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Research Article

Effect of Traditional Process Methods on the Physicochemical and Functional Properties of a Traditional Food Salt (Nikkih) Obtained from Waste Biomass Peels of *Musa paradisiaca* and *Musa acuminate*

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In Cameroon, agrofood waste biomass such as peels of *Musa paradisiaca* and *Musa acuminate* is being valorized using various traditional processing methods to produce a traditional functional food salt, potash, locally called nikkih. Nikkih has been reported to have varying physicochemical and functional properties, which negatively affect the quality and stability of food prepared using it. This work aims at evaluating the effect of traditional process methods on the physicochemical and functional properties of nikkih produced from these peels in view of the optimization of the process. The peels were preprocessed using two methods: boiling at 90^{o}C before drying and direct drying of raw samples. All samples were dried and combusted to ash at varying temperatures of 250^{o}C, 300^{o} C, and 350^{o}C and times of 30 min, 60 min, and 90 min. The ash obtained was dissolved in varied volumes of water, filtered to obtain the nikkih. Yellow achu soup was prepared through the dry gum method using water and read palm oil, with nikkih as emulsifier. The physicochemical and functional properties of nikkih on yellow achu soup were evaluated using standard methods. The ash yield ranged from $10.62 \pm 0.12\%$ to $7.10 \pm 0.05\%$, with the raw samples combusted at 300^{0}C and 250^{0}C having the highest and lowest values respectively. The pH of nikkih ranged from 10.95 ± 0 to 12.01 ± 0.056 while potash content ranged from $32.45 \pm 0.905\%$ to $72.29 \pm 1.31\%$, with the highest and lowest values obtained from the raw sample combusted at 250^{0}C and the boiled samples combusted at 350^{0}C respectively. Alkaline content ranged from $61.7 \pm 0.141\%$ to $52.8 \pm 0.141\%$, with boiled *M. acuminate* combusted at 350^{0}C having the highest value and the lowest from raw *M. paradisiaca* combusted at 250^{0}C. The foaming capacity and foam stability ranged from $6.9 \pm 0.01\%$ to $16.07 \pm 2.51\%$ and from $3.20 \pm 0.07\%$ to $11.205 \pm 2.39\%$ for *M. acuminate* and *M. paradisiaca* respectively. The emulsification index ranged from $85.62 \pm 0.09\%$ to $86.67 \pm 1.141\%$ after 24 hrs and from $26.0 \pm 0.94\%$ to $27.02 \pm 2.390\%$ after 48 hrs, with the highest value from the raw *M. acuminate* combusted at 350^{o}C and the lowest from that combusted at 300^{0}C. The potash source, pretreatment method, combustion conditions, and dilution factors all had an effect on the physicochemical and functional properties of nikkih.

1. Introduction

Food loss and waste is recognized as a serious threat to food security, the economy, and the environment [1]. Despite various measures taken to ensure the notion of zero waste so as to attain sustainable food production and consumption [2, 3], agrofood waste management still remains a serious problem in many countries [4, 5]. The agrofood industry generates high amounts of byproducts and waste, which account for more than 50% of fresh fruit and at times have a nutritional or functional value higher than the final products [6]. These byproducts and waste, constituting mainly of peels, trimmings, stems, shells, bran, and seeds, are regarded as emerging sustainable agricultural issues as many of these biomaterials are underutilized and end up in municipal landfills where they create serious environmental, economic, and social problems [7–9]. The environmental and economic impact of agrofood waste is associated with the depletion of natural resources used for its production and the costs associated with its disposal (Moron, 2016). These two problems can be solved within the context of the circular bioeconomy by valorizing these wastes for the production of value-added biochemical products or ingredients for the agrofood industry [10, 11]. The exploitation of food byproducts and waste generated in the poor regions of the world for the formulation of novel foods or food ingredient will directly benefit the local communities [12], thereby enhancing food security and contributing to the development of the circular bioeconomy.

In many regions in Cameroon, particularly in the North West and West Regions, for example, the peels of *Musa paradisiaca* and *Musa acuminate* are being valorized traditionally for the production of a traditional functional food salt, potash, locally called 'nikkih'. Nikkih constitutes the crude brownish or blackish extract produced traditionally by leaching the ashes of combusted agrofood waste with water to obtain a potassium-carbonate-rich crude bioextract [13, 14]. Their chemical composition shows that they are a mixture of salts and, thus, are made of cations and anions; the major cation is generally sodium or potassium whereas the major anions are generally carbonates, bicarbonates, sulfates, and chlorides [15–17]. These biobase functional plant extracts are fast replacing the common lake salt called "kangwa", as they are regarded as cheaper, safer, less-toxic, and readily available from food waste biomass and their production from waste biomass contributes to environmental protection. Nikkih 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 [18]. The functionalities of nikkih have been attributed to the alkalinity of the aqueous solution [19]. With respect to its functionality, the ability to reduce cooking time has been studied [20, 21].

