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Effects of pomegranate seed flour on dough rheology and bread quality

Hülya Gül and Hicran Şen

Engineering Faculty, Food Engineering Department, Süleyman Demirel University, Isparta, Turkey

ABSTRACT

The objective of this study was to determine the effects of pomegranate seed flour (PSF) on dough and bread quality. PSF with 15.66% protein, 18.24% lipid, 52.22% dietary fiber, 40.60 g/kg GAE total phenolic and 1049.10 IC50 = µg/mL antiradical activity was substituted for bread wheat flour at 0%, 5%, 7.5% and 10% levels. While 5% PSF did not show any significant effect on water absorption, stability and pressure increased and development time and extensibility decreased as addition level increased. With the addition of PSF in wheat flour, decreases were observed in volumes, widths, heights and brightness of breads, while increases were detected in dietary fiber, a and b values and textural properties such as hardness and chewiness. The study demonstrated that fiber-enriched bread with good sensory and technological quality could be produced by substituting wheat flour with 5% of PSF.

1. Introduction

Pomegranate (Punica granatum) is a perennial plant, and is usually planted in tropical and subtropical regions (Schubert, Lanksy, & Neeman, 1999). Turkey ranks third after Iran and Pakistan in terms of pomegranate production in the world totaling to 445,750 tons in 2016 (TÜIK, 2016). The production, domestic consumption and foreign trade of pomegranate has increased tremendously in recent years depending on increasing demand on fresh fruit or its juice, concentrate, canned beverages, jam, jelly or paste. Pomegranate popularity comes from the fact that they are very rich in terms of compounds such as polyphenols, flavonoids, anthocyanin, ascorbic acid, ellagic acid, caroteneoids, and tannins (Jing et al., 2012; Tasaki et al., 2008). They have gained a wide acceptance for the pharmacological activities against serious maladies such as prostate (Lansky et al., 2005), colon and liver cancers, stomach ulcers, cardiovascular diseases, digestive disorders (Ismail, Sestili, & Akhtar, 2003; Tasaki et al., 2008) and DNA damages (Guo, Deng, Xiao, Xie, & Sun, 2007). A study by Şimşek, Karadeniz, and Bayraktaroğlu (2009) reported that the pomegranate seed showed immunosuppressive effect in rats; thus they offered for utilization of it as the antioxidant in protection of erythrocytes and the treatment of leukemia. Pomegranate seed contains lignin, cellulose and polysaccharides (Dalimov, Dalimova, & Bhatt, 2003) and high concentrations of conjugated fatty acids such as conjugated linolenic acid (Kohn et al., 2004). Vroegrijk et al. (2011) concluded that dietary pomegranate seed oil ameliorates high-fat diet-induced obesity and insulin resistance in mice, independent of changes in food intake or energy expenditure. Based on the results of these studies on animal experiments, it can be said that pomegranate seed might bring potential health benefits for humans.

As mentioned earlier, studies show that, pomegranate seeds contain even higher amounts of specific nutritionally valuable and biologically active components compared to the edible fruit. During pomegranate juice processing, large amounts of pomace containing peels and seeds are generated. However, the waste products are difficult to dispose as this causes environmental pollution. Therefore, it is generally evaluated as supplement in animal feed (Akhtar, Ismail, Fraternale, & Sestili, 2015). Hence, pomegranate by-products that are rich in bioactive compounds and dietary fiber could be used as a functional ingredient in bakery foods, especially in bread which is the basic food for most people around the world. Effects of pomegranate bagasse powder on yeast...
2. Material and methods

2.1. Materials

Commercial bread wheat flour was supplied from Berberoğlu Milling Factory (Burdur, Turkey). Farinographic properties of the flour were 58.7% of water absorption, 7.9 min stability and 2.2 min of dough development time. The proximate compositions of wheat flour, analyzed by the AACC (2001) methods, were 14.5 ± 0.01% moisture, 0.61 ± 0.03% ash, 10.47 ± 0.03% protein, 29.9 ± 0.12% wet gluten, 96.2 ± 0.20% gluten index, sedimentation 31 ± 1 ml and falling number 362 ± 2 s.

Dried and milled PSF was purchased from N.Bükey AŞ (İzmir, Turkey). Salt and bread yeast were provided from the local market. Total dietary fiber assay kit was purchased from Megazyme Company (Wicklow, Ireland). Other chemicals were purchased from Merck (Darmstadt, Germany) and were of analytical grade.

