 ± 0.10$^{a}$ | 16.9 ± 0.00$^{c}$ | 27.7 ± 0.00$^{a}$ | 23.1 ± 0.00$^{ab}$ |
| | S339a | 350 | 30 | 90 | 12.87 ± 0.01$^{b}$ | 34.38 ± 0.02$^{c}$ | 29.77 ± 0.01$^{c}$ | 20.1 ± 0.00$^{bc}$ | 19.9 ± 0.00$^{b}$ |
| | S339b | 350 | 30 | 90 | 12.02 ± 0.01$^{a}$ | 36 ± 0.00$^{bc}$ | 31.01 ± 0.01$^{bc}$ | 25.3 ± 0.06$^{c}$ | 25 ± 0.06$^{b}$ |
| 7 | S339c | 350 | 30 | 90 | 12.32 ± 0.01$^{ab}$ | 28 ± 0.06$^{a}$ | 24 ± 0.01ab | 18.99 ± 0.01$^{ab}$ | 17.54 ± 0.01$^{a}$ |
| | S339d | 350 | 30 | 90 | 12.25 ± 0.01$^{ab}$ | 29 ± 0.01$^{zb}$ | 17.27 ± 0.01$^{a}$ | 15.34 ± 0.01$^{a}$ | 15 ± 0.06$^{a}$ |
| | S339e | 350 | 30 | 90 | 12.13 ± 0.02$^{a}$ | 31.02 ± 0.01$^{abc}$ | 29 ± 0.00$^{c}$ | 14.33 ± 0.00$^{a}$ | 17.01 ± 0.01$^{ab}$ |
| | S339f | 350 | 30 | 90 | 12.09 ± 0.01$^{a}$ | 35.34 ± 0.01$^{a}$ | 33.27 ± 0.01$^{c}$ | 20.19 ± 0.01$^{abc}$ | 20.21 ± 0.01$^{ab}$ |
| | S3.66a | 384.1 | 60 | 60 | 12.52 ± 0.01$^{a}$ | 35.4 ± 0.06$^{a}$ | 16.9 ± 0.06$^{a}$ | 41.5 ± 5.77$^{b}$ | 40 ± 0.06$^{b}$ |
| | S3.66b | 384.1 | 60 | 60 | 11.27 ± 0.01$^{a}$ | 30.8 ± 0.10$^{a}$ | 12.3 ± 0.06$^{a}$ | 46.2 ± 0.10$^{b}$ | 46.2 ± 0.10$^{b}$ |
| 8 | S3.66c | 384.1 | 60 | 60 | 12.43 ± 0.00$^{a}$ | 41.5 ± 0.10$^{a}$ | 16.19 ± 0.01$^{a}$ | 49.3 ± 0.00$^{b}$ | 49.3 ± 0.00$^{b}$ |
| | S3.66d | 384.1 | 60 | 60 | 12.29 ± 0.01$^{a}$ | 30.8 ± 0.00$^{a}$ | 15.3 ± 0.00$^{a}$ | 29.2 ± 0.10$^{a}$ | 29.2 ± 0.10$^{a}$ |
| | S3.66e | 384.1 | 60 | 60 | 12.05 ± 0.01$^{a}$ | 38.5 ± 0.06$^{a}$ | 10.8 ± 0.10$^{a}$ | 26.5 ± 0.06$^{a}$ | 26.5 ± 0.06$^{a}$ |
| | S3.66f | 384.1 | 60 | 60 | 11.75 ± 0.01$^{a}$ | 41.5 ± 0.00$^{a}$ | 26.2 ± 0.00$^{b}$ | 36.9 ± 0.00$^{ab}$ | 36.9 ± 0.00$^{ab}$ |
| | S393a | 350 | 90 | 30 | 13.04 ± 0.01$^{a}$ | 46 ± 0.00$^{b}$ | 17.1 ± 0.10$^{ab}$ | 20 ± 0.00$^{a}$ | 20 ± 0.00a |
| | S393b | 350 | 90 | 30 | 11.22 ± 0.00$^{a}$ | 32 ± 0.06$^{ab}$ | 25.7 ± 0.10$^{b}$ | 27.1 ± 0.06$^{ab}$ | 27.1 ± 0.06$^{ab}$ |
| 9 | S393c | 350 | 90 | 30 | 12.81 ± 0.01$^{a}$ | 40 ± 0.00$^{ab}$ | 28.6 ± 0.00$^{ab}$ | 40 ± 0.06$^{bc}$ | 38.6 ± 0.06$^{bc}$ |
| | S393d | 350 | 90 | 30 | 12.61 ± 0.01$^{a}$ | 33 ± 0.01$^{a}$ | 14.3 ± 0.10$^{ab}$ | 35.7 ± 0.06$^{bcd}$ | 35.7 ± 0.10$^{bcd}$ |
| | S393e | 350 | 90 | 30 | 12.22 ± 0.01$^{a}$ | 29.3 ± 0.05$^{a}$ | 25.7 ± 0.06$^{ab}$ | 57.1 ± 0.00$^{d}$ | 55.7 ± 0.00$^{cd}$ |
| | S393f | 350 | 90 | 30 | 11.65 ± 0.01$^{a}$ | 32 ± 0.00$^{a}$ | 14.3 ± 0.00$^{a}$ | 47.2 ± 0.10$^{cd}$ | 45.7 ± 0.06$^{d}$ |
| | S233a | 250 | 30 | 30 | 12.63 ± 0.01$^{a}$ | 43.1 ± 0.06$^{b}$ | 20 ± 0.00$^{bc}$ | 18.5 ± 0.06$^{a}$ | 16.9 ± 0.00$^{a}$ |
| | S233b | 250 | 30 | 30 | 11.16 ± 0.01$^{a}$ | 30.8 ± 0.10$^{a}$ | 25.3 ± 0.10$^{c}$ | 26.2 ± 0.00$^{a}$ | 26.2 ± 0.06$^{ab}$ |
| 10 | S233c | 250 | 30 | 30 | 12.34 ± 0.01$^{a}$ | 33.8 ± 0.06$^{ab}$ | 18.5 ± 0.06$^{ab}$ | 33.8 ± 0.10$^{b}$ | 33.8 ± 0.06$^{b}$ |
| | S233d | 250 | 30 | 30 | 12.09 ± 0.00$^{a}$ | 30.8 ± 0.00$^{a}$ | 16.9 ± 0.06$^{a}$ | 46.7 ± 0.06$^{b}$ | 46.7 ± 0.00$^{b}$ |
| | S233e | 250 | 30 | 30 | 11.80 ± 0.01$^{a}$ | 33.8 ± 0.06$^{ab}$ | 15.3 ± 0.10$^{a}$ | 35.4 ± 0.10$^{b}$ | 26.2 ± 0.10$^{ab}$ |
| | S233f | 250 | 30 | 30 | 11.42 ± 0.01$^{a}$ | 38.5 ± 0.00$^{ab}$ | 17.1 ± 0.00$^{a}$ | 41.5 ± 0.00$^{b}$ | 40 ± 0.00$^{b}$ |
| | S239a | 250 | 30 | 90 | 12.90 ± 0.01$^{ab}$ | 38.5 ± 0.00$^{ab}$ | 14.3 ± 0.06$^{a}$ | 35.4 ± 0.06$^{a}$ | 35.4 ± 0.06$^{a}$ |
| | S239b | 250 | 30 | 90 | 12.37 ± 0.00$^{ab}$ | 24.6 ± 0.06$^{ab}$ | 12.3 ± 0.10$^{ab}$ | 36.9 ± 0.06$^{ab}$ | 35.4 ± 0.00$^{a}$ |
| 11 | S239c | 250 | 30 | 90 | 12.87 ± 0.01$^{b}$ | 46 ± 0.00$^{b}$ | 24.6 ± 0.00$^{b}$ | 41.5 ± 0.00$^{ab}$ | 40 ± 0.00$^{a}$ |
| | S239d | 250 | 30 | 90 | 12.80 ± 0.00$^{ab}$ | 38.5 ± 0.06$^{ab}$ | 15.3 ± 0.06$^{ab}$ | 33.8 ± 0.06$^{ab}$ | 32.5 ± 0.06$^{a}$ |
| | S239e | 250 | 30 | 90 | 12.54 ± 0.01$^{a}$ | 20 ± 0.00$^{a}$ | 13.8 ± 0.06$^{a}$ | 41.5 ± 0.10$^{b}$ | 40 ± 0.00$^{a}$ |
| | S239f | 250 | 30 | 90 | 12.38 ± 0.00$^{a}$ | 35.4 ± 0.10$^{ab}$ | 9.2 ± 0.00$^{a}$ | 41.5 ± 0.00$^{ab}$ | 38.5 ± 0.10$^{a}$ |
| 12 | S2.66a | 215.9 | 60 | 60 | 12.62 ± 0.01$^{b}$ | 46 ± 0.00$^{ab}$ | 15.3 ± 0.06$^{a}$ | 27.7 ± 0.00$^{a}$ | 27.7 ± 0.10$^{a}$ |
| | S2.66b | 215.9 | 60 | 60 | 12.14 ± 0.01$^{a}$ | 27.7 ± 0.06$^{a}$ | 16.9 ± 0.06$^{a}$ | 46.2 ± 0.10$^{bc}$ | 43.1 ± 0.06$^{ab}$ |

Continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | S2.66c | 215.9 | 60 | 60 | 12.31 ± 0.00[ab] | 38.5 ± 0.06[ab] | 16.9 ± 0.00[a] | 41.5 ± 0.06[abc] | 41.5 ± 0.10[ab] |
| | S2.66d | 215.9 | 60 | 60 | 12.24 ± 0.01[a] | 43.1 ± 0.06[b] | 15.3 ± 0.10[a] | 36.9 ± 0.00[ab] | 29.2 ± 0.06[a] |
| | S2.66e | 215.9 | 60 | 60 | 12.18 ± 0.01[a] | 44.6 ± 0.10[b] | 18.5 ± 0.06[a] | 38.46 ± 0.01[abc] | 36.9 ± 0.06[ab] |
| | S2.66f | 215.9 | 60 | 60 | 12.15 ± 0.01[a] | 38.5 ± 1.67[ab] | 15.3 ± 0.00[a] | 49.2 ± 0.01[c] | 49.2 ± 0.00[b] |
| 13 | S333a | 350 | 30 | 30 | 12.49 ± 0.06[a] | 35.7 ± 0.00[ab] | 11.4 ± 0.06[bc] | 34.3 ± 0.06[ab] | 34.3 ± 0.00[c] |
| | S333b | 350 | 30 | 30 | 11.11 ± 0.06[a] | 14.3 ± 0.10[a] | 16 ± 0.00[c] | 24.3 ± 0.00[a] | 24.3 ± 0.10[a] |
| | S333c | 350 | 30 | 30 | 12.02 ± 0.00[a] | 35.7 ± 0.06[ab] | 11.4 ± 0.06[abc] | 27.1 ± 0.06[ab] | 27.1 ± 0.06[abc] |
| | S333d | 350 | 30 | 30 | 11.85 ± 0.06[a] | 31.4 ± 0.06[ab] | 11.4 ± 0.00[ab] | 38.6 ± 0.06[b] | 24.3 ± 0.06[ab] |
| | S333e | 350 | 30 | 30 | 11.62 ± 0.06[a] | 31.4 ± 0.00[ab] | 8.6 ± 0.06a | 28.6 ± 0.06[ab] | 28.6 ± 0.00[abc] |
| | S333f | 350 | 30 | 30 | 11.41 ± 0.00[a] | 40 ± 0.00[b] | 8.6 ± 0.10[a] | 32.9 ± 0.06[ab] | 31.4 ± 0.06[bc] |
| 14 | S299a | 250 | 90 | 90 | 12.74 ± 0.06[a] | 36.9 ± 0.06[a] | 27.7 ± 0.06[bc] | 27.7 ± 0.00[a] | 27.7 ± 0.00[a] |
| | S299b | 250 | 90 | 90 | 11.00 ± 0.00[a] | 30.8 ± 0.00[a] | 24.6 ± 0.06[ab] | 35.4 ± 0.06[a] | 33.8 ± 0.10[a] |
| | S299c | 250 | 90 | 90 | 12.40 ± 0.06[a] | 33.8 ± 0.10[ab] | 13.8 ± 0.00[a] | 27.7 ± 0.06[a] | 27.7 ± 0.06[a] |
| | S299d | 250 | 90 | 90 | 12.20 ± 0.00[a] | 38.5 ± 0.06[bc] | 23.1 ± 0.06[bc] | 30.8 ± 0.06[a] | 30.8 ± 0.06[a] |
| | S299e | 250 | 90 | 90 | 11.91 ± 0.06[a] | 41.5 ± 0.06[cd] | 35.4 ± 0.06[c] | 32.3 ± 0.06[a] | 32.3 ± 0.06[a] |
| | S299f | 250 | 90 | 90 | 11.56 ± 0.00[a] | 46 ± 0.00[d] | 26.2 ± 0.06[abc] | 30.8 ± 0.00[a] | 27.7 ± 0.00[a] |

Salts 1 - 14 are the salts gotten from the experimental runs for both plantains and *Ficus* which where mixed using the mixture designs to give 6 mixture samples (a, b, c, d, e, f) for each run.

capacity and foam stability of the yellow achu soup obtained using the mixture of the crude extract varied as seen in **Table 3**. From these results, it can be seen that, there is a relative increase in the form capacity and foam stability after enriching the salt. The un-enrich salt recorded the highest foam stability of 29.77 for plantain and 31.01 for *Ficus* while the enriched salt recorded 35.4. It was observed that samples with very high foaming capacity showed very low foam stability while those with very low foaming capacity showed very high foam stability. However, salt mixtures of sample S339 all had the highest foaming capacity as well as form stability while S369 had the lowest foaming capacity and foam stability as well. Sample S339 had the highest foaming capacity as well as foam stability, suggesting that the proportion of the two emulsifiers used was adequate to overcome the surface tension at the oil-water interface, hence leading to the production of foams with higher stability.

