**Influence of Gurma Melon Peel Powder Supplementation on the Chemical Composition and Sensory Attributes of Balady Bread**

**Abstract:**

This study examined the impact of partially substituting wheat flour (Triticum aestivum) with Gurma melon peel powder (GMPP) derived from Citrullus lanatus var. colocynthoides on the nutritional composition and sensory characteristics of Balady bread. Four bread formulations were developed, incorporating GMPP at substitution levels of 5%, 10%, 15%, and 20%, while a control sample was prepared using 100% wheat flour extraction (82% extraction rate). Analytical results revealed that GMPP contained significantly higher levels of protein, fat, ash, crude fiber, calcium, sodium, potassium, total phenolics, total flavonoids, and antioxidant activity compared to wheat flour. Conversely, wheat flour exhibited higher carbohydrate and amino acid content. Sensory evaluation by a trained panel indicated that the control sample (0% GMPP) received the highest acceptability scores, followed by bread containing lower substitution levels. Based on these results, the formulations containing 0%, 5%, and 10% GMPP were selected for further detailed analysis. As the level of GMPP substitution increased, the bread’s moisture, protein, and carbohydrate contents showed a decreasing trend, while fat, ash, and crude fiber contents increased. Additionally, the contents of calcium, sodium, and potassium rose with higher GMPP levels, whereas magnesium, manganese, phosphorus, zinc, and iron declined. The enhancement of bioactive compounds, including total phenolics, flavonoids, and antioxidant activity, was also observed with increasing GMPP incorporation.

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

**Introduction**

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, Tanta, Egypt. Dry yeast and salt (sodium chloride) were obtained from the local market in Kafr El-sheikh governorate, Egypt. Gurma melon peels was obtained from local farm in Kafr El-sheikh, Egypt. All the chemicals used in this study were obtained from EL-Gomhouria pharmaceutical company, of Tanta City, Egypt. All chemicals were in analytical grade.

**Methods:**

**Preparation of GMPP:**

Gurma melon peels were separated from the washed fresh fruits and cut into small pieces by a sharp knife for water removing by spread in trays of air oven, and dried at 45±5°C, then. Dried Gurma melon peels were finely milled using grinder mill and sieved through a 60-mesh sieve to obtain peels powder and stored in an air tight container until used.

**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 (Table 1)

Table (1): The blends used for balady bread preparation:

|  |  |  |
| --- | --- | --- |
| Treatments | (WF)  (%) | (GMPP)  (%) |
| Control (1) | 100 | 0 |
| Bread (2) | 95 | 5 |
| Bread (3) | 90 | 10 |
| Bread (4) | 85 | 15 |
| Bread (5) | 80 | 20 |

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 and stored in an incubator at 25°C for subsequent analysis (Mahdy and Abo El-Nagaa, 2018).

**Sensory Evaluation of balady bread:**

Sensory evaluation of Balady bread was conducted by twenty panelists from the staff of the Food Technology Research Institute in Sakha, Kafr El Sheikh, Egypt, following the method outlined by **Hegazy and Faheid (1990)**. The bread was assessed based on a scoring system: 20 points for taste, odor, crumb texture, and overall appearance, and 10 points for both crust color and shape. The mean overall score was then classified into descriptive categories: 90–100 points indicated "very good," 80–89 points "good," 70–79 points "satisfactory," and scores below 70 were considered "questionable."

**Chemical Composition:**

Moisture, ash, crude protein, fiber and fat were determined according to **AOAC (2015).** Carbohydrates were calculated by difference as follows: available carbohydrates = [100 - (%fat - %proteins - % fiber - %ash)].

**Minerals content:**

The concentrations of iron, zinc, calcium, magnesium, and manganese in the samples were measured using an Atomic Absorption Spectrophotometer (Model 3300, Perkin Elmer, England) as described by **Lanyon and Heald (1982)**. Total phosphorus was determined using the ascorbic acid method, following the colorimetric procedure outlined by **Murphy and Riley (1962)**. The potassium and sodium levels in the samples were quantified with a flame photometer, according to the method outlined by **Pearson (1976)**.

**Total Phenolic Compounds (TPC):**

TPC was evaluated using the method of Folin-Ciocalteu, following the procedure outlined **(Attard, 2013)** with certain modifications. In summary, 1 g of sample was put in 10 mL of 70% ethanol for 30 min in sonication. 10 µL of the sample or standard was mixed with 100 µL of diluted Folin-Ciocalteu reagent (1:10 dilution). Subsequently, 80 µL of 1M Na2CO3 was added, and the mixture was incubated for 20 minutes at room temperature in the dark. At the conclusion of the incubation period, the resultant complex, displaying a blue color, was quantified at a wavelength of 760 nm. The obtained data are expressed as means ± 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:**

In summary, a 0.1 g sample was hydrolyzed by adding 10 mL of 6N hydrochloric acid containing 0.1% mercaptoethanol in an evacuated tube, then heated at 110 °C for 24 hours. After cooling to room temperature, the hydrolyzed mixture was filtered through Whatman No. 1 filter paper. The filtrate was diluted with distilled water to a final volume of 25 mL. Next, 5 mL of the diluted filtrate was dried in a vacuum desiccator with potassium hydroxide. The resulting residue was dissolved in 1 mL of sodium citrate buffer (pH 2.2) and stored at 4 °C until analysis using an amino acid analyzer (Beckman Model 119CI) **(Duranti and Cerletti, 1979)**.

