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Nutritional Fortification of Makhrouta Using Pea and Beet Peels Powder: Reviving Heritage with Enhanced Health Benefits

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ABSTRACT

Makhrouta is a traditional dish widely consumed in several Egyptian governorates. It is eaten in a manner similar to vermicelli and is commonly prepared from 100% wheat flour, which makes it low in essential nutrients. It is usually served with sauce, soup, or sugar. The present study aims to fortify Makhrouta with pea and beet peels powder, due to their richness in minerals, dietary fibers, flavonoids, phenolic compounds, and natural antioxidants. Moreover, these peels are valuable sources of natural pigments, such as chlorophyll and betalains, which not only enhance the nutritional value but also contribute natural coloring to Makhrouta. A chemical analysis was conducted to evaluate the nutritional and functional properties of the fortified product. Partial substitution of wheat flour with pea and beet peels powder at levels of 5 and 10%, respectively produced the best samples in terms of nutritional improvement, antioxidant activity, sensory acceptance, and texture attribute. In contrast, the higher substitution level of 15% led to lower sensory scores and less desirable texture properties. These findings suggested that incorporating pea and beet peels at moderate substitution levels (5-10%) can enhance the nutritional and functional value of Makhrouta while maintaining sensory acceptability, thus offering a functional food that preserves cultural heritage and provides improved health benefits.

1. Introduction

Pea peels powder derived from the outer husk of (*Pisum sativum*), is an abundant source of plant based proteins, phenolic compounds, and essential micronutrients such as calcium, potassium, magnesium, and iron, and dietary fibers. These components not only improve nutritional quality but also provide antioxidant and prebiotic properties, supporting digestive and metabolic health (Rani and Bains, 2018; Hussain et al., 2021). Its application in cereal-based products such as noodles and pasta has been shown to enhance fibers content, improve textural quality and align with clean-label food trends (Yadav et al., 2020; Singh et al., 2022). On the other hand, beetroot peels powder (BPP), obtained from the processing waste of (*Beta vulgaris*), is gaining recognition for its high content of Betalains, phenolic compounds, dietary fibers, and essential minerals such as iron and magnesium. These bio actives contribute strong antioxidant, anti-inflammatory, and color enhancing properties, Incorporating BPP into pasta and noodle products has been reported to improve not only fiber and antioxidant activity but also visual appeal, owing to its natural pigmentation (Mahmoud et al., 2018; Aprodu et al., 2021). Fortification with agro industrial by-products such as pea peels powder (PPP) and beetroot peels powder (BPP) has shown promising results in increasing fibers, protein, antioxidant activity and minerals contents in noodles, while maintaining acceptable texture and sensory properties (Mahmoud et al., 2018; Yadav et al., 2020). This aligns with global efforts to reduce food waste, improve public health, and develop value added food products that support sustainable nutrition. Noodles are a rich source of carbohydrates and energy but Are generally low in, proteins, vitamins,

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essential minerals and dietary fibers (Hou, 2010). Despite their widespread consumption, nutritional limitations and health concerns have been raised regarding the regular intake of conventional noodles. Refined flour-based noodles tend to have a high glycemic index, which may contribute to weight gain, insulin resistance, and increased risk of type 2 diabetes when consumed frequently (Fardet, 2016). In addition, the common use of preservatives, and excess sodium in instant noodles has been linked to potential health risks such as hypertension and metabolic syndrome, particularly especially among children and adolescents (Aprodu et al., 2021). Makhrouta is a traditional steamed and dried product native to some regions of Egypt, typically handmade from wheat flour and water. On an industrial scale, it is considered a type of pasta product that can serve as a substitute for instant noodles, cornflakes, and ready-to-eat breakfast cereals. The present study aimed to produce and evaluate Makhrouta using Egyptian wheat flour (72% extraction) partially substituted with pea peel powder (*Pisum sativum*) or beetroot peel powder (*Beta vulgaris*) at three levels (5, 10, and 15%). The effects of these substitutions on flour mixing characteristics, nutritional composition, product quality, and sensory properties were investigated using a controlled experimental design that included a control group (100% semolina flour) and the fortified formulations.

2. Materials and Methods

Wheat flour (*Triticum aestivum*, 72% extraction) and salt were purchased from local markets in Giza, Egypt. Fresh pea (*Pisum sativum*) and fresh beet roots (*Beta vulgaris*) were obtained from local markets in Giza. All chemicals used were purchased from El Gomhoria Company, (Giza, Egypt) and Sigma-Aldrich (USA).

Preparation of raw materials

Primary ingredient: High-quality semolina flour (*Triticum durum)* was used as the base for all formulations.

Vegetable peels powder: Fresh pea peels and beetroot peels were thoroughly washed, dried in a controlled environment at 50°C, and ground using a laboratory-scale grinder to obtain fine powders. The powders were standardized by sieving to achieve a uniform particle size.

Water: potable water was used for dough hydration, and salt was added according to the formulation.

Makhrouta dough preparation

Three Dough Formulations were Prepared as follows:

Control sample: 100% semolina flour.

