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Characterization and process development of mango (*Mangifera indica* L.) seed flour

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ABSTRACT

This study examines the inherent properties of mango seed kernels, with the overarching goal of assessing their viability as a substitute for traditional wheat flour. Employing thin layer chromatography, we conducted an in-depth analysis to characterize the physico-chemical attributes of mango seed kernel extract. Additionally, we scrutinized the efficacy of various pretreatments aimed at mitigating discoloration. Through a meticulous examination of baked samples, we ascertained the optimal level of mango seed flour substitution by juxtaposing their quality against wheat-based counterparts. This investigation encompassed the creation and evaluation of three distinct recipes, with a focus on quality and acceptability metrics. Statistical analysis via Analysis of Variance was employed to rigorously scrutinize the samples, ultimately revealing that cupcakes exhibited the most promising potential for scaled-up production. Our findings illuminated the presence of triterpenes, fatty acids, anthraquinones, coumarins, tannins, and flavonoids within mango seed kernels, accompanied by substantial radical scavenging activity. Moreover, our study identified sodium metabisulfite as the most efficacious method for inactivating enzymes present in mango seed kernels. Based on our comprehensive investigation, we advocate for the incorporation of mango seed flour as a wheat flour substitute, ideally at a 10% substitution level, owing to its advantageous properties and widespread acceptability. This study thus paves the way for innovative applications of mango seed kernels in the realm of food science and production.

1. Introduction

Mango, often hailed as the "Monarch of Fruits," stands as a globally cherished fruit, celebrated for its delectable flavor and recognized for its salutary attributes. Within the intricate framework of mango's components, researchers have discerned a rich reservoir of phytochemicals and flavonoids inherent in its seed kernel. These bioactive compounds, predominantly esteemed for their adeptness in neutralizing free radicals, constitute the bedrock of the fruit's therapeutic potential. Its multifaceted medicinal properties encompass antitumor, antiviral, antibacterial, cardio-protective, and anti-mutagenic attributes, as evidenced by the seminal work of Đilas et al. (2009).

Comprehensive phytochemical analyses have unveiled the pervasive presence of phenolic compounds such as mangiferin, isomangiferin, homomangiferin, quercetin, kaempferol, and anthocyanins, alongside phenolic acids including gallic, pro-tocatechuic, ferulic, caffeic, coumaric, ellagic, and 4-caffeoylquinic acids. Augmenting these compounds is an array of mineral antioxidants encompassing potassium, copper, zinc, magnesium, iron, and selenium. Emanating from this constellation of constituents, mango polyphenols primarily exert their influence as antioxidants, bestowing upon them the ability to safeguard human cells from the pernicious effects of oxidative stress, which underlie lipid peroxidation, DNA damage, and the progression of chronic degenerative ailments (Sytar et al., 2018).

The burgeoning global demand for year-round mango availability has propelled the food processing industry to devise shelf-stable products with international appeal. This expansion, however, begets substantial waste, including peels, seeds, and stones. Notably, the mango seed or kernel stands out for its richness in carbohydrates, proteins, and fats,

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endowing it with the potential to serve as a valuable nutritional resource. Integration of mango kernel-derived by-products into processing protocols not only optimizes resource utilization but also augments economic returns.

Furthermore, the substitution of wheat flour with mango seed flour in baked goods has garnered attention, exemplified by the utilization of mango kernel powder (MKP) in biscuit production. This substitution has not only fortified the nutritional profile of the final product but has also enhanced its antioxidant attributes. Cumulatively, these findings underscore the promise of mango seed-derived components in diversifying and fortifying the realm of food production, bridging the realms of health, nutrition, and sustainability (Ashoush and Gadallah, 2011).

Encapsulation of compounds through the generation of double emulsions (W1/O/W2) is a promising approach for improving the bioavailability of such compounds in the small intestine, as mentioned by Zambrano-Zaragoza et al. (2018). This method allows for the controlled release and protection of the compounds, potentially increasing their biological activity. This process is called functionalization, and it involves the modification of the compound through chemical modifications or incorporation into polymer matrices, which can improve their functional properties, as reported by (Makvandi et al., 2021).

Double emulsion systems have been successfully developed for encapsulating several compounds of biological interest, such as anthocyanins, carotenoids, and quercetin, as well as plant extracts, including an olive leaf extract and aronia pomace extract, and a mango skin extract rich in polyphenols, as reported by various studies (Kanha et al., 2021; Rehman et al., 2020; Chouaibi et al., 2019; Jolayemi et al., 2021; Eisinaitė et al., 2020; Velderrain-Rodríguez et al., 2019). The protection offered by double emulsion encapsulation against adverse factors such as oxidation, pH, and hydrolysis has been reported by Simmons et al. (2004).

Although the stability and functional properties of encapsulation systems are crucial, it is also essential to study their pharmacokinetic properties, including the rate and percentage of compound release and latency time, to determine their effectiveness. The Korsmeyer-Peppas mathematical model has been used to study the release mechanics of polymeric encapsulation systems, which can be either diffusion or swelling, as reported by Paarakh et al. (2018). Furthermore, studying the dose/effect of the compound over time in zero-order kinetics, as reported by Lachi-Silva et al. (2020) and Rehman et al. (2022), can help expand the potential applications of this system. Double emulsions of hibiscus extract have been incorporated into yogurt, as reported by de Moura et al. (2019), demonstrating the versatility of this approach.

