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The Impact of Fortification of Bread with Pomegranate Peel on Nutritional, Antioxidant Activity, and Sensory Properties

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Abstract

The purpose of this research was to determine the impact of fortifying pan bread with five different concentrations (2%, 4%, 6%, 8%, 10%) of pomegranate peel on antioxidant activity and nutritional and sensory characteristics. Chemical estimates were made for pomegranate peel, wheat flour, and fortified bread. When the pomegranate peel concentration increased, the fortified pan bread's moisture, fiber, ash, and (fat only for S1, S2, and S3) content all significantly increased ($p<0.05$). While the amount of protein and carbohydrates was decreased. Additionally, fortified bread's minerals, antioxidant activity, physical characteristics, and sensory assessment were identified. Potassium, calcium, zinc, and iron in fortified bread showed considerable improvement; they rose significantly ($p<0.05$) as pomegranate peel increased. While for copper and manganese, no discernible changes were seen. Our study demonstrated that the total phenol, total flavonoid, DPPH, and FRAP were significantly increased when pomegranate peel concentration increased. According to a sensory evaluation of the fortified bread, there were no significant differences in taste and texture attributes for the S1, S2, and S3 treatments, except the S4 and S5 treatments were significantly different. No significant differences in flavor. For appearance, crust color, crumb color, and general acceptance were significantly different.

Keywords:

Pomegranate peel, nutritional, pan bread, antioxidant activity, sensory evaluation, fortification.

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Introduction

The food industry generates a lot of waste, both liquid and solid, during the food production process. These wastes indicate a significant loss of nutrients and provide increasing disposal and potential major contamination problems (Maha Lakshmi & Thaiyalnayaki, 2025). Food industry wastes have the potential to be polluting, but they may also frequently be converted into useful byproducts or raw materials for another industry (Abdel Moneim et al. 2016). The pomegranate is native to Central Asia and has since spread to the Americas and the Mediterranean region. Because they are frequently consumed fresh or used to make juice, peels and seeds have a high amount of industry waste (Wang, 2011). Furthermore, it has a high concentration of phenolic compounds, which are potent antioxidants, including hydrolysable tannins (Kupnik et al. 2022). Because of its dietary fiber content of about 24-40% (Ko et al., 2021) and phenolic compound content (primarily ellagitannins, like punicalagin), as well as its low phytic acid content (Russo et al., 2018). Pomegranate peel is the food industry important waste (Hasnaoui et al., 2014). Numerous laboratory experiments on pomegranate peel have shown that it has many distinct roles in various fields. In the food industry, it has a significant impact on the composition and sensory characteristics of food products containing pomegranate peel (Akrami et al., 2024) as a functional ingredient (Tariq et al., 2014). In the therapeutic field, it has a significant impact on chronic diseases, as food containing pomegranate peel improves high blood sugar levels, obesity, and cardiovascular diseases, as well as its role as an antioxidant and antimicrobial (Grabez et al., 2020). Bread is an important food product widely used all over the world and can be enriched with various functional and health compounds to improve its nutritional and health value, because most of the bread consumed is refined bread, which is considered nutritionally poor (Dewettinck et al., 2008) due to the loss of important nutritional parts of the wheat grains during the milling process, such as the germ and bran, which are rich in nutrients such as vitamins, minerals, antioxidants, and fiber (Previtali et al., 2014). To compensate for the deficiency of these important nutrients in bread, in addition to the emerging nutritional awareness among people of the necessity of producing healthy bread rich in the necessary healthy nutrients, a new trend has recently emerged among researchers in the field of food production to exploit food production plant wastes containing nutrients, such as fruit peels, to fortify bread with cheap components to improve the nutritional and health value (Samifanni, 2024). Hence, the aim of this study is to determine the impact of fortification of pan bread with pomegranate peel on nutritional, antioxidant activity, and sensory characteristics (Boopathy et al., 2025)

Materials and Methods

Preparation of Pomegranate Peels

Pomegranate peels were sliced into tiny pieces and painstakingly sorted. After being cleaned with extra water and dried for 24 hours at 40ºC in an oven, it was ground, sifted, and kept at –18ºC until it was needed. (Mehder, 2013)

Making Pan Bread

As stated in Table 1, making pan bread was performed as a procedure outlined by (A.A.C.C. 2000). After thoroughly mixing the ingredients (1 minute), further combine (4 minutes) for dough in a laboratory mixer. The dough was rolled out, cut, and kept for 50 minutes at 37±2ºC for fermentation. After being placed in a greased fermentation bowl. After that, it was baked for 25 minutes at 220±8ºC in an electric oven. The bread was left at 35ºC (Khasanah et al., 2022).