Pea peels powder formulation (PPP): Semolina flour was substituted with pea peel powder at three levels: 5% (P5), 10% (P10), and 15% (P15) on weight basis.

Beetroot peel powder formulations (BPP): Semolina flour was substituted with beetroot peel powder at three levels: 5% (B5), 10% (B10), and 15% (B15) on weight basis.

For each formulation, the dry ingredients were thoroughly mixed to ensure homogeneity.

Table 1. Formula of Different Makhrouta Blends (g/100g)

Ingredients \ Blends	Control sample	T1	T2	T3	T4	T5	T6
Wheat flour	99	94	89	84	94	89	84
Pea peels powder	---	5	10	15	--	---	---
Beet peels powder	---	---	----	---	5	10	15
Salt	1	1	1	1	1	1	1
Total	100	100	100	100	100	100	100

Dough preparation and forming of Makhrouta

The dry ingredients (1 kg) were first mixed thoroughly. Water (500–550ml/kilogram of flour) was gradually added to obtain a suitable dough texture. The dough was allowed to rest for 5 minutes before being portioned into smaller pieces. These pieces were then rolled using a pasta machine (Model Lillodue, Bottene, Marano Vicentino, Italy). An additional 10-15g of flour was sprinkled as needed to prevent sticking.

Forming and cutting

The dough was extruded through a stainless-steel die (0.22cm diameter) and cut into 25 cm lengths, following the method described by Rocchetti et al. (2020). Six samples were prepared: T0 (control), T1, T2, T3, T4, T5, and T6. For each formulation, six batches were produced.

Drying and steaming

The samples were dried in an oven at 50–60°C for 3 hours. Steaming was then performed using a couscoussière: samples were placed in the upper section, while the lower section contained approximately 1.5L of boiling water. The junction between the two sections was sealed with a damp cloth to ensure proper steam passage. Steaming continued for 10 minutes, after which the Makhrouta samples were transferred to dishes.

Cooking and evaluation

Cooked Makhrouta samples from each formulation were mixed with a standardized tomato-based sauce (recipe briefly described or referenced) and evaluated for sauce adhesion, structural integrity, and visual appearance.

Analytical methods

Chemical analysis

- The moisture, ash, protein, crude fibers, fat contents and Mineral elements were detected using an Atomic Absorption Spectrometer (Perkin-Elmer, Model 3300, USA) of raw materials and Makhrouta samples were determined according to the methods of the AOAC (2023) methods. - Total carbohydrates content was calculated by difference.
- The total phenols content (TPC) was determined using the Folin–Ciocalteu method (Singleton et al. 1999). Total flavonoids content (TF) was measured according to Zhuang et al. (1992).
- Antioxidants activity was assessed using the DPPH (2,2 diphenyl-1-picrylhydrazyl) radical-scavenging assay, following the procedure of Mansouri et al. (2005).
- Total chlorophylls content was determined according to Lichtenthaler and wellburn (1983).
- Betalain content was measured using a spectrophotometric analysis described by Grützner et al. (2021)

Texture profile analysis

The texture of dried instant Makhrouta samples was evaluated using a universal testing machine (Cometech, B variety, Taiwan). Samples were placed on a three-point support with a punch diameter of 5.3 mm and a distance of 15mm between supports. A punch test was performed at a crosshead speed of 60 mm/min. The force deformation curve was recorded using computer software, and the maximum breaking force and deformation were determined. The probe speed was set at 1mm/s, following Bourne (2002). Hardness values were expressed in Newtons (N).

Deamination color parameters

The external color of the grains, as well as dry uncooked and steamed Makhrouta samples, was measured using a hand-held chromameter (Model CR -400, Konica Minolta, Japan). following the guidelines of Francis (1983).

Water activity (aw)

Water activity (aw) was measured at 25±2°C using a Decagon Aqualab meter series 3TE (Pullman, WA, USA). Samples were broken into small pieces prior to analysis to ensure accuracy as described by Shahidi et al. (2008).

Sensory evaluation

Sensory attributes (color, odor, flavor, mouth feel, after taste, and overall palatability) were evaluated by more than ten panelists' (chosen randomly) at Food Technology. Res. Inst. Each panelist received approximately 50 g of the six Makhrouta formulations according to the method of Bashir et al. (2012).

Statistical analysis

Data were analyzed using analysis of variance (ANOVA) according to the method of (Steel et al., 1997). All results were expressed as means ± standard deviation (SD).

