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RESEARCH ARTICLE

Production and Evaluation of Flour from Whole Fruit and Pulp of Green Saba (*Musa acuminata x Musa balbisiana*) Banana Pretreated with Organic Acids

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Abstract

Banana is a widely cultivated and consumed fruit in the Philippines. Because it is climacteric and highly perishable, there is a need to process it into a commodity with an extended shelf life, to add value, reduce fruit waste, and minimize crop losses. This study evaluated the physicochemical and microbiological properties of green banana flour (GBF) from 'Saba' (*Musa acuminata x Musa balbisiana*) cultivar, using the whole fruit (pulp + peel) and pulp-only, pre-treated with kalamansi juice and citric acid (CA). Pulp-only flours (PF) yielded more flour than the whole fruit flours (WF), suggesting that the moisture-rich peel may not convert efficiently to flour. The pH and total titratable acidity (TTA) of CA-pretreated and untreated flours showed no significant difference ($p > 0.05$), indicating the low CA concentration was insufficient to alter acidity. In contrast, kalamansi-pretreated flours were highly acidic due to the high concentration of organic acids in the juice. Color measurements indicated light-colored flours, with neutral red-green tonality, and more yellow hue than blue. Proximate analysis for the CA-pretreated groups showed significantly higher ($p < 0.05$) %moisture and %ash in WF compared to the PF due to the peel. All microbial counts were within acceptable limits, confirming microbiological stability. Acid pretreatment minimized enzymatic browning, and inclusion of banana peel improved the nutritional profile of GBF. These findings demonstrate the potential of GBF as a functional, shelf-stable ingredient for food applications.

Keywords: *green banana flour, kalamansi, citric acid, physicochemical, microbiological quality*

Bananas (*Musa* spp.) are among the most widely cultivated tropical fruits worldwide and play a key role in the agro-economy of the Philippines. With Filipinos reportedly consuming up to 60 kg per capita annually [1], bananas are a staple fruit in Filipino households. Globally, around 120 million tons of bananas and plantains (*Musa acuminata*) are harvested each year, comprising 16% of worldwide fruit production across 112 countries [2]. In the Philippines alone, banana production reached approximately 2.40 million metric tons, placing the country among the top banana producers and exporters [3]. The majority of this production originates from Mindanao, with the Davao region leading as the top banana producer, followed by Northern Mindanao, then SOCCSKSARGEN. Of the bananas grown, around 28% are plantains or green bananas [4].

Despite the prominence of bananas in the agricultural landscape, green bananas, being highly perishable, face significant quality degradation both pre- and post-harvest. Globally, around 20% of banana exports, amounting to 4-5 million tons, are rejected due to issues like under-maturity and irregularities in appearance [5]. In the Philippines, pre-harvest losses are estimated at 30%, largely due to rotting and diseases, while post-harvest losses average 35% [6]. Rejected bananas often go to waste, contributing to environmental pollution and economic losses for farmers and processors [7]. Converting bananas into a more stable product, such as flour, is an innovative solution to minimize this waste.

Banana flour, especially from green or unripe bananas, has emerged as a promising alternative to conventional wheat flour as functional ingredient. In the Philippines, producing banana flour offers a sustainable way to reduce

banana waste while creating value-added products [8, 9]. Green banana flour (GBF) not only curbs waste but also offers numerous health benefits. It increases antioxidant activity and it is naturally high in resistant starch, dietary fiber, vitamins [9] and minerals, and bioactive compounds [10], which are associated with improved gut health, glycemic control, and satiety—attributes that are increasingly sought after in modern diets. Given the increasing incidence of diet-related health issues in the country—such as type 2 diabetes [11], and inflammatory bowel diseases (IBD)—the latter largely driven by poor nutrition, high consumption of processed food [12], and low fiber intake [13], GBF could serve as a valuable dietary intervention. Its incorporation into locally produced food products could offer an affordable, sustainable strategy to support public health, while also adding value to underutilized agricultural produce. Even banana peels, typically discarded, are rich in resistant starch, fiber, and vitamins, which could be retained in the flour production process. Banana flour has high storability potential, long shelf life, and can be readily applied to food products [9].

One of the challenges in utilizing green bananas is enzymatic browning, a process that occurs when bananas are exposed to oxygen once peeled. When processed into flour, this browning can reduce its aesthetic appeal and shorten its shelf life [14, 15]. To address this issue, various pretreatment methods, including the use of citric acid or antioxidants, can be employed to slow down enzymatic browning and preserve the flour's natural color [15, 16]. Controlling enzymatic browning is essential to maintaining the quality, taste, flavor, and nutritional value of banana-based products [15].

Citric acid (CA), commonly used as an anti -browning agent, is typically produced through fermentation using *Aspergillus niger* strains [17]. However, natural sources of citric acid, such as calamansi or kalamansi (*Citrus x microcarpa*), offer a viable alternative. Kalamansi juice, with a pH of about 2.54 and a citric acid content of approximately 5.00% [18], could serve as a natural pretreatment agent in the production of GBF. To date, the use of kalamansi juice as a pretreatment for bananas has not yet been reported, and exploring its effects on flour characteristics presents a novel scientific inquiry. Moreover, most existing studies focus only on flours derived from pulp and/or peel, with very limited research on whole fruit (pulp + peel) flour specifically of the Saba cultivar (*Musa acuminata x Musa balbisiana*). Thus, the objective of this study was to produce GBF using whole fruit and pulp alone from unripe Saba, and applying kalamansi juice or commercial citric acid as pretreatment agents. Specifically, this study aimed to (1) determine the physicochemical properties of the flours, which includes pH, titratable acidity, color, and proximate analysis, and (2) assess their microbiological quality, particularly yeast, mold, and coliform count.

Materials and Methods

Sample Source

Commercial unripe Saba banana (*Musa acuminata x Musa balbisiana*) at Stage 1 maturity or all green were purchased from one local supplier at Centro, Uhaw, Brgy. Fatima. A Saba banana with Stage 1 maturity exhibits uniformly green color [19] and has a firm texture when touched [20]. The bananas were carefully selected ensuring that they were devoid of any mechanical or pest damage. They were purchased on a weekly basis and a total of six batches were acquired, amounting to a total of approximately 16 kilograms of green bananas. On the other hand, eight kilograms of green kalamansi were purchased from a single vendor at General Santos City Public Market. The green stage of kalamansi has a characteristic green color as described by Marutani [21].

Sample Groups

After every purchase of the bananas, they were transported immediately to the laboratory for processing where they were divided into two main groups – the Whole Fruit (pulp + peel) Flour (WF) and the Pulp-only Flour (PF). Each group had a total of approximately eight kilograms of bananas. Under each group, three subgroups were created for the different pretreatment methods, and these were the Kalamansi Flour (KWF and KPF), Citric Acid Flour (CAWF and CAPF), and the Control Flour (CWF and CPF).

Preparation of Pretreatment Solutions

The 100% kalamansi extract was made by extracting the juice from the kalamansi. The seeds and the fruit fibers were strained using a coriander. The juice was then pasteurized for 10 min at 80°C to 95°C and placed inside a sterile glass bottle [22, 23]. The kalamansi juice was used within ten hours after it was extracted.