Table 1. Formulas of fortified pan bread

Sample	Wheat flour (%)	Pomegranate peel powder (%)	Instant yeast (%)	Salt (%)	Sugar (%)	Improver (%)	Oil (%)
control	100	-	1.5	1.0	1.5	1.0	1.5
S1(2%)	98	2	1.5	1.0	1.5	1.0	1.5
S2(4%)	96	4	1.5	1.0	1.5	1.0	1.5
S3(6%)	94	6	1.5	1.0	1.5	1.0	1.5
S4(8%)	92	8	1.5	1.0	1.5	1.0	1.5
S5(10%)	90	10	1.5	1.0	1.5	1.0	1.5

Determination of Composition of Bread

Moisture, fat, protein, and ash were measured for bread samples according to (Nwosu et al., 2022), fiber was estimated according to (AOAC, 2016), and carbohydrates were assessed by differences.

Determination of Minerals

Pomegranate peel and bread fortified with pomegranate peel after wet digestion were tested for minerals such as Fe, Zn, Mn, and Cu using an atomic absorption spectrophotometer fitted with many hollow cathode lamps (AOAC, 2000). Flame photometry was used to determine Ca, Na, and K.

Determination of Phenol and Flavonoid

To determine the phenol in pomegranate peel and bread fortified with pomegranate peel samples, the method described by (Singleton et al., 1999) was utilized. This included oxidizing suitable dilutions of bread sample aqueous extracts with 2.5 ml of 10% Folin-Ciocalteu, neutralizing, The measurement was at 765 nm. The technique described by (Meda et al. 2005) was used to determine flavonoid at 415 nm.

Determination of DPPH and FRAP

DPPH was determined according to (Aluko and Monu, 2003) at 516 nm, while FRAP was measured as reported by Zhang et al. (2008) at 700 nm.

Determination of Pan Bread Volume and Specific Volume

The volume of pan bread was measured according to (Xie et al., 2004). Using a 2-decimal digital weighing scale, pan bread weights were recorded. After an hour of baking, the specific volume was measured as follows:

Specific volume = volume / weight

Sensory Evaluation of Fortified Pan Bread

Twenty panelists were asked to rate the prepared pan bread on the following criteria: taste (20), appearance (20), texture (15), flavor (15), color of crust (15), crumb color (15), and overall acceptability (100). (Khorshid et al., 2011) (Jaraet al., 2010).

Statistical Analysis

One-way analysis of variance (ANOVA) was performed using SPSS version 19, and a p-value of less than 0.05 was deemed significant.

Results and Discussion

Nutritional Composition of Pomegranate Peel, Flour, and Fortified Pan Bread

Table 2. Nutritional composition of pomegranate peel, flour, and fortified pan bread with pomegranate peel (g/100g)