3. Results and Discussion

Chemical composition of makhrouta raw materials

The data presented in Table 2 show that significant variations in the chemical composition of wheat flour, pea and beet peels powder, which influence their potential applications in food formulations. Wheat flour exhibited the highest moisture content (14.72%), followed by beet peel powder (9.03%) and pea peel powder (6.41%). According to (Al-Sayed and Ahmed, 2013) low moisture in peel powder enhances shelf-life and microbial stability. Pea peels powder showed the highest protein content (16.12%), significantly surpassing wheat flour (12.58%) and beet peels powder (9.04%). Yadav et al. (2021) reported that incorporating pea peels powder into food products may improve protein quality, particularly in plant-based diets. The fat content was comparable in wheat flour (1.15%) and pea peels powder (1.24%), whereas beet peels powder contained significantly lower fat (0.61%). El-Sayed et al. (2020) highlighted that this characteristic is advantageous in designing low-fat functional foods. Beet peels powder had a remarkably high ash content (9.99%), indicating a higher concentration of total minerals comparing with pea peels powder (1.76%) and wheat flour (0.86%). Kavitha and Parimalavalli (2014) similarly reported that beet peels are rich in minerals and can serve as valuable dietary sources. Regarding crude fibers, pea peel powder contained the highest level (19.94%), followed by beet peels powder (7.45%), while wheat flour had minimal fiber (0.90%). Zhang et al. (2020) emphasized that the high fibers content in peel powders enhances their value in developing fiber-enriched products beneficial for gut health and glycemic control. Carbohydrates content of wheat flour had the highest value (69.79%) consistent with its role as a staple cereal product. In contrast, peels powder contained lower carbohydrate levels (54.53%) for pea and (63.88%) for beet due to their higher fibers and ash contents. Overall, both pea and beet peels powder demonstrate valuable nutritional properties, particularly high crude fibers and minerals contents. These findings support their potential use as functional ingredients in food product development, contributing simultaneously to waste valorization and nutritional enhancement. The biochemical composition of raw materials in Table 2 shows that significant variation in total phenols and flavonoids contents as well as antioxidant activity. Beet peels powder contained the highest levels of total phenols (1.55mg/g) and flavonoids (1.07mg/g), consistent with its rich pigmentation and antioxidant potential. Pea peels powder also exhibited higher total phenols content than wheat flour, which are in agreement with those findings of Kumar and Sharma (2021). Both pea and beet peels powder showed significantly higher antioxidant activity comparing with wheat flour. These results support previous reports by Ali and Rizvi (2020), who highlighted the potential of agro-industrial by products as natural antioxidants in food formulations.

Table 2. Chemical composition of Makhrouta raw materials (mean±SD)

Constituents % \ Raw materials	Wheat flour	Pea peels powder	Beet peels powder
Moisture content	14.72^{A}±0.01	6.41^{C}±0.02	9.03^{B}±0.03
Crude protein	12.58^{B}±0.02	16.12^{A}±0.04	9.04^{C}±0.03
Fat (Ether extract)	1.15^{A}±0.01	1.24^{A}±0.04	0.61^{B}±0.03
Ash	0.86^{C}±0.01	1.76^{B}±0.03	9.99^{A}±0.02
Crude fibres	0.90^{C}±0.01	19.94^{A}±1.04	7.45^{B}±0.06
**Total carbohydrates	69.79^{A}±0.02	54.53^{C}±0.99	63.88^{B}±0.01
Total phenols (mg/g) (as gallic acid equivalent)	0.46^{C}±0.01	1.29^{B}±0.05	1.55^{A}±0.03
Total flavonoids (mg/g) (as rutin equivalent)	0.01^{B}±0.00	0.04^{B}±0.02	1.07^{A}±0.03
Antioxidant activity by DPPH (%)	24.37^{C}±0.36	90.70^{A}±1.59	83.19^{B}±0.43

* On dry weight basis. ** Calculated by difference.
A, B & C: There is no significant difference (P>0.05) between any two means, within the same row has the same superscript letter.

The data presented in Table 3 shows that wheat flour contains significantly higher levels of potassium (K), phosphorus (P), and magnesium (Mg) compared to pea and beet peels powder. This is consistent with its widespread nutritional use in bakery products as a primary source of macronutrients and electrolytes (Kaur et al., 2020). Interestingly, pea peels powder exhibited the highest content of calcium (Ca) and sodium (Na) among the tested samples. The elevated calcium content (352.84mg/100g) highlights its potential as a functional ingredient to enrich calcium-deficient food products. Legume by-products, such as pea peels, are known to contain substantial levels of minerals due to their concentration in the seed coat and hull. These results in agreement with (Wang et al., 2021). On the other hand, beet peels powder showed the highest iron (Fe) content (26.46mg/100g), which may be attributed to its pigment-associated components and the presence of trace minerals in the outer tissues. This suggests a promising role in combating iron deficiency when incorporated into food products (Nayak et al., 2022). Overall, minerals play an essential role in human nutrition and are crucial for many metabolic processes. Incorporating such by products into food formulations offers a dual benefit of improving nutritional value and reducing agro-industrial waste (Ghosh et al., 2023).

