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Research Article

Effect of Microwave Heat Processing on Nutritional Indices, Antinutrients, and Sensory Attributes of Potato Powder-Supplemented Flatbread

Muhammad Waseem,[1] **Saeed Akhtar**,[1] **Nazir Ahmad**,[3] **Tariq Ismail**,[1,2] **Claudia E. Lazarte**,[2] **Majid Hussain**,[1] **and Muhammad Faisal Manzoor**[4,5]

[1]*Institute of Food Science & Nutrition, Bahauddin Zakariya University, Multan, Pakistan*
[2]*Department of Food Technology, Engineering and Nutrition, Lund University, Lund, Sweden*
[3]*Department of Nutritional Sciences, Faculty of Medical Sciences, Government College University, Faisalabad, Pakistan*
[4]*School of Food Science and Engineering, South China University of Technology, Guangzhou, China*
[5]*School of Food and Biological Engineering, Jiangsu University, Zhenjiang, China*

Correspondence should be addressed to Nazir Ahmad; drnazirahmad@gcuf.edu.pk, Tariq Ismail; ammarbintariq@yahoo.com, and Muhammad Faisal Manzoor; 201712800025@mail.scut.edu.cn

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This study aims at evaluating nutritional, toxicological, and sensory attributes of microwave heat-treated potato powder-supplemented unleavened flatbread. Straight-grade wheat flour (SGF) was substituted with potato powder at the rate of 2.5–10% d.w. A comparison was made for nutritional, antinutrient, and organoleptic attributes of microwave heat-treated potato powder and SGF—potato powder composite flour-based flatbreads. The results suggest processed potato powder supplementation in SGF to significantly ($p < 0.05$) improve ash (0.48 to 0.63 g/100 g), dietary fiber (2.15 to 2.61 g/100 g), and protein (8.33 to 9.91 g/100 g) contents of composite chapatis. Likewise, significant ($p < 0.05$) improvement in the concentration of microelements and trace elements was observed including Ca, Na, K, Fe, and Zn contents, which were increased from 29.7 to 33.5 mg/100 g, 2.8 to 6.3 mg/100 g, 376 to 466 mg/100 g, 3.1 to 3.4 mg/100 g, and 3.17 to 3.25 mg/100 g, respectively. Microwave heating of potato powder was observed to reduce the load of alkaloids, oxalates, tannins, and phytates of the raw potato powder at the rate of 76%, 80%, 84%, and 82%, respectively, thus anticipating a promising response to minimize toxicant load in supplemented flatbread. Supplementing potato powder in SGF elucidated significant ($p < 0.05$) improvement in color values, i.e., a^* (1.89–2.32) and b^* (10.95–13.22), and increased product hardness from 3.17 to 7.9 N. The study concludes that microwave heat-treated potato powder yield improved nutritional and safety concerns of the consumers when used alone or as a supplement for developing composite flours based on value-added products.

1. Introduction

Potato (*Solanum tuberosum* L.), a staple tuber crop of the Solanaceae family, is considered the fourth most vital staple food crop afterward wheat, rice, and corn. With a worldwide 17.3 MH area of crop cultivation, global production of potato was recorded as more than 370 million metric tons in 2019 with the People's Republic of China, India, Russia, and Ukraine as the leading potato-producing countries [1]. Historical data on potato and potato products suggest their application as a fresh crop for table consumption. Contrary to their conventional uses, recent global potato consumption trends are suggesting a shift from their fresh uses to value-added products like frozen potato, dehydrated potato flacks, and potato powder. Long-standing applications of the value-added potato products have been reported in snack foods, bakery, meat, culinary spices and seasoning, dairy industry, pharmaceuticals, textile, thermoplastic starch foams, and animal feed industry [2, 3]. Dehydrated potatoes are considered a value-added ingredient for developing products including extruded snacks, soups, muffins, cakes, steamed noodles, steamed bread, and biscuits [4–6]. Earlier literature on potatoes indicates health-promising features owing to various health-promoting bioactive compounds such as phenolics, i.e., flavones, isoflavones and flavonoids, and antioxidants that play their significant role in the prevention of numerous health calamities including different cancers, peptic ulcer, inflammation, acidity, cardiovascular maladies, and atherosclerosis [7, 8].

Potatoes are featured with substantial amounts of protein, inorganic mineral substances, vitamins, dietary fibers, bioactive phenolic compounds, carotenoids, and anthocyanins, which play their pivotal role in promoting health. Potato proteins are preferred over cereal proteins for their food applications due to the presence of balanced amino acid composition [9]. The existing pool of information on intrinsic toxins in potatoes reports the presence of numerous antinutrients such as oxalates, tannins, phytates, phytic acid, glycoalkaloids (solanine and chaconine), cyanide, and saponins [10, 11]. Several preliminary processing techniques such as soaking, microwaving, blanching, germination, fermentation, autoclaving, and steaming have been suggested to reduce antinutrients and improve nutrient bioavailability in tuber crops [12, 13].

Among bakery products, chapatti–the unleavened flatbread, and its variants have a strong position as a staple food in different cultures of Southeast Asia. On account of their wide acceptability as a cultural food, wheat flour and chapatti are used as potential carriers for food fortificants and other replacers bearing improved functional and health-promoting properties [14]. Low-carbon footprint and relatively lesser requirements of water for cultivation make potato a better choice to be considered as a staple food crop in emerging challenges of the future, i.e., climate change and food insecurity [15]. An intelligent shift from conventional staple cereals to nonconventional edible resources may reduce the emerging risks of food insecurity and malnutrition in resource-restrained countries. Alternate starch sources like potato powder, partial to substantial replacement of wheat, in staple foods are necessitated to reduce the burden on conventional staples and to promote dietary diversification. This study was, therefore, planned to reduce the antinutrient load of potato powder by microwave heat processing and to explore functional, nutritional, and sensory acceptability of unleavened flatbread developed from wheat–potato powder composite flours. This study also highlights the differences in key attributes of the product developed with raw and microwave heat-treated potato powder supplementation.