This result is in line with the results reported by [15]. The effectiveness of a surfactant as a foaming agent appears to depend both on its effectiveness in reducing the surface tension of the foaming solution and on the magnitude of its intermolecular cohesive forces [8] [9] [10] [18]. The lower the surface tension of the aqueous solution, the greater appears to be the volume of foam of the same average bubble size produced by a given amount of work under the same foaming conditions [10] and [15]. Therefore, the mixture of the two surfactants at a ratio of 85:15, 70:30, 55:45, 35:65 (S339) can be considered the most adequate for foam formation and foam stability.

#### 3.1.3. Effect of the Production Process on the Emulsification Index ($EI_{24}$ and $EI_{48}$)

As presented in Table 3, sample mixture S366d of sample 3 had the lowest emulsifying activity even after 24 hours with a value of 8.33% while sample S39.6e had the lowest emulsifying index after 48 hours with a value of 4.8%. The highest value of $EI_{24}$ for plantain peels ash extract was 41.5% ± 0.10% (S3.66a) of sample 8 while the lowest was 15.67% ± 0.01% (S366a) of sample 3 and for *Ficus* peels ash extract, 46.2% ± 0.10% (S3.66b) of sample 8 was the highest value and lowest value was 20.51% ± 0.01% (S366b) of sample 8. For EI48, the highest value was 40% ± 0.06% (S3.66a) of sample 8 for plantain and 46.2% ± 0.10% (S3.66b) of sample 8 for *Ficus* while the lowest was 13.8% ± 0.00% (S316a) of sample 4 for plantain and 19.44% ± 0.01% (S366b) of sample 3 for *Ficus*. Irrespective of the proportions difference of the emulsifiers used, all samples showed a decrease in emulsification index after 48 hours. Also, similar results were obtained by [9] and [10] where bio-surfactants, *Nikkih* and (or) kanwa showed a decrease in the emulsification index after 48 hours.

The general decrease in emulsification index after 48 hours could be due to environmental stress such as gravitational separation, flocculation, coalescence, Ostwald ripening, and phase inversion as described by [19]. The high EI24 of S393e could be because the mixture ratio resulted in a solution with a greater potential to form stronger surfactants at the oil/water interface. This is in line with the findings of [20] who observed that in situ surfactants are formed when crude oil with long-chain carboxylic acids is extracted with alkali, and the formation of the in-situ surfactants helps to form the emulsion. Crude palm oil contains stearic, oleic, palmitic acid all of which are fatty acids bearing the carboxylic acid group (COOH-). Higher emulsification was possible because interfacial tension was greatly reduced. Also, following the findings of [21] chemical reactions between alkali and organic acids that exist in crude palm oil resulted in the formation of an emulsion, therefore, the capillary pressures between the aqueous and oleic phases were reduced. When the aqueous phase and oil phase are in contact, the alkali and organic acids migrate into the interface forming surface-active species.

### 3.2. Model Proposition, Validation, and Optimization

#### 3.2.1. Effects of the Processing Parameters on the Ash Yield of the Burnt *Ficus* Peels and Plantain Peels

From the analysis of the experimental data using JMP Pro 16 software, the model equation generated was:

- **Ash yield *Ficus* (%)** $= 15.6299 + 3.3724X_1 + 5.5636X_2 - 0.3063X_3 + 3.6925X_1X_2 - 3.3806 * 10^{-17}X_1X_3 + 4.5882 * 10^{-17}X_2X_3 - 1.9755\,X_1^2 - 1.4308\,X_2^2 - 0.7858\,X_3^2$

- **Ash yield plantain (%) = 11.5391 + 3.1565$X_1$ + 5.0169$X_2$ + 0.0009$X_3$ + 3.9625$X_1X_2$ − 5.8727 * $10^{-17}X_1X_3$ + 1.0834 * $10^{-16}X_2X_3$ − 1.2221 $X_1^2$ − 1.3585 $X_2^2$ − 0.0024 $X_3^2$**

where $X_1$ is the burning temperature in ˚C, $X_2$ is the burning time in mins and $X_3$ is the extraction temperature in ˚C.

The model equation was validated because it had an $R^2$ value of 98.27% for *Ficus* and 98.65% for plantain which is greater than 70% and an RMSE value of 1.77 for *Ficus* and 1.46 for plantain which is less than 10. **Figure 1** is a Pareto diagram showing the significance of the effects of process parameters on the peels content.

The burning time and burning temperature had a very significant positive effect on the ash yield ($P < 0.05$), and this can be attributed to the fact that as the temperature increased, more energy is available for the combustion of biomass over time [22], thereby eliminating the possibility for charring to occur. Increasing the combustion temperature led to a corresponding increase in the ash yield.

Studies which were done by [22], and by [10] also showed an increase in ash yield of biomass when combusted at high temperature over a long period of time.

The graphs in **Figure 2** shows the response surface plot showing the effect of $X_1X_2$ (burning temperature/burning time) on ash yield of burnt *Ficus* peels and plantain peels. All the other linear, quadratic, and interaction factors had no significant effect on the ash yield of the burnt peels. The maximum ash yield value of 21.09% for plantain and 24.88% for *Ficus* was obtained at a burning temperature of 350˚C and a burning time of 90 mins with maximum extraction temperature of 54.59˚C. The results indicated that the ash content is significantly influenced by potash source, as well as the burning temperature, and burning time

The interaction between the burning temperature and burning time ($X_1X_2$) is represented in the equation below

- **Ash yield *Ficus* (%) = 15.6299 + 3.3724$X_1$ + 5.5636$X_2$ + 3.6925$X_1X_2$ − 1.9755 $X_1^2$ − 1.4308 $X_2^2$**
- **Ash yield plantain (%) = 11.5391 + 3.1565$X_1$ + 5.0169$X_2$ + 3.9625$X_1X_2$ − 1.2221 $X_1^2$ − 1.3585 $X_2^2$**