Table 3. Minerals Content of Makhrouta Raw Materials

Element (mg/100g) \ Raw materials	Wheat flour	Pea peels powder	Beet peels Powder
K	815.7	71.48	23.48
Mg	66.33	122.47	8.31
Na	1.99	72.91	4.17
P	160	11.5	28.38
Ca	15.77	352.84	6.2
Fe	2.44	6.58	26.46

Chemical composition of makhrouta blends with pea and beet peels powder

The data presented in Table 4 shows that, a slight increase in moisture observed with higher beet peels powder levels (from 5.35% at 10% inclusion to 5.78% at 15%) can be attributed to the high content of hygroscopic polysaccharides and phenolic compounds in beet peels, which enhance water holding capacity in food matrices. Similar trends have been reported in beverage systems fortified with beetroot peels powder, where moisture retention improved by up to 12% compared to controls (Mendez et al., 2023; Ahmed Khan and Ali, 2024). In contrast incorporating pea peels powder markedly elevated crude protein from 12.33% at 5% inclusion to 15.23% at 15%. This reflects the residual legume proteins remaining after starch extraction and aligns with findings in bread fortification studies, where 10-15% pea peels addition produced a 20-25% of protein content (Wang and Zhang, 2021). Moreover, Johnson and Lee (2023) reported that, legume byproduct powders improved protein content and amino acids profile in pasta formulations without adverse sensory effects. Pea peels powder further showed a significantly increase in crude fibers from 1.81% to 2.84% and ash content from 1.17% to 1.74% with increasing concentration, highlighting its rich insoluble fibers and minerals constituents. These results are in agreement with Chopra et.al., (2022) who reported that, a 2.5 folds rise in dietary fibers in bakery goods with pea peels inclusion, while demonstrated that up to 15% addition enhanced mineral fortification particularly of calcium, magnesium, and iron without compromising textural quality. By comparison, beet peels powder produced even higher ash levels (up to 2.71%), consistent with its abundant potassium, iron, and manganese (Singh et.al. 2020). Moreover, both peels powder reduced total carbohydrates as inclusion levels increased, from 78.72 to 74.22% in pea peel samples and from 78.96to 75.97% in beet peel samples, indicating effective replacement of digestible starches by high fibers and protein fractions. Kumari and Kumar (2023), who also reported reductions in available carbohydrates with increasing levels of pea and beet peel powders. powders. Similarly, the incorporation of pea peel powder into bakery products has been shown to significantly enhance dietary fiber content while reducing digestible starch fractions, thereby improving the functional nutritional profile. Collectively, these findings suggest that pea peel powder is particularly suitable for applications requiring elevated protein and fiber levels, such as functional breads, protein bars, and sports nutrition products. Conversely, beet peel powder, with its superior mineral composition and moisture-retention capacity, is more appropriate for hydrating beverages, infant formulas, and moist bakery items. Combining both peel powders may provide synergistic advantages by balancing protein, fiber, and mineral enrichment with improved water-holding capacity, thereby enabling the development of multifunctional food products. Furthermore, data in Table 4 show that both pea and beet peel powders led to a significant, concentration-dependent increase in total phenols. Pea peel powder increased phenolic content from 0.613 to 0.874mg GAE/g at 5% and 15% inclusion levels, respectively, reflecting its rich profile of bound and free phenolic compounds. These results agree with those of Li et al. (2022), who reported that pea peel extracts contain abundant phenolics, including flavonoids and phenolic acids, which are well known for their health-promoting properties, particularly their free radical scavenging activity. Beet peel powder also enhanced total phenolic content (0.555 to 0.717mg GAE/g), albeit to a lesser extent, consistent with its anthocyanin-dominated phenolic spectrum (Tomás-Barberán et al., 2021). Phenolics not only contribute to health benefits but also help retain flavor, taste, and color while preventing oxidative deterioration, as reported by Bhat et al. (2015). Moreover, beet peel powder outperformed pea peel powder in augmenting flavonoid content, which increased from 0.424 to 0.475mg RE/g as inclusion levels rose from 5% to 15%. This finding corroborates earlier work demonstrating that beetroot peels contain high levels of rutin and other glycosylated flavonoid compounds (Silva et al., 2021). Pea peel powder also contributed a meaningful, though smaller, increase in flavonoids (0.335 to 0.402mg RE/g), consistent with the results of Xie et al. (2023). Beet peel formulations achieved the highest antioxidant capacity (16.91% to 25.19% DPPH inhibition), attributed to synergistic effects of anthocyanins and polyphenols, in line with the findings of Mraicha et al. (2021). Pea peel samples also showed an increase in antioxidant activity (7.29% to 11.21% DPPH inhibition). Overall, these results highlight the potential of vegetable peel powders as low cost, natural antioxidants in food formulations. Pea peel powder appears especially suited for applications targeting broad phenolic enrichment, whereas beet peel powder offers superior flavonoid driven radical scavenging capacity.