The method by Tribess *et al.* [24] for the GBF production was followed. Freshly prepared 0.5 g/L citric acid solution (0.5 g citric acid in 1 L distilled water) was used every sample processing. The food-grade citric acid (China) was purchased from a local chemical supplier.

Sample Preparation

The bananas were washed with tap water to remove any dirt or surface contaminants and then

washed with distilled water. After drying, both groups were manually sliced thinly (approximately 4 mm) using a vegetable slicer and were immediately rinsed in their respective pretreatment solutions in a basin for 5-10 minutes. The soaked slices were then placed on a stainless steel mesh for another 5-10 minutes to drain any excess liquid before being placed in the dehydrator.

Green Banana Flour Production

The banana slices were dried in a dehydrator (DALLE Food Dehydrator mod. LT-93, Turkey) at 55 °C for 6 hours. After dehydration, the slices were ground and pulverized using a blender (nutribullet®, California, United States) and sieved through a 60-mesh sieve (250 μm mesh size) and stored in individual Ziplock bags in the refrigerator with a temperature maintained at 8 °C. Three technical replicates for each type of flour were produced.

Physicochemical Analysis

The physicochemical analyses were pH, titratable acidity, and color. Proximate analysis (moisture, ash, carbohydrates, and crude protein) for the CAWF and CAPF were also done. All analyses were measured in triplicate.

The pH was determined using the method of Pearson [25]. Ten grams of flour mixed with 100 mL distilled water was shaken and allowed to sit for at least 30 min. The pH of the decant was measured using a pH meter (YIERYI, mod. YY-400, China).

The titratable acidity was determined through titration as described by Wallace [26]. Ten grams of flour were suspended with 100 mL distilled water and homogenized using a magnetic stirrer, while the pH was continuously monitored with a pH meter. This suspension was then immediately titrated against 0.1 N NaOH under continuous stirring until the pH reached 6.6. The titratable acidity, expressed as %citric acid (citric acid equivalent = 0.064), was calculated using the following formula [22]:

$$\text{Titratable acidity (\%)} = \left(\frac{\text{NaOH used (mL)} \times \text{0.1N NaOH} \times \text{citric acid equivalent}}{\text{Sample weight (mL)}}\right) \times 100 \quad (1)$$

The L*a*b* color model of the Commission International de l'Enclairage (CIELAB) was evaluated using the method described by Mazjoobi *et al.* [27]. L* value represents lightness (black = 0 to white = 100), a* means greenness-redness (negative = green, positive = red), and b* means yellowness-blueness (positive = yellow, negative = blue). High resolution pictures of the flour were taken using iPhone 7 which generated images with dimensions of 3024 x 3024 pixels. The lightness, contrast, and resolution were set to 62(%), 62(%), and 300 dots per inch (dpi), respectively. Adobe Photoshop CS6 (Adobe Inc., San Jose, California, United States) was used to determine the L*, a*, and b* values of the images.

The GBF samples were submitted to Davao Laboratory, Inc., Davao City, for proximate analysis. The analyses conducted were in accordance with the Official Methods of Analysis of AOAC International, 17th edition, using the following methods: Crude Protein - 920.87, Ash – 923.03, and Moisture – 925.10. The % carbohydrates were determined by calculation (% carbohydrates = 100% – (% crude protein + % crude fat + % crude moisture + % ash).

Due to limited resources, only the CAWF and CAPF were subjected to proximate analysis. These treatments were prioritized because aside from citric acid pretreatment being widely used in published studies, the kalamansi-pretreated flours were found to be highly acidic which may limit their suitability for industrial applications. However, we recognize the value of including all treatments in proximate analysis and have acknowledged this as a limitation of the study. We have also included a recommendation for future studies to include all pretreatment groups in proximate analysis to allow for a more comprehensive nutritional evaluation.

Microbiological Analysis

The method by Maturin and Peeler [28] for the preparation of samples for microbiological analysis was used. The samples were prepared by adding 45 mL buffered peptone water (Merck BPW, Merck KgaA, Germany) to 5 g of flour to achieve a 1:10 dilution. These dilutions were shaken 25 times in a 30 cm-arc within 7 s to homogenize.

Pour plating as described by Tournas *et al.* [29] in the Bacteriological Analytical Manual (BAM) was used for the enumeration of yeasts and molds. From each dilution, 1 mL was pipetted aseptically to petri dishes. Fifteen to twenty mL of potato dextrose agar (PDA) (Merck PDA, Merck KgaA, Germany), supplemented with 10% tartaric acid (14 mL/L PDA), was poured into each dish, and swirled until the sample was evenly distributed. The plates were incubated at 35 °C for 5 days and on the seventh day, the plates were checked for any growth. Colonies were counted and colony forming units (CFU) per gram was calculated. Testing for yeast and mold for each sample was done in triplicate.

Spread plating as described by Feng *et al.*

[30] in BAM was used for the presumptive test for coliforms as well as for the confirmation test. From the homogenized sample, 0.1 mL was pipetted aseptically to a plate with Violet Red Bile Dextrose Agar (VRBD) (101406 Millipore VRB Merck KgaA, Germany). Three to four milliliters overlay of the medium was added. The plates were incubated at 35 °C for 18-24 hours. Colonies that were pink or dark-red with a diameter around 0.5 mm or more were counted as members of coliform bacteria in CFU/g and were subjected to coliform confirmation. This test was done in triplicate.

For the confirmation test for coliforms, all typical colonies from the VRBD agar plates were picked using a sterile inoculating loop. These were then inoculated into separate Brilliant Green Lactose Broth (BRILA) (Merck KgaA, Germany) tubes with inverted Durham tube. The tubes were then incubated at 35 °C and checked after 24 and 48 hours. All tubes that have displaced medium inside the Durham tube or showed effervescence when agitated was positive for the presence of coliform bacteria while absence of gas production was interpreted as a negative result.

The guideline from the Philippine FDA Circular No. 2013-010 [31] was used to determine the microbiological quality of the GBF.

Data Analysis

The GBF % flour yield was calculated by dividing the weight of the flour (from either whole fruit or pulp only) by the fresh weight of the corresponding starting material (whole fruit or pulp), then multiplying by 100 [32]. The overall weight of all the banana used for each group, overall weight of the peel from the PF, the overall weight of the banana after drying, as well as the overall flour weight are listed in Table 1.

The results of pH, titratable acidity, and CIELAB color values for the flour samples were submitted to one-way analysis of variance (ANOVA) and Games-Howell post-hoc tests using the program Jamovi version 2.3.28 (The Jamovi Project), which is an open-source statistical software, available under the AGPL3 license. A significance level of $\alpha = 0.05$ was used. For the proximate analysis results, the means of the GBF of the CAWF and the CAPF were compared using independent samples t-test using Jamovi version 2.3.28. All tests unless specified were performed in triplicate and the mean values and standard deviations were reported. The corresponding values for wheat flour, the global standard in food manufacturing and baking, as reported by Kumar *et al*. [9], were included to serve as a benchmark for comparing the properties for the GBF produced.