2. Materials and Methods

2.1. Procurement of Raw Materials, Chemicals, and Reagents. Fresh potatoes and straight-grade wheat (*Triticum aestivum*) flour were procured from the vegetables and grain market of Multan, Pakistan. Samples were stored at ambient room temperature till further appraisal. Analytical grade chemicals and reagents were purchased from Sigma Chemical Co., Ltd. (St. Louis, MO). Standard solutions used for the preparation of stock solutions for estimation of macroinorganic and microinorganic substances were procured from BDH Chemicals Ltd. (Shanghai, China).

2.2. Raw and Processed Potato Powder Preparation. Potatoes were inspected for physical and insect damages, diseases, and blemishes. Healthy potato tubers were washed and manually peeled. A known amount of peeled potatoes was mechanically sliced (Pamico Technologies, Pakistan) and microwave processed at 1.1 kW for 2 minutes. Microwaved processed potatoes were cabinet dried at $50 \pm 2^{\circ}C$ for 10–12 hours to the final moisture contents in a range between 8 and 15%. Dehydrated potatoes were converted into fine potato powder (mesh size~70–80 mm) using a commercial attrition mill (Pamico Technologies, Pakistan). Raw and processed potato powder samples were stored at ambient room temperature in airtight polyethylene bags for further appraisal [16, 17].

2.3. Nutritional Composition and Mineral Quantification. Proximate nutrient composition, i.e., moisture (protocol no. 925.10), crude ash (protocol no. 923.03), fat (protocol no. 920.85), fiber (protocol no. 32–10), and protein (protocol no. 920.87) and mineral contents of the raw and processed potato powder, and potato powder-supplemented chapatis were estimated by the standard protocols as laid down in Official Methods of Analysis [18]. Carbohydrate contents and energy were derived using equation (1), respectively.

$$\begin{aligned}\text{Carbohydrates}\,(\%) &= [100 - (\text{moisture} + \text{ash} + \text{fat} + \text{protein} + \text{fiber})],\\ \text{energy}\,(\text{kcal/g}) &= 9.00\,(\%\text{fat}) + 4.00\,(\%\text{carbohydrates} + \%\text{protein}).\end{aligned} \tag{1}$$

2.4. Product Development

2.4.1. Raw and Processed Potato Powder-Supplemented Chapati Premix Preparation. Composite premixes of SGF and potato powder were developed by replacing SGF with raw and processed potato powder at the rate of 2.5–10%. Premix formulations were stored in airtight plastic containers at $25 \pm 2^{\circ}C$ for further applications.

2.4.2. Development of Composite Flour Unleavened Flatbread. SGF and composite flour-based unleavened flatbreads were made by the method followed by Waseem et al. [19] with slight modification. Briefly, SGF and the premixes were mixed with potable water to make 50 g dough. Dough developed was allowed a rest period of 30 minutes and rolled into thin sheets to a diameter of 12 cm and a thickness of 2 mm. Evenly rolled unleavened flatbread dough was baked from both sides onto the iron plate at 210 ± 5°C. Baked chapatis were cooled and analyzed for various sensory and biochemical parameters.

2.5. Antinutrient Determination. Alkaloid contents in raw and processed potato powder and supplemented unleavened flatbread were determined using the method followed by Onwuka [20], wherein 5.0 g of each sample was poured in 50 mL, 10% acetic acid solution in ethanol and filtered using Whatman filter paper No. 41. Filtrates were titrated against conc. ammonium hydroxide and then with 1% solution of ammonium hydroxide. Alkaloid precipitates were oven-dried at 55°C for 30 minutes and were calculated using differences in initial and final weights. Amin et al. [21] method was adopted to determine the oxalate contents. One gram sample in 190 mL distilled water was acid digested in 10 mL (6 M, HCl) and centrifuged (2,000 rpm, 10 minutes). Subsequently, 50 mL of the supernatant was concentrated to 25 mL and filtered. The precipitates were washed with concentrated ammonia solution and $CaCl_2$ (10 mL, 5%) to obtain oxalate precipitates, which were titration against 0.05 M $KMnO_4$ to a pink-colored endpoint. Oxalates were calculated by multiplying the titer value by 0.1125. Tannins were assessed by Amin et al. [21]. About 0.5 g sample was boiled in 7.5 mL distilled water and centrifuged at 2,000 rpm for 20 minutes. Afterward, 1 mL of centrifuged supernatant was mixed with 5 mL Folin-Denis reagent and 10 mL (7.5%) sodium carbonate solution to adjust the final volume to 10 mL using distilled water. Spectrophotometric absorptions for tannic acid determination were measured at 700 nm against the tannic acid standard curve (10–100 mg/1000 g). However, spectrophotometric absorptions for phytate measurements were measured following the protocols as laid down by Haug and Lantzsch [22]. About 1 g of cabbage powder was extracted with 0.2 N, 10 mL HCl for phytates. Thereafter, o.5 mL extract was boiled in 1 mL ferric solution (i.e., 0.2 g $NH_4Fe(SO_4)_2$ in 2 N HCl to a volume 1 L). Afterward, centrifugation (Hermle, Z236K) was performed for 30 min at 3,000 rpm. Now, 1 mL extract was mixed with 1.5 mL 2-2′ -bipyridine solution (i.e., 25 mL of 0.25 g thioglycolic acid and 0.25 g 2-2′ -bipyridine). Spectrophotometric absorbance (UV-Vis 3000, ORI, Germany) of phytic acid standards, reagent blank, and samples was recorded at 519 nm, and contents of phytates were measured.