**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 (W.F) and (GMPP):**

Table 2 shows the chemical composition of wheat flour (W.F) and GMPP. W.F has higher moisture (11.50% vs. 9.48%) and protein content (11.22% vs. 8.09%), making it ideal for baking that requires gluten development. GMPP, on the other hand, has higher fat (3.65% vs. 1.51%), ash (14.06% vs. 1.25%), and fiber (16.47% vs. 1.41%), offering more nutritional value, especially in minerals and dietary fiber. However, GMPP has lower carbohydrate content (57.73% vs. 84.61%), making it less energy-dense and more suitable for low-carb diets.

Chemical composition of WF was near to the results obtained by **Salama *et al.* (2019)** and **Malavi *et al.* (2022).** Chemical composition of water melon peels powder showed lower amount of protein (6.705), fat (0.64%) and ash (9.42%) and higher amount of fiber (18.54%) in comparison with GMPP **(Hind, 2017)**. Near chemical composition of water melon rind were reported by **Badr (2015)**. **Al-Sayed and Ahmed (2013)** reported the composition of watermelon rind in dry weight basis for ash, fat, protein and carbohydrates were 13.09, 2.44, 11.17 and 56.00%, respectively.

Table (2): 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.

**Minerals content of WF and GMPP:**

Table (3) shows the mineral content of both WF82%extract and GMPP and the comparison between WF and GMPP showed significant differences. GMPP had higher levels of potassium (356.93 mg/100g) and calcium (80.63 mg/100g) compared to WF (16.8 and 19.3 mg/100g, respectively). However, WF contained more phosphorus (185 mg/100g) and magnesium (160 mg/100g) than GMPP (131 and 40.44 mg/100g, respectively). Additionally, WF had higher zinc and iron content than GMPP. Overall, GMPP may be a better source of potassium, calcium, and sodium, while WF offers more phosphorus, magnesium, zinc, and iron.

Table (3): 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 |

For W.F mineral content, similar values were mentioned by **El-Gammal, *et al*., (2016)** while lower content was reported by **Sharoba *et al.,* (2009**). Water melon rind contained higher amount of potassium (447.33 mg/100g), while lower amount was reported for Mg and Fe which were about 34.90 and 0.61 mg/100g, respectively in comparison with Gurma melon (**Hind, 2017)**. Ca, Mg, K and P (10.10, 13.20, 127.30 and 14.70 mg/100g content) of Gurma melon pulp were lower in comparison with Gurma melon rind (**Salama *et al*., 2019)**.

**Amino acids composition of WF and GMPP (g/100g protein).**

The amino acid composition of wheat flour (WF) and gurma melon peel powder (GMPP) highlights significant differences in their nutritional profiles. WF has a higher content of essential amino acids (27.30 g/100g protein) compared to GMPP (19.34 g/100g protein), particularly lysine, leucine, and aromatic amino acids, meeting or exceeding FAO/WHO (1973) requirements for most essential amino acids. GMPP, while lower in overall amino acid content, contains notable levels of isoleucine, phenylalanine, and arginine, which can contribute to metabolic and immune health. Both WF and GMPP are deficient in sulfur-containing amino acids (methionine + cysteine), emphasizing the need for protein complementation in formulations. GMPP's lower non-essential amino acid levels, particularly glutamic acid and proline, make it less functional for structural protein roles compared to WF. However, as a by-product, GMPP offers sustainable potential for dietary protein diversification when blended with other protein sources, aligning with findings in similar studies on fruit by-products (e.g., mango kernel and citrus peel powders) **(Hussain et al.,** 2024; **Shyu et al.,** 2014).

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

Table (5) shows the content of total phenolics, total flavonoids and antioxidant activity (DPPH) in both WF and GMPP. The results in Table (5) show that GMPP has significantly higher levels of total phenolic content, total flavonoid content, and antioxidant activity (DPPH) compared to W.F and GMPP contained almost double the total phenolic content (1.062±0.03 mg GAE/g) and a much higher flavonoid content (0.929±0.15 mg RE/g) than W.F. (0.55±0.02 mg GAE/g and 0.15±0.00 mg RE/g). Additionally, GMPP demonstrated significantly higher antioxidant activity (77.83±1.53%) compared to W.F. (30.35±0.84%). These findings suggest that GMPP is a superior natural source of antioxidants, likely due to its higher phenolic and flavonoid contents.