Results and Discussion

Percent Yield

The flour yield relates to the moisture content, accumulation of dry matter (100 – % moisture content [20] in the material, pulp-to-peel ratio, and cultivar [33]. As shown in Table 2, the pulp-only flours had higher % flour yield than the whole fruit flours. Although it is generally expected that the WF samples, which used the both pulp and peel, would yield more flour than the PF samples, the results indicate otherwise.

This discrepancy may be attributed to the characteristics of the peel, which accounts for approximately 38% of the whole fruit, consistent with the findings of Khoozani *et al.* [9]. Green banana peel contains higher levels of fiber (43-50%), polyphenols, and moisture (86-91%) and lower starch (10.1-11.7%) [9, 33, 34], which may

Table 1. Percent flour yield of the green banana flour groups based on the initial weight of whole fruit (pulp + peel) or pulp only, and flour weight.

Flour	Fresh Whole Fruit Weight (g)	Fresh Peel Weight (g)	Fresh Pulp Weight (g)	%Peel	%Pulp	Whole Fruit Weight After Drying (g)	Flour Weight (g)	Flour Yield (%)
Control Whole	3421.9	N/A	N/A	N/A	N/A	1094.37	1042.91	30.46
Control Pulp	3381.0	1283.87	2097.13	38.0	62.0	818.34	806.22	38.44
Citric Acid Whole	3236.2	N/A	N/A	N/A	N/A	1042.90	1004.32	31.04
Citric Acid Pulp	3110.2	1182.91	1927.29	38.0	62.0	821.72	791.13	41.05
Kalamansi Whole	1671.4	N/A	N/A	N/A	N/A	511.30	486.68	29.15
Kalamansi Pulp	1798.4	670.65	1127.75	37.3	62.7	478.44	464.63	41.20

*N/A = not applicable

Table 2. Mean pH and titratable acidity (% citric acid) of green banana flour (GBF) groups and reference values from banana varieties and wheat flour.

Flour	pH	% Titratable Acidity
Control Whole	6.08 ± 0.015^{a}	0.243 ± 0.017^{a}
Control Pulp	6.07 ± 0.021^{a}	0.190 ± 0.010^{a}
Citric Acid Whole	6.01 ± 0.020^{a}	0.299 ± 0.010^{a}
Citric Acid Pulp	5.99 ± 0.038^{a}	0.307 ± 0.006^{a}
Kalamansi Whole	4.61 ± 0.032^{a}	2.118 ± 0.102^{b}
Kalamansi Pulp	4.43 ± 0.025^{b}	2.144 ± 0.205^{b}
GBPuF [5]	5.0 – 5.78	ns
GBPuF [33]	5.4 – 5.8	ns
GBPuF [36]	5.582 - 5.665	ns
GBPuF [41]	4.36	0.392
GBPuF [42]	5.7	0.2
Wheat Flour [5]	6.20	0.25

not convert efficiently into flour. In contrast, the pulp has a higher starch content (64-75%) and lower levels of fiber (7.5-15%) and moisture (64-71%) [9, 33, 34], making it more suitable for flour production. In addition, Bunyameen *et a*l. [34] investigated the effects of processing conditions on the properties of unripe banana (*Musa cavendish*) pulp and peel flours and found that banana peel flours exhibited higher total polyphenol content and water-holding capacity compared to pulp flours. These characteristics can affect the efficiency of flour production, as higher polyphenol content and water retention may lead to challenges in drying and milling processes, potentially resulting in lower flour yields from banana peels.

While PF started with less mass than the WF and the processing of the whole fruit resulted in higher total flour output, the proportional yield of flour from pulp alone is greater. This suggests that, at this maturity stage, the pulp is more efficient for flour production. Supporting this, Cândido *et al.* [33] recommend prioritizing the green stage of banana for manufacturing flours, as starch and resistant starch levels are highest and the pulp's lower water content will lead higher yield.

Physicochemical Characteristics

The pH and total titratable acidity (TTA) are two interrelated concepts in food analysis that deal with acidity. They are key to understanding the flour's functional properties as these parameters provide insights into chemical reactions, enzymatic activity, fermentation processes, shelf life, and sensory attributes [26, 35]. The pH is a measure of the concentration of hydrogen ions that are released in an aqueous solution while TTA measures the total acid concentration in food or the amount of organic acids present, which does not necessarily correspond to the concentration of hydrogen ions [26]. The pH is used to assess the ability of a microorganism to grow in a specific food and TTA indicates the extent of fermentation and of how organic acids impact the flavor [35].

The pH of the samples (Table 2) ranged from 4.433 to 6.077. The typical pH range of GBF is between 5.0 and 5.8 [5, 33, 36]. The pH of the CA and the control groups slightly exceeded this range but are closer to the pH of wheat flour [5]. Previous studies generally exclude untreated GBF, resulting in limited baseline data. However, this study found no significant difference in pH between the CA-treated and the untreated flour. The concentration of the citric acid solution used as pretreatment (0.5 g/L or 0.05%) may not have been high enough to cause a significant shift in pH, likely due to the buffering capacity of the banana matrix—attributed to its natural organic acids,

minerals, and proteins.

Notably, that the kalamansi-pretreated flours (KF) exhibited much lower pH values falling within the highly acidic range (pH ≤ 4.6) [37]. This can be attributed to the high acid content of kalamansi juice, which contains 5% citric acid and other organic acids (0.213% malic acid, 0.148% succinic acid, and 0.036% ascorbic acid) [18]. These acid concentrations are at least 100 times greater than the CA solution used in this study. Acidifying agents and antioxidants, such as citric acid and ascorbic acid, and other phenolic compounds [15, 18], inactivate the polyphenol oxidase (PPO), the enzyme responsible for enzymatic browning by lowering the pH and prevent melanin formation by binding to the intermediates, respectively [15].

Moreover, KWF exhibited a significantly lower pH ($p < 0.05$) than the other groups, including its counterpart, KPF. Although both were pretreated with kalamansi, KPF had a higher pH, possibly due to the presence of the peel. Banana peel is known to contain higher levels of alkaline minerals such as calcium, potassium, and magnesium compared to the pulp [10, 38]. Evanuarini and Susilo [39] observed that increasing banana peel content in flour formulations reduced the acidity and elevated pH, likely due to the neutralizing effect of these minerals. Furthermore, the natural distribution of organic acids in bananas—being more concentrated in the pulp than in the peel [40]—further supports this observation.

The TTA ranged from 0.190 – 0.307% in the control and CA groups, while the KF exhibited significantly higher values at approximately 2.1%. Except for the KG samples, these values are consistent with those reported in previous studies for GBF [41, 42] and wheat flour [5]. The elevated TTA in KF reflects the substantially higher organic acid content of kalamansi juice — exceeding that of the CA solution over 10,000%.

Higher acidity often enhances microbial stability and affects the sensory characteristics of flour-based products [35]. Acidic flours have a lower risk of deterioration by microbial spoilage, enzymes, or no enzymatic browning, but low pH values are often linked with a sour taste and dense texture, which may reduce consumer acceptability. Highly acidic flours (pH < 4) are unsuitable for bakery and pastry applications [43] as this pH levels can inhibit the growth of yeast, a critical ingredient in bread making, which thrives best between pH 6.0 and 8.0 [44]. This implies that the KF may generally not be suitable for food applications due to its highly acidic nature.