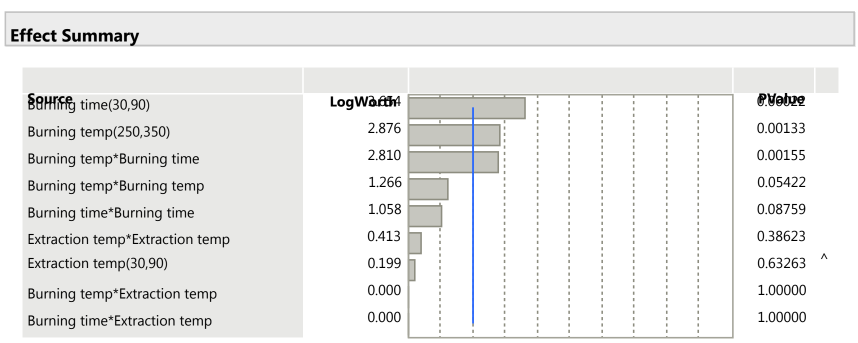


**Figure 1.** Pareto diagram showing the effect of processing parameters on the percentage of ash yield plantain and *Ficus* peels.

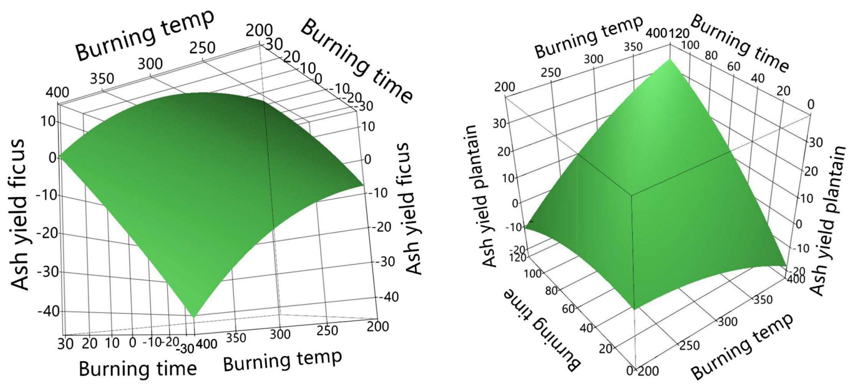


**Figure 2.** Response surface plot showing the effect of burning temperature/burning time on ash yield of burnt *Ficus* peels and plantain peels respectively.

#### 3.2.2. Effects of the Processing Parameters on the pH of the Burnt *Ficus* Peels and Plantain Peels Ash Extract

From the analysis of the experimental data using JMP Pro 16 software, the model equation generated was:

- pH *Ficus* (%) = $12.1336 - 0.1423X_1 - 0.0428X_2 + 0.1589X_3 + 0.0400X_1X_2 + 0.1375X_1X_3 - 0.3300X_2X_3 - 0.1861X_1^2 - 0.2127X_2^2 - 0.1033X_3^2$
- pH plantain (%) = $12.9131 + 0.0631X_1 - 0.0334X_2 + 0.0951X_3 + 0.1713X_1X_2 - 0.0738X_1X_3 - 0.0638X_2X_3 - 0.1244X_1^2 - 0.1315X_2^2 + 0.0103X_3^2$

where $X_1$ is the burning temperature in ˚C, $X_2$ is the burning time in mins and $X_3$ is the extraction temperature in ˚C

The model equation was validated because it had an $R^2$ value of 72% for *Ficus* and 76% for plantain which is greater than 70% and an RMSE value of 0.415 for *Ficus* and 0.212 for plantain which is less than 10. Figure 3 is a Pareto diagram showing the significance of the effects of process parameters on the pH.

Taking into consideration $P < 0.05$, no factor had a significant effect on the pH of the TFS. The maximum pH of 13.05 for plantain and 12.34 for *Ficus* was obtained at a burning temperature of 290.63˚C and a burning time of 43.67 mins with a maximum extraction temperature of 90˚C.

#### 3.2.3. Effects of the Processing Parameters on the Alkaline Content of the Burnt *Ficus* Peels and Plantain Peels Ash Extract

From the analysis of the experimental data using JMP Pro 16 software, the model equation generated was:

- Alkaline content *Ficus* (%) = $86.9460 + 0.4725X_1 - 0.2525X_2 - 0.7125X_3 + 1.7435X_1X_2 - 0.8935X_1X_3 + 0.5187X_2X_3 + 0.4031X_1^2 + 1.4817X_2^2 + 1.5659X_3^2$
- Alkaline content plantain (%) = $74.9134 - 0.2276X_1 - 0.2236X_2 + 0.9869X_3 - 3.4812X_1X_2 + 1.0562X_1X_3 - 3.2062X_2X_3 + 0.5613X_1^2 + 0.7383X_2^2 + 2.7402X_3^2$

where $X_1$ is the burning temperature in ˚C, $X_2$ is the burning time in mins and $X_3$ is the extraction temperature in ˚C

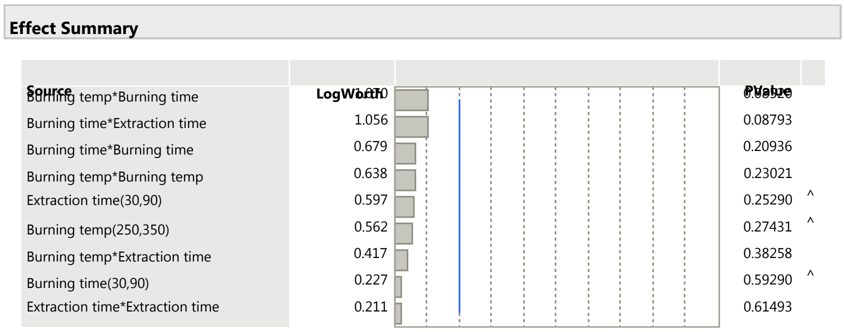


**Figure 3.** Pareto diagram showing the effect of processing parameters on the pH of plantain and *Ficus* peels.

The model equation was validated because it had an $R^2$ value of 85% for *Ficus* and 98% for plantain which is greater than 70% and an RMSE value of 1.71 for *Ficus* and 1.11 for plantain which is less than 10%. **Figure 4** is a Pareto diagram showing the significance of the effects of process parameters on the alkaline content.

Considering a significance level of P < 0.05, the quadratic effect of burning temperature and burning time ($X_1X_2$) had the highest significant positive effect on the alkaline content (P < 0.05), followed by the quadratic effect of burning time, extraction temperature ($X_2X_3$) and extraction temperature ( $X_3^2$ ) and This is as a result of converting the major components of *Ficus* and plantain peels residues which are oxidized into gaseous emission during combustion, leaving behind metal oxides and other elemental components that form a good extract of alkaline solution.