2.6. Color and Textural Properties. Color variables including L^*, a^*, and b^* values, the textural attributes of raw and processed potato powder, and supplemented baked goods were determined using Hunter Color Lab (Hunter Associates Laboratory Inc., Reston, VA, USA) and texture analyzer (TA, Stable Microsystems, TAXT-2i Texture Analyser, Godalming, Surrey, UK) by the methods as outlined by Liu et al. [23] and Kiumarsi et al. [24], respectively.

2.7. Puffed Height. Puffing heights of the SGF and raw and processed potato powder-based composite unleavened flatbreads were determined by the method suggested by Rao et al. [25], wherein the cooked flatbreads were shifted to an adjacent heater for puffing for 10–15 seconds. Afterward, the puffing heights of flatbreads were measured using a sterilized stainless steel scale (cm).

2.8. Sensory Evaluation. Sensory assessment of SGF, and raw and processed potato powder composite flour-based unleavened flatbread was evaluated for color, taste, folding ability, appearance, texture, and overall acceptability. Based on product discriminative ability, a panel of 20 trained graduate students from the Institute of Food Science and Nutrition, Bahauddin Zakariya University, was taken on board to perform preference mapping of the baked products on a 9-point hedonic scale, i.e., 9 = like extremely; 8 = like very much; 7 = like moderately; 6 = like slightly; 5 = no liking no disliking; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike very much; and 1 = dislike extremely [24]. The panelists were prebriefed about the objectives of the study and instructed about the evaluation of the finished product. The organoleptic evaluation was performed in a well-lit sensory study room free from odors and sounds, which may interfere with the results of panelists.

2.9. Statistical Analysis. Two replicates of each analysis were performed, and the values were stated as mean ± standard deviation. Statistical data on nutritional and textural quality parameters of SGF, raw and processed potato powder composite flours, and the unleavened flatbreads derived thereof were statistically analyzed using analysis of variance technique on Statistix 8.1 (Tallahassee, FL). The least significant difference (LSD) was used to assess the significance level among the means at a $p < 0.05$ confidence interval.

3. Results and Discussion

3.1. Nutritional Composition of SGF, Raw and Processed Potato Powder, and Supplemented Chapatis. The nutritional composition of SGF, raw and processed potato powder, and potato powder-supplemented chapatis is presented in Table 1. The data suggest nonsignificant differences in fat, fiber, protein, and NFE contents of the raw and processed potato powders, while a significant ($p < 0.05$) moisture and ash contents of the microwave-treated dehydrated potato were relatively lower than the raw potato flour. Concerning the SGF carrying 0.4 g/100 g ash and 2.6 g/100 g crude fiber, potato powders, either raw or processed, were carrying higher concentrations of inorganic matters and crude fibers, i.e., 2.44–2.54 g/100 g and 5.76–6.26 g/100 g, respectively. Likewise, fat (0.8–0.9 g/100 g) and NFE contents (70.7–72.1 g/100 g) of the potato powder were significantly lesser than those observed in SGF, i.e., 1.32 g/100 g and

Table 1: Nutritional composition of straight-grade wheat flour (SGF), raw and processed (microwave heat treated) potato powder, and supplemented chapatis (g/100 g).

Treatments	Moisture	Ash	Fat	Fiber	Protein	NFE[†]
SGF	10.92 ± 0.05^{a}	0.41 ± 0.03^{c}	1.32 ± 0.03^{a}	2.60 ± 0.05^{b}	8.89 ± 0.09^{a}	75.87 ± 0.14^{a}
Raw PP	9.39 ± 0.09^{b}	2.54 ± 0.01^{a}	0.90 ± 0.03^{b}	6.26 ± 0.07^{a}	10.23 ± 0.67^{a}	70.69 ± 0.74^{b}
Processed PP	8.85 ± 0.07^{c}	2.44 ± 0.05^{b}	0.81 ± 0.02^{b}	5.76 ± 0.07^{a}	10.00 ± 0.57^{ab}	72.14 ± 0.54^{b}
T_0	35.65 ± 0.07^{a}	0.48 ± 0.01^{c}	1.85 ± 0.02^{a}	2.15 ± 0.02^{c}	8.33 ± 0.01^{d}	51.52 ± 0.07^{b}
T_1	34.21 ± 0.16^{b}	0.49 ± 0.01^{c}	1.65 ± 0.01^{b}	2.24 ± 0.06^{c}	9.13 ± 0.19^{c}	52.27 ± 0.42^{b}
T_2	31.06 ± 0.08^{c}	0.51 ± 0.01^{c}	1.59 ± 0.01^{c}	2.36 ± 0.09^{bc}	9.43 ± 0.12^{bc}	55.04 ± 0.33^{a}
T_3	30.25 ± 0.07^{d}	0.55 ± 0.01^{b}	1.43 ± 0.04^{d}	2.51 ± 0.01^{ab}	9.63 ± 0.19^{ab}	55.62 ± 0.23^{a}
T_4	29.75 ± 0.07^{e}	0.63 ± 0.01^{a}	1.31 ± 0.01^{e}	2.61 ± 0.16^{a}	9.91 ± 0.16^{a}	55.79 ± 0.38^{a}

Values are means ± S.D. ($n = 2$). Values having identical lettering in each column are nonsignificant at $p > 0.05$. $T_0 = 100\%$ straight-grade wheat powder chapatis (control), $T_1 = 2.5\%$ processed potato powder (PP), $T_2 = 5\%$ processed PP, $T_3 = 7.5\%$ processed PP, and $T_4 = 10\%$ processed PP. [†]Nitrogen-free extract = 100–(moisture + ash + fat + fiber + protein).

