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From waste to taste: Nutritional and sensory insights into mango peel-infused cake

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Abstract

This research investigated the nutritional qualities of cakes supplemented with mango peel powder. The experiment included analyzing the proximate composition, which included mineral content level evaluation for phosphorus measurement using a spectrophotometer; sodium and potassium determination via flame photometry; and iron, zinc, calcium and magnesium levels quantification using atomic absorption spectrophotometry in accordance with A.O.A.C (1990) guidelines. It also measured radical scavenging activity assays parameterized under DPPH radicals and assessed antioxidant potential through total polyphenolic content assessment using the Folin-Ciocalteu method, which revealed that cake samples mixed with varying amounts of mango peel had higher values than wheat flour alone. A serial dilution approach was used to count fungus in order to detect the presence of microorganisms, while a water activity meter was used to evaluate the moisture levels of the cake samples. The texture analyzer determined hardness, whereas the colorimeter determined color values (L*, a*, b*). We used a 9-point hedonic scale to measure consumer satisfaction with each cake sample. To quantitatively analyze findings across different mango peel powder incorporation levels in cakes vs control cake samples, ANOVA was used, followed by an LSD post-test. Incorporating 10%, 15% and 20% mango peel powder resulted in considerably greater ash, crude fat and crude fiber levels ($p<0.05$), but reduced protein and carbohydrate levels ($p>0.05$). Cakes with additions had higher sodium, potassium, calcium, magnesium, iron, zinc ($p<0.05$), total phenol and antioxidant qualities. Cakes having 15% or 20% mango peel powder earned approval ratings of ≥6. Thus, the study showed that including simple cakes recipe using mango peels had favorable impacts on nutritional profiles, sensory appeal and suppressing microbial growth, minimizing waste via our results valuable towards creation of healthy bake products.

Keywords: Mango Peel Powder; Nutritional Enhancement; Antioxidant Properties; Sensory Evaluation; Sustainable Food Innovation and Microbial Growth Suppression

1. Introduction

Mango *Mangifera indica* is the second major fruit of Pakistan after citrus in terms of area and production. The major varieties of mango in Pakistan are Sindhri, Chaunsa, Langra, Began Pali and Anwar Retaul, but Chaunsa dominates and are considered best for industry use [1]. Mango, one of the most popular tropical fruits, are extensively consumed in both fresh and processed versions. Storing them at room temperature or greater chilled temperatures, on the other hand it might result in postharvest losses due to moisture loss or microbial activity. The ripening process is also accelerated by postharvest hot water quarantine treatment [2]. Approximately 35–60% of the waste generated from the commercial processing of mangoes into juice, nectar, pulp, puree, fruit leather and jam consist of peel, kernel and cull fruit [3]. Produced byproducts are frequently thrown away, which may be quite detrimental to producers. Obtaining polyphenols from excess fruits and vegetables may help manufacturers deal with such wastes at a lower cost [4].

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Mangoes are particularly rich in bioactive substances like polyphenols, vitamin C, carotenoids, anthocyanins and flavonoids that have health benefits. Furthermore, mango peel has been touted as an excellent source of dietary fiber (DF), which plays a crucial role in several bodily processes such as preventing diabetes, cancer, hypertension, liver cirrhosis and constipation. Due to the importance of DF, novel sources from various raw materials are actively being researched for use within food production. These days, cereal-based DF products have become the most commonly consumed. The source and methods used to process the grains have a significant impact on the quantity of DF present in products derived from grains. Fruit DF offers higher levels of total dietary fiber (TDF) and soluble dietary fiber (SDF), as well as a more balanced composition and strong functional qualities, including high water absorption capacity (WAC) and high oil absorption capacity (OAC) [5].

Studies have shown the beneficial health potential of mango peel powder incorporation. Mango peel is rich in dietary fibers and antioxidants which are impactful in controlling blood sugar levels and supports digestive health. MMP also may have anti-inflammatory properties. MPP also adds a unique flavor and natural color, and its antimicrobial properties could make it last longer on the shelf life. By reducing food waste, this addition promotes sustainability while also catering to health-conscious customers. In order to get the most out of mango peel powder's health benefits and functionality, ongoing research is looking into the balance amounts and effects it can have on various bakery products.

2. Material and methods

2.1. Procurement of ingredients

The natural mango product, wheat flour (WF) and any remaining ingredients for basic cakes were purchased from a nearby market (Peshawar, KPK, Pakistan). The synthetics and reagents used in the tests were of scientific quality.

2.2. Preparation of mango peel powder

Clean faucet water was used to wash the gathered mango peels. The peels were placed in airtight plastic bags and stored at room temperature after being grinded (Universal mill Power grinder US-196) and dried in the shade.

2.3. Preparation of cake samples

The stored mango peel powder was used to make plain cakes at concentrations of 10%, 15% and 20%. The cake with no incorporation of mango peel was used as a control. Table I includes a description of the recipes. The eggs and brown sugar were whipped into a cream with a mixer (Super Star HM-220) for 4 minutes until a semi-firm foam formed. Emulsifiers were then added and blended for an additional 2 minutes. The sugar-egg foam was then blended with the flour mixture and baking powder for one minute. The cake batter was then placed in a dish and cooked for 15 minutes in a cooking range (WC-666) at 180°C. Following baking, the simple cakes were allowed to cool at 28 ± 2 °C. The cake experiments were labelled, packed in plastic zipper bags and wrapped in polyethylene grip wrap. After that, the bags were stored at 4ºC for analysis.