The starch in the endosperm of the mango seed kernel feeds the embryo (Fig. 1), but the endosperm can also have oils and protein. Because of this, the endosperm can be a source of food for people.

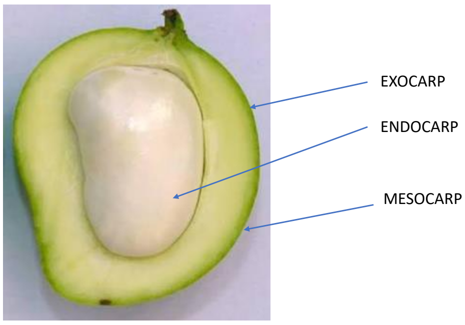

Fig. 1: Parts and cross-section of mango seed

According to Zou et al. (2021), mango seed (*Mangifera indica* L.) is a by-product that contains several compounds with potential biological benefits, including mangiferin and quercetin, which have anticancer and chemoprotective properties. Additionally, ellagic acid and gallic acid have demonstrated antioxidant and anti-inflammatory activity, respectively, as reported by Blancas-Benitez et al. (2018) and Bertha et al. (2019). Thus, it is necessary to find alternatives that enhance the availability of this compound for absorption.

The mango is an excellent food choice for anyone looking to get their fill of various polyphenolic components. Mangiferin, catechins, quercetin, kaempferol, rhamnetin, anthocyanins, gallic and ellagic acids, propyl and methyl gallate, benzoic acid, and protocatechuic acid are the primary polyphenols found in mangoes. These polyphenols are responsible for the mango's antioxidative capacity and/or its high polyphenolic content.

The levels of the various polyphenolic compounds that are found in the mango (pulp, peel, seed, bark, leaf, and flower) vary from one part to the next, with the majority of polyphenols being present in all of the mango's sections. Mango polyphenols, like other polyphenolic compounds, function primarily as antioxidants. This property enables them to protect human cells against damage caused by oxidative stress, which can lead to lipid peroxidation, DNA damage, and a wide variety of degenerative diseases. Mango polyphenols are found in mangoes. It has been discovered that the use of pure isolated compounds is less effective than the use of crude mixtures derived from a particular part of the mango, which suggests that synergism between the various polyphenols in mango is important for achieving the highest possible level of antioxidative activity (Andriambeloson et al., 1998).

According to data gathered by the Food and Agriculture Organization of the United Nations, Thailand produced 2.5 million tons of mango in 2008. This placed it in third place behind India (13.6 million tons) and China (4.2 million tons). Mangoes are often considered to be the most delicious of all fruits in Thailand. Mangoes that have reached maturity are processed into a variety of end products, including those that are frozen, canned, dehydrated, and ready-to-drink (Nagel et al., 2014).

The industrial processing of mangoes resulted in the generation of significant quantities of mango seeds and mango peels, both of which were disposed of as garbage. The processing of by-products emerged as an approach that was not only feasible and cost-effective but could even be profitable in resolving the issue of trash disposal.

Ashoush and Gadallah (2011) carried out research to determine the impact of varying amounts of mango peel powder (MPP) and mango kernel powder (MKP) on biscuits. The levels of MPP used were 5, 10, 15, and 20%, while the levels of MKP used were 20, 30, and 50%. The rheological, physical, sensory, and antioxidant qualities of biscuits were analyzed and evaluated by the researchers. Biscuits with an acceptable mango flavor might be made by integrating up to 10% MPP and using MKP in concentrations of up to 40%.

Further studies on the exploitation of starchy seeds that are abundant in the area have been carried out, and there have been several of these studies. Researchers have conducted studies on the seeds of eatable fruits such as jackfruit (Chowdhury et al., 2012). The study was conducted to investigate the functional properties of raw and blended jackfruit seed flours with the goal of providing useful information for its effective utilization along with wheat flour for various food formulations. The seeds, which are typically thrown away as waste, were found to be rich in carbohydrate and protein. Because of this, the study was undertaken to investigate the functional properties of raw and blended jackfruit seed flours. It was discovered that lye-peeled seeds had a lower nutritious content than their untreated counterparts, but they have a more favorable acceptability in terms of color and flavor. According to the findings of this study, jackfruit seed flour offers a significant amount of untapped potential for use in new formulations with wheat flour. Research was conducted to investigate the elements that had an effect on the functional behaviors of raw and blended jackfruit seed flours. Because the flours and their blends have good water and oil absorption capacities, it is possible that up to 15% blending might be proposed for use in the development of bread with equivalent sensory and chemical evaluation to the control. In addition to being utilized as a protein supplement and as a functional ingredient in food formulations, it can also be employed for the development of bakery items.