Studies which were done by [22], and by [10] also showed an increase in ash yield of biomass when combusted at high temperature over a long period of time.

The alkaline content generally increased with increase in burning temperature, burning time and extraction temperature.

Similar report has been reported by [10] and [11]. Since non-alkali content is derived from the value of alkali content, all the parameters which affected the alkali content also affected the non-alkali content.

**Figure 5** above represents the surface plot showing the effect of $X_1X_2$ on alkaline content of burnt *Ficus* peels and plantain peels. All the other linear, quadratic, and interaction factors had no significant effect on the alkaline content of the burnt peels. The maximum alkaline content of 79.06% for plantain and 91.58% for *Ficus* was obtained at a burning temperature of 250˚C and burning time 30 mins with maximum extraction temperature of 90˚C.

The interaction between burning temperature and burning time ($X_1X_2$) is represented in the equations below

- **Alkaline content *Ficus* (%) = $86.9460 + 0.4725X_1 - 0.2525X_2 + 1.7435X_1X_2 + 0.4031X_1^2 + 1.4817X_2^2$**
- **Alkaline content plantain (%) = $74.9134 - 0.2276X_1 - 0.2236X_2 - 3.4812X_1X_2 + 0.5613X_1^2 + 0.7383X_2^2$**

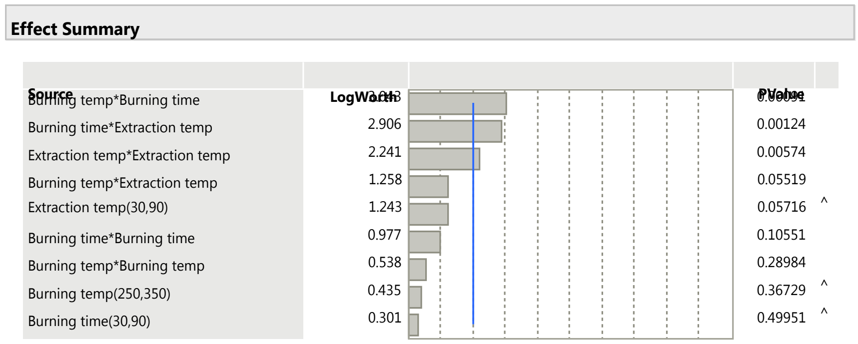


**Figure 4.** Pareto diagram showing the effect of processing parameters on the alkaline content of plantain and *Ficus* peels.

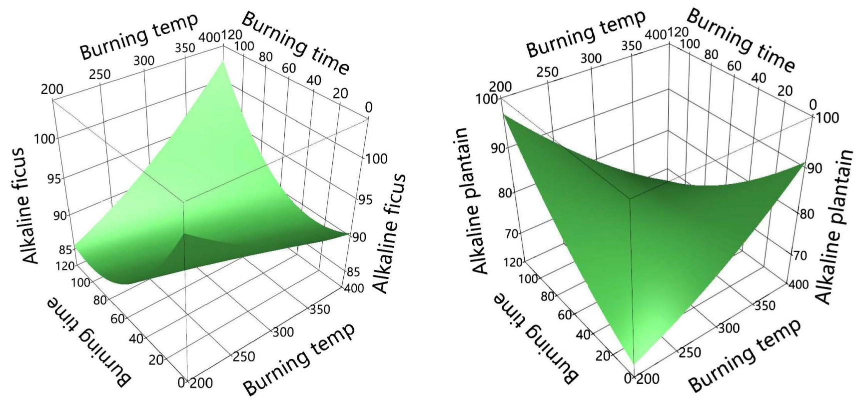


**Figure 5.** Response surface plot showing the effect of $X_1X_2$ on alkaline content of burnt *Ficus* peels and plantain peels.

The interaction between burning time and extraction temperature ($X_2X_3$) is represented in the equations below and the graphs for their interactions, for *Ficus* and for plantain peels can be seen in **Figure 6** and **Figure 7** respectively

- **Alkaline content *Ficus* (%) = 86.9460 − 0.2525$X_2$ − 0.7125$X_3$ + 0.5187$X_2X_3$ + 1.4817 $X_2^2$ + 1.5659 $X_3^2$**
- **Alkaline content plantain (%) = 74.9134 − 0.2236$X_2$ + 0.9869$X_3$ − 3.2062$X_2X_3$ + 0.7383 $X_2^2$ + 2.7402 $X_3^2$**

The interaction between extraction temperature ($X_3^2$) is represented in the equations below and the graphs for their interactions, for *Ficus* and for plantain peels can be seen in **Figure 8** and **Figure 9** respectively

- **Alkaline content *Ficus* (%) = 86.9460 − 0.7125$X_3$ + 1.5659 $X_3^2$**
- **Alkaline content plantain (%) = 74.9134 − 0.9869$X_3$ + 2.7402 $X_3^2$**

#### 3.2.4. Effects of the Processing Parameters on the Emulsifying Index of the Burnt *Ficus* Peels and Plantain Peels Ash Extract

From the analysis of the experimental data using JMP Pro 16 software, the model equation generated was:

- **Emulsifying index 24 *Ficus* (%) = 20.6030 + 0.9384$X_1$ − 3.2944$X_2$ − 0.7227$X_3$ + 2.5986$X_1X_2$ − 3.3188$X_1X_3$ − 0.4061$X_2X_3$ + 5.0800 $X_1^2$ + 0.7848 $X_2^2$ + 4.0546 $X_3^2$**

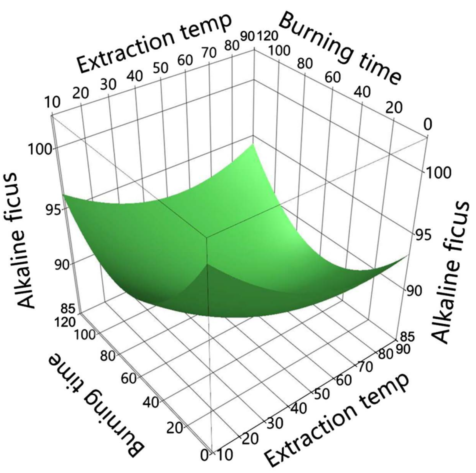


**Figure 6.** Response surface plot showing the interaction effect of $X_2X_3$ on alkaline content of burnt *Ficus* peels.