Table 1 Ingredients formulation of the control and incorporated cakes

Ingredients	Control	10% incorporated	15% incorporated	20% incorporated
Wheat Flour (g)	150	135	127.5	120
Mango Peel Powder (g)	0	15	22.5	30
Eggs	2	2	2	2
Sugar (g)	50	50	50	50
Oil (g)	35	35	35	35
Baking Powder (g)	4.5	4.5	4.5	4.5
Baking soda (g)	1.7	1.7	1.7	1.7

2.4. Proximate composition.

The AOAC (2000) [6] procedures were used to conduct analyses of the mango peel powder incorporated cakes for moisture (method 934.01), crude protein (method 960.52), crude fat (method 963.15), crude fibre (method 962.09) and ash (method 923.03).

2.5. Mineral analysis

According to [7], a spectrophotometer was used to evaluate phosphorus, while a flame photometer was used to evaluate sodium and potassium. Iron, zinc, calcium and magnesium were analysed using an atomic absorption spectrophotometer in line with the A.O.A.C. (1990) [8] method.

2.6. Determination of total phenols and antioxidant activity

Sample extraction for total phenolic and antioxidant activity.
One gram of ground cake was carefully measured and placed into falcon tubes in order to set up the samples. Each sample received 10ml of 99% Methanolic HCl (consisting of 99ml Methanol and 1ml HCl) as support for the extraction cycle. To ensure thorough and consistent blending, the samples in the falcon tubes were gently mixed by agitation and the cylinders were arranged uniformly in a test tube rack. The sample solution blend-containing falcon tubes were then submerged in a water shaker bath. For an hour, the samples were incubated at a constant temperature of 25°C while being vigorously extracted with 100 agitations per minute. Following incubation, the falcon tubes were transferred to a centrifuge and centrifuged for 20 minutes at 3000 revolutions per minute (rpm). This process separated the constituent parts of the sample extract. After centrifugation, the top part of the sample extract, or supernatant, was carefully removed from each Falcon tube using a sterile micropipette. In order to maintain test reliability, the separated supernatants were subsequently transferred to glass vials that had been previously labeled, sanitized and securely wrapped with aluminum foil. The final stage was storing the vials in a cold environment with a temperature of -20°C to ensure that the samples would be preserved for the subsequent analysis.

2.7. Total phenol determination

The Folin-Ciocalteu method, as reported by [9], was employed to determine total phenolic content. 1ml of FC reagent was mixed with 10ml of distilled water to make the 10 folds FC reagent solution. During the experiment, a 0.2ml sample removal was placed in a clean glass test tube. Then, using a micropipette, 0.8ml of the FC reagent solution was transferred to a comparable test tube containing the 0.2ml sample separate. For 3 minutes, the test tubes were placed in the dark. After the three minutes, 2 milliliters of a 15% sodium carbonate solution were added to each test tube and 2 more milliliters of distilled water were added to make the total volume 5 milliliters. After being protected from light, the solution was let to stand at room temperature for one hour. Following an hour of incubation, the combination's absorbance was measured four times at 760 nm using a spectrophotometer (Genesys 10 UV). As a clear for alignment, pure water was used and Gallic acid in concentrations ranging from 0 to 0.5mg/ml was used to establish a standard reference. The results were reported in milligrams of Gallic acid identical per sample.

2.8. Determination of antioxidant activity through DPPH Assay

The antioxidant activity of cake samples was evaluated using the DPPH assay, following [10] technique. 3.943mg of DPPH powder was weighed and placed in a clean flask, wrapped with aluminum foil for protection. From then on, 100 milliliters of methanol were added and mixed, resulting in a dark purple solution. Little glass test tubes were cleaned and then filled with 2.85 milliliters of the pre-made DPPH solution. Subsequently, 150ul of sample extracts were added and the initial absorbance was recorded in triplicate using a spectrophotometer at 517nm. The samples were then placed in a dark environment and the final absorbance of the samples containing the DPPH solution was recorded after 30 minutes. Control samples were also made in place of the sample extract by adding 150ul of methanol to 2.85ml of the DPPH solution. Trolox was used as a standard in concentrations ranging from 0 to 1mM and was decomposed in methanol. The results of the antioxidant activity, which was still undetermined by the DPPH measurement, were reported as percent inhibition (%I) using a specific equation.

$$\% I = [(Ac- As /As)] \times 100$$

3. Microbiological Analyses

3.1. Total fungi count

Following the serial dilution method, enumerations of fungi, molds and yeasts within the produced cake samples were conducted at the intervals of 7, 14- and 21-days during storage at room temperature. A series of dilution tubes containing a sterile diluent (such as sterile saline solution) were prepared and labelled accordingly. A representative cake sample weighing 1g was accurately weighed and placed in the first dilution tube, which marked the starting point for the dilution sequence. The cake sample was thoroughly mixed with the diluent to ensure even distribution. From the first dilution tube, a 1ml portion of the mixture was transferred to the second dilution tube and mixed. This transfer

and mixing process was repeated for each subsequent dilution tube in the series. With each transfer, the dilution factor increased, resulting in progressively diluted samples. Following the dilution process, a defined volume of 1ml from the appropriate dilution tube was aseptically spread onto the surfaces of agar plates suitable for promoting fungal growth. The sample was evenly distributed on the agar surface using a sterile spreader. This plating procedure was repeated for all dilutions and replicate plates were prepared as necessary. The agar plates were incubated at the optimal temperature for fungal growth, typically 25-30°C, for 7, 14 and 21 days. Visual inspections were conducted at each incubation time and significant colonies were counted. Molds and yeasts were identified based on their settlement appearance and properties. The colony counts for each type of fungus were meticulously recorded. For each type of fungus and time point, the colony-forming units per gram (cfu/g) of the cake sample were calculated, considering the appropriate dilution factors introduced by the dilution series and the volume of the sample plated.