Minerals Content in Makhrouta Blends with Pea Peels and Beet peel Powders

Data in Table 5. show that Pea peels powder elevated K from 491.4 to 672.0mg/100g at 15%, representing a 36.7% increase. This enrichment aligns with Li et al. (2023), who reported that the cell wall matrix of legume hulls retains high levels of potassium during milling and drying. On the other hand, beet peels powder exhibited a biphasic response: a decline to 283.2mg/100g at 5%, partial recovery to 432.5 mg/100g at 10%, and finally reaching 672.0mg/100g at 15%, comparing with the pea treatments. Chen et al. (2022) attributed early reductions to leaching of soluble salts, while higher inclusion levels overcame dilution effects and restored K content. Both powders moderately increased Ca content. Pea peel increased Ca from 30.3 to 34.3mg/100g at 15%, while beet peels reached 34.1mg/100g at the same level. Pea peels increased P content from 155.6 to 247.2 mg/100g at 15%, these in consistent with Li et al. (2023) who noted that hulls are rich in phytate-bound phosphorus that withstands heat processing. Beet peel achieved a similar endpoint (247.2mg/100g), though levels dipped to 177.0mg/100g at 10%. These results are in harmony with Kumar and Singh (2021), who attributed such losses to the leaching of soluble phosphate salts during processing. Moreover, iron content increased from 2.14mg/100g in the control to over 18 mg/100g at 15% inclusion for both powders. Wang et al. (2024) reported that, beet by-products are particularly effective in augmenting non-heme iron, while pea peels contribute chelated forms that enhance bioavailability. Pea peels also elevated Mg content from 43.6 to 79.7mg/100g, whereas beet peel provided an even higher level (89.1mg/100g at 15%). These findings are in agreement with Ali et al. (2022), who emphasized that legume and root vegetable peels are valuable sources of dietary magnesium, contributing up to 50% of the daily recommended intake when incorporated into fortified cereals. Generally, increasing in the K, P, Fe, and Mg contents particularly at 15% inclusion highlight pea and beet peel powders as potent, low-cost mineral fortifiers. Moreover, pea peels are especially advantageous when sodium preservation and consistent calcium enrichment are required, while beet peels is more effective in boosting iron and magnesium. Blending the two may offer synergistic mineral profiles for addressing micronutrient deficiencies in cereal-based foods.

Table 4. Chemical composition of Makhrouta blends with pea and beet peels powder (mean±SD)

Blends / *Constituents (%)	Control	Blend concentration (%)			
		Samples	5	10	15
Moisture content	4.60^{aB} ±0.07	Pea peels powder	4.70^{bAB} ±0.09	4.79^{bA} ±0.04	4.66^{bAB}±0.07
	4.60^{aC} ±0.07	Beet peels powder	5.51^{aB} ±0.13	5.78^{aA} ±0.06	5.35^{aB}±0.06
Crude protein	11.24^{aD}±0.02	Pea peels powder	12.33^{aC} ±0.15	13.34^{aB}±0.08	15.23^{aA}±0.27
	11.24^{aD}±0.02	Beet peels powder	11.60^{bC} ±0.05	12.75^{bC} ±0.02	13.87^{bA}±0.14
Fat	1.03^{aC} ±0.01	Pea peels powder	1.27^{aB} ±0.01	1.30^{aA} ±0.01	1.31^{aA}±0.01
	1.03^{aA} ±0.01	Beet peels powder	0.61^{bD} ±0.00	0.64^{bC} ±0.01	0.67^{bB}±0.01
Ash	0.89^{aD} ±0.02	Pea peels powder	1.17^{bC} ±0.01	1.64^{bB} ±0.01	1.74^{bA}±0.01
	0.89^{aD} ±0.02	Beet peels powder	2.41^{aC} ±0.02	2.64^{aB} ±0.02	2.71^{aA}±0.01
Crude fibers	0.82^{aD} ±0.01	Pea peels powder	1.81^{aC} ±0.01	2.75^{aB} ±0.01	2.84^{aA}±0.02
	0.82^{aD} ±0.01	Beet peels powder	0.91^{bC} ±0.01	0.99^{Bb} ±0.03	1.43^{bA}±0.04
**Total carbohydrates	81.42^{aA}±0.08	Pea peels powder	78.72^{bB} ±0.08	76.18^{bB} ±0.09	74.22^{bB}±0.33
	81.42^{aA}±0.08	Beet peels powder	78.96^{bB} ±0.11	77.20^{bC} ±0.12	75.97^{bD}±0.13
Total phenols (mg/g) (as gallic acid)	0.558^{Ad}±0.001	Pea peels powder	0.613^{aC}±0.010	0.663^{aB}±0.007	0.874^{aA}±0.006
	0.558^{aC}±0.001	Beet peels powder	0.555^{bC}±0.027	0.614^{bB} 0.001	0.717^{bA}±0.009
Total flavonoids(mg/g) (as rutin)	0.238^{aD}±0.001	Pea peels powder	0.335^{bC}±0.005	0.374^{bB} 0.002	0.402^{bA}±0.004
	0.238^{aD}±0.001	Beet peels powder	0.424^{aC}±0.007	0.453^{aB} 0.001	0.475^{aA}±0.003
Antioxidant activity by DPPH (%)	3.01^{aC}±0.41	Pea peels powder	7.29^{bB} ±0.06	10.07^{bA} ±0.02	11.21^{bA}±0.00
	3.013^{aD}±0.407	Beet peels powder	16.907^{aC}±0.53	19.38^{aB} ±0.09	25.187^{aA}±0.08

*: On dry weight basis. ** Calculated by difference.
a, b & c: There is no significant difference (P>0.05) between any two means for each parameter, within the same column have the same superscript letter. A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the