Optimizing pH and TTA is essential for achieving desirable sensory and storage characteristics in GBF. While specific TTA values for ideal flavor profiles in GBF are not extensively documented, studies indicate that a TTA range of 0.25% to 0.56% and a pH between 5.0 and 5.8 are associated with favorable sensory attributes in banana-based products [45, 46]. TTA values exceeding 0.5% may suppress the natural sweetness of banana flour, while values below 0.1% may lead to blandness. Thus, maintaining TTA and pH within these ranges can enhance both flavor and microbial stability.

Color

Color is a critical quality parameter that influences consumer preference and also reflects changes occurring during handling, processing, and storage [47]. Figure 1 presents the GBF samples of the different groups while Table 3 shows their corresponding L**a**b* values, along with comparative data from published studies [48, 49] and wheat flour [5].

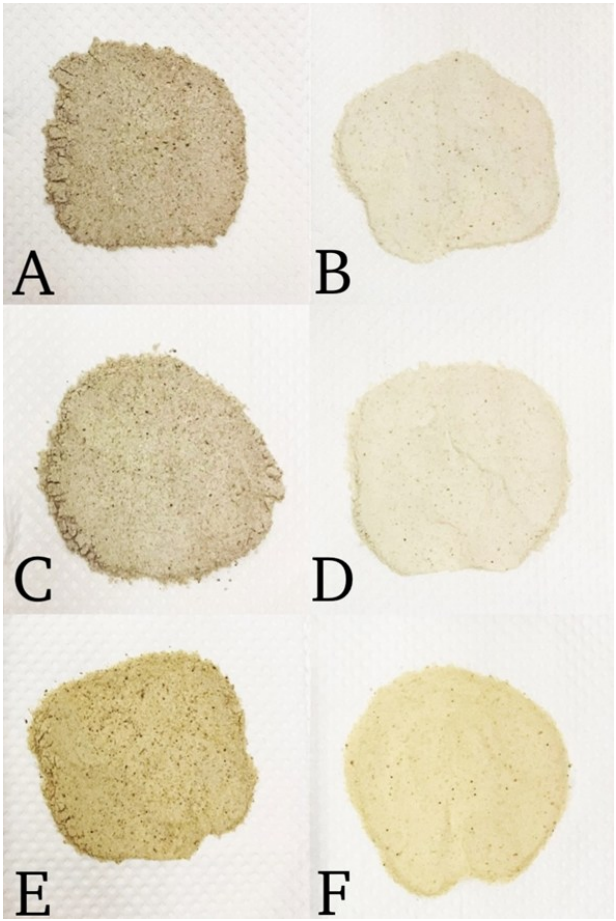

Figure 1. Photographs of the different green banana flour groups. (A) Control Whole Fruit Flour (CWF), (B) Control Pulp Flour (CPF), (C) Citric Acid Whole Fruit Flour (CAWF), (D) Citric Acid Pulp Flour (CAPF), (E) Kalamansi Whole Fruit Flour (KWF), and (F) Kalamansi Pulp Flour (KPF).

Table 3. Color characteristics of green banana flour (GBF) groups and reference values from banana varieties and wheat flour.

Flour	L*	a*	b*
Control Whole	76.67 ± 1.53[a]	0.00 ± 1.00[a]	17.0 ± 1.00[a]
Control Pulp	82.67 ± 1.15[b]	0.333 ± 1.53[a]	16.3 ± 1.53[a]
Citric Acid Whole	86.67 ± 1.53[b]	-1.00 ± 0.00[a]	20.3 ± 1.15[a]
Citric Acid Pulp	91.00 ± 1.73[b]	-1.33 ± 5.77[a]	14.0 ± 1.00[c]
Kalamansi Whole	78.33 ± 1.53[c]	0.00 ± 1.00[a]	33.0 ± 2.00[b]
Kalamansi Pulp	89.33 ± 0.58[b]	-0.667 ± 0.58[a]	29.3 ± 1.53[b]
GBPuF [48]	71.77 – 85.79	-0.09 – 0.79	13.04 – 19.12
GBPuF [49]	87.79	1.14	13.59
Wheat Flour [5]	88.50	-9.46	12.65

Note: Values are mean ± standard deviation of triplicate determinations. Different superscripts in the same column indicate significant difference ($p < 0.05$).

*GBPuF = Green Banana Pulp Flour

From visual observation, WFs generally appeared browner compared to the PF. Among all groups, CAPF exhibited the highest L* value, indicating the lightest color, followed by KPF, CAWF, CPF, KWF, and lastly, CWF. The WF were consistently darker than their pulp-only counterparts, which may be attributed to the natural pigments present in the banana peel. Since banana peels are typically darker and richer in pigments than the pulp, their inclusion during flour processing likely contributed to the darker appearance of the WF [50]. As mentioned earlier, the peel contains higher levels of phenolic compounds than the pulp [34, 51], which serve as substrates for PPO, leading to increased enzymatic browning activity in the peel [52-54]. This may explain why CWF and KWF showed significantly lower L* values compared to other groups. Notably, the KWF had a darker shade despite pretreatment. This may be attributed to the pasteurization of kalamansi juice, which could have led to the degradation of bioactive compounds such as ascorbic acid, polyphenols, flavonoids, and volatiles—many of which are heat-sensitive and best retained at temperatures between 40–70 °C [55]. The combination of peel inclusion and reduced antioxidant activity may have limited the effectiveness of kalamansi in inhibiting enzymatic browning in KWF. Interestingly, CAWF—despite also containing peel—did not differ significantly in lightness from the other groups. This suggests that citric acid pretreatment effectively inhibited enzymatic browning regardless of starting material.

All the groups exhibited similar negative a* values implying a green tonality. No significant differences were observed among them. These values are close to zero, which suggests that the flour exhibits a relatively balanced or less pronounced red-green color, leaning toward neutrality [52]. In other words, the GBFs do not exhibit a strong red or green hue and is more likely to have a color that is closer to a neutral tone.

The b* values were all positive indicating yellowness. KWF and KPF recorded the highest value, signifying yellowness, with significant differences ($p < 0.05$) from other groups. The pronounced yellowness observed in the kalamansi groups could be due to the natural yellow pigments of both kalamansi juice and banana pulp [56], which likely contributed to a yellow hue in the resulting flour. In contrast, CAPF, the lightest in color (L* = 91.00), had the lowest b*, indicating minimal yellow coloration. This suggests that citric acid does not impart a yellow hue to the flour, unlike kalamansi.

Pretreatment with organic acids plays a

significant role in preventing browning during processing, drying, and storage of light-colored fruits like bananas [15]. In this study, pretreatment of the bananas likely contributed to the relatively high L* values and near-zero a* values, indicating lighter coloration compared to GBF and wheat flours reported in previous studies. These results suggest that CA-treated flours will more likely appeal to consumers due to their lighter color and reduced browning.

Proximate Analysis

The proximate compositions of the GBF of the CA pulp and whole fruit groups are presented in Table 4. Significant differences ($p < 0.05$) were observed in moisture and ash, and no significant differences ($p > 0.05$) for carbohydrates, and crude protein.