3.2. Water activity

To measure water activity, 1-gram samples of the designated material were collected and securely sealed to prevent any changes in moisture content. These samples were stored in a controlled environment until the analysis. A measurement chamber designed for precise water activity measurements was set up. It was essential for this chamber to maintain a consistent and stable temperature, as this greatly affected the accuracy of the measurements. The sample was placed within the measurement chamber in a way that prevented direct exposure to elements like heaters or coolers, ensuring the reliability of the readings. The equilibration procedure was initiated. The sample entered a chamber, releasing humidity due to differences in moisture content and relative humidity. Over time, the humidity stabilized as the sample's moisture content adapted to the chamber's conditions and an electrical sensor was used to detect relative humidity. This sensor measured moisture levels in the air and converted them into a corresponding electrical signal. The detecting element was a critical component of the measurement process. The device could be a conductive polymer that adjusts its electrical conductivity based on humidity levels, or an electrical component like a saturated lithium chloride solution, which provides a stable relative humidity environment for accurate calibration and measurements.

3.3. Physical Analysis

3.3.1. Hardness

Cake samples were cut into 1-inch-thick slices using a clean, sharp knife. For the analysis, a texture analyzer (Model TX.XT plus, Stable Microsystems) was utilized. This instrument is specifically designed to evaluate various textural attributes of food samples. Prior to beginning the examination, the texture analyzer was adjusted adhering to the producer's guidelines. A 45N load cell was connected to the texture analyzer to gauge the force applied to the sample during pressure. A cylindrical probe with a 25.4 mm width was connected to the texture analyzer to interact with the cake sample during testing. The software associated with the texture analyzer was used to control the testing process and obtain results. Hardness values were configured following the AACC 74-09 methods and the approach outlined by [11]. Each cake slice was placed on a stable, flat surface, ensuring consistent centering and alignment for every test. The texture analyser's probe was positioned directly above the center of the cake slice. The test was initiated by activating the texture analyser software. The texture analyser gradually lowered the probe toward the cake slice at a controlled speed of 100 mm/minute. The probe compressed the cake slice to a depth of 5 mm. During the compression, the texture analyser's load cell measured the force exerted by the cake slice in response to the probe's movement.

3.3.2. Colour measurement

A colorimeter, a specialized device designed for measuring various colour attributes of samples, was used. The colorimeter was calibrated before measurements. The calibration technique comprised positioning a gauge on a dark surface and then correcting with a white surface to get precise readings. To ensure accuracy, the colorimeter's calibration was meticulously performed in accordance with the manufacturer's standards. A prepared cake slice was placed on a stable, level surface to measure the colour of the cake. The colorimeter's measurement probe or aperture was positioned directly on the cake's surface. The colour measurement was activated by engaging the colorimeter's measurement mode. This action prompted the colorimeter to automatically assess and record the colour attributes L*, a* and b* according to the CIELAB colour space. Lightness/darkness (L*), green/red (+/ -) chromaticity (a*) and blue/yellow (+/ -) chromaticity (b*) are represented by these parameters. At least three unique readings were collected from different points on the cake slice surface to ensure an accurate portrayal of the cake's hue. After obtaining the required number of readings, the colorimeter underwent recalibration to maintain measurement precision. Recalibration began by establishing a baseline using a black surface and then calibrating with a white surface.

3.3.3. Sensory Evaluation

Sensory evaluation of cake samples was conducted in the Department of Human Nutrition, involving both faculty members and students. To carry out the evaluation, we organized ten groups, each comprising five individuals, resulting in a total of fifty consumers participating in the assessment. Every consumer received a piece of freshly baked cake that was randomly coded to maintain anonymity during the evaluation. There were ten groups in all; nine of them were randomly assigned to different treatment and one was used as a control. Customers were asked to rate the cake on a 9-point hedonic scale that included appearance, flavour, texture and general acceptance. Nine was the greatest score on this scale, meaning "liking very much," and one was the lowest, meaning "disliking very much." The average customer scores were then used to compute the overall acceptability of the cake, considering all areas evaluated. The average customer scores were then used to compute the overall acceptability of the cake, considering all areas evaluated.

3.4. Statistical analysis

The acquired data were analysed with the Statistical Packages for Sociology (SPSS 21). The mean values for each element were calculated, along with their standard deviations (SD). A one-way analysis of variance (ANOVA) was used to determine the effect of combining mango peel powder on the outcomes. Following the ANOVA, a post-test was performed for each association using the least significant difference (LSD) approach. All analyses were conducted with a significance threshold of 0.05.

4. Results and discussion

4.1. Proximate composition

The cakes with combination showed moisture content levels going from 3.01% to 3.82%, while the control cake's moisture content was estimated at 4.25%. That's what the outcomes showed, when contrasted with the control cake, the moisture content of each cake including consolidation was altogether lower ($p<0.05$). Cakes with mango peel powder showed a decrease in moisture content as the level of consideration increased. Cakes with 10% mango peel powder had higher moisture content than 15% and 20% cakes, revealing significant differences ($p<0.05$). The expansion of powdered mango peel brought about a huge decrease in moisture content. The powdered mango peel's capacity to assimilate moisture makes sense of this drop-in moisture content. The discoveries of [12], who showed that using mango and banana peel in cake planning diminishes moisture content, certified these outcomes.