2.2. Chemical analysis of PSF

PSF was analyzed for moisture (Method 44-01.01; AACC, 2001), ash (Method 08-01.01; AACC, 2001), total lipid (Method 30-25.01; AACC, 2001), protein-N × 6.25 (Method 46-12.01; AACC, 2001), total dietary fiber (Method 32-05.01; AACC, 2001), total phenolic (TP) (Singleton & Rossi, 1965) and antiradical activity by using α-diphenyl-β-picrylhydrazyl (DPPH) ((Dorman, Pettoketo, Hyunen, & Tikkken, 2003). Colors of dried and ground pomegranate seed samples and breads were determined with Minolta CR 400 (Minolta Co Ltd., Tokyo, Japan).

2.3. Rheological characteristics

PSF blends at 0%, 5%, 7.5% and 10% levels were prepared by replacing wheat flour. The effect of PSF on the mixing profile of the dough was studied using farinograph (Brabender, Duisburg, Germany) according to the standard AACC Method-54-21.02 (AACC, 2001). The elastic properties of the dough was studied using SMS/Kieffer Dough and gluten extensibility ring and dough inflation system of Texture analyser (TA-XT2, Stable Micro Systems, Surrey, UK) according to the methods of Kieffer, Wieser, Henderson, and Graveland (1998) and Dobraszczyk (1997), respectively.

2.4. Bread making

Bread making method was applied according to AACC Method 10-10.03 (AACC, 2001) with some modifications. Four bread formulations were prepared by replacing the flour with 0%, 5%, 7.5% and 10% (w/w) of PSF. The other ingredients were yeast (3 g/100 g), salt (1.5 g/100 g) and water (variable depending on the farinograph absorption, can be seen at Table 2). Batch size (dough weight in the mixer) of control and 5% PSF containing doughs were 1632 ± 1 g, for 7.5% and 10% PSF containing doughs were 1637 ± 1 and 1642 ± 1 g, respectively. Dough was optimally mixed until dough development by a mixer (Günsa, Industrial Kitchen Equipment, İzmir, Turkey), rested for 30 min at 25°C and 75% relative humidity. After first fermentation, dough was scaled into pieces according to 100 g flour weight basis (each dough was divided into 10 pieces because totally 1 kg of flour or flour + PSF was used to make breads), hand-rounded, molded and placed into baking pans for the second fermentation at 25°C and 75% relative humidity for 90 min. Baking was carried out at 275°C for 15 min in a stone flour electrical oven (Enkomak, Antalya, Turkey). Breads were cooled at room temperature, and packed in plastic bags until further analysis.

2.5. Bread quality evaluation

Loaf volume of breads prepared in triplicate was measured by rapeseed displacement method (AACC Method 10-05.01) 6 h later after baking. Width, length and height of breads from each batch were measured by a calliper.

2.6. Textural analysis of breads

After cooling for 4 h, breads were cut into slices of 25 mm thickness with a bread knife. The central two slices were used to perform textural analysis on a texture analyzer (TA-XT2, Stable Micro Systems) equipped with a cylindrical probe of 36 mm in diameter (pretest speed: 1 mm/s, test speed:1.7 mm/s, posttest speed:10 mm/s and strain: 40%). Based on texture profile analysis (TPA), hardness, adhesiveness, springiness, cohesiveness and chewiness values were obtained.

2.7. Sensory analysis of breads

Sensory evaluation was carried out 4 h after the breads were prepared. Fifteen trained judges evaluated breads for appearance characteristics (loaf volume, symetry, crust color and crust structure), internal properties (color of crumb, grain structure, texture), taste, flavor and overall quality. A five-point hedonic scale ranging from ‘like extremely’ to ‘dislike extremely’, corresponding to the highest and lowest scores of 5 and 1, respectively, was used. The purchase intent was also evaluated on a five-point scale, ‘definitely would buy’ to ‘definitely would not buy’ corresponding to the highest and the lowest scores of 5 and 1, respectively (Meilgaard, Civille, & Carr, 1999).
2.8. Statistical analysis

Analysis of variance was conducted by using the SPSS 16.0 (SPSS Inc., Chicago, IL, USA) procedures. The calculated mean values were compared using Duncan’s multiple range test with significance defined at P < 0.01. All experiments were carried out in triplicate and the mean values were expressed.