75.9 g/100 g, respectively (Table 1). Product analysis yielded significantly ($p < 0.05$) lower moisture contents in potato powder-supplemented flatbread, i.e., 29.8 g/100 g than observed for 100% SGF-based control (35.7 g/100 g). Such a reduction that may be attributed to reduced water-binding ability of the potato powder resulted in higher NFE contents of the supplemented flatbread at 5–10% level of substitution. Potato powder supplementation also improved ash, crude fiber, and crude protein contents of the composite flour flatbread from 0.48 to 0.63 g/100 g, 2.2 to 2.6 g/100 g, and 8.3 to 9.9 g/100 g, respectively.

Improved inorganic residues in potatoes have also been reported to yield better ash contents of the baked goods developed with potato powder supplementation at a level <10% [23]. The referred study had also reported lower fat contents in the potato powder-supplemented steam bread that may be attributed to the proportionally lower lipid profile of the potato powder. Substituting conventional cereal produce like wheat flour with fat devoid and a balanced protein composition may improve consumer acceptability and reduce the likelihood of chronic ailments such as cardiovascular disease [4].

Potato powder as a promising carrier of dietary fibers can yield value-added baked goods with better fiber contents as has been observed in this study, wherein fiber contents of the 100% SGF-based flatbread increased from 2.15% to 2.6% at 10% substitution. Improved fiber contents of the steam bread supplemented with raw potato powder have also been reported by Liu et al. [23] suggesting relatively higher fiber contents in the supplemented bread when compared with our findings. Such a difference may be attributed to the difference in potato cultivar bearing relatively higher fiber contents when compared with our findings.

Potato powder is considered to hold balanced amino acid composition [26], which offers the product a significant place to replace cereal proteins. Dehydrated potatoes accentuate about 18 amino acids including all essential amino acids, i.e., valine, isoleucine, methionine, histamine, phenylalanine, and threonine, and semiessential amino acids, e.g., arginine and lysine [26]. Our study reported raw and processed potato powder to offer significantly ($p < 0.05$) comparable protein contents to those of the SGF suggesting wheat flour value addition with potato powder to anticipate comparable protein contents and improved protein quality. Supplementing potato powder @10% of the recipe has also yielded ~19% improvement in protein contents of the composite flatbread suggesting partial replacement of SGF with potato powder to also anticipate better protein yield. Compositing cereals with grains and other nonconventional food ingredients holding relatively better nutrient composition has been termed to serve as a complementary approach in addressing various functional and nutritional shortcomings to foods. Earlier, the substitution of wheat flour with potato peel powder @ 5% has been reported to demonstrate better protein and fiber contents of the composite cake with good sensory attributes [27]. The study suggests potato peel powder as a health-oriented product with higher fiber and comparatively low-caloric contents. The essential amino acid composition of potato protein had been reported comparable to egg protein for some amino acids including lysine, tryptophan, and leucine, while a moderate amount of isoleucine, phenylalanine, threonine, valine, histidine, arginine, and methionine is the key differentials between the quality of potato and cereal protein [28]. Thus, potato powder supplementation or partially substituting wheat flour with potato powder may help in improving nutritional inadequacies in staple foods of communities that rely more on wheat as their principal food [4, 23, 29].

3.2. Mineral Profile of SGF, Raw and Processed Potato Powder, and Supplemented Chapatis. Potato powder embodies greater magnitudes of calcium (Ca), potassium (K), sodium (Na), magnesium (Mg), phosphorus (P), iron (Fe), and zinc (Zn), which might help in preventing various nutritional and health complications [11]. Our results present significantly higher amounts of Ca, Na, and K in raw and processed potato powder when compared with the SGF (Table 2). Ca concentration recorded in raw and processed potato powder insignificantly differed from each other, i.e., 61.5 mg/100 g, and 59 mg/100 g, respectively, while the significantly lower concentration of Ca was observed in SGF, i.e., 42.5 mg/100 g. Likewise, the amount of Na and K was also lower in SGF, i.e., 5.8 mg/100 g and 445 mg/100 g, respectively, than its counterpart raw and processed potato powder carrying significantly ($p < 0.05$) higher amounts of Na (47.3–50 mg/100 g) and K (973–987 mg/100 g). Raw and processed potato powder was observed relatively low in essential microminerals including Fe (1.51–1.55 mg/100 g) and Zn (0.76–0.87 mg/100 g) (Table 2). Substituting SGF with processed potato powder significantly improved Ca contents of 100% SGF-based flatbread from 29.7 mg/100 g to 33.5 mg/100 g anticipating a 13% increment at 10% supplementation (Table 2). Mean values for Na contents of raw and processed potato powder varied between 47 and 50 mg/100 g, which were markedly higher than observed in SGF, i.e., 5.7 mg/100 g. Na contents of the flatbread were also progressively increased from 2.8 mg/100 g to 6.3 mg/100 g at 10% potato powder supplementation, while the rate of increment in K levels of flatbread at the same supplementation level was ~24%. The amount of Fe and Zn in potato powder-supplemented flatbreads were insignificantly different ($p \geq 0.05$) from SGF and SGF-based flatbreads that may be associated with lower contents of referred minerals in potato powder (Table 2).