4.2. Ash Content

According to the results, the integrated cakes' ash content increased from 3.00% to 4.33%, while the control cake's ash level remained at 2.16%. The results showed that all of the combined cakes contained significantly more ash than the control cake ($p<0.05$). An increasing pattern in the ash pleased with the fusion of mango peel powder was seen during investigation. There were no truly remarkable differences between the 15% and 20% cakes ($p>0.05$), although the ash content of the 20% integrated cake was significantly greater than that of the 15% and 10% cakes ($p<0.05$). The ash concentration increased significantly as the amount of powdered mango peel increased. This suggests that the powdered mango peel might be a significant source of minerals, contributing to the cakes' greater ash level. The results of this study were consistent with those of [13], who evaluated the nutritious and tactile qualities of cake prepared by combining high-dietary-fiber mango (*Mangifera indica* var. Chokanan) peel and mash flours.

4.3. Crude Protein

The average crude protein content of the control cake was 9.27%. The incorporated cakes had crude protein content ranging from 8.17% to 8.49%. When compared to the control cake, all the integrated cakes had significantly lower protein content ($p<0.05$). The use of powdered mango peel reduced the cake's protein content, but the 10% integrated cake had a significantly higher protein content and was larger compared to the 15% and 20% combined cakes. With the addition of more mango peel powder, the crude protein content showed a declining trend, however the differences were not appreciably significant for each integrated level. The decrease in crude protein level may have been due to mango peel powder having lower protein content as compared to flour. The results of this investigation were in line with [14], where they explored the addition of roselle and mango peel powder to tortilla chips as a strategy for enhancing their functionality.

4.4. Crude Fat

The average crude fat content of the control cake was 9.83%. In the incorporated cakes, it ranged from 10.81% to 11.81%. All the incorporated cakes had higher crude fat content than the control cake. Among the different

incorporation levels, the 20% level exhibited the highest crude fat content compared to other levels. The average outcomes of the cakes that were included showed that the fat content increased as inclusion increased. All of the integrated cakes exhibited statistically significant changes from the control group, with the exception of the 10% level, when no significant alterations were seen. With the 20% cake, a noticeable rise in fat content was seen. Mango peel powder's greater fat content than flour may have contributed to the study's finding of a small increase in crude fat level. This is consistent with the research on mango waste materials conducted by [15].

4.5. Crude Fiber

The control cake had an average crude fiber content of 6.53%. In the incorporated cakes, it ranged from 7.03% to 7.90%. All the incorporated cakes contained more crude fiber than the control cake. Among the different integration levels, the 20% incorporation level had significantly higher crude fiber content ($p<0.05$). According to the study, crude fiber content rose as cake incorporation levels did. The 20% cake had a considerably greater crude fiber content than the control cake ($p<0.05$), but there were no significant differences between the 15%, 10% and control cakes ($p>0.05$). The study discovered that, presumably as a result of fiber components, the crude fiber content rose with increasing amounts of mango peel powder integration. This is consistent with the findings of [15] study, which sought to increase the dietary fiber content and antioxidant qualities of biscuits.

4.6. Carbohydrate Content

The control cake had an average carbohydrate content of 67.94%. The cakes that were combined showed values ranging from 64.76% to 66.79%. The combined cakes had a much-reduced carbohydrate content ($p<0.05$) than the control cake. As the degrees of incorporation increased, the amount of carbohydrates in cakes consolidated with powdered mango peel decreased. The carbohydrate content of the 20% cakes was significantly lower than that of the control cake ($p<0.05$), however the differences were not statistically significant for other levels of mango peel powder incorporation ($p>0.05$). Credited to the high fibre content in mango peel powder. The discoveries of this study lined up with the exploration led by [14], which included the wholesome and tactile quality assessment of cake ready by incorporated mango (*Mangifera indica* var. Chokanan) mash and peel powder containing high dietary fibre.

Table 2 Proximate composition of cake samples incorporated with mango peel powder

Cake Samples	Proximate composition (%)					
	Moisture	Ash	Crude protein	Crude fat	Crude fiber	Carbohydrate
Control	4.25±0.2a	2.16±0.9c	9.27±0.0a	9.83±0.9b	6.53±1.5b	67.94±2.2a
10% MPP	3.82±0.1b	3.00±0.5b	8.49±0.4b	10.81±0.7ab	7.03±0.2ab	66.79±0.2ab
15% MPP	3.58±0.0c	3.83±0.3a	8.34±0.1b	11.35±0.4a	7.36±0.3ab	65.51±0.3b
20% MPP	3.01±0.1d	4.33±0.3a	8.17±0.7b	11.81±0.4a	7.90±0.3a	64.76±1.6b

Each value represents mean three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.7. Mineral Content

The mean sodium level of the control cake was 42 mg/100 g. The cakes that had been included had sodium contents ranging from 50 mg to 60 mg/100 g. Significantly, there was an overall increase in the sodium content of the cakes with integration compared to the control cake ($p<0.05$). With the escalation of mango peel powder incorporation, there was a concurrent rise in the sodium content within the cakes. Remarkable disparities in sodium content were evident among the cake samples. Notably, the 20% sample exhibited the most elevated sodium content, signifying a statistically significant distinction from both the 10% and 15% cake samples ($p < 0.05$). The augmentation of sodium content was attributed to the introduction of mango peel powder, which inherently possesses a higher sodium content compared to flour. This observation aligns with the findings of [16] in their study titled "Nutritional evaluation of toast bread fortified with mango peels and seed kernels powder."