An additional investigation was conducted by Akter and Haque (2018), focusing on the utilization of Jackfruit and Tiesa seed flour as potential substitutes for wheat flour in the preparation of snack foods such as doughnuts, polvorons, and palitao. The overarching objective of this study was to assess the feasibility of partially replacing wheat flour with alternative seed flour. The study's outcomes revealed that a composite flour comprising Jackfruit and Tiesa flours could indeed be formulated for incorporation into baked goods and snack items. It is recommended that doughnuts be prepared with a composition of 50% jackfruit seed flour and 50% wheat flour, while the inclusion of tiessa seed flour should constitute 25% of the mixture. Furthermore, a palitao with a composite of up to 75% jackfruit-tiessa flour was deemed feasible.

Mango, renowned for its delectable taste and health-promoting attributes attributable to its rich phytochemical and flavonoid content with antioxidant properties, represents a popular fruit. The food processing industry generates substantial mango-related waste, including peels and seeds. However, researchers have identified the potential to convert mango seed kernels into shelf-stable products of high nutritional value, particularly flour for baked goods. The encapsulation of bioactive compounds through double emulsion systems offers a means to enhance their bioavailability, while pharmacokinetic studies contribute to the assessment of their efficacy. Mango seeds harbor several bioactive compounds, including mangiferin, quercetin, ellagic acid, and gallic acid, endowed with antioxidant, anti-inflammatory, anticancer, and chemoprotective attributes. Consequently, the exploration of alternative approaches to optimize their utilization across various applications becomes imperative.

It is noteworthy that while mango seeds, in general, are acknowledged for their robust radical scavenging activity, pertinent research pertaining to the locally available mango variety remains conspicuously absent. Despite the utilization of mango kernel in seed flour production, the ideal pretreatment method for preserving its antioxidant and phenolic constituents remains elusive. Furthermore, the optimal level of flour substitution in baked products has yet to be definitively established, thus underscoring the rationale behind the initiation of this study.

2. Materials and methods

2.1. Utensils/equipment

Measuring spoon, baking sheet, measuring cup, muffin molder, plates, macaroon molder, mixing bowl, weighing scale, knife, blender, wooden ladle, electric mixer, strainer, and oven are the utensils and equipment used for the preparation.

2.2. The raw material

Indian mangoes were bought from retailers at Solano and Bayombong public markets. Seed kernels were obtained from this variety since it is cheaper, abundant, and has bigger seeds. The fruits were processed within 24 hours after harvest.

Preparation of mango seed flour. The seeds were dehusked, and pericarp removed then immersed in 5ppm sodium metabisulfited water to prevent discoloration. These were diced and pureed, then hydrated with 5ppm sodium metabisulfited water twice its volume then allowed to settle for one hour, drained, oven-dried to three (3) constant weights, and pulverized. Fig. 2 presents the flowchart for the preparation of mango seed flour.

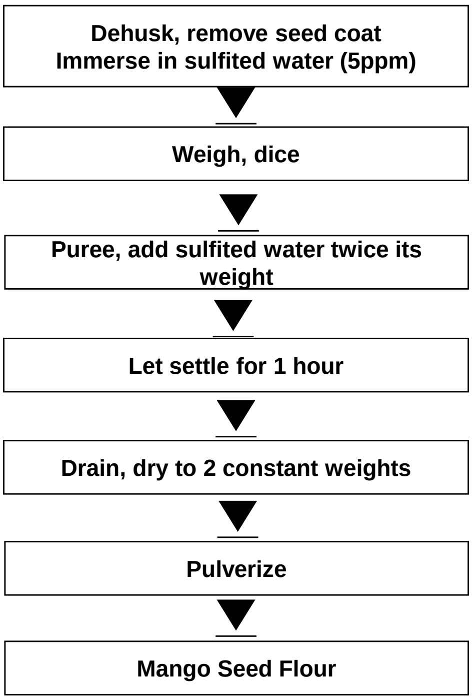

Fig. 2: Flowchart for the preparation of mango seed flour

2.3. Methods

The study made use of Experimental Design. This research is composed of four studies:

1. Determination of Physico-chemical Characteristics, and Radical-Scavenging Activity of Mango Seed/Kernel: Phytochemical Screening and Radical Scavenging Activity. Mango seed kernels were submitted to the Analytical Laboratory Service Center of SMU for chemical assay. The pure extract was used to make a stock solution diluted to 1000 ppm and incubated in the dark at 37°C for 30 minutes. Absorbance readings were monitored at 517 nm using a UV-VIS spectrophotometer. Lower absorbance of the reaction mixture was taken to indicate higher free radical scavenging activity. Absorbance readings were done in triplicate.
2. Effectivity of pretreatments in preventing discoloration: The phenolic compounds have a strong tendency to be oxidized and thus discolor in the presence of polyphenol oxidase or PPO which hastens the reaction. To prevent discoloration and preserve the radical-scavenging activity of the polyphenol the enzyme must be inactivated. Three methods were thus applied as pretreatment to determine which is the most effective in preventing discoloration. These are a) metabisulfite b) boiling water and c) steaming. The appearance/color of the treated seeds was subjected to sensory evaluation by a semi-trained laboratory panel. The enzyme inactivation process is illustrated in Fig. 3. Fig. 3 presents the process of making macaroons. Wheat flour was measured and divided into four treatments: T1-control, T2-10%, T3-15%, and T4-20%, to which desiccated coconut, melted butter, condensed milk, egg yolks, and vanilla were combined and mixed well. In a separate bowl, egg whites were beaten until soft peaks formed, to which sugar was gradually added while continuously beating. The desiccated coconut mixture was folded into the egg white mixture, and a ¼ cup of the mixture was poured into each macaroon molder. The macaroons were baked at 375°F for 25-30 minutes or until golden brown and served for evaluation.