Moisture

Moisture content is a critical parameter influencing food quality, marketability, shelf life, and susceptibility to deterioration [57]. In this study, the moisture content of CAPF was 7.20%, which is significantly lower than that of CAWF at 10.1%. Despite this difference, both values fall within the maximum allowable limit of 15% [58] and the expected range of 5–10% for dried banana flour [20]. Furthermore, their moisture contents are consistent with values reported in related studies [10, 33, 59], as shown in the table.

The higher moisture content of CAWF compared to CAPF can be attributed to the inclusion of banana peel in the whole fruit sample, as unripe banana peel generally contains and retains more moisture than the pulp. During ripening, the moisture content of the peel decreases due to water loss through transpiration and osmosis—where water transfers from the peel to the pulp [20]. This explanation is supported by data from multiple studies, which reported that the average moisture content of banana pulp was 71.07% and 60.65%, while the corresponding peel moisture contents were 87.01% and 83.78% [59]; 62.1% and 84.9% for pulp and peel, respectively [60]; and 64–73% for pulp and 86–91% for peel in another study [33]. In all cases, the peel exhibited consistently higher moisture content than the pulp at the unripe stage.

Ash

The ash content of food depends on the quality of flour and it indicates the total amount of minerals present [57]. Banana flour is a rich source of potassium (1314 – 1687 mg/100 g GBF), magnesium (110 – 140 mg/100 g GBF), calcium (126 – 390 mg/100 g GBF) and other minerals [36]. The ash content of the two GBF are 3.61 and 2.16% for the CAWF and CAPF, respectively, which are compatible with the findings from different studies. Moreover, the ash content of CAWF and CAPF in this study are significantly different. There is evidence that the presence of banana peel tends to increase the ash content.

Table 4. Proximate analysis of green banana flour (GBF) from the citric acid-treated whole fruit and pulp groups and reference values from banana varieties and wheat flour.

Flour	% Moisture	% Ash	% Carbohydrates	% Crude Protein
Citric Acid Whole	10.1 ± 0.1^{a}	3.61 ± 0.06^{a}	81.8 ± 0.6^{c}	3.97 ± 0.3^{d}
Citric Acid Pulp	7.20 ± 0.1^{b}	2.16 ± 0.01^{b}	83.6 ± 3.3^{c}	3.50 ± 0.3^{d}
GBWF [10]	7.48	3.58	80.72	6.28
GBPuF [33]	6.1	2.3	80.0 – 83.9	3.9
GBPuF [59]	6.34	2.45	87.9	3.72
GBPuF [10]	9.94	2.46	79.89	6.77
GBPeF [33]	6.5	3.0	47 - 76	2.7 – 5.2
GBPeF [59]	7.16	4.27	81.86	5.51
Wheat Flour [5]	11.64	1.86	ns	10.99

Note: Values are mean ± standard deviation of triplicate determinations. Different superscripts in the same column indicate significant difference ($p < 0.05$).

*GBWF = Green Banana Whole Fruit; GBPuF = Green Banana Pulp Flour; GBPF = Green Banana Peel Flour; ns = not specified

According to Haslinda *et al.* [10], mineral content was found to increase with addition of peel in the flour. The sodium and calcium concentrations increased by almost four times and two times upon addition of peel, respectively. Potassium content of banana flour made with whole fruit banana is 33.33% more compared to the pulp ones.

Carbohydrates

The carbohydrate content for the CAWF and CAPF are 81.8 and 83.6%, respectively, and no significant difference was observed. These results also corroborate with the findings in other studies. Carbohydrate content is high in the unripe stage since it is rich in starch and dietary fiber [61]. Starch is the main component, ranging from 73-77%, consisting of cellulose, hemicellulose, lignin, starch, and dietary fiber [61].

Protein

Protein content are 3.97 and 3.50% for CAWF and CAPF, respectively, and have no significant difference. Similar results are reported in other studies as presented in the table. Compared to other nutrients and functional components, the protein content is lower and presents low biological value [33] but affects the functional properties of flour, such as foaming capacity or the ability of the flour to foam [61].

Microbiological Quality

The results from the assessment of the microbiological quality of the GBF are presented in Table 5. Among the microbial groups analyzed, yeast were the most prevalent across all samples, followed by molds and then coliforms. The most frequent (modal) counts in flour for yeast and mold is 2.0 log CFU/g [62]. Among the GBF groups, KPF and KWF exhibited the lowest microbial counts, followed by CAPF and CAUG, while CPF and CWF recorded the highest counts. This suggests that pretreatment influences GBF microbial counts [37, 63]. Despite these variations, all microbial counts remained within the acceptable limits set by the Philippine FDA (Circular No. 2013-10), which are attainable under Good Manufacturing Practice (GMP) [31].

The pH of the GBF samples, which ranged from slightly acidic to highly acidic, may have influenced microbial counts. The lower pH values corresponded with reduced yeast, mold, and coliform counts. Among pretreatments, kalamansi extract was most effective at inhibiting yeast, mold, and coliform growth.

Microbial growth, including yeasts, molds, and bacteria, is affected by the pH of food products, as low pH levels can inhibit growth [64], making the environment for microbes unfavorable. However, very few foods have pH levels low enough to completely prevent growth of organisms like yeasts and molds, which thrive between pH 2 and 9. In contrast, bacteria typically grow best at near-neutral pH values (6-7.5) [29, 37], and coliforms grow optimally at pH 6.0-7.0, and are less likely to thrive at pH 4.0-5.0 [63].

In addition to pH, the low microbial counts may also be attributed to the low moisture content of the GBF. Flour or fruit powders with moisture below 13% are stable from microbial deterioration [65], while moisture levels below 10% are suitable for extended shelf life [66]. In contrast, mold can grow at moisture levels of 15%, and a combination of mold, yeast, and bacteria can thrive at 17% [64]. These findings support the understanding that the green banana flours, which are low-water-activity commodities, are generally regarded as

Table 5. Mean yeast, mold, and coliform counts (CFU/g) of green banana flour (GBF) groups on triplicate determinations.

Flour	Yeast (CFU/g)	Mold (CFU/g)	Coliform (CFU/g)
Control Whole	3	5	1
Control Pulp	4	4	1
Citric Acid Whole	3	$<1 \times 10^{-1}$	$<1 \times 10^{-1}$
Citric Acid Pulp	2	$<1 \times 10^{-1}$	$<1 \times 10^{-1}$
Kalamansi Whole	1	$<1 \times 10^{-1}$	$<1 \times 10^{-1}$
Kalamansi Pulp	$<1 \times 10^{-1}$	1	$<1 \times 10^{-1}$
FDA Circ. 2013-10 Acceptable Limits	10	10^2	10

microbiologically safe [62].