Results suggest potato powder supplementation anticipates significant improvement in electrolyte contents of the supplemented flatbreads. Earlier, potato powder and the peel fraction of the tuber crop have been suggested as promising sources of Ca and K and trace minerals including Fe and Zn, and their dietary intake to support the prevention of micronutrient inadequacies [5, 30]. Supplementation of wheat flour with noncereal flour-like amaranth aimed at improving nutritional attributes of the baked chapatis was reported by Banerji et al. [31]. The study referred to significant ($p < 0.05$) increment in Ca, Na, K, Fe, and Zn in wheat–amaranth composite flatbreads from 68 to 139 (104% ↑), 493 to 503(2% ↑), 383 to 497(30% ↑), 4.3 to 7.5 (74% ↑), and 2.6 to 3.1 (19% ↑) mg/100 g, respectively, at 40% substitution level.

3.3. Reduction in Antinutrients in Processed Potato Powder and Supplemented Chapatis. Dehydrated tubers like potatoes may be ranked among vegetables bearing a high load of intrinsic toxicants including oxalates, alkaloids, tannins, cyanogenic glycosides, and phytates, which might pose the risks of adverse health effects such as dizziness, depression, gastrointestinal ailments, kidney stones, vomiting, anemia, rickets, osteoporosis, osteomalacia, and intestinal inflammation [32–34]. Our work identified raw potato powder to hold higher amounts of intrinsic toxicants like alkaloids, oxalates, tannins, and phytates, while the microwave heat treatment of the powder was found to significantly reduce the load (Table 3). The rate of reduction in toxicants was in a range between 76 and 84%, while an individual decline in a load of alkaloids was 76% (60 mg/100 g to 14.5 mg/100 g), oxalates was 80% (31.2 mg/100 g to 6.2 mg/100 g), tannins was 84% (91.4 mg/100 g to 14.6 mg/100 g), and phytates was 82% (44.9 mg/100 g to 7.9 mg/100 g) (Table 3). A threshold level of phytic acid in food is suggested as lesser than 25 mg per 100 g of phytate-containing food [35]. Likewise, a reasonable goal to limit the dietary intake of oxalates by the patients with enteric hyperoxaluria is less than 100 mg daily [36]. Microwave treatment of the raw potato powder brought a significant decline in phytate and oxalate contents of the processed potato powder making it safer for the consumers with suspected health complications like iron deficiency, anemia, and hyperoxaluria. Unlike potato powder, SGF in this study was not detected for the listed toxicants, and hence, there was a meager transfer of phytates, oxalates, tannins, and alkaloids from the processed potato powder to the baked flatbread. The results suggested a consistent increment in intrinsic toxicant load in composite flour-baked flatbread with an increasing level of potato powder supplementation (Table 3). Composite flour flatbreads were observed to hold alkaloids, oxalates, tannins, and phytates up to 3.1 mg/100 g, 0.7 mg/100 g, 1.6 mg/100 g, and 0.8 mg/100 g, respectively, at 10% supplementation of the microwave-treated potato powder. The lowest concentrations of the listed nutrient inhibitors were recorded in flatbreads developed with 2.5% potato powder supplementation. Earlier studies validate alkali treatment, soaking, boiling, fermentation, microwaving, and blanching to significantly alter antinutrient load in foods [21, 33]. A study by Rytel et al. [37] elucidated thermally processed potato chips, potato purees, and French fries to reduce total alkaloid load by 84, 83, and 97%, respectively, while Omayio et al. [38] and Donald [39] reported a significant ($p < 0.05$) decline in alkaloids of blanched, boiled, and microwaved potatoes from 39 to 94%. Likewise, shorter cooking duration as has been practiced for microwave heating and cooking under vacuum has also been reported to reduce the production of undesirable reaction products during potato cooking [40]. A majority of the antinutrients are reported to make complexes with food components including proteins and microelements. At an instant, relatively large proteins with hydrophobic properties form complexes with tannins [41, 42]. Alike, the phytic acid being a negatively charged structure generally binds with the charged food components, e.g., metal ions including Fe, Zn, Mn, Mg, and Ca [43]. Microwave heating instantaneously generates heat within the product by molecular motion and disrupts hydrogen bonding. Such treatment does not merely promote the migration of dissolved ions but also affects protein structures that may lead to the dissolution of antinutrient–nutrient bonds and improved bioavailability of the nutrients.

3.4. Hunter Color Lab, Instrumental Texture, and Puffing. Color is a pivotal physical parameter that unswervingly impacts nutritional quality, edibility, and consumer preference. Potato powder embodies starch alongside natural pigments like carotenoids, beta-carotene, and anthocyanin, which enhances the attractive appeal of foods and explicates antioxidant properties [44]. The data presented in Table 4 suggest raw potato powder to exhibit significantly ($p < 0.05$) higher L^* and b^* values, i.e., 88.3 and 14.5 than recorded for processed potato powder and SGF. The study exhibited a significant ($p < 0.05$) increase in a^* values from 1.9 to 2.3 (21% ↑) and b^* values from 10.9 to 13.2 (21% ↑), while a gradual decline in L^* values from 83 to 72 (13% ↓) was noticed on maximum replacement of SGF with processed potato powder (Table 4). An increase in a^* and b^* values in processed potato powder-supplemented chapatis could be

Table 2: Mineral composition of straight-grade flour, raw and processed potato powder, and supplemented chapatis (mg/100 g).