3. Results and discussion

3.1. Some characteristics of PSF

Proximate composition of the PSF was 10.67% moisture, 3.21% ash, 15.66% crude protein, 18.24% total lipid and 52.22% total dietary fiber content (dry basis). The contents of TPs was 40.60 g/kg GAE and antiradical activity was 1049.10 IC50 = μg/mL. Its L, a and b color values were determined as 48.80, 5.57 and 10.83, respectively.

The results of proximate crude fat and crude protein (Fadavi, Barzegar, & Azizi, 2006; Gölüküçü, Tokgóz, & Kiralan, 2008) composition are in agreement with those of other workers. On the other hand, protein content of PSF was found higher than lemon pomace powder (Chang, Li, & Shiau, 2015), white cabbage powder (Gül, Yanık, & Acun, 2013b), grape pomace powder (Gül, Acun, Şen, Nayır, & Türk, 2013a), apple pomace powder (Masoodi & Chauhan, 1998) and found close to artichoke by-product obtained from a canning factory (Frutos, Guilabert-Antó, Toma’s-Bellido & Herna’endez-Herrero, 2008) and potato peel powders (Jed dou et al., 2017).

Over the years, high dietary fiber containing by-products has received much positive attention with regard to its potential as a foodstuff, due to its ability to reduce cholesterol, diabetes and coronary heart disease and ease constipation (OShea, Arendt, & Gallagher, 2012). Saura-Calixto (1998) have stated that, in order to have a vegetable material to be defined as antioxidant dietary fiber, it must contain dietary fiber more than 50% in terms of dry matter. To authors’ opinion, the PSF used in our research and having 52.22% dietary fiber content can be used as an ingredient with specific functions in food production. High level of dietary fiber was also stated for mango peel (Ajila, Aalami, & Prasada Rao, 2009), grape pomace (Gül et al., 2013a; Llobera & Canellas, 2008; Llobera & Cañellas 2007) and orange peel (Figueroa, Hurtado, Estevé, Chiffelle, & Asenjo, 2005).

TPs of PSF was measured as 40.60 g/kg GAE. This is more than the TP content (7.20 ± 0.08 mg/g) of pomegranate fruit (Gölüküçü, Tokgóz, & Çelikyurt, 2005; Gölüküçü et al., 2008) and pomegranate seed (Dalimov et al., 2003). The difference between chemical can be resulted from the variance in species, climate condition, soil and maturity.

Antioxidant activity of PSF is assessed by scavenging of the stable DPPH radical. The IC50 for the PSF was 1.05 mg/mL DPPH radical. EC50 value of China-grown pomegranate seeds was found by Jing et al. (2012) between 6.4 and 13.1 mg flour equivalents/mL. Adil, Cetin, and Bayindirli (2007) found that antiradical efficiencies of the extracts were 3.30 and 1.5 mg DPPH radical/mg sample for apple and peach pomaces, respectively.

3.2. Rheological properties

Results from the farinograph analysis show that water absorption was not affected from the addition of PSF up to 5% level but after that it began to increase (Table 2). This is an expected result, because the dietary fibers of PSF holds more water than wheat flour. Similar results were obtained by Chang et al. (2015) for lemon fiber and by Sudha, Baskaran, and Leelavathi (2007) for apple pomace. Slight decrease at dough development time for dough’s containing PSF were observed. Upon addition of PSF, significant increase in stability was recorded especially at 10% addition level of PSF. Results of a study done by Peressini and Sensidoni (2009) also showed that the addition of dietary fiber led to a considerable increase in stability.

For further dough processing, it is essential to know the extensional properties of dough. Thus, extensional measurements were performed at texture analyzer (TA-XT2i; Stable Micro Systems) by using Kieffer dough and gluten extensibility rig. Table 1 listed the resistance to extension (R), extensibility (E) and area under the curve (A) of control doughs and doughs enriched with various substitution levels of PSF. The R value was increased while E value decreased as the PSF substitution increased (0–10%). With increase in PSF content to 10%, the R value was increased from 20.7 to 32.0 g and extensibility values decreased from 22.6 to 17.83 mm. Hence, the addition of excessive PSF resulted in a stiffer and less extensible dough. The extensibility of dough (E), an indicator of the handling characteristics of the dough, was greatly reduced by fibers addition. There was no significant differences between A values of all samples. The effect of PSF on the rheological properties of dough was consistent with previous research using different dietary fibers from fruit and vegetable by-products, such as apple pomace (Sudha et al., 2007), fibers from pea pod and broad bean pod (Fendri et al., 2016), pineapple core fiber