Conclusion

Green banana flour (GBF) from whole fruit (pulp and peel), WF, and pulp-only, PF, Saba banana pretreated with kalamansi extract and commercially available citric acid (CA) were produced. The PF had higher % flour yield which was influenced by its higher starch content, low fiber and moisture compared to the peel. The kalamansi-pretreated (KG) flours were highly acidic ($pH \leq 4.6$) which may render it unusable for baking and pastry applications. The CA-pretreated and untreated flours were only slightly acidic (~pH 6.0) and not significantly different ($p > 0.05$) from each other suggesting that the low acid concentration of CA solution does not cause a significant shift in pH. Acid pretreatment resulted in relatively lighter-colored flours and the KG flours were distinctly yellow. The inclusion of the peel significantly increased the %moisture and % ash of the CAPF than the CAWF. Higher %ash content indicates higher mineral content which may enhance the nutritional value of the flour. The low moisture of the flours indicate that they are microbiologically stable, important for an extended shelf life.

Further research is recommended to evaluate the nutritional and functional potential of GBFs pretreated with kalamansi. Investigating the effects of lowering the pasteurization temperature of kalamansi juice (below 70 °C) and using diluted juice on the resulting flour's color, pH, and TTA are suggested. In addition, analyzing the resistant starch content would be particularly relevant, as this could position GBF as a potential functional food ingredient.

Overall, this study underscores the potential of green banana flour (GBF) as a functional food ingredient. The incorporation of kalamansi extract with the right concentration, not only enhances microbial stability but also introduces additional bioactive compounds such as vitamin C and polyphenols, potentially improving the flour's overall antioxidant profile. These findings suggest that GBF has strong potential for application (bread, pasta, confectionaries, gluten-free products) in health-oriented food products, such as gluten-free baked goods, functional snacks, or dietary supplements, especially within the growing wellness market in Southeast Asia.

Notably, despite the Philippines being one of the top banana-producing countries, GBF is not yet commercially produced or widely available in the local market. This highlights a significant opportunity for local agri-food sectors to innovate by utilizing surplus or non-export quality green bananas, which are often underutilized or discarded. By demonstrating a viable, low-cost pretreatment method using locally sourced natural acidulants, this study contributes a practical, scalable approach that aligns with sustainable food production and value-addition goals.

Author's Contribution

KPA is credited for the overall management of the study, data analysis and for the writing of the final manuscript, LER for the concept of this study and the initial writing of the proposal, and BSG for the conduct of the experiments and data analysis.

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References

[1] Food and Drug Administration. (2013). Guidelines for the Assessment of Microbiological Quality of Processed Foods. 2013-010. Retrieved May 14, 2022, from https://www.fda.gov.ph/wp-content/uploads/2021/03/FDA-Circular-No.-2013-010.pdf

[2] WFP, WHO (2017) the state of food security and nutrition in the world 2017. Building Resilience for Peace and Food Security Food and Agriculture Organization, Rome (2017).

[3] Philippine Statistics Authority. (2021). *Major Fruit Crops Quarterly Bulletin, October-December 2021*. Philippine Statistics Authority. May 1, 2022, from https://psa.gov.ph/fruits-crops-bulletin/banana.

[4] Banana Link. (2021). *The Philippines*. https://www.bananalink.org.uk/partners/the-philippines/

[5] Kumar, P. S., Saravanan, A., Sheeba, N., & Uma, S. (2019). Structural, functional characterization, and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa spp.*). *LWT - Food Science and Technology, 116,* 108524. https://doi.org/10.1016/j.lwt.2019.108524

[6] Mopera, L. E. (2016). Food loss in the food value chain: the Philippine agriculture scenario. *Journal of Developments in Sustainable Agriculture*, *11*(1), 8-16. https://doi.org/10.11178/jdsa.11.8

[7] Suresh Kumar, P., Shiva, K. N., Mayil Vaganan, M., & Uma, S. (2018). Waste utilization and functional foods from

Banana. *Indian Hortic*, *63*(4), 43-6.

[8] Yani, A., Arief, R. W., & Mulyanti, N. (2013). Processing of banana flour using a local banana as raw materials in Lampung. *International Journal on Advanced Science, Engineering and Information Technology*, *3*(4), 289. Retrieved May 18, 2022, from https://core.ac.uk/download/pdf/296919071.pdf

[9] Khoozani, A.A., Birch, J, Bekhit, A.E.A. (2019). Production, application and health effects of banana pulp and peel flour in the food industry. *J Food Sci Technol*. 56(2):548-559. https://doi:10.1007/s13197-018-03562-z.

[10] Haslinda, W.H., Cheng, I.H., Chong, I.C. and Noor Aziah, A.A. (2009). Chemical composition and physicochemical properties of green banana (*Musa acuminata* x *balbisiana* Colla cv. Awak) flour. *International Journal of Food Sciences and Nutrition*, 60(4), 232-239. https://doi.org/10.1080/09637480902915525.

[11] Tan, G. H. (2015). Diabetes Care in the Philippines. Association of ultra-processed food intake with risk of inflammatory bowel disease: prospective cohort study. *Annals of Global Health*, 81(6):863-9. https://doi.org/10.1016/j.aogh.2015.10.004

[12] Narula, N., Wong, E. C., Dehghan, M., Mente, A., Rangarajan, S., Lanas, F., ... & Yusuf, S. (2021) Association of ultra-processed food intake with risk of inflammatory bowel disease: prospective cohort study, *BMJ*, 374. https://doi.org/10.1136/bmj.n1554

[13] Deng, M., Dan, L., Ye, S., Chen, X., Fu, T., Wang, X. & Chen, J. (2023). Higher dietary fibre intake is associated with lower risk of inflammatory bowel disease: prospective cohort study. Alimentary Pharmacology & Therapeutics, 58(5), 516-525. https://doi.org/10.1111/apt.17649

[14] Quevedo, R., Jaramillo, M., Díaz, O., Pedreschi, F., & Aguilera, J. M. (2009). Quantification of enzymatic browning in apple slices applying the fractal texture Fourier image. *Journal of Food Engineering,* 95(2), 285-290. https://doi.org/10.1016/j.jfoodeng.2009.05.007

[15] Moon, K. M., Kwon, E. B., Lee, B., & Kim, C. Y. (2020). Recent trends in controlling the enzymatic browning of fruit and vegetable products. *Molecules*, *25*(12), 2754. https://doi.org/10.3390/molecules25122754

[16] Arora, S., Siddiqui, S., Gehlot, R., & Ahmed, N. (2018). Effects of anti-browning pretreatments on browning of banana pulp. *Int. J. Curr. Microbiol. Appl. Sci*, *7*(04), 242-249. https://doi.org/10.20546/ijcmas.2018.704.027

[17] Show, P. L., Oladele, K. O., Siew, Q. Y., Aziz Zakry, F. A., Lan, J. C. W., & Ling, T. C. (2015). Overview of citric acid production from *Aspergillus niger*. *Frontiers in Life Science*, *8*(3), 271–283. https://doi.org/10.1080/21553769.2015.1033653

[18] Cheong, M. W., & et al. (2012). Characterisation of calamansi (*Citrus microcarpa*). Part II: volatiles, physico-chemical properties and non-volatiles in the juice. *Food Chemistry, 2012*. https://doi.org/10.1016/j.foodchem.2012.02.139

[19] Reginio Jr, F. C., Ketnawa, S., Shiina, T., & Ogawa, Y. (2018). Effect of maturity on in vitro starch digestibility of Saba banana [Musa 'saba'(Musa acuminata x Musa balbisiana)]. *Journal of Food Science and Agricultural Technology (JFAT)*, *4*, 23-28. Retrieved May 20, 2022, from http://rs.mfu.ac.th/ojs/index.php/jfat