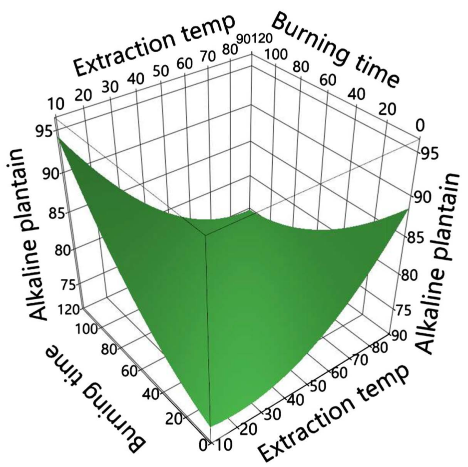


**Figure 7.** Response surface plot showing the interaction effect of $X_2X_3$ on alkaline content of burnt plantain peels.

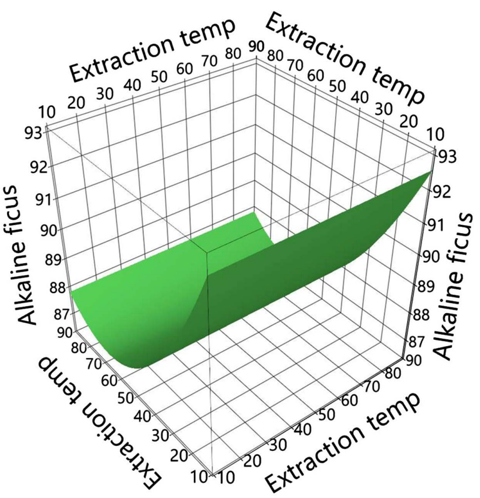


**Figure 8.** Response surface plot showing the interaction effect of $X_3^2$ on alkaline content of burnt *Ficus* peels.

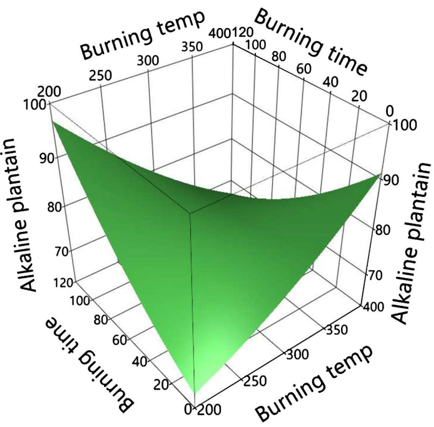


**Figure 9.** Response surface plot showing the interaction effect of $X_3^2$ on alkaline content of burnt plantain peels.

- **Emulsifying index 24 plantain (%) = 15.4636 + 0.5922$X_1$ − 0.7267$X_2$ + 1.6083$X_3$ + 3.3235$X_1X_2$ + 1.7435$X_1X_3$ + 5.1814$X_2X_3$ + 8.1432 $X_1^2$ + 1.5330 $X_2^2$ + 1.8879 $X_3^2$**

where $X_1$ is the burning temperature in ˚C, $X_2$ is the burning time in mins and $X_3$ is the extraction temperature in ˚C.

The model equation could not be validated for *Ficus* because it had an $R^2$ value of 56% which is lesser than 70 and an RMSE value of 11.89 which is greater than 10 but was validated for plantain because it had an $R^2$ of 94% which is greater than 70% and an RMSE value of 4.30 for plantain which is less than 10. **Figure 10** is a Pareto diagram showing the significance of the effects of process parameters on the emulsification index 24.

Taking into consideration P < 0.05, the quadratic effect of burning temperature ( $X_1^2$ ) had a significant positive effect on the emulsifying index 24 (P < 0 This is a result of converting the major components of *Ficus* and plantain peel residues which are oxidized into gaseous emissions during combustion, leaving behind metal oxides and other elemental components that form a good extract of alkaline solution that is able to form an emulsion.

Studies carried out by [22], and by [10] also showed an increase in alkaline content when combusted at high temperatures over a long period of time. This is in line with the findings of [20] who observed that in situ surfactants are formed when crude oil with long chain carboxylic acids is extracted with alkali, and the formation of the *in-situ* surfactants helps to form the emulsion. Crude palm oil contains stearic, oleic, palmitic acid all of which are fatty acids bearing the carboxylic acid group (COOH-).

Higher emulsification was possible because interfacial tension was greatly reduced. Also, following the findings of [21] chemical reactions between alkali and organic acids that exist in crude palm oil resulted in the formation of an emulsion, therefore, the capillary pressures between the aqueous and oleic phases were reduced. When the aqueous phase and oil phase are in contact, the alkali and organic acids migrate into the interface forming surface-active species.

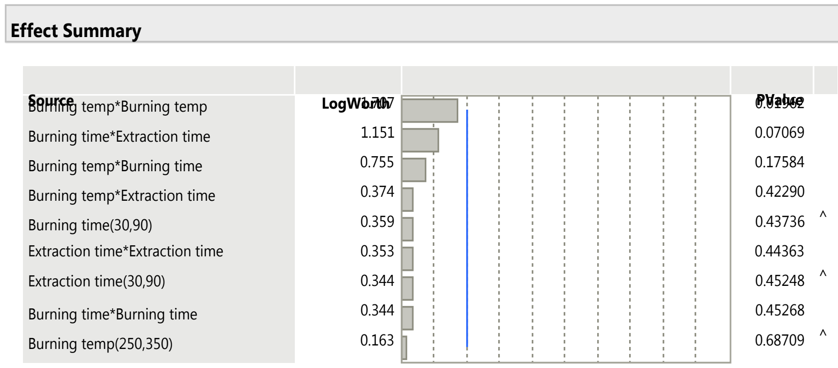


**Figure 10.** Pareto diagram showing the effect of processing parameters on the emulsification index 24 of plantain and *Ficus* peels ash extract.

The alkaline content generally increased with an increase in burning temperature, burning time and extraction temperature.

**Figure 11** presents the surface plot showing the effect of the process parameters on the emulsification index 24 of burnt *Ficus* peels and plantain peels ash extract. All the other linear, quadratic, and interaction factors had no significant effect on the emulsification index of the burnt peels. The maximum emulsification index 24 of 35.80% for plantain and 32.47% for *Ficus* was obtained at a burning temperature of 250˚C and a burning time of 30 mins with a maximum extraction temperature of 30˚C.

The interaction between burning temperature ( $X_1^2$ ) is represented in the equations below and the graphs for their interactions, for *Ficus* and for plantain peels can be seen in **Figure 12** and **Figure 13** respectively.