### Table 1. Rheological properties of doughs.

| Addition level of PSF (%) | Farinograph parameters | SMS/Kieffer dough and gluten extensibility parameters | Dough inflation system parameters |
|---------------------------|------------------------|-----------------------------------------------------|----------------------------------|
|                           | WA (g × mm)            | Resistance to extension (R) (g)                     | Pressure (P) (mm)                |
|                           | DDT (min)              | Extensibility (E) (mm)                              | L (mm)                           |
|                           | Stability (min)        | Area (A) (g × mm)                                  | W (J ×10,000)                    |
| 0                         | 58.7c                  | 20.7b                                               | 89.2b                            |
|                           | 2.2a                   | 22.60ab                                             | 37.3a                            |
|                           | 7.9c                   | 239.6a                                              | 97.6a                            |
| 5                         | 58.6c                  | 23.3b                                               | 153.5a                           |
|                           | 1.8b                   | 26.27a                                              | 16.6b                            |
|                           | 9.2b                   | 256.3a                                              | 96.4a                            |
| 7.5                       | 59.2b                  | 21.13ab                                             | 144.5a                           |
|                           | 1.8b                   | 270.3a                                              | 20.7b                            |
|                           | 9.3b                   |                                                      | 99.7a                            |
| 10                        | 59.7a                  | 32.0a                                               | 146.5a                           |
|                           | 1.9b                   | 17.83b                                              | 12.5c                            |
|                           | 10.4a                  | 238.3a                                              | 76.0b                            |

Mean values in the table in the same column followed by different letters are significantly different (P < 0.01).

WA: water absorption; DDT: dough development time; L: drum distance; W: deformation energy.

Los valores medios en la misma columna de la tabla seguidos de distintas letras son significativamente diferentes (P < 0.01).

WA: Absorción de agua, DDT: Tiempo de desarrollo de la masa, L: Distancia del tambor; W: Energía de deformación.
level of PSF. But $W$ became smaller at 10% level of PSF indicating weaker baking strength. Our findings were in line with the observations realized by Anil (2007), who reported a decrease on elasticity and an increase on resistance to extension of dough prepared by incorporating hazelnut testa as sources of dietary fiber.

### 3.3 Bread properties

Loaf volume, height, width and length values of bread samples are presented in Table 2. However, fiber breads enriched with PSF had similar or slightly less length values than the control breads; loaf volume, height and width of fiber breads were found significantly lower than those of control breads ($P < 0.01$). Increasing levels of PSF (0–10%) caused decreases in these parameters of breads (Figure 1). As can be seen from the rheological parameters, high level of PSF caused doughs to become more rigid and less elastic, so during bread making these doughs could not expand (oven spring) sufficiently, due to the adverse effect of PSF on the formation of gluten network by fiber. The result of deterioration effect of PSF in this study is consistent with the report of Bhol et al. (2015) stating that increasing the substitution of flour by pomegranate whole fruit bagasse resulted in a lower specific volume of bread. Similarly, after adding fibers such as carob and green pea fiber, increases in bread height were reported (Balestra, Cocci, Pinnavaia, & Romani, 2011). Addition of PSF or other dietary fibers might cause the dilution of gluten protein, so gluten network might not formed exactly.

The effect PSF addition on the strength to resist the expansion (pressure, $P$), extensibility ($L$) and deformation energy ($W$) of wheat flour dough was measured with Dobraszczyk/Roberts Dough Inflation System of texture analyzer. The data are given in Table 1. Substitution by PSF increased the $P$ compared with the controls, but no significant difference were found between pressures of PSF added doughs ($P > 0.01$). Dough became harder and denser as a result of competition between non-starch polysaccharides such as cellulose and hemicellulose with gluten for water through PSF addition. The results of Fourier Transform (FT) Infra Red spectroscopy (Nawrocka, Mis & Niewiadomska, 2017) and FT-Raman spectroscopy (Nawrocka, Miś, & Chargot, 2016) confirmed that the addition of dietary fiber preparations caused aggregation of gluten proteins leading to stronger and compact dough. Likewise, the extensibility ($L$) of doughs with PSF at all substitution levels were significantly lower than control doughs (Table 1). The lowest $L$ values were observed at 10% level. As expected, the dough extensibility was decreased with an increase in $P$. On the contrary, high extensibility is a prerequisite for high volumes of the processed bread which is a desired attribute. The baking strength ($W$), which is represented by the area under the curve, did not show any significant change up to 7.5% level of PSF. But $W$ became smaller at 10% level of PSF indicating weaker baking strength. Our findings were in line with the observations realized by Anil (2007), who reported a decrease on elasticity and an increase on resistance to extension of dough prepared by incorporating hazelnut testa as sources of dietary fiber.