Traditionally, nikkih is produced using two methods of pretreatment of the peels of *M. paradisiaca* and *M. acuminate*: boiling of the raw peels before drying or direct drying of the peels. The drying process is followed by combustion of the biomass to produce ash and leaching of the ash with water to obtain a crude brownish or blackish extract. This potassium-carbonate-rich crude extract [13, 14] produced in an indigenous manner contains a lot of impurities responsible for its color [22] and has been reported to have varied functional properties when used in food as an emulsifier and stabilizer, especially in yellow achu soup. Yellow achu soup is an emulsion of crude palm oil in water, stabilized by kanwa and more recently by nikkih, in which a mixture of ground local spices is added. The soup is eaten with a traditional delicacy called achu, obtained by pounding the tubers of *Colocasia esculenta*. In the traditional method of nikkih production, the biomass pretreatment methods vary as a function of the source of the peels along the food value chain: boiling of the *Musa sp.* with peels before drying or peeling off the peels to dry directly. On the other hand, the combustion and extraction are done under undefined temperature and time process conditions.

Till date, most studies on traditional plant based food salts have been focused on their chemical composition [23, 24], their effect on the nutritional quality of foodstuffs [19, 25, 26], their effect on the taste of food preparations [19], and their toxicological effect [12, 27]. The variability and functionalities of traditional salts used in traditional African food preparations were studied by Ngoualem et al. [28] while Ngwasiri et al. [29] studied the effect of the incorporation of crude extract from *Ficus carica* seed peels into crude extract from plantain peel ash to improve on its functional properties and the sensory properties of the yellow achu soup. Furthermore, Franklin et al. [30] reviewed the chemistry and functionalities of lake deposits and plant-based salts used in food preparations. All these studies basically highlighted the relationships among chemical composition and physicochemical properties of traditional alkaline salts when used in solution as well as their functionalities. Studies attempting to evaluate the effect of the traditional process methods on the physicochemical and functional properties of this traditional food salt are very scarce.

The physicochemical and functional properties of traditional plant based food salt seem to be related to the nature of plants used for their preparation and the biomass processing conditions [31]. There are numerous reports of ash salts having been produced all over South and Central America [32] and in Africa, including Cameroon [30], but reports on the effect of processing methods on the physicochemical and functional properties of this traditional food salt are scarce. Processing factors such as the number of cycles and duration of filtration have been reported to affect some properties of the salt such as its color [30]. In addition, the degree of compaction of banana/plantain peels and stalks during combustion has been reported to determine the color of the salts: green with low compaction or black or white with high compaction. Phanice et al. [33] reported the effect of the transformation, preparation method, storage conditions, and time on Iodine and Iron (II) present in Reed Salt, a traditional plant based salt in Kenya. The valorization of these biomass into quality and safe functional traditional food salt as such faces a certain number of problems like differences in the biomass pretreatment methods, boiling of biomass before drying and direct drying of biomass, and the combustion conditions.

Biomass pretreatment and the different process conditions during the thermochemical process, such as temperature, reaction time, heating rate, and pressure, have been reported to affect the quality of intermediates and the products generated [34]. Currently there are scarcity of information on the effect of the traditional pretreatment and processing methods used for nikkih production on its functional quality and the sensory property of yellow achu soup. From these findings, checking the influence of the process method and process factors on the physicochemical and functional properties of traditional food salts appears as research questionable issues. This will help in the determination of the best process conditions for the production of nikkih with optimal functional and sensory qualities. This research is therefore aimed at studying the effect of the two traditional process methods on the physicochemical and functional properties of food grade lime (nikkih) obtained from waste biomass peels of *Musa paradisiaca* and *Musa acuminate*.

2. Materials and Methods

2.1. Materials for Nikkih and Yellow Achu Soup Preparation. Fresh unripe *Musa paradisiaca* and *Musa acuminate* peels were obtained from a local market in Bambili-Bamenda and transported to the laboratory in a flask at 4^0C where it was stored in a refrigerator at 4^0C before usage so as to avoid any ripening. Red palm oil and all other spices for the preparation of the yellow achu soup were obtained from the Bambili market.

2.2. Pretreatment of Musa paradisiaca and Musa acuminate Peels. The waste biomass peels were pretreated following the two traditional methods commonly applied in the North West region of Cameroon. Unripe *Musa paradisiaca* and *Musa acuminate* peels were washed with clean running tap water to remove all debris. The peels were separated into two portions each, which were subjected to two pretreatment methods as locally done, before drying and combustion to produce ash. One portion of the peels from *Musa paradisiaca* and *Musa acuminate* was maintained raw (RS) while the second portion was boiled (BS) for 90 mins at 90^{o}C. This was followed by drying of all the portions separately in a food dehydrator at 70^{o}C for 48 hrs. The dried peels were weighed and stored in dry airtight polyethylene bags for further processing.