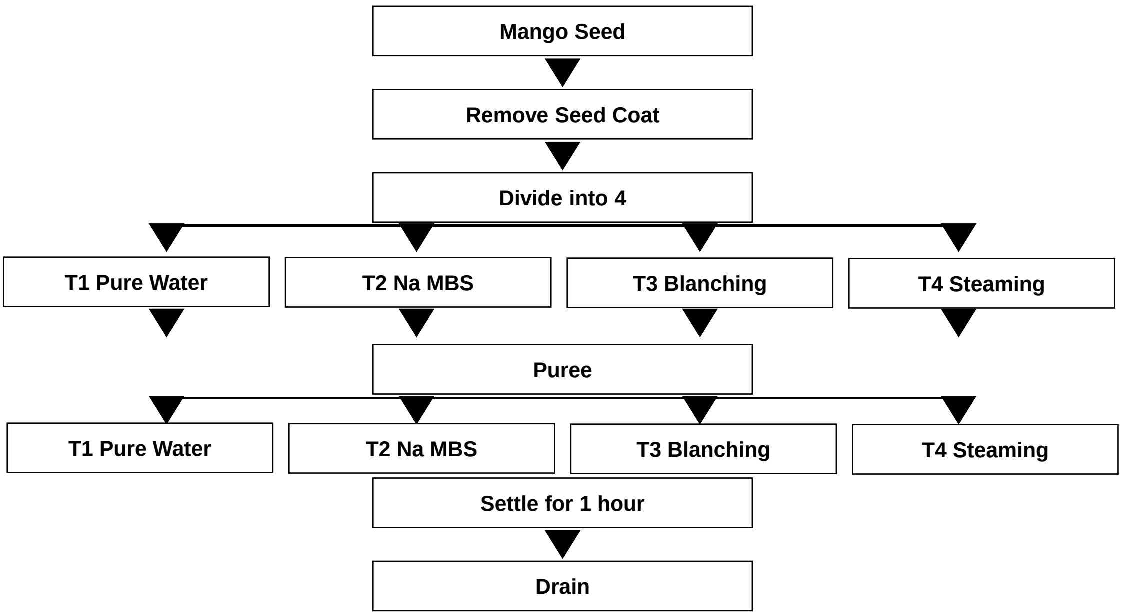

Fig. 3: Flowchart for the effectivity of antioxidants

3. Determination of the optimum level of use (10, 15, and 20%) of mango seed flour as a wheat flour substitute: This study determined the optimum level of MSF that can be used as a wheat flour substitute in macaroons. Levels of substitution serving as treatments are as Table 1. Fig. 4 presents the process of preparing macaroons. Preparation of macaroons at this stage followed the same procedure used in Study 2. However, only the recipe using 10% mango seed flour as a substitute for wheat flour was used.

Table 1: Level of treatment

Treatments	Wheat flour	Mango seed flour
1 (Control)	480g	0g
2- 10%	432g	48g
3- 15%	408g	72g
4- 20%	384g	96g

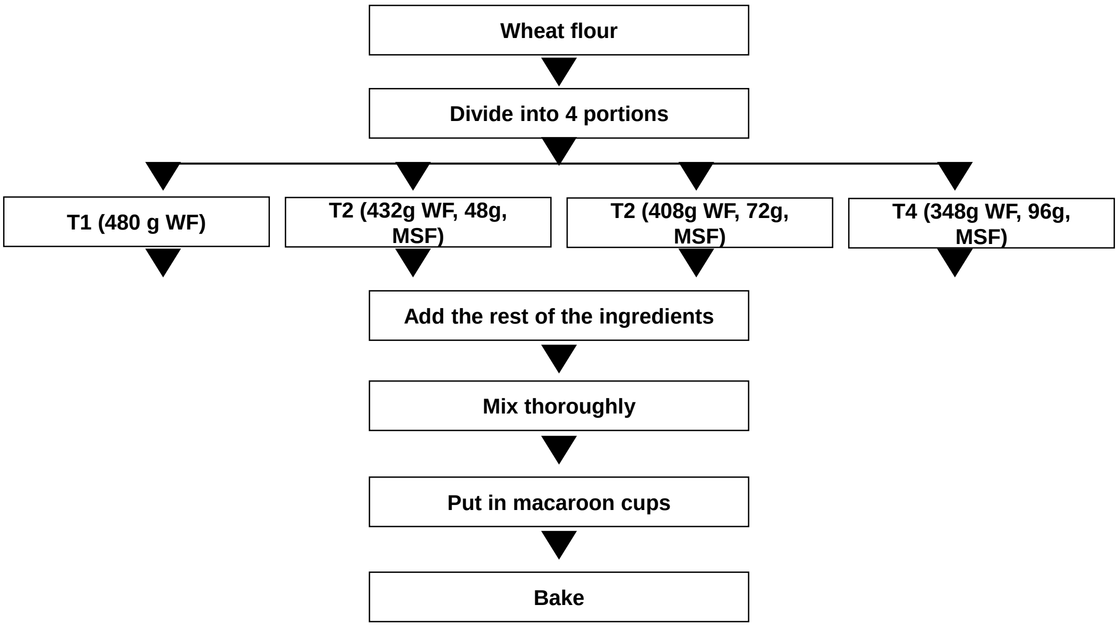

Fig. 4: Flowchart for the preparation of macaroons

4. Utilization of optimum level determined/established in study 2 in three baked recipes: macaroons, cookies, and cupcakes. Ingredients for experimental baked products are the following:

