**Effect of Gurma Melon Peel Powder Addition on the Chemical and Sensory Properties of Balady Bread**

**Abstract:**

This study investigated the effect of Gurma melon peel powder (GMPP) supplementation on the chemical composition, mineral profile, antioxidant activity, and sensory attributes of Balady bread. GMPP exhibited higher fat (3.65%), ash (14.06%), fiber (16.47%), total phenolics (1.062 mg GAE/g), flavonoids (0.929 mg RE/g), and antioxidant activity (77.83%) compared to wheat flour (WF). Conversely, WF showed higher protein (11.22%) and carbohydrate (84.61%) contents. When substituted into Balady bread at 5% and 10%, GMPP led to increased ash, fiber, calcium, potassium, and antioxidant capacity, alongside decreased moisture and protein. Bread with 10% GMPP (Bread 2) showed the highest phenolic (0.13 mg GAE/g), flavonoid (0.09 mg RE/g), and DPPH activity (20.74%), indicating significant functional improvement. However, sensory scores decreased with higher GMPP content; Bread 1 (5% GMPP) maintained good sensory acceptance while enhancing nutritional properties moderately. Thus, Bread 1 (5% GMPP) achieved the best balance between improved nutritional value and consumer acceptability, while Bread 2 (10% GMPP) maximized functional benefits at the expense of some sensory attributes.

***Keywords:*** Evaluation, Gurma melon, Chemical, Sensory, properties, Balady Bread.

**Introduction**

Balady bread, also known as Egyptian flatbread, is a traditional staple food consumed daily across Egypt and other parts of the Middle East. It is typically prepared using wheat flour (WF) with an 82% extraction rate, contributing significantly to energy and nutrient intake. However, despite its cultural and dietary significance, Balady bread made from refined wheat flour is often limited in dietary fiber, essential minerals, and bioactive compounds. In recent years, rising wheat flour prices and concerns about its nutritional limitations have driven efforts to explore healthier, more sustainable alternatives. One promising approach is the partial substitution of wheat flour with locally available, nutrient-rich by-products to improve both the nutritional quality and functional properties of bakery products (Al-Hajj, 2023; Wang & Jian, 2022).

The global consumption of fruits and vegetables has increased significantly due to their appealing taste, preventive role against chronic diseases, and health-promoting nutrients such as vitamins, minerals, dietary fiber, and various bioactive compounds (Ribeiro et al., 2013). However, this growing demand also generates large quantities of agricultural waste, particularly in the form of peels and seeds. Notably, these by-products are rich in valuable bioactive compounds and essential nutrients, often surpassing the nutritional value of the edible fruit pulp itself (Morais et al., 2015; Moo-Huchin et al., 2015). Nevertheless, the high moisture content of peels renders them highly perishable. To improve their shelf life and preserve their nutritional value, techniques such as hot air drying and freeze-drying have been employed (Santos et al., 2011).

Gurma melon (Citrullus lanatus var. colocynthoides), a member of the Cucurbitaceae family, is an ancient variety of watermelon, commonly referred to as Nubian melon or seed melon. It has been cultivated in Egypt since antiquity and remains an important local crop today (Ziyada & Elhussien, 2008; Elsebaie et al., 2022). In 2015, Egypt cultivated approximately 223,113 feddans of Gurma melon, yielding around 115,201 tons of fruit (EMAL, 2015). While the plant’s green parts are typically used as animal fodder, the pulp is characterized by a creamy color and mildly sweet taste, and it is rich in pectin and proteins (Salama et al., 2019). The seeds are considered the most economically valuable component and are extensively exported due to their nutritional and commercial value (Korish, 2015; El-Shabraewy & Hatem, 2008). Gurma melon is particularly favored in northern Egypt due to its low water requirements and adaptability to arid climates (Abo El-Magd et al., 2006). Nutritionally, the fruit and its by-products are rich in dietary fiber (>5%), protein (~20%), fat (~35%), and key minerals such as magnesium, calcium, potassium, phosphorus, iron, and zinc. Furthermore, they possess functional properties that make them suitable for baking applications (Wan Shafiin et al., 2021).

Given the rising cost and fluctuating availability of wheat flour (WF), coupled with increasing consumer demand for healthier and more sustainable food options, there is growing interest in exploring alternative flours for partial substitution in bakery products (Wang & Jian, 2022). Replacing a portion of WF with nutrient-rich powders derived from fruit by-products can not only reduce reliance on traditional wheat sources but also improve the nutritional profile, fiber content, and sensory appeal of the final product (Al-Hajj, 2023). Gurma melon peels, typically regarded as waste, offer a sustainable and innovative ingredient for such purposes. Rich in dietary fiber and antioxidants, the peels have potential as functional additives in bakery formulations. Their incorporation into bread production aligns with the global shift towards sustainable food systems and health-oriented diets, contributing to waste valorization, enhanced nutritional quality, and product diversification (Wang & Jian, 2022).

This study represents a pioneering effort to explore the nutritional and functional potential of Gurma melon peel powder (GMPP), a by-product that has not been previously investigated in the context of food applications. To the best of our knowledge, no prior research has evaluated the impact of GMPP incorporation into wheat-based bread. This research aims to fill this gap by analyzing the chemical composition and sensory properties of Balady bread enriched with varying levels of GMPP (5%, 10%, 15%, and 20%). The primary objective is to assess the influence of this substitution on the bread’s nutritional value and consumer acceptability. Through this novel investigation, the study contributes valuable insights to the fields of food science, agricultural waste utilization, and sustainable product development, potentially paving the way for broader applications and future research on Gurma melon and its by-products.