2.3. Combustion of Musa paradisiaca and Musa acuminate Peels for Ash Production. The waste biomass peels were combusted following the traditional method commonly applied in the North West region of Cameroon, with a variation of the combustion temperature and time. A known weight of the pretreated dried *M. paradisiaca* and *M. acuminate* peels was combusted in a furnace to ash using different combustion temperature-time combination of 250^{o}C, 300^{o}C, and 350^{o}C for 30 mins, 60 mins, and 90 mins, respectively. The ash was then collected, weighed, and stored in dried airtight containers for further processing and analyses.

2.4. Preparation of the Liquid Extract (Nikkih). The liquid crude extract from the ashes of *M. paradisiaca* and *M. acuminate* peels was produced as described by Kumar [35] and illustrated in Figure 1. 100 g of the ashes was weighed and placed in separate bottles and varied volumes of water of 500 ml, 1000 ml, and 1500 ml at 80^{o}C were measured and poured in the respective bottles. The bottles were corked, mixed vigorously, and allowed to stand for 12 hours. The resulting clear liquid solution was filtered into well labelled plastic bottles using Whatman N^{o}. 41 filter paper.

2.5. Experimental Design. The custom screening design was used to carry out the experiment. The four traditional process parameters evaluated were the pretreatment of the waste biomass (peel), the combustion time and temperature and the dilution/extraction volume. The two pretreatments consisted of using raw *M. paradisiaca* and *M. acuminate* peels noted as RwMp and RwMa and the heat treated (boiled peels) at 90^{o}C noted as Mp90 and Ma90 respectively. A commercial sample, *X* (com), was used as the control. An experimental matrix with 13 runs and 6 responses was generated as presented in Table 1 using the Custom Design from JMP.

2.6. Preparation of Yellow (Achu) Soup. The achu soup was prepared using the traditional dry gum method as presented in Figure 2. In the dry gum method, the emulsifying agent is mixed with the red palm oil before the addition of water to form the emulsion. The red palm oil was heated for 1 min and 20 ml was measured and poured into separate bowls. 10 ml of the nikkih, acting as the emulsifier (nikkih), and ½ teaspoon of achu spices were then added to each bow followed by 50 ml of hot water at 80^0C. The mixture was stirred thoroughly to form a homogenous mixture.

2.7. Physicochemical Analysis

2.7.1. Determination of Ash Yield of the Biomass. The ash content is defined as the inorganic residue that remained after the organic matter was burnt away. The ash yield was determined volumetrically as described by Vladimir [36]. A known weight (M1) of each oven-dried sample was ashed in a furnace at 600^0C. The ashed samples were allowed to cool and the final weight (M2) was determined using an electronic balance. The ash content was calculated using the formula below:

$$\text{Ash yield} = \frac{M2}{M1} \times 100. \qquad (1)$$

2.7.2. Determination of pH Value. The pH of the extracts was determined using Apera instruments, pH700 pH meter following standard analytical method. The pH meter was calibrated using buffer solutions of pH 7, the pH of each extract subsequently determined. The results were recorded in duplicate.

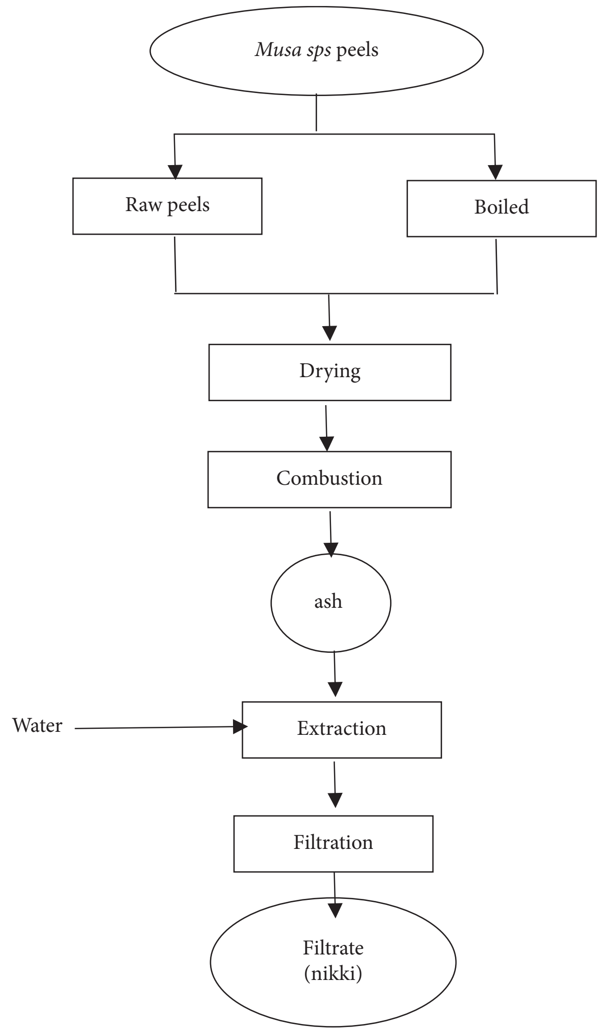

Figure 1: Synoptic diagram of the traditional preparation of plant based ash solution (nikkih).