Table 5. Minerals content (mg/100g) in makhrouta blends with pea peels or beet peels powder

Element (mg/100g) / Blends	Control	Blend concentration (%)			
		Samples	5	10	15
K	491.43^{Aa}	Pea peels powder	584.22^{aA}	542.92^{aA}	672.03^{aA}
	491.43^{Aab}	Beet peels powder	283.23^{bB}	432.49^{aAB}	672.04^{aA}
Ca	30.29^{Ac}	Pea peels powder	31.11^{aBC}	33.33^{aAB}	34.30^{aA}
	30.29^{aB}	Beet peels powder	30.75^{aB}	30.59^{aB}	34.11^{aA}
Na	598.65^{aA}	Pea peels powder	592.69^{aA}	599.2^{aA}	672.03^{aA}
	598.65^{aA}	Beet peels powder	424.84^{bB}	467.47^{aB}	474.41^{bA}
P	155.64^{aC}	Pea peels powder	204.00^{aB}	210.09^{aAB}	247.20^{aA}
	155.64^{aC}	Beet peels powder	204.46^{aB}	177.03^{bB}	247.24^{aA}
Fe	2.14^{aC}	Pea peels powder	12.64^{aB}	12.55^{aB}	18.15^{aA}
	2.14^{aC}	Beet peels powder	12.77^{aB}	15.52^{aAB}	18.64^{aA}
Mg	43.60^{aB}	Pea peels powder	$59.06a^{AB}$	59.64^{aAB}	79.72^{aA}
	43.60^{aB}	Beet peels powder	40.35^{aB}	73.46^{aA}	89.06^{aA}

A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter.
a, b & c: There is no significant difference (P>0.05) between any two means for each element, within the same column have the same superscript letter.

Effect of pea and beet peels powder on makhrouta blends texture

Table 6 presents the hardness values of blends supplemented with different levels (0–15%) of pea and beet peels powder. Addition of 5% pea peels powder produced the highest hardness value (3.58 Newton), comparing with the control sample (2.89 Newton) and higher concentrations of 10% (2.62N) and 15% (2.26N). The moderate incorporation level (5%) likely increased hardness due to its dietary fibers and insoluble matter, which can reinforce the food matrix structure. However, excessive addition (10 -15%) may disrupt the texture, leading to reduced hardness. In contrast, beet peels powder exhibited a different trend. The control and 10% concentrations showed comparable hardness values 2.89 and 2.66N, respectively, while hardness decreased significantly at 5% (1.92N) and 15% (2.19N). This suggests that beet peels may interact differently with the matrix, possibly due to its higher moisture-binding capacity or its distinct fibers composition. These results are in agreement with Ali et al. (2021) and El-Messery et al. (2020), who reported that plant-based fibers can modulate textural properties depending on concentration, fiber type, and interactions with other ingredients.

Table 6. Effect of pea and beet peels powder on Makhrouta blends texture (Newton)

Concentration (%)	Pea peels powder	Beet peels powder
Control sample 0 %	2.89^{bA} ±0.08	2.89^{aA} ±0.08
5 %	3.58^{aA} ±0.17	1.92^{bB} ±0.02
10 %	2.62^{bcA} ±0.18	2.66^{aA} ±0.17
15 %	2.26^{cA} ±0.00	2.19^{bA} ±0.12

a, b & c: There is no significant difference (P>0.05) between any two means for each element, within the same column have the same superscript letter.
A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter.

Effect of pea and beet peels powder on color values of makhrouta blends

The incorporation of pea (PPP) and beet peels powder (BPP) into Makhrouta significantly altered its lightness (L*) values. The control sample recorded the highest L* (72.41), whereas PPP treatments (T1–T3) showed reduced value of 65.00, 57.83, and 56.69. BPP treatments (T4-T6) dropped further to 41.72, 40.05, and 38.11. This progressive darkening confirms that high-pigment plant powders reduce surface reflectance in cereal matrices as reported by (Pathare et al., 2013). The red-green coordinate (a*) also shifted markedly. The control sample was near neutral (0.06) while PPP samples displayed negative values (–2.79 to –3.53), indicating a greenish hue imparted by chlorophylls and flavonoids in pea peels. In contrast, BPP samples exhibited positive a* value (5.86–6.50), reflecting the dominance of red–purple betacyanins inherent to beetroot residues in agreement with (Cai et al., 2001; Sharma and Gujral, 2010). For the yellow–blue axis (b*), PPP treatments remained relatively consistent (18.31–18.46), suggesting minimal impact on yellowness. However, BPP addition caused a marked decrease from 9.30 (T4) to 6.19 (T6), as the intense red pigments masked the base dough's yellow–brown tones, consistent with earlier findings on color masking by high-pigment powders in baked products (Eisele and Modler, 2012). Overall color difference (ΔE) relative to the control diminished with increasing powder concentration. PPP samples ranged from 45.26 to 37.72, while BPP samples fell further between 21.10 and 16.58, indicating a plateau in perceptible color change at higher pigment loadings. Generally, color is the primary sensory attribute by which consumers judge food products, shaping immediate perceptions of freshness, flavor, and overall quality.