**Materials and methods:**

**Materials:**

Wheat flour (*Triticum aestivum*, 82% extraction rate) was purchased from Delta Middle and West Milling Company, located in Tanta, Egypt (Latitude: 30.7865° N, Longitude: 31.0019° E). Dry yeast and salt (sodium chloride) were obtained from the local market in Kafr El-Sheikh Governorate, Egypt (Latitude: 31.1118° N, Longitude: 30.9391° E). Gurma melon peels were sourced from a local farm also located in Kafr El-Sheikh, Egypt. All chemicals used in this study were of analytical grade and were obtained from El-Gomhouria Pharmaceutical Company in Tanta City, Egypt (Latitude: 30.7865° N, Longitude: 31.0019° E).

**Methods:**

**Preparation of GMPP:**

Gurma melon peels were separated from the washed fresh fruits and cut into small pieces using a sharp stainless-steel knife. The pieces were spread evenly in trays and dried in a hot air oven at 45 ± 5 °C until a constant weight was achieved. Drying was performed using a Memmert Universal Oven Model UFE 400 (Memmert GmbH + Co. KG, Schwabach, Germany). The dried Gurma melon peels were then ground into a fine powder using a Moulinex Grinder, Model AR1100 (Groupe SEB, France). The powder was passed through a 60-mesh sieve to ensure uniform particle size and stored in airtight containers at room temperature until further use.

**Preparation of balady bread treatments:**

Four treatments were prepared for the study, differing in the substituting percentage of wheat flour extracted (82%) with a percentage from Gurma melon peel powder (5, 10, 15 and 20%) and control was prepared from wheat flour 82%. Balady bread was made by mixing 100 g from the flour of each treatment with 0.5 g of active dry yeast, 1.5 g of salt, 1 g of sugar, and 65–70 mL of water. The ingredients were mixed by hand for approximately 10 minutes until a smooth dough was formed.

The dough was left to ferment for 1 hr. then divided into 125 g pieces. The pieces were arranged on a wooden board and were left to ferment for about 45 min. The pieces of fermented dough were flattened to be about 20-cm in diameter, then baked at 300–350°C for 1–2 minutes. After baking, the loaves were cooled at room temperature for 1 hour, then packaged in polyethylene bags (Mahdy and Abo El-Nagaa, 2018).

**Sensory Evaluation of balady bread:**

The sensory evaluation of Balady bread samples was carried out using a structured sensory panel consisting of 20 trained panelists (12 females and 8 males, aged 30–55 years) from the Food Technology Research Institute, Sakha, Kafr El-Sheikh, Egypt. The evaluation procedure followed standard guidelines as described by Hegazy and Faheid (1990), with modifications based on ISO 8586:2012 for sensory analysis. Attributes were rated using a 9-point hedonic scale, where 9 = "like extremely" and 1 = "dislike extremely." Sensory sessions were conducted in a sensory evaluation room under controlled lighting and ambient conditions.

**Chemical Composition:**

Moisture, ash, crude protein, fiber and fat were determined according to **AOAC (2015).**

**Minerals content:**

The concentrations of iron, zinc, calcium, magnesium, and manganese in the samples were measured using an Atomic Absorption Spectrophotometer (AAS) (Model 3300, PerkinElmer, England), following the standard procedures described in AOAC Official Method 999.11 **(AOAC, 2019)**. Total phosphorus content was determined using the ascorbic acid colorimetric method according to the protocol described by USEPA Method 365.1 **(USEPA, 2012)**. Potassium and sodium concentrations were quantified using a flame photometer, based on the methodology outlined in AOAC Official Method 969.23 **(AOAC, 2019)**.

**Total Phenolic Compounds (TPC):**

The total phenolic content (TPC) of the samples was determined using the Folin–Ciocalteu colorimetric method, with modifications adapted from Attard (2013). Briefly, 1 g of the dried sample was extracted using 10 mL of 70% aqueous ethanol. This concentration of ethanol was chosen to improve solubility and extraction efficiency of both hydrophilic and moderately lipophilic phenolic compounds. The mixture was placed in an ultrasonic water bath (40 kHz) for 30 minutes at room temperature to enhance extraction through sonication. After extraction, the sample was filtered, and 10 µL of the clear extract was mixed with 100 µL of Folin–Ciocalteu reagent (previously diluted 1:10 with distilled water). After 5 minutes of reaction time, 80 µL of 1 M sodium carbonate (Na₂CO₃) was added to the mixture to promote color development. The reaction mixture was incubated in the dark at room temperature for 20 minutes. The absorbance of the resulting blue-colored complex was measured at 760 nm using a UV–Vis spectrophotometer. Gallic acid was used as the standard, and results were expressed as milligrams of gallic acid equivalents per gram of sample (mg GAE/g). All analyses were performed in triplicate and data were reported as mean ± standard deviation (SD).

**Total flavonoid content:**

The total flavonoid content (TFC) was determined using the aluminum chloride colorimetric method outlined by **Chang *et al*., (2002)**, with minor modifications. Briefly, 1 g of sample was put in 10 mL of 70% ethanol for 30 min in sonication, then the extract was diluted with methanol to a concentration of 100 mg/mL. A calibration curve was prepared by diluting quercetin in methanol (0–100 mg/mL). To measure the flavonoid content, 2.0 mL of either the extract or quercetin solution was mixed with 0.1 mL of 10% (w/v) aluminum chloride solution and 0.1 mL of 0.1 mM potassium acetate solution. The mixture was allowed to react at room temperature for 30 minutes. Finally, the absorbance of the solution was measured at 415 nm using a UV-Vis spectrophotometer.