Table 1: Custom design experimental matrix for study of effect of process parameters on quality of potash from *M. paradisiaca and M. acuminate* peels.

Experimental factors				Responses					
Potash source	Burning time (min)	Burning temp (°C)	Dilution (mL)	*p*H	Ash content (%)	Potash content (%)	EI (24 hrs/ 48 hrs) (%)	Alkali content/ nonalkali (%)	Foam capacity/ foam stability (%)
RwPt	30	350	500						
RwBa	30	300	1500						
RwBa	60	350	1000						
Pt90	90	350	500						
Pt90	30	300	1500						
Ba90	30	250	1000						
RwPt	90	300	1000						
Pt90	60	250	1000						
Ba90	60	300	500						
RwBa	90	250	500						
Ba90	90	350	1500						
RwPt	60	250	1500						
Com									

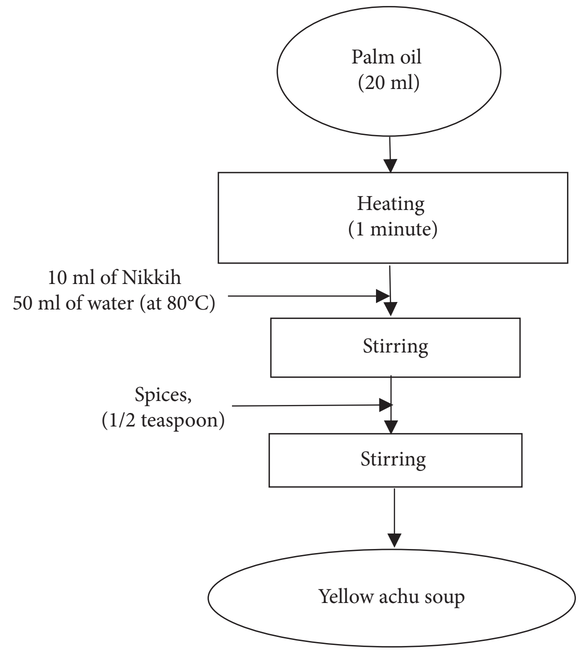

Figure 2: Synoptic diagram presenting the preparation of yellow achu soup using the produced potash.

2.7.3. Determination of Potash and Nonpotash 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 described by Babayemi [37]. A known weight of the peels was completely combusted to ash and a known weight of the ash (W1) 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 (2) while (3) was used for the nonpotash content (NPCa) (% of ash):

$$\mathrm{PCa} = \left[\frac{\mathrm{w2}}{\mathrm{v1}} \times v\right] \times \frac{1}{w1} \times 100, \quad (2)$$

$$\mathrm{NPCa} = 100 - \left[\frac{\mathrm{w2}}{\mathrm{v1}} \times v\right] \times \frac{1}{w1} \times 100. \quad (3)$$

2.7.4. Determination of Alkali Content and Nonalkali Content of Potash. The alkali content of potash consists of the potassium and/or sodium carbonates. The total alkali content was determined by acid-base titrimetry, using methyl orange and/or phenolphthalein indicator(s) as described by Adewuyi et al. [13]. A known weight (2 g) of the solid potash of each sample was dissolved in distilled water in a 250 ml volumetric flask. 25 ml of the solution was pipetted and titrated against 0.1 M HCl using methyl orange indicator for the determination of total alkaline content while the phenolphthalein indicator was used for the determination of the hydroxide content. Analyses were carried out in replicates and the average titres were used to calculate the alkali content of the crude potash.

$$K_2CO_{3(aq)} + 2HCl_{(aq)} \longrightarrow 2KCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$$
or
$$NaCO_{3(aq)} + 2HCl_{(aq)} \longrightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}.$$

2.8. Determination of the Functional Properties of Nikkih

2.8.1. Calculation of Foaming Capacity and Foam Stability. The effect of nikkih on the foaming capacity and foam stability of the yellow achu soup was analyzed as described by Liu et al. [38], with slight modifications. 10 ml of each of the prepared yellow achu soup samples was placed in test tubes. For the determination of the foaming capacity, the initial total height of the mixture, B in cm, was registered. The mixture was then whipped for 30 mins and the total height, A in cm, noted. The foaming capacity was calculated using (4). The whipped samples were allowed to stand for 3 minutes, the height, C in cm, recorded and the foaming stability calculated using (5):

$$Foam\ capacity\,(\%) = \frac{(A - B)}{B} \times 100, \quad (4)$$

$$Foam\ stability\,(\%) = \frac{A - C}{C} \times 100. \quad (5)$$

2.8.2. Calculation of Emulsification Index. The emulsifying activity of the different nikkih samples used in the preparation of yellow achu soup was evaluated as described by McClements [39] with slight modifications.10 ml of the seven samples of yellow achu soup obtained was placed in different test tubes, vortexed at high speed, and allowed to stand. The production of creamy emulsion was observed at time intervals of 24 hours and 48 hours and the emulsification index (EI) calculated using

$$EI = \frac{\text{height of the emulsified layer}}{\text{total height of emulsion}} \times 100. \quad (6)$$

2.9. Statistical Analysis. All analysis was carried out in duplicates and their average was calculated. The data were analyzed using JMP (Jump) statistical software and Microsoft Excel.