Treatments	Ca	Na	K	Fe	Zn
SGF	42.50 ± 0.50^{b}	5.75 ± 0.25^{c}	445.00 ± 2.00^{c}	3.77 ± 0.04^{a}	3.94 ± 0.02^{a}
Raw PP	61.50 ± 0.71^{a}	49.59 ± 0.39^{a}	986.50 ± 0.71^{a}	1.55 ± 0.02^{b}	0.87 ± 0.01^{b}
Processed PP	59.00 ± 0.71^{a}	47.34 ± 1.27^{b}	973.30 ± 1.41^{b}	1.51 ± 0.14^{b}	0.76 ± 0.04^{c}
T_0	29.71 ± 0.22^{cd}	2.78 ± 0.01^{d}	375.80 ± 0.28^{e}	3.08 ± 0.01^{a}	3.17 ± 0.07^{a}
T_1	29.24 ± 0.34^{d}	3.11 ± 0.02^{d}	392.59 ± 2.25^{d}	3.10 ± 0.14^{a}	3.07 ± 0.03^{a}
T_2	30.47 ± 0.67^{c}	4.13 ± 0.19^{c}	417.18 ± 1.66^{c}	3.16 ± 0.26^{a}	3.08 ± 0.02^{a}
T_3	32.21 ± 0.30^{b}	5.20 ± 0.28^{b}	439.76 ± 3.91^{b}	3.30 ± 0.38^{a}	3.14 ± 0.08^{a}
T_4	33.45 ± 0.64^{a}	6.26 ± 0.38^{a}	465.85 ± 1.20^{a}	3.41 ± 0.49^{a}	3.25 ± 0.21^{a}

Values are means ± S.D. ($n = 2$). Values having identical lettering in each column are nonsignificant at $p > 0.05$. $T_0 = 100\%$ straight-grade wheat flour chapatis (control), $T_1 = 2.5\%$ processed potato powder (PP), $T_2 = 5\%$ processed PP, $T_3 = 7.5\%$ processed PP, and $T_4 = 10\%$ processed PP.

Table 3: Antinutrient contents of straight-grade flour, raw and processed potato powder, and supplemented chapatis (mg/100 g).

Treatments	Alkaloids	Oxalates	Tannins	Phytates
SGF	ND**	ND**	ND**	ND**
Raw PP	59.98 ± 0.03^{a}	31.22 ± 0.40^{a}	91.39 ± 1.75^{a}	44.92 ± 0.80^{a}
Processed PP	14.49 ± 0.01^{b}	6.19 ± 0.80^{b}	14.59 ± 1.41^{b}	7.89 ± 0.54^{b}
Reduction)	(*76*)	(*80*)	(*84*)	(*82*)
T_0	ND**	ND**	ND**	ND**
T_1	0.77 ± 0.04^{d}	0.18 ± 0.02^{d}	0.38 ± 0.03^{d}	0.22 ± 0.04^{d}
T_2	1.55 ± 0.07^{c}	0.34 ± 0.01^{c}	0.76 ± 0.05^{c}	0.42 ± 0.05^{c}
T_3	2.37 ± 0.18^{b}	0.45 ± 0.08^{b}	1.19 ± 0.15^{b}	0.64 ± 0.08^{b}
T_4	3.11 ± 0.16^{a}	0.66 ± 0.02^{a}	1.55 ± 0.14^{a}	0.81 ± 0.03^{a}

Values are means ± S.D. ($n = 2$). Values having identical lettering in each column are nonsignificant at $p > 0.05$. $T_0 = 100\%$ straight-grade wheat flour chapatis (control), $T_1 = 2.5\%$ processed potato powder (PP), $T_2 = 5\%$ processed PP, $T_3 = 7.5\%$ processed PP, and $T_4 = 10\%$ processed PP. **Not detected.

Table 4: Instrumental texture, Hunter Color Lab and puffing of straight grade flour, raw and processed potato powder, and supplemented chapatis.

Treatments	Hunter Color Lab					Instrumental texture			Puffing height (cm)
	L^*	a^*	b^*	Hue	Chroma	Hardness (N)	Springiness (mm)	Gumminess (N, mm)	
SGF	80.93 ± 0.28^{c}	2.18 ± 0.05^{a}	11.85 ± 0.07^{b}	79.56 ± 0.42^{b}	12.05 ± 0.08^{b}	—	—	—	—
Raw PP	88.33 ± 0.47^{a}	0.44 ± 0.02^{b}	14.45 ± 0.64^{a}	88.22 ± 0.16^{a}	14.46 ± 0.64^{a}	—	—	—	—
Processed PP	87.10 ± 0.14^{b}	0.31 ± 0.01^{b}	10.61 ± 0.54^{b}	88.32 ± 0.01^{a}	10.61 ± 0.54^{b}	—	—	—	—
T_0	82.82 ± 0.83^{a}	1.89 ± 0.01^{c}	10.95 ± 0.07^{e}	80.18 ± 0.03^{e}	11.11 ± 0.07^{e}	3.17 ± 0.25^{e}	1.27 ± 0.04^{a}	3.10 ± 0.14^{a}	6.35 ± 0.07^{a}
T_1	80.10 ± 0.14^{b}	1.73 ± 0.04^{d}	11.56 ± 0.02^{d}	80.66 ± 0.01^{d}	11.69 ± 0.01^{d}	4.85 ± 0.07^{d}	1.11 ± 0.01^{b}	2.32 ± 0.03^{b}	5.83 ± 0.10^{b}
T_2	77.15 ± 0.21^{c}	1.84 ± 0.03^{c}	12.11 ± 0.02^{c}	80.92 ± 0.04^{c}	12.25 ± 0.03^{c}	5.94 ± 0.06^{c}	1.00 ± 0.02^{c}	1.95 ± 0.05^{c}	4.60 ± 0.14^{c}
T_3	75.52 ± 0.03^{d}	2.05 ± 0.07^{b}	12.67 ± 0.04^{b}	81.27 ± 0.05^{b}	12.84 ± 0.05^{b}	6.95 ± 0.08^{b}	0.78 ± 0.03^{d}	1.70 ± 0.03^{d}	3.87 ± 0.13^{d}
T_4	72.06 ± 0.08^{e}	2.32 ± 0.06^{a}	13.22 ± 0.04^{a}	81.51 ± 0.05^{a}	13.43 ± 0.04^{a}	7.89 ± 0.13^{a}	0.53 ± 0.03^{e}	1.47 ± 0.07^{e}	2.68 ± 0.26^{e}