**Antioxidant activity:**

DPPH (2,2-diphenyl-1-picryl-hydrazyl-hydrate) scavenging activity was carried out using the procedure explained by **Boly *et al*., (2016)**. Briefly, 1 g of sample was put in 10 mL of 70% ethanol for 30 min in sonication, then 100 µL extract were mixed with freshly prepared 0.1% DPPH dissolved in methanol, the reaction was left in at room temperature for 30 min (in dark). Distilled water was used as a blank instead of the GMPP sample. The reduced color intensity of DPPH was measured at 520 nm. Data are presented as averages ± SD according to the following equation:

*% inhibition= (Absorbance of blank-Absorbance of sample)/(Absorbance of blank)×100*

**Amino acids composition:**

Amino acid composition was determined following the protocol outlined by AOAC Official Method 994.12 **(AOAC, 2019)** with minor modifications. Briefly, 0.1 g of the finely ground sample was weighed into a hydrolysis tube and mixed with 10 mL of 6N hydrochloric acid (HCl) containing 0.1% (v/v) mercaptoethanol as a protective agent against oxidative degradation of sensitive amino acids. The tube was sealed under vacuum and hydrolyzed at 110 °C for 24 hours in a drying oven. After hydrolysis, the sample was allowed to cool to room temperature and filtered through Whatman No. 1 filter paper. The filtrate was quantitatively transferred and diluted to a final volume of 25 mL with deionized water. A 5 mL aliquot of the hydrolysate was evaporated to dryness in a vacuum desiccator over potassium hydroxide (KOH) pellets. The residue was reconstituted in 1 mL of sodium citrate buffer (pH 2.2) and stored at 4 °C until analysis. Quantification of amino acids was performed using an automatic amino acid analyzer (Biochrom 30+, Biochrom Ltd., Cambridge, UK), calibrated with a standard amino acid mixture. The results were expressed as grams of amino acid per 100 grams of protein (g/100 g protein). All determinations were carried out in triplicate.

**Statistical Analysis**

The data were analyzed using SPSS software (Version 16.0, SPSS Inc., Chicago, IL) to assess variance through one-way analysis of variance (ANOVA). The means and standard deviations were computed from three repetitions.

**Results and Discussion:**

**Gross Chemical Composition of Wheat Flour (W.F) and Gurma Melon Peel Powder (GMPP)**

Table 1 presents the proximate chemical composition of wheat flour (W.F, 82% extraction rate) and Gurma melon peel powder (GMPP) on a dry weight basis. The results reveal significant differences (p < 0.05) between the two ingredients in all measured components.

Wheat flour exhibited significantly higher moisture content (11.50%) compared to GMPP (9.48%). This elevated moisture level in W.F is typical of refined flours and contributes to its soft texture and improved dough handling characteristics. The relatively lower moisture content in GMPP enhances its shelf stability and microbial resistance, making it more suitable for use as a dry ingredient in composite flour formulations.

In terms of protein content, W.F showed a notably higher value (11.22%) than GMPP (8.09%). The superior protein level in W.F, particularly its gluten-forming components (gliadin and glutenin), is critical for the viscoelastic properties required in breadmaking. Conversely, the protein content in GMPP, although lower, still provides a meaningful nutritional contribution, particularly in fiber-rich, composite bakery products. These findings are in close agreement with those reported by Salama et al. (2019) and Malavi et al. (2022), who documented similar protein contents in refined wheat flour used in baking applications.

GMPP demonstrated significantly higher fat content (3.65%) compared to W.F (1.51%). This increased lipid concentration may be attributed to the residual seed oil fractions and cellular membranes present in melon peel tissues. While higher fat content may influence storage stability due to susceptibility to oxidation, it also offers energy and contributes positively to flavor and texture in baked goods. Ash content, which reflects the total mineral content, was considerably greater in GMPP (14.06%) than in W.F (1.25%). This substantial difference suggests that GMPP is a rich source of essential minerals, which will be discussed further in the mineral composition section. The high ash content confirms the potential of GMPP as a functional additive for mineral fortification in food products. Dietary fiber content showed a significant disparity, with GMPP recording 16.47% fiber compared to only 1.41% in W.F. This elevated fiber content in GMPP enhances its nutritional profile, offering health benefits such as improved digestive function, satiety regulation, and glycemic control. These results align with the findings of Hind (2017), who reported high fiber levels in dried watermelon peel powder, though slightly higher (18.54%) than the value observed for GMPP in this study.

Carbohydrate content, calculated by difference, was markedly higher in W.F (84.61%) than in GMPP (57.73%). This reflects the refined nature of wheat flour, which is primarily composed of starch. In contrast, GMPP’s lower carbohydrate content, coupled with its higher fiber and ash contents, makes it more suitable for low-energy and high-fiber food formulations. Al-Sayed and Ahmed (2013) similarly observed lower carbohydrate values (56.00%) in watermelon rind, closely matching our findings.

Overall, these compositional differences highlight the potential of GMPP as a valuable complementary ingredient to wheat flour. While W.F provides superior protein and starch necessary for bread structure and energy, GMPP contributes functional components such as dietary fiber, fat, and minerals. Incorporating GMPP into bakery products may thus enhance nutritional quality and promote sustainability through agricultural by-product utilization. However, careful formulation is required to balance functional properties and maintain desirable sensory characteristics in the final product.

Table (1): Chemical composition (%) of WF and GMPP (on dry weight).

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Moisture | Protein | Fat | Ash | Fiber | Carbohydrate |
| WF(82%extract) | 11.50±0.34\* | 11.22±0.2\* | 1.51±0.11 | 1.25±0.11 | 1.41±0.13 | 84.61±0.45\* |
| GMPP | 9.48±0.15 | 8.09±0.09 | 3.65±0.18\* | 14.06±0.78\* | 16.47±1.04\* | 57.73±0.85 |

\* Significant differences were occurred between two groups.