- Macaroons: 150 grams desiccated coconut, 3 pieces of eggs, ½ cup sugar, ½ teaspoon vanilla, ½ cup butter, 480 grams flour, and ½ cup condensed milk.
- Cookies: 480 grams of flour, 1 egg, ½ cup of butter, ½ teaspoon of lemon extract, 1 cup of shredded cheese, 2 ½ teaspoons of salt, and 1 cup of sugar.
- Cupcakes: 480 grams of flour, 4 medium eggs, 2 cups of butter, 2 teaspoons of baking powder, 2 cups of sugar, 2 teaspoons of vanilla, and ½ tablespoon of salt.

Fig. 5 presents the process of preparing cookies. The shortening was creamed until light and fluffy, and all other ingredients including the wheat flour and 10% mango seed flour were combined. Chopped peanuts were added and mixed well. One-fourth cup portions are dropped onto a greased baking sheet and baked in a preheated oven at 375oF for 10-20 minutes or until the color becomes golden brown.

Fig. 6 presents the process of preparing cupcakes. The butter and sugar were blended until pale and fluffy, and then the dry ingredients including wheat and 10% mango seed flour were added. The eggs were lightly beaten before the vanilla was added. This was then spooned into cupcake cups about ¾ full and then baked for about 18- 20 minutes at 375°F. The three baked products were served and evaluated by 9 semi- trained panelists in the laboratory room of the College of Human Ecology of Nueva Vizcaya State University using the 9-point Hedonic Scale to determine their quality in terms of appearance/color, texture, flavor, and taste as well general acceptability.

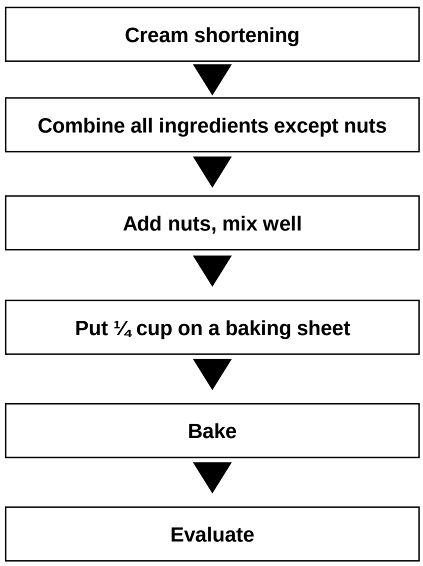

Fig. 5: Flowchart for the preparation of cookies

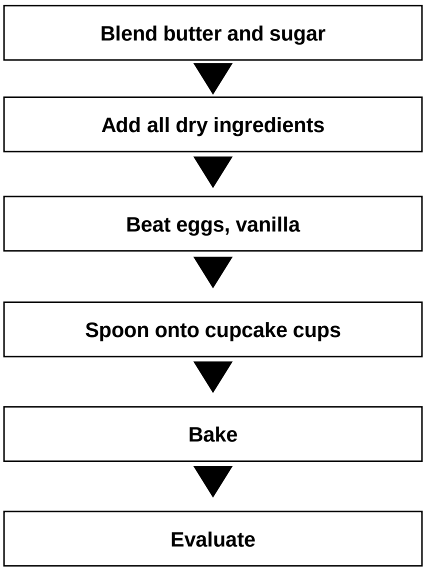

Fig. 6: Flowchart for the preparation of cupcakes

2.4. Data gathering and statistical treatment of data

The seeds underwent a series of preparatory steps, commencing with dehusking and the removal of the pericarp. Subsequently, they were immersed in twice their resultant volume to forestall discoloration. These seeds were further subjected to dicing and subsequent pureeing, followed by rehydration with an equivalent volume of water. After rehydration, the seeds were allowed to settle for a duration of one hour and then subsequently drained. The mango seed/kernel's physico-chemical characteristics and radical scavenging activity were meticulously assessed through chemical assays conducted at the Analytical Laboratory Service Center of Saint Mary's University, Bayombong Campus, Bayombong, Nueva Vizcaya. The determination of phytochemical constituents within the mango seed kernel was accomplished employing Thin Layer Chromatography (TLC), with all components being analyzed in triplicate.

To forestall discoloration in mango seeds, three distinct pretreatment methodologies were systematically applied, with the objective of ascertaining the most efficacious method for discoloration prevention. These methodologies encompassed: a) pure water treatment, b) sodium metabisulfite treatment, c) blanching, and d) steaming. The sample collection transpired within the Food and Nutrition Laboratory Room of the College of Human Ecology, Bayombong Campus, Bayombong, Nueva Vizcaya, during the month of December 2017. The assessment of the most effective antioxidant in averting mango seed kernel discoloration was conducted via a sensory evaluation, with 9 semi-trained panelists utilizing Kramer's Rank Sum Test to adjudicate the color and overall appearance of the samples.