3. Results

3.1. Effect of Processing Method on the Physicochemical Properties of Nikkih

3.1.1. Variation of Ash Yield. The values for the ash yield ranged from $6.89 \pm 0.05\%$ to $10.62 \pm 0.12\%$ as shown in Table 2, with *M. acuminate* having higher values compared to *M. paradisiaca*. The raw *M. acuminate* samples had the highest ash yield compared to the boiled samples, with RwMa combusted at 300^0C for 30 min having the highest percentage ash yield of $10.62 \pm 0.12\%$ while that combusted at 250^0 C for 90 min had the lowest of $7.37 \pm 0.04\%$.

Table 2: Percentage of ash yield from *M. acuminate* and *M. paradisiaca* peel biomass as a function of process conditions.

Biomass treatment process method	Combustion time (min)	Burning temp (°C)	Ash yield (%)
RwMp	30	350	8.89 ± 0.04
RwMa	30	300	10.62 ± 0.12
RwMa	60	350	8.23 ± 0.05
Mp90	90	350	7.90 ± 0.04
Mp90	30	300	8.59 ± 0.08
Ma90	30	250	7.89 ± 0.05
RwMp	90	300	7.73 ± 0.29
Mp90	60	250	7.35 ± 0.26
Ma90	60	300	7.38 ± 0.04
RwMa	90	250	7.37 ± 0.04
Ma90	90	350	7.10 ± 0.05
RwMp	60	250	9.27 ± 0.07

The result represents the mean of three readings ± standard deviation.

3.1.2. Effect of Biomass Treatment Method on Crude Extract pH. The pH obtained for all samples and treatments ranged from 10.95 to 12.04 as presented in Table 3, which confirmed the alkali production from both *M. acuminate* and *M. paradisiaca* under different biomass pretreatment and combustion conditions. This suggests good alkalinity in the production of an emulsion base from these agrofood wastes required for yellow achu soup. As observed with the case of ash yield, the raw *M. acuminate* (RwMa) had a higher alkalinity, with sample RwBa combusted at 250°C for 90 mins having the highest value of 12.01 ± 0.05 while RwMa combusted at 300°C for 30 mins having the lowest pH value of 10.95 ± 0.

3.1.3. Variation of Potash Content as a Function of M. acuminate and M. paradisiaca Peel Biomass Treatment Method. The potash content ranged from 31.81% to 72.01% as presented in Table 4. Generally, *M. paradisiaca* had a higher potash content than *M. acuminate*, with the raw sample having the highest potash content. The raw *M. paradisiaca* sample, RwMp, combusted at 250°C for 60 mins had the highest potash content of 72.81 ± 1.13 while the boiled *M. acuminate* combusted at 350°C for 90 mins had the lowest of 32.45 ± 0.90.

3.1.4. Variation of Alkali Content and Nonalkali Content of Potash. The alkali content ranged from $52.8 \pm 0.14\%$ to $61.7 \pm 0.14\%$, while the nonalkali content ranged from $38.3 \pm 0.14\%$ to $47.2 \pm 0.14\%$ as presented in Table 5. The *M. paradisiaca* had a higher alkaline content than *M. acuminate*, with the boiled sample, Mp90 combusted at 350^{0}C for 90 mins having the highest alkali content while the raw *M. acuminate* sample RwMa combusted at 250^{0}C for 90 mins had the lowest value of 52.8 ± 0.141. On the other hand, *M. acuminate* gave a higher nonalkali content with the raw sample RwMp combusted at 250^{0}C for 90 mins having the highest nonalkali content while boiled *M. paradisiaca* sample, Mp90, combusted at 350^{0}C for 90 mins had the lowest nonalkaline content of 38.3 ± 0.14. The alkaline contents of all the samples were higher than that of the commercial control sample while the nonalkaline contents were lower than the control sample, which had a value of 48.7 ± 0 and 51.3 ± 0 respectively.

3.2. Effect of Processing Method on the Functional Properties of Nikkih

3.2.1. Emulsification Index 24 hrs and Emulsification Index 48 hrs. The results obtained for emulsification index 24 hrs and emulsification index 48 hrs are found in Table 6. Sample RwMp at 350°C displayed the highest emulsifying activity after 24 hours with a value of $86.67 \pm 1.141\%$. Even after 48 hours, its emulsifying activity remains the highest with a value of $85.62 \pm 0.0968\%$. Sample RwMp at 300°C had the lowest emulsifying activity even after 48 hours with a value of $27.02 \pm 2.390\%$ and $26.0 \pm 0.947\%$ after 24 hours and 48 hours respectively.