**Mineral Composition of Wheat Flour (W.F) and Gurma Melon Peel Powder (GMPP)**

The mineral profiles of wheat flour (W.F, 82% extraction) and Gurma melon peel powder (GMPP) are presented in Table 2. The data reveal statistically significant differences (p < 0.05) between the two samples across all analyzed minerals, highlighting the complementary nutritional contributions of each ingredient. Potassium (K) was the most abundant macro-mineral in GMPP, with a concentration of 356.93 mg/100 g, significantly surpassing that in W.F (16.8 mg/100 g). Potassium is essential for maintaining fluid balance, nerve transmission, and muscle function. The markedly high potassium content in GMPP confirms its potential as a dietary source of this electrolyte, aligning with values reported by Hind (2017) for watermelon rind (447.33 mg/100 g), though slightly lower in this case.

Calcium (Ca) content was also considerably higher in GMPP (80.63 mg/100 g) compared to W.F (19.3 mg/100 g). Calcium plays a vital role in bone mineralization and cellular signaling. The elevated levels in GMPP may be attributed to its fibrous, mineral-rich structure and its origin from fruit rind tissues, which typically accumulate calcium. This supports prior findings by Salama et al. (2019), who noted that the rind of Gurma melon contains more Ca than its pulp. Sodium (Na) levels were likewise greater in GMPP (21.57 mg/100 g) than in W.F (4.8 mg/100 g). While sodium is essential in small amounts, excessive intake can pose health risks; thus, careful consideration is needed in formulations to avoid exceeding recommended intake levels.

In contrast, phosphorus (P) and magnesium (Mg) were more abundant in W.F, with concentrations of 185 mg/100 g and 160 mg/100 g, respectively, compared to 131 mg/100 g and 40.44 mg/100 g in GMPP. Phosphorus is integral to energy metabolism and nucleic acid synthesis, while magnesium functions in over 300 enzymatic reactions. The higher phosphorus content in W.F reflects its starchy endosperm origin, where phosphorus is stored as phytic acid. These results agree with El-Gammal et al. (2016), who reported similar phosphorus and magnesium values for Egyptian wheat flour.

Regarding micronutrients, W.F exhibited significantly higher concentrations of zinc (4.5 mg/100 g) and iron (2.8 mg/100 g) than GMPP (0.163 and 0.88 mg/100 g, respectively). Zinc supports immune function and enzyme activity, while iron is essential for hemoglobin synthesis. Although GMPP had lower levels of these trace elements, it still offers a meaningful contribution, particularly when used in combination with other flours. Notably, Hind (2017) reported even lower iron levels (0.61 mg/100 g) in watermelon rind, suggesting that Gurma melon peel may offer comparatively improved iron bioavailability. Manganese (Mn) content followed the same trend, with W.F containing 2.02 mg/100 g, substantially higher than the 0.081 mg/100 g found in GMPP. While GMPP is not a strong source of manganese, its high potassium and calcium levels highlight its mineral diversity.

These findings indicate that GMPP is particularly rich in potassium, calcium, and sodium, making it valuable for enhancing the electrolyte and bone-supportive properties of bakery products. Meanwhile, W.F contributes greater amounts of phosphorus, magnesium, zinc, and iron, essential for metabolic and enzymatic functions. When combined, these two ingredients can offer a more balanced mineral profile, supporting both functional food development and dietary diversification. The current results confirm and extend the compositional observations of earlier studies on watermelon rind and Gurma melon pulp and peels (Sharoba et al., 2009; Hind, 2017; Salama et al., 2019), and support the use of GMPP as a functional, nutrient-enhancing additive in wheat-based food products.

Table (2): Minerals content of WF and GMPP (mg/100g on dry weight basis).

|  |  |  |
| --- | --- | --- |
| Minerals | Treatments | |
| WF | GMPP |
| Ca | 19.3 | 80.63 |
| Mg | 160 | 40.44 |
| Na | 4.8 | 21.57 |
| K | 16.8 | 356.93 |
| P | 185 | 131 |
| Mn | 2.02 | 0.081 |
| Zn | 4.5 | 0.163 |
| Fe | 2.8 | 0.88 |

**Amino Acid Composition of Wheat Flour (W.F) and Gurma Melon Peel Powder (GMPP)**

The amino acid profiles of wheat flour (W.F) and Gurma melon peel powder (GMPP), expressed per 100 g of protein, are presented in Table 3. These data highlight significant compositional differences between the two materials, particularly in terms of essential amino acid (EAA) content and overall protein quality.

Wheat flour demonstrated a superior total essential amino acid content (27.30 g/100 g protein) compared to GMPP (19.34 g/100 g protein), indicating that W.F protein more closely aligns with human nutritional requirements as established by the FAO/WHO (1973). W.F provided notably higher levels of lysine (2.80 g), leucine (7.60 g), and the aromatic amino acids phenylalanine and tyrosine (6.80 g combined). These amino acids are crucial for protein synthesis, neural development, and metabolic regulation, and their abundance in W.F supports its role as a staple source of functional protein in breadmaking.

Conversely, GMPP exhibited a lower EAA profile, though it still contained nutritionally relevant levels of isoleucine (3.68 g), phenylalanine (3.55 g), and arginine (3.05 g). Arginine, although classified as non-essential for adults, plays critical roles in immune function and nitric oxide metabolism, and its presence in GMPP may enhance its functional benefits. Interestingly, GMPP had slightly higher isoleucine content than W.F, suggesting potential complementary effects when both ingredients are blended.

A common limitation observed in both W.F and GMPP was the insufficient presence of sulfur-containing amino acids (methionine + cysteine), which were below the FAO/WHO (1973) recommended level of 3.5 g/100 g protein. W.F and GMPP recorded combined values of 1.90 g and 1.54 g, respectively. This deficiency underscores the need for protein complementation—ideally by incorporating legume-based or animal-source proteins—to enhance the biological value of formulations using either of these ingredients.