Water activity (a_w) of makhrouta blends with pea and beet peels powder

Water activity (a_w) measured the proportion of "free" water in the food matrix that can support microbial growth and chemical reactions. Lower a_w typically correlates with improved microbial stability and slower deterioration, whereas excessively low a_w may negatively affect texture and rehydration properties. This distinction makes a_w a more reliable predictor storage stability than total moisture content. (Juarez-Enriquez, et al., 2019). Data in Figure 1 shows that increasing pea peels powder from 5 to 15% progressively lowered a_w from 0.29 to 0.25. This trend agrees with (Beniwal et al., 2022) who reported that, reported that pea shell powder exhibits high water-holding and absorption capacities, attributes that help immobilize free water. Whereas, at 5%, beet peels powder (BPP) produced the lowest a_W (0.23), but higher additions resulted in slightly elevated levels (0.25–0.24). This pattern is consistent with Sahni and Shere (2017), who noted that beet peels are rich in fibrous polysaccharides, antioxidants, and Betalain pigments, all of which contribute to water holding functionality. Previous studies (Beniwal et al., 2023) have confirmed that reducing a_w in dried products significantly enhances shelf stability by limiting microbial growth during storage. Thus, the incorporation of pea or beet peels powder not only aids preservation but also improves the nutritional quality of products by enriching them with dietary fiber, protein, essential minerals, and antioxidants.

Table 7. Color values of makhrouta blends with pea and beet peels powder

Blends	*L	*a	*b	Δ E
Control	72.41	0.06	17.53	51.37
T1 (PPP) 5%	65	-2.79	18.38	45,26
T2 (PPP)10%	57.83	-2.22	18.46	38.57
T3 (PPP)15%	56.69	-3.53	18.31	37.72
T4 (BPP) 5%	41.72	6.50	9.30	21.10
T5 (BPP)10%	40.05	5.86	9.13	19.47
T6 (BPP) 15%	38.11	6.16	6.19	16.58

lightness (*L) values , yellow–blue axis (*b) , red-green coordinate (*a) Color difference (ΔE)

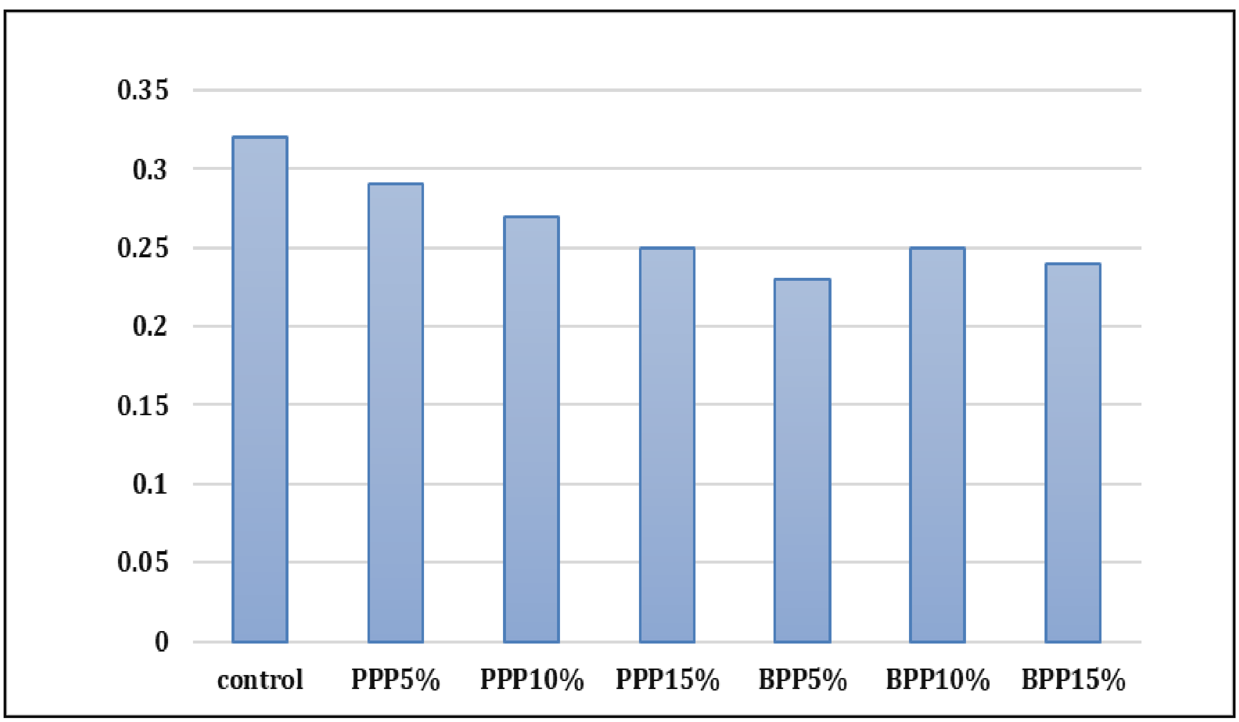

Figure 1. Water activity (a_W) of Makhrouta Blends with pea and beet peels powder