Values are means ± S.D. ($n = 2$). Values having identical lettering in each column are nonsignificant at $p > 0.05$. $T_0 = 100\%$ straight-grade wheat flour chapatis (control), $T_1 = 2.5\%$ processed potato powder (PP), $T_2 = 5\%$ processed PP, $T_3 = 7.5\%$ processed PP, and $T_4 = 10\%$ processed P.

linked with higher magnitudes of phenolics, anthocyanins, beta-carotene, reducing sugars, and to some extent from the products of Maillard reaction [6, 44]. A study by Banerji et al. [31] on flatbread prepared from wheat-amaranth composite flour (60 : 40) anticipates a significant increase in a^* values from 2.5 to 3.5 (40% ↑) and b^* values from 16.4 to 17.4 (6% ↑) while a decrease in L^* values from 64 to 62 (3% ↓).

Textural features of processed potato powder-substituted chapatis delineated a significant ($p < 0.05$) increase in hardness (3.2–7.9 N, 147% ↑) at 10% SGF substitution. Hardness is measured as an index of all-inclusive textural attributes. Springiness and gumminess of processed potato powder-supplemented chapatis were also significantly ($p < 0.05$) declined from 1.3 to 0.5 mm (58% ↓) and 3.1 to 1.5 mm (53% ↓), respectively, at 10% SGF substitution levels (Table 4). Earlier, studies by Liu et al. [23] and Ben Jeddou et al. [27] reported a linear increase in hardness of potato peel powder-based cakes from 0.37 to 0.74 mm (100% ↑) and a significant reduction in springiness from 0.4 to 0.2 mm (50% ↓) at ~10% supplementation.

Puffing is an important quality parameter indicating the physical quality of the baked flatbread [45]. The results from