Regarding non-essential amino acids (NEAAs), W.F displayed substantially higher levels (57.90 g/100 g protein) than GMPP (32.99 g/100 g protein). Notably, glutamic acid (30.50 g) and proline (7.00 g) were dominant in W.F, contributing to the viscoelastic properties of dough, which are essential for bread volume, texture, and gas retention. The significantly lower levels of these structure-forming amino acids in GMPP (15.97 g glutamic acid and 3.47 g proline) suggest that GMPP alone cannot provide the same functional performance in baked goods, particularly in gluten development.

Nevertheless, GMPP’s amino acid profile reflects its potential as a complementary protein source, particularly in sustainable and plant-based food systems. While its overall amino acid content is lower than W.F, its richness in arginine, isoleucine, and phenylalanine makes it suitable for broadening the amino acid spectrum of bakery products when blended with cereals or legumes. This observation is consistent with prior studies that examined the amino acid profiles of other fruit by-products such as mango kernels and citrus peel powders, which were found to contribute unique amino acid compositions to composite flour formulations (Hussain et al., 2024; Shyu et al., 2014). In summary, while wheat flour remains a superior protein source in terms of essential and functional amino acids, GMPP offers complementary nutritional value, especially in terms of select EAAs and its potential role in dietary diversification and sustainable food formulation.

Table (3): Amino acids composition of wheat flour (WF) and gurma melon peel powder (GMPP) (g/100g protein).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Amino acids | Treatments | | | FAO/WHO (1973) |
| WF | | GMPP |
| Essential amino acids | | | | |
| Threonine | 1.20 | | 0.89 | 4.00 |
| Valine | 2.30 | | 2.56 | 5.00 |
| Methionine | 1.30 | | 0.99 |  |
| Cysteine | 0.60 | | 0.55 |  |
| Methionine + Cysteine | 1.90 | | 1.54 | 3.5 |
| Isoleucine | 3.10 | | 3.68 | 4.00 |
| Leucine | 7.60 | | 3.69 | 7.00 |
| Histidine | 1.60 | | 1.11 |  |
| Phenylalanine | 4.10 | | 3.55 |  |
| Tyrosine | 2.70 | | 1.26 |  |
| Phenylalanine + Tyrosine | 6.80 | | 4.81 | 6.00 |
| Lysine | 2.80 | | 1.06 | 5.50 |
| TEAA | 27.30 | | 19.34 |  |
| Non-Essential amino acids | | | | |
| Aspartic acid | | 5.10 | 3.87 |  |
| Glutamic acid | | 30.50 | 15.97 |  |
| Serine | | 3.20 | 3.08 |  |
| Glycine | | 4.20 | 2.11 |  |
| Arginine | | 3.20 | 3.05 |  |
| Alanine | | 4.70 | 1.44 |  |
| Proline | | 7.00 | 3.47 |  |
| TNEAA | | 57.90 | 32.99 |  |
| Total amino acids | | 85.20 | 52.33 |  |

TEAA= Total essential amino acids; TNEAA= Total non-essential amino acids.

**Total Phenolic Content, Total Flavonoids, and Antioxidant Activity (DPPH) of Wheat Flour (W.F) and Gurma Melon Peel Powder (GMPP)**

The antioxidant properties and bioactive compound contents of wheat flour (W.F) and Gurma melon peel powder (GMPP) are presented in Table 4. The results indicate statistically significant differences (p < 0.05) between the two samples in terms of total phenolic content (TPC), total flavonoid content (TFC), and DPPH radical scavenging activity, highlighting the superior biofunctional profile of GMPP.

GMPP recorded a total phenolic content of 1.062 ± 0.03 mg gallic acid equivalents (GAE)/g sample, which was nearly double that of W.F (0.550 ± 0.02 mg GAE/g). Similarly, total flavonoid content in GMPP was substantially higher at 0.929 ± 0.15 mg rutin equivalents (RE)/g compared to 0.150 ± 0.00 mg RE/g in W.F. These results underscore the richness of GMPP in polyphenolic and flavonoid compounds, which are known to exhibit potent antioxidant, anti-inflammatory, and health-promoting effects.

Correspondingly, the antioxidant capacity, measured using the DPPH radical scavenging assay, was markedly greater in GMPP (77.83 ± 1.53%) compared to W.F (30.35 ± 0.84%). This nearly 2.5-fold increase in antioxidant activity confirms the functional potential of GMPP as a natural source of antioxidants that can scavenge free radicals and mitigate oxidative stress. The strong correlation observed between TPC, TFC, and DPPH values suggests that the antioxidant activity of GMPP is primarily driven by its high phenolic and flavonoid content.

The elevated levels of bioactive compounds in GMPP can be attributed to its origin from melon rind tissues, which are typically exposed to environmental stress and accumulate secondary metabolites such as phenolics and flavonoids as protective agents. Moreover, the drying and milling processes used in this study may have enhanced the release of bound phenolic compounds, as reported by Dewanto et al. (2002), who demonstrated that thermal processing can increase the bioaccessibility of phenolic constituents.

These findings are consistent with literature reports highlighting the biofunctional properties of fruit and vegetable peels. For instance, Dieng et al. (2017) reported high TPC and TFC values in watermelon peels, suggesting their suitability for functional food applications. In contrast, Neglo et al. (2021) observed lower values for phenolics (0.087 mg GAE/g) and DPPH activity (55.75%) in watermelon peel powders, which may be due to differences in melon variety, processing conditions, or extraction solvents.

The significantly higher antioxidant profile of GMPP compared to W.F positions it as a promising functional ingredient for enhancing the nutritional value and oxidative stability of wheat-based bakery products. Its incorporation could not only contribute to health benefits associated with antioxidant intake but also improve product shelf life by reducing lipid oxidation. The data strongly support the valorization of Gurma melon peel, an agricultural by-product, as a natural antioxidant source in food systems.