4.7.1. Potassium

Potassium level in the control cake was typically 162 mg/100 g. Potassium values in integrated cakes ranged from 183 mg to 280 mg/100 g. Remarkably, the cakes including incorporation showed a significant increase in potassium content ($p<0.05$) in comparison to the control cake. The potassium levels in the cake samples varied greatly, with the

"20% MPP" sample having the greatest amount (2804.5 mg/100g), which differed significantly from the "Control" and "10% MPP" samples and a statistically significant difference ($p<0.05$) between the "15% MPP" and "20% MPP" samples. The consideration of mango peel powder, which typically has higher potassium levels, was connected to the increase in potassium content as compared to flour. This observation is consistent with the results reported by [16] in their research titled "Nutritional evaluation of toasted bread fortified with mango peels and seed kernels powder."

4.7.2. Calcium

The control cake displayed an average calcium content of 122mg/100g. Cakes enriched with additional ingredients exhibited calcium concentrations ranging from 183mg to 280mg/100g. It is worth noting that the cakes with incorporated ingredients demonstrated a noteworthy elevation in calcium content when compared to the control cake (with a significance level of $p<0.05$). The sample marked as "20% MPP" (198±0.3 mg/100g) was found to have the best calcium content, which separated it altogether from other samples as "Control" (122±0.2 mg/100g) and "10% MPP" (146±0.6 mg/100g). There was a significant difference ($p<0.05$) between the "15% MPP" (186±0.4 mg/100g) and "20% MPP" samples. The increase in calcium content can be attributed to the incorporation of mango peel powder, which inherently possesses higher calcium levels compared to flour. This observation aligns with the outcomes detailed by [16] in their study titled "Nutritional evaluation of toasted bread fortified with mango peels and seed kernels powder."

4.7.3. Magnesium

The average magnesium content of the control cake was 24mg/100g. Cakes enriched with supplementary ingredients exhibited varying magnesium levels, ranging from 31mg to 41mg/100g. Importantly, the cakes containing these added ingredients demonstrated a substantial increase in magnesium content in comparison to the control cake, with a statistical significance of ($p<0.05$). Critical differences in magnesium content were obvious among the different cake samples. Outstandingly, the "20% MPP" sample (41±0.3 mg/100g) showed the most noteworthy magnesium content, showing a huge difference from the "Control" (24±0.1 mg/100g), "10% MPP" (31±0.5 mg/100g) and "15% MPP" (38±0.1 mg/100g) samples. The variation between the "15% MPP" and "20% MPP" samples held factual importance ($p<0.05$). The rise in magnesium content can be attributed to the inclusion of mango peel powder, which inherently contains higher magnesium levels compared to flour. This observation aligns with the findings elucidated by [16] in their research titled "Nutritional evaluation of toasted bread fortified with mango peels and seed kernels powder."

4.7.4. Iron

The iron content of the control cake averaged 1.9mg/100g. Cakes enhanced with additional ingredients had iron content ranging from 2.4mg to 2.9mg/100g. Importantly, the cakes with these extra ingredients had a significantly higher iron content than the control cake ($p<0.05$). The iron content of the cake samples differed significantly. The iron level of the "20% MPP" sample was the greatest, with statistically significant changes when compared to the "Control" and "10% MPP" samples. There were statistically significant differences ($p<0.05$) between the "15% MPP" and "20% MPP" samples. Incorporating mango peel powder, which inherently holds a higher iron content than flour, is responsible for the rise in iron concentration. This inference aligns with the outcomes reported in the research conducted by [16] titled "Nutritional evaluation of toasted bread fortified with mango peels and seed kernels powder."

4.7.5. Zinc

The zinc level of the control cake averaged 0.5mg/100g. Zinc levels in cakes enhanced with additional components ranged from 0.8mg to 1.1mg/100g. Notably, the cakes containing these extra minerals had significantly higher zinc content than the control cake, with statistical significance ($p<0.05$). Significant differences in zinc concentration were found among the cake samples. The "20% MPP" sample had the greatest zinc concentration, with statistically significant differences from the "Control" and "10% MPP" samples. There were statistically significant differences in zinc levels between the "15% MPP" and "20% MPP" samples ($p<0.05$). Incorporating mango peel powder, which possesses a naturally higher zinc content than flour, leads to the heightened zinc concentration. This deduction aligns with the results unveiled in the research by [16] titled "Nutritional evaluation of toasted bread fortified with mango peels and seed kernels powder."

4.7.6. Phosphorus

The control cake displayed an average phosphorus level of 102mg per 100g. Cakes enriched with additional ingredients exhibited phosphorus concentrations spanning from 118mg to 135mg per 100g. Importantly, the cakes incorporating these supplemental minerals demonstrated a statistically significant increase in phosphorus content compared to the

control cake ($p< 0.05$). significant difference in phosphorus content were obvious among the cake samples. Especially, the "20% MPP" sample (135mg/100g) displayed an essentially higher phosphorus level in contrast with both the "Control" (102mg/100g) and "10% MPP" (118mg/100g) samples. Factual importance was seen between the phosphorus levels of the "15% MPP" (124mg/100g) and "20% MPP" samples ($p< 0.05$). Concorporating mango peel powder, which has a normally higher phosphorus content than flour, prompts the elevated phosphorus content.