The establishment of the optimal proportion of mango seed flour for substituting wheat flour in macaroons was executed, followed by baking and evaluation by a sensory panel comprising nine semi-trained assessors. This panel employed a preference-based ranking system for the assessed samples.

The utilization of the identified optimal level of wheat flour substitution was subsequently assessed across three distinct baked recipes through sensory evaluations. This evaluation encompassed assessments of quality attributes such as appearance, color, texture, flavor, and taste, in addition to an overall acceptability rating using the 9-point Hedonic scale. Furthermore, a preference-based ranking was conducted to identify the product with the highest market potential.

The amassed data from study 4 underwent statistical scrutiny, employing Analysis of Variance (ANOVA) within the framework of a Completely Randomized Design. To discern significant distinctions among treatments, Duncan's Multiple Range Test (DMRT) was applied. Furthermore, the results of the preference-based ranking were statistically analyzed utilizing Kramer's Rank Sum Test.

3. Results and discussions

This research endeavor was undertaken to address the following key objectives:

1. Characterization of the physico-chemical attributes inherent to mango seed kernel
2. Evaluation of the efficacy of various pretreatment methods in preventing undesirable discoloration
3. Determination of the optimal proportion of mango seed flour incorporation within a selected baked recipe
4. Application of the identified optimal proportion in the production of three distinct baked products
5. Discernment of the consumer's preference to identify the product with the highest level of acceptance

3.1. Phytochemical screening and radical scavenging activity of mango seed

The pure extract diluted to 1000ppm and incubated at 37°C for 30 minutes were subjected to Absorbance readings monitored at 517nm using a UV VIS spectrophotometer in triplicate runs. Lower absorbance of the reaction mixture was taken to indicate higher free radical scavenging activity. Results of the assays on the antioxidant or radical scavenging activity (%RSA) of mango seed are presented in Table 2. The %RSA of mango seed extract (52.38 % w/w) is not very far from that of the standard or control (68.40%w/w). According to Masibo and He (2009), the major polyphenols in mango in terms of antioxidative capacity and/or quantity are mangiferin, catechins, quercetin, kaempferol, rhamnetin, anthocyanins, gallic and ellagic acids, propyl and methyl gallate, benzoic acid, and protocatechuic acid. Mango polyphenols, like other polyphenolic compounds, work mainly as antioxidants, a property that enables them to protect human cells against damage due to oxidative stress leading to lipid peroxidation, DNA damage, and many degenerative diseases. The %RSA of mango obtained in this study is in agreement with other research which showed that mango seed indeed contains large amounts of phenolic compounds as indicated in its %RSA which approaches that of the standard.

The outcomes of the phytochemical analysis of mango seeds, conducted through the utilization of Thin Layer Chromatography (TLC), have been systematically documented in Table 3. Notably, mango seeds were found to contain a spectrum of bioactive constituents, including triterpenes, fatty acids, anthraquinones, coumarins, tannins, and flavonoids. In accordance with the insights presented by Abdullah et al. (2014), it has been postulated that extracts derived from mango seed kernels hold potential as an alternative approach to cancer treatment. However, it is imperative to underscore the necessity for further investigations pertaining to the anticancer properties of these extracts, as well as the feasibility of deploying the entire extract or its purified compounds for therapeutic purposes. Abdullah referenced previous research endeavors, which provided indications that the cytotoxic effects observed on breast cancer cells might arise from the synergistic interactions among the various compounds present within the seed kernel extract. It has been documented previously that the synergistic interplay among distinct bioactive compounds within such extracts leads to the attainment of maximal bioactivity, underscoring the complexity and potential of these natural constituents in the context of their biomedical applications (Masibo and He, 2009).

Table 2: Antioxidant/radical scavenging activity of mango seed flour

Sample	Mean absorbance	% Scavenging activity (RSA)
Mango seed	0.110	52.38%
Control	0.073	68.40%

Table 3: Phytochemicals in mango seed kernel determined by thin layer chromatography (TLC)

Sample	Phytochemical content/components
Mango seed	Triterpenes, fatty acids, anthraquinones, coumarines, tannins, and flavonoids

3.2. Effectiveness of pretreatments in preventing discoloration

The color/appearance of mango seed flour produced from pretreated seeds was ranked for preference by a laboratory panel. The data obtained are presented in Table 4.

Table 4: Ranking for preference on the color of mango seed flour

Kramer's range	Antioxidants and heat treatments	Total	Rank
	T1 – Pure water	36	4th
13-20	T2 - sulfite(250ppm)	9	1st
15-30	T3- Blanching in water (90 deg C)	20	2nd
	T4 – Steaming (90 deg C)	25	3rd

According to the Kramer's Range analysis, it is observed that the cumulative rank totals falling beyond the upper critical values within the range of 13 to 20 exhibit a significant difference, validated at a level of significance of 0.01. Specifically, the color attributes of the flour derived from the pretreated mango seeds with sodium metabisulfite, yielding a total rank of 9, significantly surpass those of all other pretreatment methods. These findings conclusively suggest that the most efficacious approach for enzyme inactivation within the mango seed kernel involves the utilization of sodium metabisulfite. The resultant mango seed flour originating from sulfite-treated samples notably demonstrates superior color and appearance when compared to flour derived from other pretreated counterparts.