3.2.2. Foam Capacity and Foam Stability. The results recorded for the foam capacity and foam stability are shown in Table 7. It was observed that the values of foaming capacity were higher than those of foaming stability with respect to the raw material. The foam capacity ranged from $6.9 \pm 0.01\%$ to $21.05 \pm 0.52\%$, sample RwMa at 250°C had the highest foaming capacity, and sample Mp90 at 300°C had the lowest. Foam stability ranged from $3.20 \pm 0.07\%$ to $11.205 \pm 2.39\%$, and sample RwMa at 300°C had the highest foaming stability, while sample RwMp at 350°C had the lowest value.

4. Discussion

Combustion of biomass produces biomass ashes. Ash content and behavior during combustion are particularly important in regard to biomass fuels [40]. The results indicated that the ash content is significantly influenced by potash source, as well as the biomass pretreatment method, burning temperature, and burning time ($P < 0.05$). Generally, from Table 2, it was observed that the ash yield decreased with increase in burning temperature and burning time with respect to material. Similar results were obtained for combustion of banana peel biomass [41] and molasses [42]. This can be explained by the fact that the total amount of biomass

Table 3: pH of potash as a function of *M. acuminate and M. paradisiaca* peel biomass treatment method.

Biomass treatment method	Combustion time (min)	Combustion temp (°c)	Dilution (mL)	pH values
RwMp	30	350	500	11.74 ± 0.01
RwMa	30	300	1500	10.95 ± 0
RwMa	60	350	1000	11.98 ± 0.04
Mp90	90	350	500	11.17 ± 0.19
Mp90	30	300	1500	11.475 ± 0.07
Ma90	30	250	1000	11.25 ± 0.15
RwMp	90	300	1000	11.565 ± 0.43
Mp90	60	250	1000	11.75 ± 0.01
Ma90	60	300	500	11.62 ± 0
RwMa	90	250	500	12.01 ± 0.05
Ma90	90	350	1500	11.13 ± 0
RwMp	60	250	1500	11.735 ± 0.20
Com				13.04 ± 0.04

The result represents the mean of three readings ± standard deviation.

Table 4: Potash content as a function of *M. acuminate* and *M. paradisiaca* peel biomass pretreatment and combustion conditions.

Biomass treatment method	Combustion time (min)	Combustion temp (°c)	Dilution (mL)	Potash content (%)
RwMp	30	350	500	61.82 ± 0.43
RwMa	30	300	1500	39.38 ± 1.23
RwMa	60	350	1000	39.96 ± 0.82
Mp90	90	350	500	43.01 ± 1.41
Mp90	30	300	1500	51.67 ± 2.34
Ma90	30	250	1000	48.13 ± 2.65
RwMp	90	300	1000	54.085 ± 1.09
Mp90	60	250	1000	51.905 ± 0.67
Ma90	60	300	500	36.36 ± 0.35
RwMa	90	250	500	48.275 ± 1.95
Ma90	90	350	1500	32.45 ± 0.90
RwMp	60	250	1500	72.81 ± 1.13
Com				35.42 ± 7.15

The result represents the mean of three readings ± standard deviation.

Table 5: Alkaline content of potash as a function of *M. acuminate* and *M. paradisiaca* peel biomass pretreatment and combustion conditions.

Biomass treatment method	Combustion time (min)	Combustion temp (°c)	Dilution (mL)	Alkaline cont (%)	Nonalkaline cont (%)
RwMp	30	350	500	58.5 ± 0.14	41.5 ± 0.14
RwMa	30	300	1500	58.1 ± 0	41.9 ± 0
RwMa	60	350	1000	59.1 ± 0	40.9 ± 0
Mp90	90	350	500	61.7 ± 0.14	38.3 ± 0.14
Mp90	30	300	1500	57.1 ± 0	42.9 ± 0
Ma90	30	250	1000	56.25 ± 0.21	43.75 ± 0.21
RwMp	90	300	1000	57.4 ± 0	42.6 ± 0
Mp90	60	250	1000	53.45 ± 0.20	46.55 ± 0.21
Ma90	60	300	500	60.25 ± 0.21	39.75 ± 0.14
RwMa	90	250	500	52.8 ± 0.14	47.2 ± 0.14
Ma90	90	350	1500	60.45 ± 0.14	39.65 ± 0.21
RwMp	60	250	1500	54.4 ± 0.14	45.6 ± 0.14
Com				48.7 ± 0	51.3 ± 0

The result represents the mean of three readings ± standard deviation.

ashes obtained from combustion is variable depending on the type of material and combustion process [43]. At high burning temperature and burning time more minerals are lost as the sample approaches complete combustion; hence, there is a decrease in mass. Ashing at low temperatures and short times may fail to combust all the organic matter, whereas higher temperatures may cause dehydration of structural hydroxyl groups of minerals in the peels [44].

The observed pH values, which ranged from 10.95 to 12.04, are in agreement with the findings by Gopalakrishna [45] and Mianpeurem et al. [16] who found the pH of traditional vegetable salts of Papua New Guinea to be highly

Table 6: Emulsification index (EI24 hrs and EI48 hrs) of potash on yellow achu soup as a function of *M. acuminate* and *M. paradisiaca* peel biomass pretreatment and process conditions.