Sample	Moisture	Carbohydrate	protein	Fat	Fiber	Ash
Pomegranate peel powder	8.47±0.13^{b}	68.67±0.32^{b}	3.23±0.03 ^{h}	2.61±0.03^{f}	18.53±0.74^{a}	2.81±0.03^{a}
Wheat Flour	12.27±0.21^{a}	84.14±0.18^{a}	12.34±0.04^{a}	1.23±0.10^{e}	0.33±0.03^{g}	0.42±0.01^{e}
Control bread	28.51±0.12^{d}	78.62 ±0.18^{a}	12.11±0.06^{b}	3.35 ±0.04^{d}	0.32±0.02^{g}	0.53±0.01^{de}
S1 (2%)	29.31±0.18^{c}	72.36±0.57^{b}	11.84±0.07^{c}	3.42±0.03^{d}	0.68±0.06^{f}	0.55±0.02^{de}
S2 (4%)	29.51±0.14^{c}	71.21±0.54^{b}	11.64±0.07^{d}	3.46±0.02^{d}	1.12±0.05^{e}	0.61±0.03^{cd}
S3 (6%)	30.21±0.13^{b}	68.57±0.99^{c}	11.43±0.08^{e}	3.97±0.01c	1.42±0.06^{d}	0.67±0.02^{bc}
S4 (8%)	30.42±0.16^{b}	64.46±0.72^{d}	11.15±0.06^{f}	4.51±0.03^{b}	1.72±0.04^{c}	0.72±0.02^{b}
S5(10%)	31.23±0.18^{a}	63.01±0.03^{d}	10.95±0.10^{g}	5.23±0.04^{a}	1.96±0.06^{b}	0.76±0.01^{de}

Table 2 displays the composition of pomegranate peel, flour, and pomegranate bread. The moisture, carbohydrate, protein, fat, fiber, and ash content for peels were 8.47%, 68.67%, 3.23%, 2.61%, 18.53%, and 2.81%, respectively, and for wheat flour were 12.27%, 84.14%, 12.34%, 1.23%, 0.33%, and 0.472%, respectively. According to our findings, pomegranate peel can contribute a respectable quantity of ash and fiber to bread. These findings concur with those of (Sayed-Ahmed, 2014). According to these findings, pomegranate peel powders should be used to fortify foods with fiber and ash, as described by (Rowayshed et al., 2013), as a functional component. Adding pomegranate peels to bread had a significant impact on the bread's ingredients, increasing the moisture, fat, fiber, and ash and decreasing the carbohydrate and protein when the pomegranate peels. This may be attributed to the composition of peels. The fat in the bread contributes to the bread's larger size and more uniform color distribution. It also acts as an anti-stalling agent, extending the bread's shelf life. Hence, adding peel of pomegranate to bread could be utilized as a unique component to improve the quality of bread. These results are consistent with what was found by (Sayed-Ahmed, 2014) and (Amiza et al., 2022).

Mineral content of pomegranate peel and fortified pan bread

Table 3. Mineral content of pomegranate peel and fortified pan bread with pomegranate peel (mg/kg)

Sample	Fe	Na	Ca	Zn	K	Cu	Mn
Pomegra-nate peel	1.21±0.02a	592.94±1.38g	1192.04±2.70a	3.68±0.09a	2749.46±3.78a	0.02±0.00a	0.02±0.00
Control bread	0.46±0.02e	770.91±0.95a	46.90±1.04g	2.65±0.08f	327.26±2.47g	0.01±0.00b	0.02±0.00
S1 (2%)	0.48±0.04e	765.42±2.51b	79.55±0.83f	2.67±0.10ef	382.25±1.14f	0.01±0.00b	0.02±0.00
S2 (4%)	0.50±0.03de	758.86±1.53c	104.70±0.71e	2.69±0.07de	444.04±2.01e	0.01±0.00b	0.02±0.00
S3 (6%)	0.51±0.05cd	754.00±1.29d	127.78±0.91d	2.72±0.09cd	495.76±0.94d	0.01±0.00b	0.02±0.00
S4 (8%)	0.54±0.06bc	749.07±0.83e	149.54±1.43c	2.75±0.10bc	545.63±1.38c	0.01±0.00b	0.02±0.00
S5(10%)	0.56±0.07b	743.84±0.58f	175.41±0.48b	2.77±0.08b	598.61±1.62b	0.01±0.00b	0.02±0.00

The minerals of peels and bread fortified with pomegranate peels (mg/kg) are displayed in Table 3. The study's findings demonstrated that pomegranate peel had high concentrations of potassium (2749 mg/kg), calcium (1192.04 mg/kg), and sodium (592.94 mg/kg), as well as reasonable amounts of zinc (3.68 mg/kg)

and iron (1.21 mg/kg). As a result, potassium, calcium, zinc, and iron in fortified bread with pomegranate peel were significantly improved ($p<0.05$) when the pomegranate peel increased. As pomegranate peel in the bread increased, no discernible changes in copper and manganese amounts were discovered. No significant differences were found in copper and manganese. Pomegranate peel has been described as a rich component in calcium, potassium, magnesium, iron, and zinc (Fawole and Opara, 2012). Thus, adding mineral-rich plant materials, like pomegranate peel, to food, like in this study, may be a good way to address the issue of mineral deficiencies in economically disadvantaged populations (Prentice and Bates, 1993).