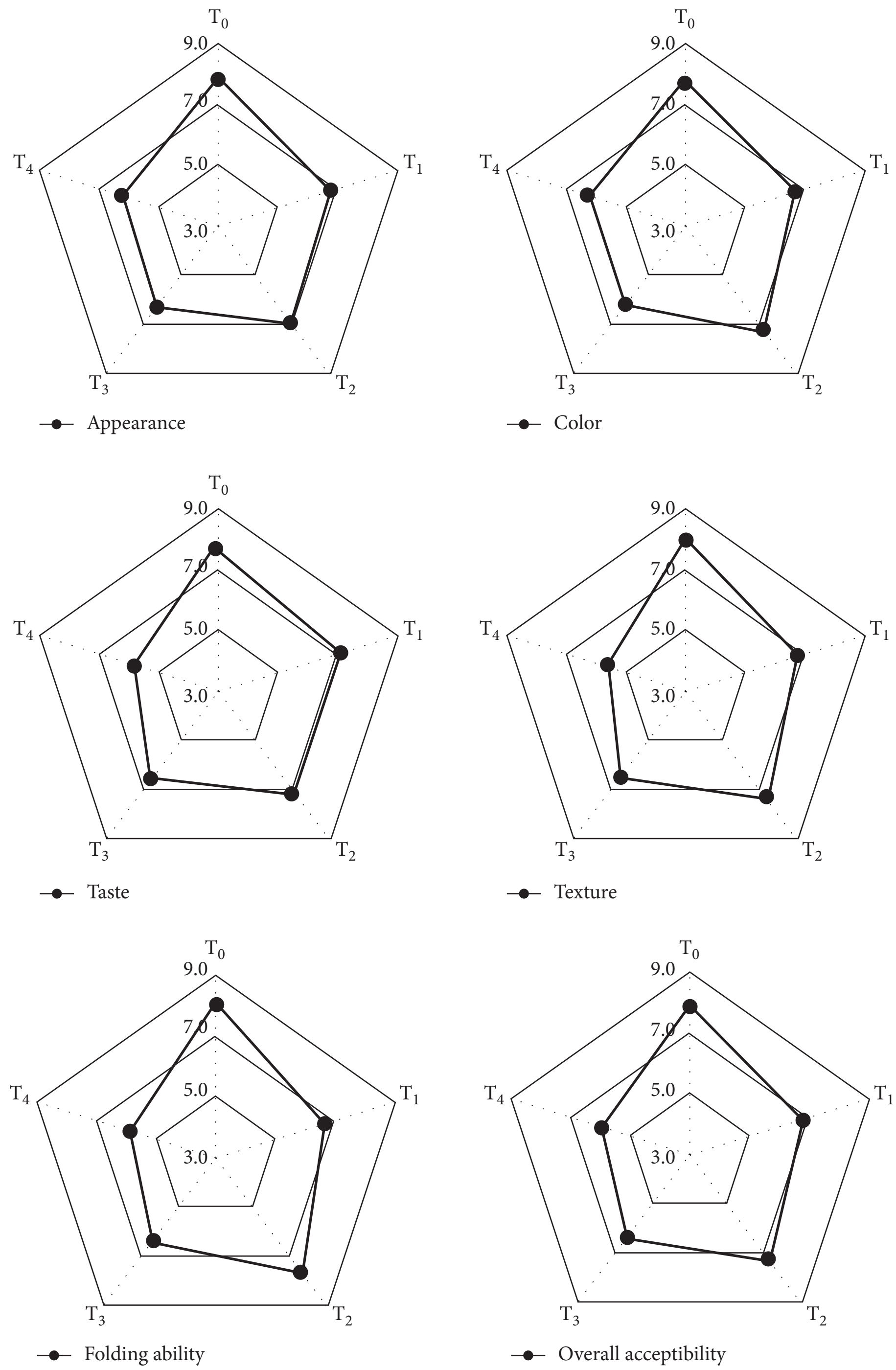

FIGURE 1: Sensory evaluation of straight-grade flour, raw and processed potato powder, and supplemented chapatis.

this study elaborated a significant ($p < 0.05$) decrease in puffed height of the processed potato powder-supplemented flatbread from 6.4 mm (100% SGF) to 2.7 cm at 10% potato powder supplementation (Table 4). Comparable findings for puffing were reported by Cheng and Bhat, [45] wherein supplementation of jering seed flour at substantially higher amounts in wheat flour resulted in a significant decline of the puffed height of flatbreads. Reduction in puffing traits of composite flours may be linked with the presence of higher magnitudes of fibers, nongluten proteins, stronger intermolecular bonds, and low water-holding ability of nonwheat flours, which results in low steam formation and consequently reduced puffed height [45, 46].

3.5. Organoleptic Attribute Assessment of Processed Potato Powder-Supplemented Chapatis. Sensory attributes are incumbent parameters for evaluating the edibility of value-added foods. Data on the appearance of processed potato powder-supplemented flatbreads revealed a maximum sensory score for control ~7.8 followed by the product prepared at 5% processed potato powder supplementation bearing an overall acceptability score of 6.9. Color being an imperative quality attribute that enhances the eye appeal and acceptability of finished goods was assigned the highest score of 7.7 and for the control followed by 5% potato powder-supplemented flatbreads that were assigned a 7.2 color score (Figure 1). Substituting wheat flour with potato powder ~10% was observed to drastically affect all sensory attributes of the baked flatbread potato powder supplementation. Contrarily, potato powder supplementation ~5% was found to anticipate better acceptability of the baked product for various sensory attributes. The color of the potato powder-supplemented product was ranked lower at a high degree when compared with the normal control that may be linked with color pigments of the potato powder and products of Maillard reaction generated during baking and microwave heating. Varying degrees of sensory acceptability of composite flour-based flatbreads have been reported earlier emphasizing sensory properties and the physical and biochemical composition of the supplementing ingredients to yield either acceptable or nonacceptable sensory scores. At an instant, a significant decline in the taste of processed potato powder-supplemented flatbread at ≥a 7.5% level of supplementation may be ascribed to the tannins that contribute astringency to the product with increasing concentration. A similar response was documented by Menon et al. [47] linking the hydrolyzable and nonhydrolyzable tannins to significantly alter the taste and color of the bread. Albeit the sensory score of SGF-processed potato powder-supplemented flatbreads was notably decreased with increasing potato powder supplementation levels, the edibility of the product remained acceptable at a 9-point hedonic scale. A higher texture acceptability score may be yielded at processed powder supplementation below 7.5%, and a similar proposal was made by Joshi et al. [6] suggesting better texture acceptability of the muffins carrying grilled potato powder at a level below 10%. Significant decline in texture score of the processed powder-supplemented flatbread may be ascribed to higher fiber contents of the product and reduced water-holding capacity of the potato powder. In line with the findings of Ben Jeddou et al. [27] on sensory acceptability of potato peel powder-supplemented cakes, a higher consumer acceptability score for SGF-processed potato powder composite flatbread may be achieved at 5% potato powder supplementation.

4. Conclusions

Microwave-treated potato powder supplementation in flatbread demarcated increased nutritional value of the baked good suggesting commercial applicability of potato powder as a natural ingredient for value-added product development. With a least to nonsignificant effect on the nutritional composition of potato powder, microwave heat treatment significantly reduced antinutrients in potato powder and the flatbreads. Furthermore, the processed potato powder addition in supplemented flatbreads below 7.5% was found to enhance its nutritional traits mildly to moderately affecting sensory traits of the finished goods. It may be suggested that microwave heating at 1.1 kW for 2 minutes mitigates antinutrient load in potato powder and helps in improving dietary fiber and microelement concentrations in wheat-potato powder composite conventional baked goods of South Asia. Partial substitution of wheat flour with processed potato powder in developing traditional foods may further reduce the dietary burden on conventional cereals and promote food diversification.

Data Availability

The dataset supporting the conclusions of this article is included within the article.

Disclosure

The article is the part of doctoral degree of Mr. Muhammad Waseem working under the supervision of Prof. Dr. Saeed Akhtar and Dr. Tariq Ismail at the Institute of Food Science and Nutrition, Bahauddin Zakariya University, Multan, Pakistan.

Conflicts of Interest

The authors declare no conflicts of interest.

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