Table (4): **Total phenolic, total flavonoid contents and antioxidant activity (DPPH)% of WF and GMPP**.

|  |  |  |  |
| --- | --- | --- | --- |
| Treatments | Total phenolic compounds  (mg GAE/g sample) | Total flavonoid compounds  (mg RE/g sample) | Antioxidant activity (DPPH %) |
| WF | 0.550±0.02 | 0.150±0.00 | 30.35±0.84 |
| GMPP | 1.062±0.03\* | 0.929±0.15\* | 77.83±1.53\* |

\* Significant differences were occurred between two groups.

**Sensory Evaluation of Balady Bread Supplemented with Gurma Melon Peel Powder (GMPP)**

The sensory attributes of Balady bread enriched with varying levels of Gurma melon peel powder (GMPP) are summarized in Table 5. The evaluation covered six major parameters: taste, odor, crust color, crumb texture, roundness (shape), and overall appearance, using a trained panel. The results revealed a consistent trend: as the percentage of GMPP substitution increased from 5% to 20%, there was a gradual and statistically significant decline (p < 0.05) in all sensory attributes compared to the control (100% wheat flour).

The control bread received the highest mean scores across all parameters, indicating optimal consumer acceptability in terms of flavor, aroma, and texture. Substituting 5% of wheat flour with GMPP (Bread 1) resulted in minimal changes, with only slight, non-significant reductions in taste, odor, and appearance scores. Panelists described this formulation as comparable to the control, with good palatability and acceptable crust and crumb characteristics. The slight increase in fiber and color from GMPP was not considered detrimental at this level.

At 10% GMPP substitution (Bread 2), a moderate but noticeable decline in taste and odor scores was observed, though the bread was still rated as "good" overall. Some panelists reported a slightly earthy or vegetal aftertaste and a denser crumb texture, likely due to the higher fiber content and reduced gluten matrix development caused by dilution of wheat flour proteins.

However, breads with 15% (Bread 3) and 20% GMPP (Bread 4) exhibited significantly lower scores across all evaluated parameters. The taste and odor were rated as less desirable, and the crumb texture became notably coarse and less cohesive. Crust color darkened and shape uniformity was reduced, contributing to lower scores in appearance and roundness. These changes are likely attributed to the high dietary fiber, ash, and phenolic content in GMPP, which can interfere with gluten network formation, gas retention, and Maillard reactions during baking. High substitution levels may also intensify non-familiar flavors, affecting consumer acceptance.

Despite the functional benefits of GMPP, such as increased antioxidant activity and fiber enrichment, its incorporation at high levels (>10%) negatively impacted key sensory traits. These findings are in line with previous studies that explored the sensory effects of fruit and vegetable by-product powders in bakery products. For example, Badr (2015) reported similar sensory challenges in bread enriched with watermelon rind powder, where acceptable quality was maintained up to a 10–12% inclusion level.

In conclusion, while higher GMPP levels enhance the nutritional profile of Balady bread, they also introduce sensory challenges that may limit consumer acceptability. Based on the panelists’ feedback and statistical analysis, the optimal inclusion range for GMPP in Balady bread appears to be between 5–10%, which offers a balance between nutritional enhancement and acceptable sensory quality.

Table (5): Sensory evaluation of balady bread prepared from WF substituting by proportions of GMPP.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Taste  (20) | Odor  (20) | Crust color  (10) | Crumb texture  (20) | Rounder shape  (10) | Appearance  (20) | Overall score | Grade |
| Control | 18.80±1.03a | 18.80±1.03a | 9.10±0.74a | 18.50±0.85a | 9.50±0.71a | 18.80±0.79a | 93.5 | V.G |
| Bread 1 | 17.90±1.10ab | 18.40±0.97a | 8.90±0.57a | 17.50±0.85ab | 9.20±0.79a | 18.40±0.84a | 90.3 | V.G |
| Bread 2 | 16.90±1.10ab | 17.10±1.20ab | 8.50±0.70ab | 16.90±0.99ab | 8.50±0.97ab | 17.70±0.82ab | 85.6 | G |
| Bread 3 | 16.20±1.62bc | 16.00±1.15b | 7.40±0.70bc | 16.00±1.33bc | 7.40±0.70bc | 16.30±1.16bc | 79.3 | S |
| Bread 4 | 15.80±1.82c | 15.60±1.43b | 6.30±0.95c | 15.00±1.41c | 6.30±0.48c | 15.30±0.95c | 74.3 | S |

Means ± standard deviations with different superscript letters in the same column indicate significant differences at (*P ≤ 0.01*). Control= (100% WF 82% extraction), Bread 1= (95% WF +5% GMPP), Bread 2= (90% WF +10% GMPP) , Bread 3=(85% WF +15% GMPP), Bread 4= (80% WF +20% GMPP).

**Chemical Composition of Balady Bread Supplemented with Gurma Melon Peel Powder (GMPP)**

The proximate composition of Balady bread samples prepared with 0% (control), 5%, and 10% substitution of wheat flour (W.F) with Gurma melon peel powder (GMPP) is shown in Table 6. The data reflect significant (p < 0.05) changes in all measured parameters, demonstrating the nutritional impact of GMPP incorporation into bread formulations.

Moisture content exhibited a clear declining trend with increasing GMPP levels. The control bread recorded the highest moisture value (8.64%), while the 10% GMPP bread showed the lowest (6.00%). This reduction in moisture may be attributed to the higher fiber and dry matter content in GMPP, which decreases water retention capacity in the dough matrix and results in a firmer, drier crumb structure. From a technological perspective, this drier texture may influence consumer mouthfeel and shorten product shelf life unless compensated by hydration adjustments during baking.