[20] Dadzie, B. K., & Orchard, J. E. (1997). Routine post-harvest screening of banana/plantain hybrids: Criteria and methods. *INIBAP Technical Guidelines 2*. International Plant Genetic Resources Institute; International Network for the Improvement of Banana and Plantain; ACP-EU Technical Centre for Agricultural and Rural Cooperation. Retrieved February 28, 2024, from https://cgspace.cgiar.org/server/api/core/bitstreams/295b5ef7-3a0f-4f6c-bec3-661330300f40/content

[21] Marutani, M. (2018). Calamansi (×*Citrofortunella microcarpa*) for potential citrus fruit production for the island of Guam. Acta Hortic. 1205, 419-424. https://doi.org/10.17660/ActaHortic.2018.1205.49

[22] Chew, S. K., Noor, M. N., Maizura, M., Tan, T. C., & Rusul, G. (2018). Effect of pasteurization treatment and calamansi (*Fortunella japonica*) juice on the physicochemical, microbiological, and sensory characteristics of black stem sugarcane juice. *International Food Research Journal*, *25*(3), 1007-1015. Retrieved May 20, 2022, from https://docslib.org/doc/915656/effect-of-pasteurization-treatment-and-calamansi

[23] Yang, J. & College of Natural & Applied Sciences, University of Guam. (2016). *Preparing Shelf-Stable Citrus Juice and Drinks at Home*. Food Processing. Retrieved June 2, 2023, from https://www.uog.edu/_resources/files/extension/publications/Citrus_Drink.pdf

[24] Tribess, T.B., Hernández-Uribe, J.P.,

Méndez-Montealvo, M.G.C., Menezes, E.W., Bello-Perez, A., Tadini C.C. (2009).Thermal properties and resistant starch content of green banana flour (Musa cavendishii) produced at different drying conditions. *LWT Food Sci Technol* 42:1022–1025. https://doi.org/10.1016/j.lwt.2008.12.017.

[25] Pearson, D. (2003). The chemical analysis of foods. 7th ed. Harlow, UK: Longman Group Ltd.

[26] Wallace, D. (2024). Titratable Acidity (TTA) | Baking Processes | BAKERpedia. BAKERpedia. Retrieved April 29, 2023, from https://bakerpedia.com/processes/titratable-acidity-tta/

[27] Majzoobi, M., Ghiasi, F., Habibi, M., Hedayati, S., & Farahnaky, A. (2014). Influence of soy protein isolate on the quality of batter and sponge cake. *Journal of Food Processing and Preservation*, *38*(3), 1164-1170. https://doi.org/10.1111/jfpp.12076

[28] Maturin, L., & Peeler, J. T. (2001). *BAM chapter 3: Aerobic plate count*. U.S. Food and Drug Administration. Retrieved May 17, 2022, from https://www.fda.gov/food/laboratory-methods-food/bam-chapter-3-aerobic-plate-count.

[29] Tournas, V., Stack, M. E., Mislivec, P. B., Koch, H. A., & Bandler, R. (2001). BAM chapter 18: yeasts, molds and mycotoxins. *Bacteriological analytical manual*.

[30] Feng, P., Weagant, S. D., Grant, M. A., Burkhardt, W., Shellfish, M., & Water, B. (2002). BAM chapter 4: Enumeration of *Escherichia coli* and the Coliform Bacteria. *Bacteriological Analytical manual*, 13(9), 1-13.

[31] Food and Drug Administration. (2013). Guidelines for the Assessment of Microbiological Quality of Processed Foods. 2013-010.

[32] Salih, Z. A., Siddeeg, A., Taha, R. T. A., Bushra, M., Ammar, A.-F., & Ali, A. O. (2017). Physicochemical and functional properties of pulp and peel flour of dried green and ripe banana (Cavendish). *International Journal of Research in Agricultural Sciences*, *4*(6), 348–353. Retrieved from https://ijras.com/administrator/components/com_jresearch/files/ publications/IJRAS_638_Final.pdf

[33] Cândido, H. T., Marzullo, Y. O. T., & Leonel, M. (2022). Green banana flour technology: From raw material to sensory acceptance of products made with green banana flour in the Brazilian scenario. *Brazilian Archives of Biology and Technology, 66*(e23210543), 1–13. https://doi.org/10.1590/1678-4324-2023210543

[34] Bunyameen, N., Perin, A. & Donlao, N. (2020). Utilization of Banana Agricultural Waste—Effects of Processing Conditions on Properties of Unripe Banana (*Musa cavendish*) Pulp and Peel Flours. *Engineering in Agriculture, Environment and Food*, 13(4):129-138. https://doi.org/10.37221/eaef.13.4_129

[35] Tyl, C., & Sadler, G. D. (2017). pH and titratable acidity. In *Food analysis* (pp. 389–406). Springer. https://doi.org/10.1007/978-3-319-45776-5_22

[36] Savlak, N., Türker, B., & Yeşilkanat, N. (2016). Effects of particle size distribution on some physical, chemical and functional properties of unripe banana flour. *Food Chemistry, 213*, 180–186. https://doi.org/10.1016/j.foodchem.2016.06.064

[37] McGlynn, W. (2016.). The importance of food pH in commercial canning operations. *Oklahoma State University Cooperative Extension Service*. Retrieved March 18, 2022, from https://openresearch.okstate.edu

[38] Khoozani, A.A., Bekhit, A.E.A., Birch, J. (2019). Effects of different drying conditions on the starch content, thermal properties and some of the physicochemical parameters of whole green banana flour. *Int J Biol Macromol*. 130:938-946. https://doi.org/10.1016/j.ijbiomac.2019.03.010

[39] Evanuarini, H., & Susilo, A. (2020). The quality of low-fat mayonnaise using banana peel flour as stabilizer. *IOP Conference Series: Earth and Environmental Science, 478*(1), 012091. https://doi.org/10.1088/1755-1315/478/1/012091

[40] Aquino, C. F., Salomão, L. C. C., Cecon, P. R., Siqueira, D. L., & Ribeiro, S. M. R. (2017). Physical, chemical, and morphological characteristics of banana cultivars depending on maturation stages. Caatinga Magazine, 30 (1). https://doi.org/10.1590/1983-21252017v30n110rc

[41] Falade, K. O. and Oyeyinka, S. A. (2014). Color, Chemical and Functional Properties of Plantain Cultivars and Cooking Banana Flour as Affected by Drying Method and Maturity. *Journal of Food Processing and Preservation* ISSN 1745-4549. https://doi.org/10.1111/jfpp.12292

[42] Escobar, A., Rocha-Gomes, A., Reis, C. G. M. dos, Herrera, K. N. S., Guedes, T. de J., Silva, A. A. da, Lessa, M. R., Pinto, N. A. V. D. & Riul, T. R. (2020). Unripe banana flour (Musa cavendishii) promotes decrease in weight gain and elimination of fecal cholesterol in Wistar rats. *Nutrition & Food Science*, 50(1), 157-167. https://doi.org/10.1108/nfs-12-2018-033

[43] Melese, A. D., & Keyata, E. O. (2022).