Table 3 Mineral content of cake samples incorporated with mango peel powder

Cake Samples	Minerals content (mg/100g)						
	Sodium	Potassium	Calcium	Magnesium	Iron	Zinc	Phosphorus
Control	42±0.1^{d}	162±1.5^{d}	122±0.2^{d}	24±0.1^{d}	1.9±0.0^{d}	0.5±0.0^{d}	102±0.2^{d}
10% MPP	50±0.1^{c}	183±5.3^{c}	146±0.6^{c}	31±0.5^{c}	2.4±0.1^{c}	0.8±0.0^{c}	118±0.2^{c}
15% MPP	54±0.3^{b}	241±4.5^{b}	186±0.4^{b}	38±0.1^{b}	2.6±0.1^{b}	0.9±0.0^{b}	124±0.0^{b}
20% MPP	60±0.1^{a}	280±4.5^{d}	198±0.3^{a}	41±0.3^{a}	2.9±0.1^{a}	1.1±0.0^{a}	135±0.1^{a}

Each value represents mean three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.8. Total phenols

The phenolic content of the control sample was to be 2.2±0.3 mg GAE/g. While contrasting this with other cake samples containing MPP, it became clear that even a minor consideration of 10% MPP prompted a slight rise in phenol content, bringing about a worth of 2.3±0.3 mg GAE/g. This perception, while not measurably huge, recommends that even little increases of MPP could add to the phenolic content of the cakes. More imperative changes in total phenolic content were seen as the incorporation levels of MPP was increased. Cake samples with 15% MPP displayed phenolic content of 2.8±0.1 mg GAE/g, while those containing 20% MPP had a significantly higher phenolic content of 2.9±0.1 mg GAE/g. These results were significantly higher than those of both the control and the 10% MPP incorporation. The observed pattern of elevated total phenolic content with greater concentrations of MPP is in accordance with earlier research conducted by [17]. Their study, which explored the incorporation of roselle and mango peel powder into tortilla chips, demonstrated a similar trend of heightened functionality with increased additive content. This alignment in findings underpins the potential utility of MPP as a functional component within bakery products. Beyond enhancing flavor and color, the variations in total phenolic content underscore its role in conferring antioxidant properties to the final products.

4.8.1. DPPH

In the control group, the DPPH scavenging activity was measured at 42±0.2, indicating its inherent antioxidant capacity. When compared to the cake samples containing MPP, it became apparent that even a modest incorporation of 10% MPP resulted in a slight increase in DPPH scavenging activity, yielding a value of 44±0.0. While the difference was not statistically significant in comparison to the control group, this observation suggested the potential of MPP to contribute to the antioxidant attributes of the cakes. However, more pronounced shifts in DPPH scavenging activity were evident as the MPP concentration was elevated. Cake samples enriched with 15% MPP exhibited a DPPH scavenging activity of 48±0.1, while those incorporating 20% MPP demonstrated a higher scavenging activity of 51±0.1. Importantly, these values were statistically higher than both the control group and the cakes with 10% MPP. The rise in DPPH scavenging activity as MPP concentrations increased was in accordance with the findings of [18]. Their study, which investigated the enhancement of whole wheat bread quality by incorporating tropical fruit by-products, exhibited a parallel trend in results. This alignment reaffirmed the potential of MPP to act as a natural antioxidant source. By incorporating MPP into cakes, their collective antioxidant properties were enhanced, aligning with the prevailing trend of harnessing natural plant-based components to elevate the functional attributes of food products. The elevation in DPPH scavenging activity with higher MPP concentrations highlighted the presence of bioactive compounds in mango peel, which are known to confer antioxidant benefits. These compounds, including phenolic components, have been acknowledged for their ability to counteract free radicals and oxidative stress within the body.

Table 4 Total phenols and Dpph content of cake samples incorporated with mango peel powder

Cake Samples	Total Phenols (mg GAE/g)	Dpph
Control	2.2±0.3[b]	42±0.2[d]
10% MPP	2.3±0.3[b]	44±0.0[c]
15% MPP	2.8±0.1[a]	48±0.1[b]
20% MPP	2.9±0.1[a]	51±0.1[a]

Each value represents mean of three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.9. Total fungal count

In the control group, the fungal count increased from 2.3*10^5 CFU/g on Day 7 to 2.33*10^6 CFU/g on Day 21, indicating natural fungal proliferation. Cake samples with 10% and 15% Mango Peel Powder (MP) showed similar patterns, with higher counts on Day 14 but a decrease by Day 21. However, samples with 20% MP displayed a unique trend, starting with a lower count on Day 7, a slight increase on Day 14 and a notable rise on Day 21, suggesting a potential influence of higher MP concentration on fungal growth in later stages. These observed trends in fungal counts were likely influenced by a range of factors, including the baseline fungal load in the raw materials, environmental conditions and the potential antimicrobial properties of the MP. While MP is thought to contain bioactive compounds with potential antimicrobial effects, the fluctuating fungal counts across different concentrations hinted at a complex interplay between these compounds and the fungal population.