Biomass treatment method	Combustion time (min)	Combustion temp (°C)	Dilution (mL)	EI 24 hrs (%)	EI 48 hrs (%)
RwMp	30	350	500	86.67 ± 1.14	85.62 ± 0.09
RwMa	30	300	1500	71.83 ± 1.99	70.13 ± 0.98
RwMa	60	350	1000	80.38 ± 0.89	78.48 ± 1.78
Mp90	90	350	500	83.45 ± 1.78	82.11 ± 1.73
Mp90	30	300	1500	50.0 ± 2.02	46.43 ± 1.03
Ma90	30	250	1000	70.205 ± 0.65	65.92 ± 2.05
RwMp	90	300	1000	27.02 ± 2.39	26.0 ± 0.94
Mp90	60	250	1000	31.23 ± 0.95	28.73 ± 2.40
Ma90	60	300	500	30.28 ± 0.99	27.46 ± 0.95
RwMa	90	250	500	34.0 ± 0.64	33.38 ± 0.56
Ma90	90	350	1500	52.73 ± 0.96	49.32 ± 0.03
RwMp	60	250	1500	69.8 ± 0.66	68.0 ± 1.88
Com				82.03 ± 1.85	79.49 ± 0.73

The result represents the mean of three readings ± standard deviation.

Table 7: Foam capacity and foam stability of potash on yellow achu soup as a function of *M. acuminate* and *M. paradisiaca* peel biomass pretreatment and process conditions.

Biomass treatment method	Combustion time (min)	Combustion temp (°C)	Dilution (mL)	Foam capacity (%)	Foam stability (%)
RwMp	30	350	500	8.06 ± 2.28	3.20 ± 0.07
RwMa	30	300	1500	11.29 ± 2.28	11.205 ± 2.39
RwMa	60	350	1000	7.57 ± 2.14	4.545 ± 2.14
Mp90	90	350	500	12.86 ± 2.02	7.14 ± 2.02
Mp90	30	300	1500	6.9 ± 0.01	3.345 ± 0.07
Ma90	30	250	1000	7.16 ± 0.34	5.175 ± 2.45
RwMp	90	300	1000	7.32 ± 1.77	5.71 ± 0
Mp90	60	250	1000	15 ± 2.36	8.345 ± 2.36
Ma90	60	300	500	16.07 ± 2.51	10.66 ± 0.07
RwMa	90	250	500	21.05 ± 0.52	8.465 ± 2.33
Ma90	90	350	1500	12.04 ± 6.54	3.385 ± 0.09
RwMp	60	250	1500	15 ± 2.36	8.34 ± 2.36
Com				12.06 ± 2.43	6.79 ± 0.16

The result represents the mean of three readings ± standard deviation.

alkaline, ranging from 9.2 to 10.1 for seven types of salts. Mianpeurem et al. [16] observed an alkaline pH for salts obtained from pawpaw due to presence of high anions of sodium, potassium, and calcium. This observation clearly supports the presence of alkaline anions like hydroxide and carbonate, among others [45], in nikkih, therefore leading to an alkaline pH as observed. Anions of sodium, potassium, and calcium decompose during the ashing process at high temperatures [45]. Generally, the *M. acuminate* sample had higher pH value than the *Musa paradisiaca* sample as shown in Table 3, which is due to differences in their composition [46].

Combustion time had a great impact on the pH value ($P < 0.05$) as varying the time affected the pH values significantly. The pH values of RwMa and RwMp increased with an increase in combustion time. The pH values of both samples of Mp90 and Ma90 increased slightly from 30 min to 60 mins, because the major components of *M. acuminate* and *Musa paradisiaca* residues are oxidized into the gaseous emission during prolonged combustion time, leaving behind metal oxides and other elemental components that form a good alkaline solution. The pH value increased with the increase in burning temperature and burning time for plantain peels, and it decreased from raw samples to boiled samples at all temperatures, while for banana it decreased from raw to boiled samples at all temperatures except 300°C. This is due to the dilution. These results are similar with the reports of Uzodinma et al. [47], Udoetok [48], and Israel and Akpan [49] that ashes are usually alkaline (pH > *l*0) because they are composed primarily of calcium carbonate, potassium chloride, and sodium chloride. The commercial sample had a pH value of 13.04, which is higher than all the pH values obtained here.

Potash yield depends on the type of plant material, the nature of soil where the plants grow, and the efficiency of extraction technology used [50]. From Table 4, it is observed that the potash content is in accordance with the potash content in the peels of some varieties of Nigeria grown plantain and banana as reported by Babayemi et al. [50] ranging from 69.0 to 81.9%. The raw peels had a higher potash content than the boiled peels. This indicates that during the boiling pretreatment, some minerals were leached from the peels into the boiling water. Similar results were obtained by Adeparusi [51] when boiling *Lima* beans

(*Phaseolus lunatus* L.). The potash content varied like that for all the samples except for RwMa burnt for 30 mins. The burning temperature, burning time, and dilution had little impact on the potash content ($P > 0.05$). When the peels are combusted slowly, they will not burn completely and this affects the concentration of the potash [52]. The above results are related to those reported by Babayemi et al. [37]. The potash content in the peels of some varieties of Nigeria grown plantain and banana ranged from 69.0 to 81.9%. The commercial sample had a potash content value of $35.42 \pm 7.15\%$, which is lower than the values obtained in this work.