It is imperative to recognize that sulfite serves as an antioxidant by selectively interacting with oxygen, thereby eliminating it as a reactant within the enzymatic browning reaction. This antioxidative action serves to uphold the integrity of phenolic compounds present in mango seed flour, effectively shielding them from oxidation. Consequently, this preservation of phenolic compounds ensures the sustenance of their radical scavenging activity within the body upon ingestion. It is worth noting that an equally vital objective in employing antioxidants within this study is the attainment of well-pigmented flour, which is crucial for its utility in various baked snack products.

3.3. Optimum level of mango seed flour as a wheat flour substitute

Macaroons were chosen as the recipe for determining the optimum level of mango seed flour that can be used as a wheat flour substitute. The evaluation panel ranked the samples according to their preference. The results of the evaluation are presented in Table 5.

Table 5: Ranking preference on the optimum level of flour substitution

Kramer's range	Mango seed flour (% flour substitution)	Total	Rank
	0%	22	2nd
15-30	10%	17	1st
17-28	15%	24	3rd
	20%	26	4th

In accordance with Kramer's Range analysis, it becomes evident that cumulative rank totals that fall outside the lower critical range, ranging from 17 to 28, exhibit a statistically significant divergence at the 0.05 level of significance. Specifically, the sample infused with 10% mango seed flour yielded a rank total of 17, which stands as significantly distinct from all other product samples. These discernments underscore that the optimal degree of substitution, amounting to 10%, garners the most favorable sensory attributes. It is noteworthy that elevating the substitution level beyond this threshold leads to the production of items characterized by comparatively diminished sensory quality.

3.4. Utilization of the optimum level of mango seed flour in three baked products

The optimal proportion of mango seed flour, as established in Study 3, and found to be 10%, was subsequently employed in the formulation of three distinct baked recipes, namely, macaroons, cookies, and cupcakes. The primary aim was to ascertain which among these three recipes exhibits the greatest potential for large-scale production. To evaluate these products comprehensively, a sensory assessment was conducted, encompassing attributes such as color/appearance, flavor, texture, and overall acceptability, utilizing the 9-point Hedonic scale. The ensuing results of this comprehensive evaluation are presented herewith.

Statistical analysis in Tables 6, 7, and 8 shows that there were significant differences among treatments. The mean ratings on the color and appearance of the three baked products with 10 % mango seed flour showed that both the macaroons and cupcakes with the same mean rating of 6.6 were significantly more desirable than the cookies. The cookies with a mean rating of 5.5 have a descriptive equivalent of "slightly desirable."

Table 9 shows that in terms of flavor and taste, the three baked products did not differ from each other. Their mean ratings ranged from 6.8 to 7.1 with a descriptive equivalent of "moderately desirable" on the 9-point Hedonic scale. This result implies that the addition of 10% mango flour in the three baked products exerted no negative effect on the flavor and taste of the products. These results are in agreement with the study of Ashoush and Gadallah (2011) who used mango kernel powder on biscuits and came out with similar findings.

Table 6: Mean ratings on the color and appearance of the samples with 10% mango seed flour

Treatment	Mean	Description
Macaroons	6.6	Moderately desirable
Cookies	5.5	Slightly desirable
Cupcakes	6.6	Moderately desirable

Table 7: Analysis of variance for color and appearance

Sources of variation	Degree of freedom	Sum of squares	Mean squares	F-value	
				Computed	Tabular
Treatments	2	8.96	4.48	4.77	2.96 (.05)
Panel	8	9.85	1.23		
Error	16	15.04	0.94		
Total	26	33.85			

Table 8: Mean ratings on the flavor and taste of the three baked products with 10% mango seed flour

Treatment	Mean	Description
Macaroons	7.1	Moderately desirable
Cookies	6.8	Moderately desirable
Cupcakes	7.0	Moderately desirable

Table 9: Analysis of variance for flavor and taste

Sources of variation	Degree of freedom	Sum of squares	Mean squares	F-value	
				Computed	Tabular
Treatments	2	1.33	0.67	0.42 ns	3.63 (0.05)
Panel	8	2	0.25		
Error	16	2.67	0.33		
Total	26	6			

Statistical analysis in Tables 10 and 11 shows that the mean ratings on texture were not significantly different from each other. This result shows that the addition of 10% mango seed flour in the three baked products did not exert any negative effect on the texture of the products which were all rated as "Moderately Desirable" by the panel of evaluators who rated the products using the 9-point Hedonic scale. This result is not surprising because the baked products which were chosen in the study require less gluten to produce a better-textured, less sticky/adhesive product.