Table (5): **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.

**Neglo *et al*., (2021)** reported lower total phenolic compounds content and antioxidant activity (DPPH) of watermelon peels (0.087 mg GAE/g and 55.75%, respectively) compared to our results, while in contrast, **(Dieng *et al*., 2017)** reported higher total phenolic and flavonoid content of watermelon peels.

**Sensory evaluation of balady bread prepared from WF** **substituting by proportions of GMPP.**

The data shown in Table (6) showed the sensory evaluation of balady bread made with varying proportions of GMPP (5% to 20%) and revealed that increasing GMPP content led to a decrease in sensory attributes such as taste, odor, crust, crumb, rounder, and appearance. The control sample made from 100% wheat flour (W.F.) had the highest scores across all parameters. As GMPP increased, sensory scores declined, with notable decreases in attributes like taste, odor, and crumb texture. The crust, rounder, and appearance were significantly affected when GMPP exceeded 15%. At 5% GMPP substitution, the bread retained most of its desirable qualities, while at 10%, there was a noticeable decline, but the bread remained somewhat good. These findings suggest that GMPP can be included in bread formulations at controlled levels (5-10%) to balance health benefits with sensory quality.

Table (6): 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 prepared from WF and GMPP.**

The results presented in Table (7) compare the nutritional composition of control balady bread with bread formulations incorporating 5% and 10% GMPP as a substitution for (W.F). A noticeable trend is observed in the moisture content, which decreases from 8.64% in the control to 6.00% in the bread with 10% GMPP substitution, indicating a drier texture in the GMPP-enriched breads. Protein content also decreases with increasing GMPP substitution, from 11.19% in the control to 8.56% in the bread with 10% GMPP, which could affect the nutritional value and bread structure. Conversely, there is an increase in ether extract (fat content) and ash (mineral content) with more GMPP, which could imply a higher nutritional value in terms of minerals and energy but could also impact flavor and shelf life. The fiber content significantly increases with GMPP, from 1.76% in the control to 4.86% in the bread with 10% GMPP, suggesting a potential health benefit. These changes indicate that GMPP incorporation affects the nutritional profile and possibly the texture and taste of the bread, which could be beneficial from a health perspective but might require consumer adaptation to the altered sensory properties.

Table (7): 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*)

**Minerals content of balady bread prepared from WF and GMPP.**

Table (8), the mineral content in balady bread produced from blends of W.F and GMPP showed distinct trends based on the proportion of GMPP used (Table 8). As the percentage of GMPP in the bread increased from 0% (control) to 10%, there was a noticeable increase in calcium (Ca) and potassium (K) levels, from 18.81 and 16.2 mg/100g to 24.63 and 48.82 mg/100g, respectively. Sodium (Na) levels also increased with more GMPP, from 5.3 mg/100g in control to 6.95 mg/100g in bread made with 10% GMPP. Conversely, magnesium (Mg), phosphorus (P), manganese (Mn), zinc (Zn), and iron (Fe) levels decreased as the proportion of GMPP increased. For instance, (Mg) decreased from 158 mg/100g in the control to 146.06 mg/100g in the 10% gurma melon blend, and Zn decreased from 4.3 to 3.89 mg/100g. These results suggested that incorporating GMPP into W.F bread altered the mineral profile, enhancing certain minerals.

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

The results in Table (9) indicated that incorporation of GMPP into bread formulations (5% and 10%) resulted in dose-dependent improvements in bioactive compound content and antioxidant activity, with Bread 2 (10% GMPP) showing the highest phenolic (0.13 mg GAE/g), flavonoid (0.09 mg RE/g), and antioxidant activity (20.74%) among the bread samples.

**Table (9): 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*)

These findings align with **Badr (2015)**, who enriched pan bread with watermelon rind powder (WRP). WRP similarly improved antioxidant properties, with increasing substitution levels (up to 12%) boosting DPPH activity and phenolic content. Likewise, **Lau et al. (2021)** and **Sharma *et al.* (2022)** demonstrated that fruit and vegetable by-products, such as peels, significantly enhance antioxidant and bioactive compound content in baked goods due to their high levels of phenolic and flavonoid compounds. Additionally, **Dewanto *et al.* (2002)** observed that thermal processing of plant-based ingredients further enhances antioxidant activity by releasing bound phenolic compounds. This effect likely contributed to the increased activity in GMPP-enriched breads. The findings also resonate with **Balasundram *et al.* (2006)**, who reported that agri-food by-products are excellent sources of antioxidants and bioactive compounds, improving the functional properties of food matrices. These comparisons highlight the potential of GMPP as a functional ingredient for health-promoting food products.

**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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