Generally, it was observed that the pretreatment method and the combustion temperature and time had an effect on the alkaline and nonalkaline contents of the samples. The alkali content generally increased with increase in burning temperature. This is because the major components of plantain and banana residues are oxidized into gaseous emission during combustion, leaving behind metal oxides and other elemental components that form a good alkaline solution. The results obtained in this study are similar to those reported by Adewuyi et al. [13] who obtained alkali content within the range from 69.0 to 81.9%. Since nonalkali content is derived from the value of alkali content, all the parameters which affected the alkali content also affected the nonalkali content. Furthermore, the boiling pretreatment method led to a lower alkalinity of nikkih as compared to the unboiled samples. This can be explained by the fact that biomass metallic salts are mostly soluble and the metallic salts are easily leached out during the boiling pretreatment [53].

The results in Table 6 indicated that emulsification index is significantly influenced by burning temperature and burning time while the potash source and dilution did not have a significant influence on the emulsification index ($P > 0.05$). Irrespective of the nikkih sample used, all samples showed a decrease in emulsification index after 48 hours. Also, similar results were obtained from the work done by Mbawala et al. [54]. In his research work, biosurfactants, nikkih and kanwa showed a decrease in 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 McClements [39]. The emulsification index of the raw samples was higher than those of the boiled samples since minerals were leached out during boiling. A higher emulsification was possible because interfacial tension was greatly reduced. Following the findings of Langnes et al. [55], chemical reactions between alkali and organic acids that exist in crude palm oil resulted in the formation of the surfactant and emulsification; 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 [56].

The results in Table 7 indicated that foam capacity and foam stability of the potash on yellow achu soup, an oil-water emulsion, were significantly influenced by burning time ($P < 0.05$). Oil-water emulsion has a continuous phase formed of hydrophobic materials (oil) and water (globules) that make up the dispersed phase which is stabilized by an emulsifier [57]. According to Fennema [58], the foaming capacity is characterized as the interfacial area that can be created by a protein while the foaming stability is related to the ability to remain stable in the presence of gravitational or mechanical forces. In this study, proteins were absent; rather the emulsion formed as a result of the interaction between water and red palm oil using the alkali (nikkih) as an emulsifier was responsible for foaming (Ngwasiri et al., 2021). RwMa at 300°C had the highest foaming capacity but a lower foam stability, suggesting that the proportion of the emulsifiers used (as compared to the others) was not strong enough to overcome the surface tension at the oil-water interface, hence leading to the production of foams which are not very stable. This can be explained by the fact that the effectiveness of an emulsifier 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 [59]. The burning time had a great impact on the foaming capacity and foam stability as the p value was significant ($P < 0.05$). The potash source, burning temperature, and dilution factor had little impact on the foam capacity and foam stability ($P > 0.05$).

5. Conclusions

The results of this study showed that pretreating the peels and burning them at different temperatures and different times had an effect on the ash yield. The pretreated samples had lower ash yield than the ones not pretreated, and the samples combusted at higher temperatures and longer time had lower ash yield. All the process parameters (pretreatment, potash source, burning time, burning temperature, and dilution) had an impact on the physicochemical properties of nikkih. The results also showed that potash from the peels of *Musa species* is a very good source of the much needed alkali as a raw material for various alkali-based products. Ash and potash have compositions which vary with plant materials used. Varying all the process parameters had an influence on the functional properties of nikkih. Nikkih obtained from the raw peels had better emulsifying and foaming properties capable of stabilizing yellow achu soup than the boiled peels.

Data Availability

All data generated during this study are presented in the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Conceptualization and methodology are done by Ngwasiri Pride Ndasi and Adanmengwi Vivian Akah; software is provided by Ngwasiri Pride Ndasi and Adanmengwi Vivian Akah.; validation is carried out by Noumou Thierry, Dobgima John, and Ngwabie Martine Ngwa.; formal analysis is performed by Adanmengwi Vivian Akah; investigation is done by Ngwasiri Pride Ndasi and Adanmengwi Vivian Akah; resources are provided by Ngwasiri Pride Ndasi and Adanmengwi Vivian Akah and Ngwa Martine Ngwabie; data curation is done by Ngwasiri Pride Ndasi, Dobgima John F., and Adanmengwi Vivian Akah; original draft preparation is done by Ngwasiri Pride Ndasi and Adanmengwi Vivian Akah; review and editing is carried out by Wilson Agwanande A. Martin Benoit Ngassoum and Ejoh Richard Aba.; supervision is done by Ngwasiri Pride Ndasi. All authors have read and agreed on the published version of the manuscript.

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