Protein content also decreased proportionally with higher GMPP inclusion, dropping from 11.19% in the control to 8.56% in the 10% GMPP bread. This is expected due to the lower protein content in GMPP compared to W.F and the lack of gluten-forming proteins in fruit peels. As a result, the dilution of wheat protein may weaken dough elasticity and reduce gas retention during fermentation, impacting volume and structure. This aligns with the sensory findings of reduced crumb quality at higher GMPP levels.

On the other hand, ether extract (fat content) increased from 1.54% in the control to 1.99% in the 10% GMPP bread. The rise in fat content reflects the inherent lipid fraction in GMPP, which may enhance energy density and mouthfeel. However, it also necessitates monitoring for oxidative stability and potential flavor changes during storage.

A notable increase in ash content was observed, rising from 1.32% in the control to 3.35% in the 10% GMPP bread. This indicates higher total mineral content in GMPP-enriched formulations, consistent with the earlier findings on GMPP’s high ash and mineral levels. Such enrichment can improve the micronutrient value of bread, particularly in terms of calcium and potassium, and supports the use of GMPP as a functional ingredient for mineral fortification.

Crude fiber content showed the most prominent enhancement, increasing from 1.76% in the control to 4.86% in the bread containing 10% GMPP. This significant improvement highlights GMPP’s value in addressing dietary fiber deficiencies common in refined wheat products. Increased fiber intake is associated with various health benefits, including improved digestive health, enhanced satiety, and reduced risk of chronic diseases such as type 2 diabetes and cardiovascular disorders.

Conversely, available carbohydrate content slightly decreased from 84.19% in the control to 81.24% in the 10% GMPP bread. This reduction reflects the substitution of starch-rich wheat flour with fibrous, lower-carb GMPP. From a nutritional standpoint, this decrease may be favorable for calorie-conscious consumers or those managing glycemic responses.

Overall, the incorporation of GMPP into Balady bread results in a more nutrient-dense product with enhanced dietary fiber, fat, and mineral content, albeit with reductions in protein and moisture. These changes underscore the dual challenge and opportunity presented by functional ingredient incorporation: while nutritional quality improves, adjustments to processing conditions or consumer acceptance strategies may be needed to maintain palatability and textural quality. The results support the potential of GMPP as a sustainable and health-enhancing wheat flour substitute when used at moderate substitution levels (5–10%).

Table (6): Chemical composition of balady bread prepared from WF and GMPP:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Moisture | Protein | Ether extract | Ash | Fiber | Available carbohydrate |
| Control | 8.64±0.63a | 11.19±0.41a | 1.54±0.08c | 1.32±0.05c | 1.76±0.11c | 84.19±0.87a |
| Bread 1 | 7.39±0.36b | 9.98±0.22b | 1.80±0.10b | 2.15±0.08b | 3.16±0.12b | 82.91±0.25b |
| Bread 2 | 6.00±0.25c | 8.56±0.58c | 1.99±0.05a | 3.35±0.14a | 4.86±0.32a | 81.24±1.09c |

Means ± standard deviations with different superscript letters in the same column indicate significant differences at (*P ≤ 0.01*)

**Mineral Content of Balady Bread Supplemented with Gurma Melon Peel Powder (GMPP)**

The mineral composition of Balady bread samples prepared with 0%, 5%, and 10% substitution of wheat flour (W.F) by Gurma melon peel powder (GMPP) is shown in Table 7. The results demonstrate significant and consistent trends in mineral content as a function of GMPP inclusion level, reflecting the distinct mineral profile of the two raw materials.

A noticeable increase in calcium (Ca) and potassium (K) concentrations was observed with increasing GMPP substitution. Specifically, calcium content increased from 18.81 mg/100 g in the control to 24.63 mg/100 g in the 10% GMPP bread, while potassium rose substantially from 16.20 to 48.82 mg/100 g. These enhancements can be attributed to the naturally high levels of these minerals in GMPP, as previously confirmed in its proximate and mineral analysis (Section 3.2). Calcium plays a pivotal role in bone health, muscle contraction, and nerve function, whereas potassium is essential for fluid balance and cardiovascular regulation. The enrichment of these minerals through GMPP inclusion highlights its potential as a functional fortifier in bakery formulations, particularly in regions where micronutrient deficiencies are prevalent.

Sodium (Na) levels also showed a slight but consistent increase, rising from 5.30 mg/100 g in the control to 6.95 mg/100 g in the 10% GMPP bread. Although GMPP naturally contains more sodium than W.F, the levels detected in the bread remain within acceptable dietary ranges. However, sodium intake should be considered carefully when formulating for hypertensive or salt-sensitive populations.

In contrast, the concentrations of magnesium (Mg), phosphorus (P), manganese (Mn), zinc (Zn), and iron (Fe) declined gradually with higher GMPP substitution. For example, magnesium dropped from 158 mg/100 g in the control to 146.06 mg/100 g in the 10% GMPP bread. Phosphorus decreased from 183.00 to 177.73 mg/100 g, while zinc and iron declined from 4.30 to 3.89 mg/100 g and from 2.30 to 2.23 mg/100 g, respectively. This downward trend is likely due to the dilution effect resulting from the replacement of mineral-rich wheat flour with GMPP, which contains comparatively lower levels of these specific micronutrients.

Despite the slight reductions in some minerals, the overall mineral profile of the GMPP-enriched bread is more diverse, with notable enhancements in calcium and potassium that could offer specific health advantages. From a formulation perspective, this shift may be beneficial for targeting certain dietary needs, such as bone health, electrolyte replenishment, or mineral diversity, even if magnesium and zinc are modestly reduced. Fortification strategies using complementary ingredients or mineral premixes could be considered if balancing specific mineral targets is required.