Sensory Evaluation of Makhrouta Blends with Pea and Beet Peels Powder

Table 8 presents the sensory evaluation of the Makhrouta blends supplemented with pea peels powder (PPP) or beet peels powder (BPP). Color, in particular, strongly influences perceived taste and overall product quality. Therefore, the incorporation of PPP up to 10% did not significantly affect the color, odor, flavor, mouthfeel, or aftertaste of the Makhrouta blends comparing with the control sample. This demonstrates that low-level substitution with legume by-products can be achieved without compromising key sensory attributes. These results are consistent with Ozer et al. (2014), who reported that up to 10% pea peel addition in bread maintained overall acceptability and did not introduce perceptible off-flavors or textural defects. However, at 15% inclusion, color scores declined significantly (8.17 vs. 9.00 in control sample), likely due to increased particulate visibility and light scattering within the fibrous matrix (Ozer et al., 2014; Stone and Sidle 2017). Moreover, BPP Makhrouta blends followed a similar trend. Sensory scores remained statistically unchanged at 5% and 10% inclusion, but at 15% significant declines were observed across all parameters (e.g., overall palatability 40.20 vs. 45.90 in control sample, $P < 0.05$). Such decreases are consistent with Constantin et al. (2025), who reported that high levels of beetroot peel impart strong earthy notes and markedly alter product hue, reducing consumer preference. Nevertheless, the preservation of flavor, mouthfeel, and after taste at up to 10% inclusion indicates that finely milled peel powders can be successfully incorporated into the dough matrix without disrupting sensory harmony. Overall palatability scores above 45 for both peel types at moderate levels underscore the potential of vegetable by-products to enhance nutritional value by providing dietary fibers and bioactive compounds while maintaining consumer acceptance. These findings are in agreement with Sullivan and Thompson (2020), who concluded that up to 10% peel incorporation offers an optimal balance between functional enrichment and sensory quality in bakery products.

Table 8. Sensory evaluation of Makhrouta samples with pea peels or beet peels powder

Samples	Parameters	Blend concentration (%)			
		Control sample	5	10	15
Pea peels powder	Color	9.00^{A}±0.24	8.94^{A}±0.19	9.11^{A}±0.11	8.17^{B}±0.37
	Odor	9.50^{A}±0.14	9.17^{AB}±0.20	9.22^{AB}±0.15	8.56^{B}±0.34
	Flavor	9.17^{A}±0.20	9.39^{A}±0.14	9.38^{A}±0.21	8.72^{A}±0.41
	Mouth feel	9.11^{A}±0.26	9.11^{A}±0.26	9.16^{A}±0.18	8.72^{A}±0.30
	After taste	9.06^{A}±0.06	9.17^{A}±0.19	9.06^{A}±0.18	8.67^{A}±0.29
	Overall palatability	45.83^{A}±0.57	45.88^{A}±0.47	45.86^{A}±0.57	42.85^{B}±1.16
Beet peels powder	Color	9.20^{A}±0.20	9.20^{A}±0.20	9.65^{A}±0.13	8.20^{B}±0.20
	Odor	9.05^{A}±0.16	9.20^{A}±0.13	8.70^{A}±0.15	8.00^{B}±0.21
	Flavor	9.35^{A}±0.22	9.20^{A}±0.20	8.90^{AB}±0.28	8.30^{B}±0.33
	Mouth feel	9.20^{A}±0.13	9.05^{A}±0.16	8.60^{A}±0.30	7.80^{B}±0.33
	After taste	9.10^{A}±0.10	9.10^{A}±0.18	8.70^{A}±0.26	7.90^{B}±0.31
	Overall palatability	45.90^{A}±0.61	45.95^{A}±0.65	44.85^{A}±0.93	40.20^{B}±1.11

A, B & C: There is no significant difference (P>0.05) between any two means, within the same row have the same superscript letter

4. Conclusion

This study demonstrated the potential of fortifying Makhrouta, a traditional Egyptian heritage food, with pea peel powder (PPP) and beetroot peel powder (BPP) as sustainable functional ingredients. Incorporation of PPP and BPP at moderate levels (5–10%) significantly improved the nutritional composition, antioxidant activity, and natural pigment content of the product, while maintaining favorable texture and sensory acceptability. In contrast, higher substitution levels (15%) resulted in lower sensory scores and less desirable texture, indicating that balanced fortification is essential to achieve both nutritional benefits and consumer acceptance.

The findings highlight that utilizing agro-industrial by-products such as pea and beet peels not only reduces food waste but also supports the development of healthier alternatives to conventional cereal-based products, particularly instant noodles, which are often linked to negative health effects. Thus, fortified Makhrouta represents a culturally relevant, clean-label, and functional food option that combines nutritional enhancement with heritage preservation. Future studies should focus on optimizing large-scale production, investigating additional functional properties, and evaluating the long-term health impacts of incorporating PPP and BPP into daily diets.

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