Antioxidant activity of pomegranate peel and fortified pan bread

Table 4. Antioxidant activity of pomegranate peel and fortified pan bread

Sample	Phenol (mg GAE/100g)	Flavonoid mg Que/100g	DPPH(%)	FRAP (mmol/100g)
Pomegranate peel	185.65±3.04^{a}	42.46±2.30^{a}	86.34±2.30^{a}	217.09±1.34^{a}
Control bread	9.46±1.98^{g}	3.29±1.86^{e}	29.30±1.86^{e}	0.78±0.03^{e}
S1 (2%)	15.52±2.25^{f}	4.15±1.88^{d}	35.26±1.88^{d}	5.62±0.10d^{e}
S2 (4%)	17.27±2.01^{e}	5.12±2.25^{d}	39.48±2.25^{d}	9.85±0.09^{cd}
S3 (6%)	20.62±2.20^{d}	6.78±2.00^{c}	45.28±2.00^{c}	13.79±0.24^{c}
S4 (8%)	±1.55^{c} 23.82	8.17±1.60^{bc}	48.39±1.60^{bc}	17.98±0.16^{b}
S5 (10%)	±1.86^{b} 25.92	9.68±2.12^{b}	51.42±2.12^{b}	21.91±0.81^{b}

The phenol and antioxidant activity of peels and fortified bread are displayed in Table 4. The study's findings showed that the pomegranate peel samples and bread fortified with pomegranate peel had substantial levels of antioxidants. Peels are rich in phenol (185.65 mg GAE/100g), flavonoid (42.46 mg Que/100g), DPPH (86.34%), and FRAP (217.09 mmol/100g). Therefore, the polyphenols in pomegranate peel contributed to an important increase in phenol, flavonoid, DPPH, and FRAP in bread samples as the concentration of peels in bread increased. Pomegranate peel and bread samples had greater levels of total phenol than those reported by (Akuru et al., 2020). Pomegranate peel has a higher DPPH value than that discovered by (Sharayei et al., 2019). According to (Han and Koh, 2011), white flour used in bread production has a lower phenolic profile and antioxidant. Medicinal plants and plant extracts like pomegranate peel have been described as rich materials in phenol and antioxidant activity (Hussain et al., 2024). Hence, our findings thus supported the significant and advantageous effect of pomegranate peel addition on the phenolics and antioxidant profile of bread fortified with pomegranate peel.

Physical properties of fortified pan bread

Table 5. Physical properties of fortified pan bread

Sample	Volume (cm^3)	Specific volume (cm^3/g)	Weight (g)	Height (cm)
Control bread	442.34± 13.39^{a}	2.97±0.08^{a}	148.64±1.67^{a}	7.19±0.05^{a}
S1 (2%)	416.47±5.48^{b}	2.76±0.03^{b}	150.78±3.69^{a}	6.76±0.02^{b}
S2 (4%)	379.72±21.89^{c}	2.50±0.12^{c}	151.68±.3.64^{a}	6.28±0.02^{c}
S3 (6%)	356.51±11.78^{d}	2.33±0.05^{d}	152.42±61^{a}	5.73±0.04^{d}
S4 (8%)	339.32±15.59^{e}	2.20±0.08^{e}	154.23±1.97^{a}	5.39±0.03^{e}
S5 (10%)	332.48±13.87^{e}	2.13±0.05^{f}	155.57±1.78^{a}	5.03±0.02^{f}