Table 10: Mean rating on the texture of the three baked products with 10% mango seed flour

Treatment	Mean	Description
Macaroons	7.1	Moderately desirable
Cookies	7.0	Moderately desirable
Cupcakes	7.1	Moderately desirable

Table 11: Analysis of variance for texture

Sources of variation	Degree of freedom	Sum of squares	Mean squares	F-value	
				Computed	Tabular
Treatments	2	0.78	0.39	0.25 ns	3.63 (0.05)
Panel	8	1.41	0.18		
Error	16	1.81	0.11		
Total	26	4			

In terms of general acceptability (Tables 12 and 13), there were no significant differences among the three baked products. The mean ratings of 7.1 to 7.2, had a descriptive equivalent of "moderately desirable" in the Hedonic scale. These results show that the 10% mango seed flour when used as a substitute in baked products does not cause any significant negative effect on the general acceptability of the three products. The slight differences observed in the color and appearance of the samples appear to have no significant impact on the overall acceptability of the products.

Table 12: Mean ratings on the general acceptability of the three baked products with 10% mango seed flour

Treatment	Mean	Description
Macaroons	7.2	Moderately desirable
Cookies	7.1	Moderately desirable
Cupcakes	7.1	Moderately desirable

Table 13: Analysis of variance for general acceptability

Sources of variation	Degree of freedom	Sum of squares	Mean squares	F-value	
				Computed	Tabular
Treatments	2	0.07	0.04	0.04 ns	3.63 (0.05)
Panel	8	1.18	0.15		
Error	16	0.6	0.04		
Total	26	1.85			

In accordance with Kramer's Range analysis, as depicted in Table 14, it becomes evident that cumulative rank totals exceeding the upper critical values within the range of 13 to 24 exhibit a statistically significant distinction at a significance level of 0.01. Notably, the baked products featuring 10% MSF, which achieved a total rank of 12, are markedly preferred in comparison to the cookies, which garnered an average rating of 27. These findings unequivocally signify that, among the three baked recipes under scrutiny, cupcakes emerge as the most promising candidate for scaling up production to meet larger demands.

Table 14: Ranking for the most preferred sample

Kramer's range	Treatments	Rank total	Rank
13-24 14-22	Macaroons	15	2nd
	Cookies	27	3rd
	Cupcakes	12	1st

4. Conclusion and recommendations

The primary objectives of this study encompassed the determination of the physico-chemical attributes inherent to mango seed kernels, the assessment of the efficacy of various pretreatment methods in preventing discoloration, the identification of the optimal degree of mango seed flour substitution, and the evaluation and comparison of the quality and acceptability of three distinct baked recipes, namely macaroons, cupcakes, and cookies. Mango seeds were revealed to contain a spectrum of bioactive compounds, including triterpenes, fatty acids, anthraquinones, coumarins, tannins, and flavonoids, endowing them with a relatively robust radical scavenging activity in comparison to the control or standard.

The most effective means of enzyme inactivation within the mango seed kernel was discerned to be the utilization of sulfite, as evidenced by superior color attributes in the sulfite-treated samples when compared to their untreated counterparts.

Regarding the utilization of mango seed flour as a substitute for wheat flour across three varying levels (10%, 15%, and 20%) within the selected baked product, macaroons, the 10% substitution level yielded superior results compared to the sample with 20% MSF.

Among the three baked recipes incorporating the predetermined optimal flour substitution level, no statistically significant distinctions were observed in terms of quality, with the exception being color. In the ranking for preference, both macaroons and cupcakes exhibited superior ratings in comparison to cookies. This implies that, of the three baked recipes, macaroons and cupcakes hold greater potential for scalability in production than cookies.

The analysis revealed that mango seed kernels are enriched with a repertoire of biochemical compounds, commonly referred to as phytochemicals, and exhibit a relatively robust radical scavenging activity. These attributes substantiate their potential therapeutic and health benefits. Furthermore, the utilization of sulfite was identified as the most effective method for inactivating polyphenol oxidase, an enzyme catalyzing the oxidation of phenolic compounds and, consequently, contributing to the discoloration of the seed kernel. In the context of substituting wheat flour, the optimal proportion identified across all three baked products was determined to be 10%. Both macaroons and cupcakes displayed comparable superiority over cookies, indicating their considerable potential for scalability in the production process.

It is advisable for individuals, particularly mothers within household settings, to consider incorporating mango seed flour into their dietary practices. This recommendation stems from the recognition of the therapeutic potential associated with mango seed flour consumption. Health professionals can also derive substantial benefits from this study by endorsing the utilization of mango seed flour in various applications, particularly targeting individuals afflicted by lifestyle-related ailments or those vulnerable to elevated levels of free radicals.

The established optimal proportion of mango seed flour as a substitution for wheat flour may be explored in diverse baked recipes and food formulations, extending its versatility in culinary contexts. Given that macaroons and cupcakes have exhibited superior attributes in terms of color, taste, texture, and overall acceptability, a noteworthy proposition is the initiation of scaled-up production endeavors for macaroons and cupcakes, particularly for entrepreneurial purposes.

Furthermore, the scientific and healthcare communities may contemplate the incorporation of mango seed components in clinical trials, with a specific focus on patients grappling with cancer. Such trials can provide valuable insights into the efficacy of mango seed constituents in ameliorating the symptoms associated with this ailment.

Compliance with ethical standards

Ethical consideration

Ethical standards were adhered to in every step of the procedure when analyzing data sets derived from a particular source. The references appropriately credit the many data sources and list them for the reader's convenience.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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