- **Emulsifying index 24 *Ficus* (%) = 20.6030 + 0.9384$X_1$ + 5.0800 $X_1^2$**
- **Emulsifying index 24 plantain (%) = 15.4636 + 0.5922$X_1$ + 8.1432 $X_1^2$**

#### 3.2.5. Effects of the Processing Parameters on the Emulsifying Index 48 of the Burnt *Ficus* Peels and Plantain Peels Ash Extract

From the analysis of the experimental data using JMP Pro 16 software, the model equation generated was:

- **Emulsifying index 48 *Ficus* (%) = 19.5118 + 1.5553$X_1$ − 3.8042$X_2$ − 1.2846$X_3$ + 2.9768$X_1X_2$ − 2.4056$X_1X_3$ − 0.9193$X_2X_3$ + 5.4879 $X_1^2$ − 0.1862 $X_2^2$ + 4.1365 $X_3^2$**
- **Emulsifying index 48 plantain (%) = 14.6441 + 0.4310$X_1$ − 1.4013$X_2$ + 1.2336$X_3$ + 3.4138$X_1X_2$ + 1.4763$X_1X_3$ + 4.6736$X_2X_3$ + 8.3216 $X_1^2$ − 1.1634 $X_2^2$ − 1.7254 $X_3^2$**

where $X_1$ is the burning temperature in ˚C, $X_2$ is the burning time in mins and $X_3$ is the extraction temperature in ˚C. The model equation was validated because it had an $R^2$ value of 68% for *Ficus* which is less than 70% and 95% for plantains which is greater than 70% and an RMSE value of 10.31 for *Ficus* which is greater than 10 and 4.07 for plantain which is less than 10. **Figure 14** is a Pareto diagram showing the significance of the effects of process parameters on the emulsification index 48.

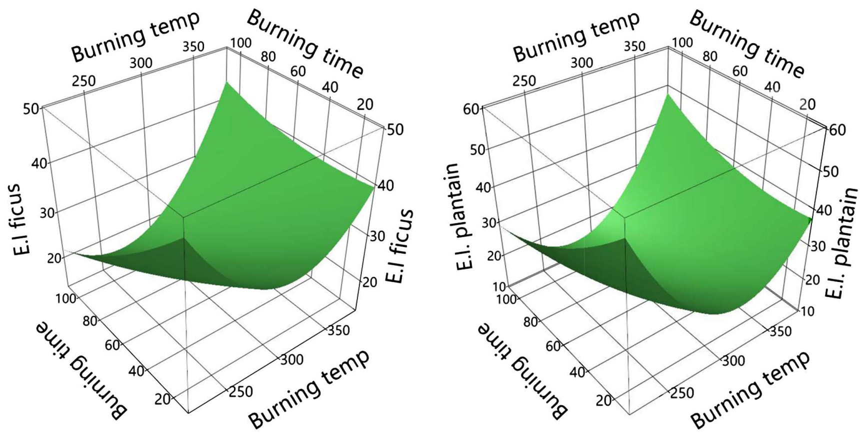


**Figure 11.** Response surface plot showing the effect of the process parameters on the emulsification index 24 of burnt *Ficus* peels and plantain peels ash extract.

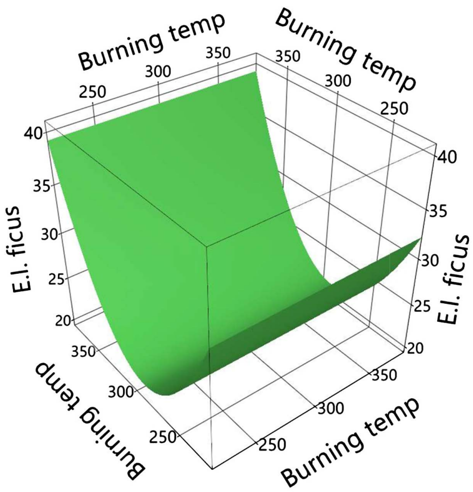


**Figure 12.** Response surface plot showing the effect of $X_1^2$ on the emulsification index of burnt *Ficus* peels ash extract.

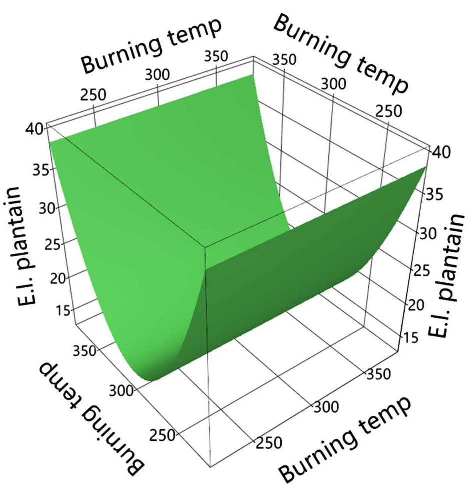


**Figure 13.** Response surface plot showing the effect of $X_1^2$ on the emulsification index of burnt plantain peels ash extract.

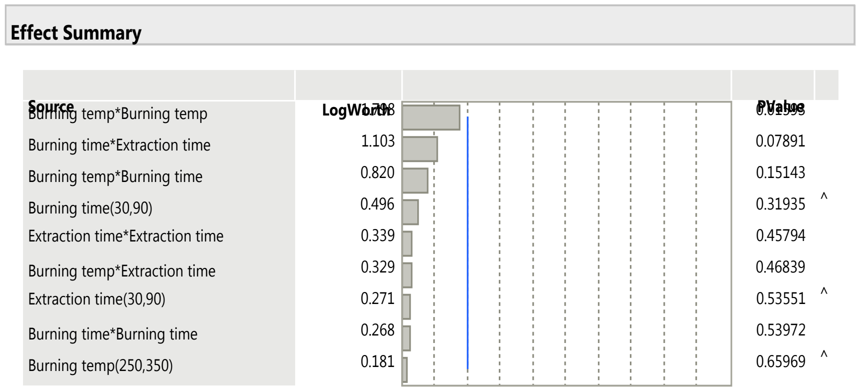


**Figure 14.** Pareto diagram showing the effect of processing parameters on the emulsification index 48 of plantain and *Ficus* peels ash extract.

Taking into consideration P < 0.05, the quadratic effect of burning temperature ( $X_1^2$ ) had a significant positive effect on the emulsifying index 48 (P < 0.05) This is a result of converting the major components of *Ficus* and plantain peel residues, which are oxidized into gaseous emission during combustion, leaving behind metal oxides and other elemental components that form a good extract of alkaline solution that is able to form an emulsion.

Studies done by [22], and by [10] also showed an increase in alkaline content when combusted at high temperatures over a long period of time. This is in line with the findings of [20] who observed that in situ surfactants are formed when crude oil with long chain carboxylic acids is extracted with alkali, and the formation of the in-situ surfactants helps to form the emulsion. Crude palm oil contains stearic, oleic, palmitic acid all of which are fatty acids bearing the carboxylic acid group (COOH-).

Higher emulsification was possible because interfacial tension was greatly reduced. Also, following the findings of [21] chemical reactions between alkali and organic acids that exist in crude palm oil resulted in the formation of an emulsion, therefore, the capillary pressures between the aqueous and oleic phases were reduced. When the aqueous phase and oil phase are in contact, the alkali and organic acids migrate into the interface forming surface-active species.