Table 5 displays the physical properties of fortified pan bread, such as volume, weight, specific volume, and height. According to our research, adding more pomegranate peel to the bread slightly boosted its weight. When the pomegranate peel in bread is increased, the volume and specific volume of fortified bread are decreased, where the volume decreased from 442.34 cm^3 in the control to 416.47, 379.72, 356.51, 339.32, and 332.48 cm^3 at substitution concentrations in bread fortified with pomegranate peel of 2%, 4%, 6%, 8%, and 10%, respectively. These declines may be attributed to fiber of peels, sluggish construction of gluten structure, and gluten dilution (Pomoranz et al., 1977). According to (Sosulski and Cadden, 1982), this might be because dietary fiber components have a strong capacity to swell and absorb more water. The specific volume of bread was also reduced from 2.97 cm^3/g in the control to 2.76, 2.50, 2.33, 2.20, and 2.13 cm^3/g at substitution concentrations in bread fortified with pomegranate peel of 2%, 4%, 6%, 8%, and 10%, respectively. These findings were comparable to those of (Chen et al., 1988). Additionally, the study's findings showed differences in the height of fortified bread compared to control bread.

Sensory evaluation of fortified pan bread

Table 6. Sensory scores of fortified pan bread

Sample	Taste (20)	Flavor (15)	Appearance (20)	Crust color (15)	Crumb color (15)	Texture (15)	Overall acceptability (100)
Control	17.79 ± 0.61^{a}	13.62 ± 0.64^{a}	17.93 ± 0.32^{a}	14.34 ± 0.25^{a}	13.73 ± 0.24^{a}	13.61 ± 0.26^{a}	91.02 ± 1.21^{a}
S1 (2%)	17.11 ± 0.67^{ab}	13.71 ± 0.32^{a}	16.87 ± 0.40^{b}	12.82 ± 0.31^{bc}	12.53 ± 0.31^{bc}	12.91 ± 0.30^{ab}	85.95 ± 1.46^{b}
S2 (4%)	17.42 ± 063^{ab}	13.92 ± 0.42^{a}	16.24 ± 0.43^{b}	12.76 ± 0.39^{b}	12.24 ± 0.36^{b}	12.19 ± 0.31^{a}	84.77 ± 1.50^{b}
S3 (6%)	16.93 ± 0.77^{ab}	13.53 ± 0.49^{a}	15.79 ± 0.54^{b}	12.32 ± 0.33^{cd}	11.56 ± 0.28^{cd}	12.43 ± 0.26^{ab}	82.56 ± 1.87^{bc}
S4 (8%)	$16.17\pm083.^{b}$	13.39 ± 0.38^{a}	14.89 ± 0.55^{b}	12.24 ± 0.32^{d}	11.06 ± 0.41^{d}	12.10 ± 0.37^{b}	79.85 ± 2.11^{c}
S5 (10%)	15.01 ± 0.69^{b}	13.37 ± 0.47^{a}	14.05 ± 0.51^{b}	12.10 ± 0.30^{cd}	10.89 ± 0.38^{d}	11.49 ± 0.21^{b}	76.96 ± 1.96^{c}

Table 6 shows the fortified bread sensory assessment. When compared to fortified pan bread with pomegranate peel, our study's findings revealed that the control samples had the greatest marks for every sensory feature. Additionally, the study's findings showed significant differences in appearance, crust color, crumb color, and overall acceptability. No significant differences were discovered between the control and treatments in taste and texture sensory attributes for the S1, S2, and S3 treatments, with the exception of the S4 and S5 treatments, which were different from the control. For the flavor attribute, no significant differences were seen between the control and treatments.

Conclusion

In conclusion, pomegranate peel, which is rich in dietary fiber, minerals, antioxidants, and medicinal properties, is one example of food industry waste that can be incorporated into nutritious foods as functional ingredients. Fortification of pan bread with pomegranate peel powder increased many important nutritional components and may have important benefits for chronic diseases, such as lowering LDL-cholesterol concentrations, improving sugar levels, and lowering lipid profiles. The contents of potassium, calcium, zinc, and iron in pan bread fortified with pomegranate peel showed significant improvements. The impact of these wastes and their products on pan bread's staling, shelf life, and other quality attributes require**s** additional studies.

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