Table 5 Total fungal count of cake samples incorporated with mango peel powder

Sample	Day 7(cfu/g)	Day 14(cfu/g)	Day 21(cfu/g)
Control	2.3*10^5	1.66*10^6	2.33*10^6
MP 10%	4.6*10^5	1.11*10^6	1.42*10^6
MP 15%	4.4*10^5	1.12*10^6	2.24*10^6
MP 20%	1.4*10^5	2.2*10^5	5.6*10^5

4.10. Water activity

The regular cake had a mean water activity of 0.761 aw. When additional ingredients were added to the cakes, the water activity varied from 0.708 to 0.712 aw. Interestingly, the control cake showed significantly higher water activity than the cakes with added ingredients ($p<0.05$). Examining the various inclusion levels, it was found that the cake with 10% incorporation had a higher water activity compared to the other levels. Nevertheless, there were no notable differences between the 10%, 15% and 20% incorporation levels ($p>0.05$). The water activity measurements suggest that adding MPP to cake formulations resulted in a decrease in the water activity of the cakes. The cakes enriched with MPP demonstrated lower water activity values compared to the control cake, suggesting improved microbial stability and potential extension of shelf life. These outcomes aligned with the research conducted by [15], where the addition of roselle and mango peel powder was explored as a strategy to enhance the functionality of tortilla chips.

Table 6 Water activity values of cake samples incorporated with mango peel powder

Cake Samples	Water Activity (aw)
Control	0.761±0.0[a]
10% MPP	0.712±0.0[b]
15% MPP	0.710±0.0[b]
20% MPP	0.708±0.0[b]

Each value represents mean of three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.11. Physical analysis

Adding mango peel powder (MPP) to the cake samples at levels of 10%, 15% and 20% led to a decrease in hardness compared to the control cake without MPP (6.4 N). Interestingly, the cakes enriched with 10% and 15% MPP showed identical hardness values of 5.0 N, suggesting similar texture characteristics. In contrast, the cake infused with 20% MPP showed a slightly higher hardness measurement of 5.3 N compared to the cakes containing 10% and 15% MPP. This discrepancy implied a slightly more robust texture in the cake with 20% MPP. The resemblance in hardness between the 10% and 15% MPP cakes indicated that the elevation of MPP content beyond 10% did not have a significant impact on the cake's hardness. However, the slightly greater hardness observed in the 20% MPP cake suggested the possibility of an optimal MPP concentration for achieving the desired textural properties. The study indicated that the incorporation of MPP into cake formulations influenced the hardness or textural properties of the cakes. The cakes enriched with MPP tended to exhibit a softer texture when compared to the control cake that lacked MPP. However, it appeared that there was an optimal MPP concentration at which the hardness was not significantly affected. The results of this study align with the research conducted by [18].

Table 7 Texture values of cake samples incorporated with mango peel powder

Cake Samples	Hardness (N)
Control	6.4 ± 0.6^{a}
10% MPP	5.0 ± 0.4^{b}
15% MPP	5.0 ± 0.6^{b}
20% MPP	5.3 ± 0.6^{ab}

Each value represents mean of three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.11.1. Color

The L* values represented the luminance of the cake samples, where higher values were indicative of lighter colors. Notably, the control cake exhibited the highest L* value (56), signifying a considerably lighter color compared to the cakes with incorporated MPP ($p<0.05$). This substantial difference established it as the sample with the lightest color among all the variants. Among the MPP cake samples, the 15% MPP cake showed the most reduced L* value (25), recommending that it had the darkest color inside this subgroup. Both the 10% and 20% integrated cakes displayed fundamentally higher L* values contrasted with the 15% samples, yet no difference was seen between the L* values of the 10% and 20% cakes ($p>0.05$). The variation in color might have been credited to the presence of pigments and compounds found inside Mango Peel Powder (MPP). These pigments could have interacted with light, leading to observable alterations in lightness, hue and color intensity. The outcomes of this study aligned with [19], where they employed mango peels and seed kernel powders as sources of phytochemicals in biscuits.

The control cake has an a* value of 9, suggesting a slight greenish tint. The 10% MPP cake has the highest a* value (14), indicating a redder color compared to the other MPP-enriched cakes. Among the incorporated cakes, the 10% cake shows significantly higher a* value than the 15% and 20% cakes ($p<0.05$), but statistically, there were no differences between the 10%, 15% and 20% cake samples ($p>0.05$). The presence of pigments and chemicals found in Mango Peel Powder (MPP) could explain the color variations. These pigments may have interacted with light, causing visible changes in lightness, hue and color intensity. The findings of this study were consistent with the findings of [19] study, in which they used mango peels and seed kernel powders as sources of phytochemicals in biscuits.

The b* values represent the blue-yellow color component. The control cake has a b* value of 25, indicating a yellowish color. The 15% MPP cake has the lowest positive b* value (15), suggesting a slightly less yellow color compared to the control and 20% MPP cakes. The control cake exhibited significantly higher values than the cakes with incorporated ingredients ($p<0.05$). The 10% MMP sample showed essentially higher values contrasted with the cakes with 15% and 20% MMP samples ($p<0.05$). There was no difference among the control, 10% and 20% cake samples ($p>0.05$). The 15% sample showed no factual distinction when compared with the 10% and 20% samples ($p>0.05$). The alterations in color may have been ascribed to the existence of pigments and compounds present within Mango Peel Powder (MPP). These pigments might have interacted with light, resulting in noticeable changes in lightness, hue and color intensity. The results of this study were in agreement with the research conducted by [19], where they utilized mango peels and seed kernel powders as phytochemical sources in biscuits.

Table 8 Color values of cake samples incorporated with mango peel powder

Cake Samples	Colour (%)		
	L*	a*	b*
Control	56±2.1[a]	9±1.3[b]	25±7.1a
10% MPP	32±2.0[b]	14±1.4[a]	20±4.1[ab]
15% MPP	25±1.9[c]	12±1.6[a]	15±1.6[b]
20% MPP	35±2.7[b]	12±0.6[a]	18±1.0[ab]

Each value represents mean of three replicates± standard deviation. Means in the same column with different superscript letters are significantly different at P≤0.05.