The trends observed in this study are consistent with earlier reports on mineral variation in composite flours. Previous studies, such as those by Badr (2015) and Salama et al. (2019), have similarly noted that blending fruit or vegetable by-products with cereal-based flours often leads to selective mineral enrichment, particularly with potassium and calcium, which tend to be more abundant in plant rinds and peels.

In summary, the incorporation of GMPP into Balady bread significantly alters its mineral composition. While calcium, potassium, and sodium are enhanced—offering potential health benefits—minor reductions in magnesium, phosphorus, iron, and zinc suggest that balanced formulation is essential. Nevertheless, the mineral diversity contributed by GMPP supports its value as a functional ingredient for nutrient-enhanced bakery applications.

Table (7) Minerals content of balady bread prepared from WF and GMPP (mg/100g).

|  |  |  |  |
| --- | --- | --- | --- |
| Minerals  (mg/100g) | Control | Bread 1 | Bread 2 |
| Ca | 18.8 | 22.12 | 24.63 |
| Mg | 158 | 150.30 | 146.06 |
| Na | 5.30 | 6.14 | 6.95 |
| K | 16.20 | 30.21 | 48.82 |
| P | 183.00 | 178.89 | 177.73 |
| Mn | 1.97 | 1.91 | 1.86 |
| Zn | 4.30 | 4.10 | 3.89 |
| Fe | 2.30 | 2.29 | 2.23 |

**Total Phenolic Content, Total Flavonoids, and Antioxidant Activity (DPPH) of Balady Bread Supplemented with Gurma Melon Peel Powder (GMPP)**

The bioactive compound content and antioxidant capacity of Balady bread samples formulated with 0% (control), 5%, and 10% Gurma melon peel powder (GMPP) are presented in Table 8. The results indicate a clear dose-dependent enhancement in total phenolic content (TPC), total flavonoid content (TFC), and antioxidant activity as GMPP inclusion increased.

Bread made with 10% GMPP substitution (Bread 2) exhibited the highest values across all three parameters: 0.13 ± 0.01 mg gallic acid equivalents (GAE)/g for TPC, 0.09 ± 0.01 mg rutin equivalents (RE)/g for TFC, and 20.74 ± 0.41% DPPH scavenging activity. These values were significantly higher (p < 0.05) than those of both the control (0.05 ± 0.00 mg GAE/g, 0.04 ± 0.01 mg RE/g, and 12.62 ± 0.27%) and the 5% GMPP bread (0.09 ± 0.01 mg GAE/g, 0.07 ± 0.00 mg RE/g, and 17.83 ± 0.52%).

The progressive improvement in antioxidant capacity with increasing GMPP levels can be attributed to the naturally high phenolic and flavonoid content of the melon peel. These phytochemicals are known to exhibit strong radical-scavenging properties and play a protective role against oxidative stress, which is implicated in the pathogenesis of chronic diseases such as cardiovascular disorders, diabetes, and cancer.

The findings are consistent with previous studies on the incorporation of fruit and vegetable by-products in baked products. Badr (2015) reported that pan bread enriched with watermelon rind powder (WRP) exhibited significantly increased phenolic content and antioxidant activity, particularly at substitution levels up to 12%. Similar results were reported by Lau et al. (2021) and Sharma et al. (2022), who observed that the inclusion of fruit peels and agricultural waste materials in baked goods effectively enhanced their functional properties, especially antioxidant potential.

Furthermore, the enhanced antioxidant activity observed in GMPP-enriched breads may also be influenced by thermal processing. According to Dewanto et al. (2002), heat treatment of plant-based ingredients can break down cellular matrices and release bound phenolic compounds, thereby improving extractability and bioavailability. In this study, the baking process likely contributed to this effect, enabling greater expression of antioxidant activity in the final product.

These results also support the findings of Balasundram et al. (2006), who emphasized that agri-food waste, especially fruit peels, is an underutilized source of bioactive compounds. Their inclusion in food formulations not only improves functional quality but also promotes sustainability by reducing food waste and enhancing nutritional value.

In summary, the incorporation of GMPP into Balady bread significantly improved the functional quality of the final product, especially in terms of antioxidant capacity. The enhanced levels of phenolic and flavonoid compounds in GMPP-enriched bread highlight its potential as a functional ingredient for developing health-promoting baked goods. However, optimization of substitution levels is essential to balance sensory acceptability and biofunctional enhancement.

**Table (8): Total phenolic, total flavonoid contents and antioxidant activity (DPPH)% of balady bread prepared from WF and GMPP**:

|  |  |  |  |
| --- | --- | --- | --- |
| Sample | Total phenolic compounds (mg GAE/g sample) | Total flavonoid compounds (mg RE/g sample) | Antioxidant activity (DPPH %) |
| Control | 0.05±0.00c | 0.04±0.01c | 12.62±0.27c |
| Bread 1 | 0.09±0.01b | 0.07±0.00b | 17.83±0.52b |
| Bread 2 | 0.13±0.01a | 0.09±0.01a | 20.74±0.41a |

Means ± standard deviations with different superscript letters in the same column indicate significant differences at (*P ≤ 0.01*)

**Conclusion:**

The study successfully demonstrated that GMPP could be incorporated into bread formulations to enhance nutritional and functional properties. Substitution of W.F with 5% and 10% GMPP resulted in bread with increased dietary fiber, fat, ash, and certain essential minerals, notably calcium, sodium, and potassium. The increase in nutritional constituents like fiber and minerals suggests a beneficial trade-off for health-conscious consumers. Furthermore, the incorporation of GMPP significantly elevated the concentrations of total phenolics, flavonoids, and antioxidant activities in the bread, underscoring GMRP's potential as a valuable source of natural antioxidants for improving dietary health benefits. Also, the substitution of W.F by GMPP will help to reduce the gob between wheat production and consumption.

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