Impacts of pretreatment techniques on the quality of tuber flours. *The Scientific World Journal, 2022*(1), 9323694. https://doi.org/10.1155/2022/9323694

[44] Charpentier, R. (04.05.2023). Pro Tip: Understanding the 9 factors affecting pH levels in break baking. Bakingbusinees.com. Retrieved on April 30, 2025 from https://www.bakingbusiness.com/articles/58797-pro-tip-understand-the-9-factors-affecting-ph-levels-in-bread-baking

[45] Franca, L. G. da, Holanda, N. V. de, Carneiro Aguiar, R. A., Reges, B. M., Costa, F. B. da, Souza, P. A. de, Silva, A. G. F. da, Sales, G. N. B., & Moura, C. F. H. (2020). Elaboration and characterization of green banana flours. *Research, Society and Development, 9*(7), e271973798. https://doi.org/10.33448/rsd-v9i7.3798

[46] Abioye, V. F., Ade-Omowaye, B. I. O., Babarinde, G. O., & Adesigbin, M. K. (2011). Chemical, physico-chemical and sensory properties of soy-plantain flour. *African Journal of Food Science, 5*(4), 176–180. https://doi.org/10.1016/S0924-2244(00)89023-8

[47] Akeem, S. A., Yerumoh, O., Leigh, O., Bamgbala, K., Okeke, G., Sokunbi, F., & Olayiwola, I. (2018). Physicochemical properties, colour characteristics, and sensory evaluation of full-cream cow-coconut milk yoghurts. *Croatian Journal of Food Science and Technology, 10*(2), 226–233. https://doi.org/10.17508/CJFST.2018.10.2.13

[48] Adeniji, T. A., & Tenkouano, A. (2008). Effect of processing and storage on the colour of plantain and banana products. *Agro-Science, 7*(2), 88–92. https://doi.org/10.4314/as.v7i2.1590

[49] Cheok, C. Y., Sulaiman, R., Manan, N. A., Zakora, A. J., Chin, N. L., & Hussain, N. (2018). Pasting and physical properties of green banana flours and pastas. *International Food Research Journal, 25*(6), 2585–2592

[50] Salih, Z. A., Siddeeg, A., Taha, R. T. A., Bushra, M., Ammar, A.-F., & Ali, A. O. (2017). Physicochemical and functional properties of pulp and peel flour of dried green and ripe banana (Cavendish). *International Journal of Research in Agricultural Sciences, 4*(6), 348–353. https://doi.org/10.2348-3997

[51] Vu, H. T., Scarlett, C. J., Vuong, Q. V. (2018). Phenolic compounds within banana peel and their potential uses: A review. Journal of Functional Foods, 40, 238-248. https://doi.org/10.1016/j.jff.2017.11.006

[52] Alkarkhi, A. F., bin Ramli, S., Yong, Y. S., & Easa, A. M. (2011). Comparing physico-chemical properties of banana pulp and peel flours prepared from green and ripe fruits. *Food Chemistry, 129*(2), 312–318. https://doi.org/10.1016/j.foodchem.2011.04.060

[53] Teeranud, R., Jingtair, S., Yoshinori, U., Kazuhiro, A. & Kazuo, C. (2005). Changes in concentrations of phenolic compounds and polyphenol oxidase activity in banana peel during storage. *Food Preservation Science*, Vol. 31, No. 3, 111-115. https://doi.org/10.5891/jafps.31.111

[54] Wohlt, D., Schwarz, E., Schieber, A. & Bader-Mittermaier, S. Effects of Extraction Conditions on Banana Peel Polyphenol Oxidase Activity and Insights into Activation Kinetics Using Thermal and Cold Plasma Treatment. (2021). *Foods*, 10(5), 1022. https://doi.org/10.3390/foods10051022

[55] Yang, C., Nong, Z., Lu, J., Lu, L., Xu, J., Han, Y., Li, Y. & Fujita, S. (2004). Banana Polyphenol Oxidase: Occurrence and Change of Polyphenol Oxidase Activity in Some Banana Cultivars during Fruit Development. *Food Science and Technology Research*, 10 (1), 75-78. https://doi.org/10.3136/fstr.10.75.

[56] ElGamal, R., Song, C. Rayan, A., Liu, C., Al-Rejaie, S. & ElMasry, G. Thermal Degradation of Bioactive Compounds during Drying Process of Horticultural and Agronomic Products: A Comprehensive Overview. (2023). Agronomy, 13(6):1580. https://doi.org/10.3390/agronomy13061580

[57] Pragati, S. Genitha I. and Ravish, K. (2014). Comparative study of ripe and unripe banana flour during storage. *Journal of Food Processing & Technology* 5(11). https://doi.org/10.4172/2157-7110.100038

[58] Walters, R. (2023). Wet vs dry basis moisture content relationships. *Advancing Agronomy Notes*. Retrieved February 28, 2024, from https://agrosphere-international.net/Documents/AdvanceAg/Wet-vs-Dry-Basis-Moisture-Relationships.pdf

[59] Hoffmann Sardá, F. A., de Lima, F. N. R., Lopes, N. T. T., Santos, A. D. O., Tobaruela, E. D. C., Kato, E. T. M., & Menezes, E. W. (2015). Identification of carbohydrate parameters in commercial unripe banana flour. *Food Research International, 81*, 203–209. https://doi.org/10.1016/j.foodres.2015.11.016

[60] Kachru, R. P., Kotwaliwale, N., & Balasubramanian, D. (1995). Physical and mechanical properties of green banana (*Musa paradisiaca*) fruit. *Journal of Food Engineering, 26*(3), 369–378. https://doi.org/10.1016/0260-8774(94)00054-D

[61] Hasmadi, M., Addrian, I., Adawiyah, U. B., Mansoor, A. H., & Zainol, M. K. (2021).

Evaluation of physicochemical and functional characteristics of flour from three cultivars of unripe banana (*Musa spp.*) cultivated in Sabah, Malaysia. *Food Research, 5*(4), 135–144. https://doi.org/10.26656/fr.2017.5(4).642

[62] Berghofer, L. K., A. D. Hocking, D. Miskelly, and E. Jansson. (2003) Microbiology of wheat and flour milling in Australia. *Int. J. Food Microbiol*. 85:137–149. https://doi.org/10.1016/s0168-1605(02)00507-x

[63] Yang, R. J., & Choi, E. H. (2000). Enumeration of coliform bacteria in various fermented soybean products and comparison of enumeration methods using chungkookjang. Food Science and Biotechnology, 9(2), 104-110. Retrieved April 17, 2022, from https://www.earticle.net/Article/A86045

[64] International Commission on Microbiological Specifications for Foods. (2000). Microorganisms in foods 6: Microbial ecology of food commodities. Blackie Academic and Professional, London. https://doi.org/10.1007/0-387-28801-5

[65] Potter NN, Hotchkiss (1995) Food science (5thedn). Chapman and Hall, Inc., New York.

[66] Nasir, M., Masood, S.B., Faqir, M.A., Kamran, S., Rashid, M. (2003). Effects of moisture on the shelf life of wheat flour, *International Journal of Agriculture and Biology,* (5)4, 458-459