The alkaline content generally increased with an increase in burning temperature, burning time, and extraction temperature. Irrespective of the different type of emulsifiers used, all samples showed a decrease in emulsification index after 48 hours. Also, similar results were obtained by [9] and [10] where bio-surfactants, *Nikkih* and (or) kanwa showed a decrease in the emulsification index after 48 hours.

The general decrease in emulsification index after 48 hours could be due to environmental stress such as gravitational separation, flocculation, coalescence, Ostwald ripening, and phase inversion as described by [19].

**Figure 15** represents the surface plot showing the effect of the process parameters on the emulsification index 48 of burnt *Ficus* peels and plantain peels ash extract. All the other linear, quadratic, and interaction factors had no significant

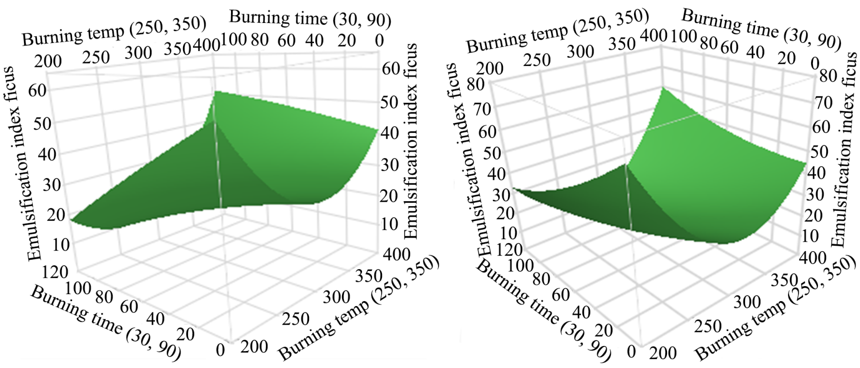


**Figure 15.** Response surface plot showing the effect of the process parameters on the emulsification index 48 of burnt *Ficus* peels and plantain peels ash extract.

effect on the emulsification index of the burnt peels. The maximum emulsification index 48 of 35.15% for plantain and 32.13% for *Ficus* was obtained at a burning temperature of 250˚C and a burning time of 30 mins with a maximum extraction temperature of 30˚C.

#### 3.2.6. Sensory Attribute of Achu Soup Prepared with the Enriched TFS

The perception of consumers in terms of taste, texture and appearance is one of the major factors considered when selecting a product [23]. The quantity of the TFS used for each sample soup were the same. A total of 5 samples and 2 controls were selected and presented to the sensory panelists.

For general acceptability, out of the thirty panellist involved in the sensory evaluation, 53.3% generally accepted sample S393c, 40% accepted sample S239c, 10% accepted sample S339c and 3.3% preferred sample S2.66c. The mean scores of the sensory attributes of the achu soup samples are shown in **Table 4**. The scores by panelists for colour, viscosity/thickness, flavor/aroma, and alkaline taste varied between the different samples.

The mean scores for the color/appearance of the achu soup samples ranged from 2.1 to 6. Sample COM1 (control sample 1) had the lowest score for appearance, while sample S239c (sample combusted at 250˚C for 30 mins and extracted at temperature 90˚C) had the highest score for appearance, followed by sample S339 (sample combusted at 350˚C for 30 mins and extracted at temperature 90˚C and COM2 respectively There was no significant difference in the mean score for appearance of samples S366, and S2.66. Differences in appearance can be attributed to the differences in temperature/time combinations used in the production of the samples. The lower the temperature/time combination for combustion and extraction, the darker the soup.

The mean score for the viscosity/thickness of the achu soup samples ranged from 1.8 (S366c) to 9.7 (COM1). At a not too high burning temperature, an increase in burning time and extraction temperature results in a good base that is capable of forming a better emulsion. Sample COM1 (control sample 1) had the highest score of 9.7, followed by sample S239c (sample combusted at 250˚C for 30 mins and extracted at 90˚C) with the score of 7.9. Sample S366 (sample

**Table 4.** Mean scores of sensory attributes of the achu soup.

| | S366c | S339c | S393c | S239c | S2.66c | COM 1 | COM 2 |
|---|---|---|---|---|---|---|---|
| Appearance | 3 | 3.9 | 5.1 | 6 | 2.7 | 2.1 | 4.5 |
| Viscosity/thickness | 1.8 | 3.6 | 5.3 | 7.9 | 5.3 | 9.7 | 2.7 |
| Flavour/aroma | 2.7 | 3 | 7.8 | 9 | 6 | 2.1 | 1.8 |
| Alkaline taste | 1.2 | 2.7 | 5.4 | 6.9 | 4.2 | 2.4 | 1.2 |

combusted at 300˚C for 60 mins and extracted at 60˚C had the lowest score of 1.8. The mean values for flavor/aroma ranged from 1.8 (COM2) to 9 (S239c). Sample S239c (sample combusted at 250˚C for 30 mins and extracted at 90˚C) had the highest score of 9.0 followed by sample S393 (sample combusted at 350˚C for 90 mins and extracted at 30˚C with the score of 7.8. COM2 had the lowest score of 1.8. The mean values for the alkaline taste of the achu soup samples ranged from 1.2 (S366c and COM2) to 6.9 (S239c). Sample S239c (sample combusted at 250˚C for 30 mins and extracted at temperature 90˚C) had the highest score of 6.9 followed by sample S393c (sample combusted at 350˚C for 90 mins and extracted at temperature 30˚C with the score of 5.4. COM2 and S366c had the lowest score of 1.2. An increase in extraction temperature resulted to a better salt.

## 4. Conclusion

This study was aimed at studying the effect of enriching plantain peel ash extract (*Nikkih*) by the addition of *Ficus carica* fruit peel ash extract in order to improve the stability and acceptability of yellow achu soup. The addition of *Ficus* carica fruit peel ash extract to the plantain peel ash extract, *Nikkih*, improves the stability of the yellow achu soup, but the degree of stability depends on the quantity added. Among the production conditions, higher temperature and combustion time resulted in higher ash yield from *Ficus*, which gave an emulsifier (*Nikki*) with a higher pH, alkaline and potash content, and better emulsifying properties. The burning temperature, burning time and extraction temperature resulted in enriched emulsifier (*Nikki*) with good pH, alkaline content, and a higher emulsification index. Results gotten from the sensory evaluation indicated that yellow achu soup prepared from the enriched salt was generally accepted, with the highest acceptability at a mixture ratio of 70:30.

## Conflicts of Interest

The authors declare no conflicts of interest.

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