4.12. Sensory Attributes

Table 8 shows the results of the sensory evaluation did on both the control cakes and those with MMP incorporation. A gathering of fifty untrained panelists took part in the assessment, using a nine-point hedonic scale. This evolution intended to decide the adequacy of the item inside the local area. The assessment enveloped four sensory assessments, with the discoveries introduced as follows.

4.12.1. Appearance

The mean sensory score for the control cake was 7.7. In contrast, the cakes with incorporated ingredients exhibited scores ranging from 4 to 6. Notably, there was a statistically significant difference observed in terms of appearance between the control cake and the cakes with incorporated ingredients ($p<0.05$). The cakes with incorporated mango peel powder demonstrated a decline in appearance scores with increasing levels of incorporation. Notably, the cake with 10% incorporation exhibited significantly higher appearance scores compared to cakes with 20% incorporation ($p<0.05$). There was difference seen between the 10% and 15% integration levels. Also, no difference was distinguished between the 15% and 20% incorporation levels ($p>0.05$).

4.12.2. Texture

The average sensory score for the control cake stood at 4.9. In contrast, cakes infused with incorporated ingredients showcased scores that spanned from 5.6 to 6.9. It is worth highlighting that a statistically significant distinction was identified concerning the aspect of texture when comparing the cakes containing incorporated ingredients with the control cake ($p<0.05$). As the level of incorporation of mango peel powder increased, the cakes exhibited a gradual increase in their texture scores. Notably, the cake with 20% incorporation displayed significantly higher texture scores compared to cakes with 10% incorporation ($p<0.05$).

4.12.3. Flavour

The mean sensory score for the control cake was 4.7. Conversely, cakes enriched with incorporated ingredients displayed scores ranging from 5.9 to 8. Notably, a statistically significant difference was observed in terms of flavour when comparing the cakes with incorporated ingredients to the control cake ($p<0.05$). With the escalation of mango peel powder incorporation, the cakes displayed a progressive augmentation in their flavour scores. Remarkably, the cake incorporating 20% displayed significantly higher flavour scores in contrast to cakes with 10% and 15% incorporation ($p<0.05$). Moreover, the 15% cake sample also exhibited a significant difference in comparison to the 10% sample ($p<0.05$).

4.12.4. Overall Acceptability

The average sensory score for the control cake was 5.3. In contrast, cakes enhanced with incorporated ingredients exhibited scores ranging from 5.7 to 7. It's important to note that a statistically significant difference was identified in relation to the overall acceptability when comparing the cakes containing incorporated ingredients with the control cake ($p<0.05$). The cakes' overall acceptability scores gradually improved as the level of mango peel powder incorporation increased. Eminently, the cake containing 20% MMP showed higher overall acceptability scores contrasted with cakes with 10% and 15% MMP sample ($p<0.05$). The sensory evaluation of the cake samples demonstrated a notable influence of MPP addition on appearance, texture, flavor and overall acceptability of the cakes. The cakes enriched with MPP, particularly those containing 15% and 20% MPP, were positively received by the evaluators in terms of sensory attributes and overall preference. These findings were consistent with the study

conducted by [16], where mango waste materials (peel, kernel) were employed to increase dietary fiber content and antioxidant properties of biscuits.

Table 9 Sensory attributes of cake samples incorporated with mango peel powder

Cake Samples	Sensory score			
	Appearance	Texture	Flavour	Overall Acceptability
Control	7.7±1.7^{a}	4.9±2.5^{c}	4.7±2.1^{d}	5.3±1.9^{c}
10% MPP	6.0±1.5^{b}	5.6±1.5^{bc}	5.9±1.5^{c}	5.7±1.4^{bc}
15% MPP	5.0±2.0^{bc}	6.0±1.5^{ab}	6.9±1.3^{b}	6.3±1.6^{ab}
20% MPP	4.0±2.9^{c}	6.9±1.7^{a}	8.0±1.2^{a}	7.0±1.4^{a}

Values are means ± SD. Means in the same columns with different letters are significantly different (P < 0.05, LSD test). Data collected on a 9-point hedonic scale (1 = dislike extremely; 9 = like extremely).

5. Conclusion

The approximate composition of cakes revealed that cakes with mango peel powder have considerably increased crude fat, crude fiber and ash content but lower moisture, protein and carbs content ($p<0.05$). The mineral content of the integrated cakes was higher. Cakes using mango peel powder had greater total phenol concentrations when compared to the control cake ($p<0.05$). Cake samples with mango peel powder demonstrated greater DPPH scavenging activity. Scavenging activity was highest in the cake sample with 20% inclusion ($p<0.05$). Incorporated cake samples revealed decreased fungal count and lower water activity, which can effectively contribute to better microbiological stability and shelf life ($p<0.05$). Mango peel powder-infused cake samples had a softer texture than the control cake ($p<0.05$). Color examination of incorporated cake samples with mango peel powder revealed that incorporated cake samples had higher a* values, while control cake had lower L* and b* values ($p<0.05$). Sensory qualities revealed that the control cake had a high appearance score, whereas cakes using mango peel powder had greater flavour, texture and overall acceptability. Cake samples with 20% inclusion were strongly liked ($p<0.05$).

Compliance with ethical standards

Disclosure of conflict of interest

Authors have no conflict of interest.

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