**Table 2. Bread properties.**

| Properties            | 0          | 5          | 7.5         | 10         |
|-----------------------|------------|------------|-------------|------------|
| Loaf volume (cm³)     | 562.8a     | 439.7b     | 396.1c      | 357.8d     |
| Width (cm)            | 77.1a      | 72.7b      | 69.8c       | 70.1c      |
| Length (cm)           | 131.7a     | 130.7ab    | 129.6b      | 129.5b     |
| Height (cm)           | 68.5a      | 55.4b      | 53.5c       | 50.7d      |
| Total dietary fiber % | 5.4d       | 7.3c       | 8.0b        | 9.7a       |
| $L$                   | 63.7a      | 48.6b      | 46.4c       | 44.4c      |
| $a$                   | 0.3c       | 5.0b       | 5.2ab       | 5.5a       |
| $b$                   | 7.6b       | 9.9a       | 9.8a        | 9.7a       |
| $a_1$ first day       | 0.943de    | 0.943d     | 0.950a      | 0.940abc   |
| $a_2$ second day      | 0.941de    | 0.942de    | 0.949ab     | 0.949abc   |
| $a_3$ third day       | 0.940e     | 0.941de    | 0.946c      | 0.947bc    |

Mean values in the table in the same line followed by different letters are significantly different ($P < 0.01$).

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Figure 1. Cross-sectional appearance of breads (Control, 5%, 7.5% and 10% PSF breads from left to right).
likely to have the same meaning for the consumer, may only be made where the product contains at least 6 g of fiber per 100 g (Eur-lex, 2006). Therefore, breads containing 7.5% and 10% PSF can be labeled as ‘high in fiber’, while 5% PSF containing breads can be labeled as a ‘source of fiber’.

3.3.1. Color of breads

The effects of PSF addition on the bread color are shown in Table 2. Significant differences were observed between the colors of control breads and those of PSF supplemented breads. The L value, indicator of the brightness, was decreased as the level of PSF increased. Both a (redness) and b (yellowness) values of the crumb of breads were increased with the substitution by PSF. Breads with 5%, 7.5% and 10% of the ingredient were not significantly different in terms of a and b values, except a slight difference was measured at the a value of 5% PSF breads. While the L value of breads was primarily affected by the amount of PSF, a and b values were not affected from the different levels of PSF. The results are in agreement with those reported in bread formulated with the addition of black currant and strawberry seed flour (Korus et al., 2012), and Jerusalem artichoke inulin (Rubel, Pérez, Manrique & Genovese, 2015).

With regards to the water activity (aw), its values differ significantly as well. On the first, second and third day of analysis blending, the wheat flour with 5% PSF generally did not alter the aw of breads compared with the controls (Table 2). However, increasing the PSF to 7.5% or 10% increased the aw values significantly. This was an expected result because farinograph water absorption of these blends were found higher than control and 5% PSF containing blends. The flour with more dietary fiber is more prone to water absorption. During the assessments conducted on the third day, it was determined that aw values were decreased in all bread samples due to the moisture loss during storage.

3.3.2. Textural properties of breads

On the basis of TPA, firmness, adhesiveness, springiness, cohesiveness and chewiness were measured. Results are shown in Table 3. Texture measurements can be very valuable for the quality control and process optimization as well as for the development of new products with desirable properties and characteristics. Especially, crumb firmness is a common quality characteristics for bakery products since it is strongly correlated with consumer’s perception of bread freshness. In general, the greater the product volume the lower will be the firmness value (i.e. it will be softer). In the present study, loaf volume of control sample was found to be the highest (Table 2) and as a consequence it showed the lowest value of firmness. Significant differences (P < 0.01) were observed when comparing the control to the 5%, 7.5% and 10% PSF breads, as firmness increased by 55.8%, 100.14% and 113.41%, respectively. Similar results were reported by Masoodi and Chauhan (1998), Szukudlarz, Wojtasik, Szwengiel, and Pacyński (2011) and Chang et al. (2015) when wheat flour was substituted with apple pomace, grape by-products and lemon pomace fiber, respectively.

No significant difference (P > 0.01) was observed in adhesiveness between 5% PSF-enriched and control breads. However, adhesiveness with the substitution of PSF was significantly increased up to 7.5% and 10%. This might be due to higher water holding capacity of excessive fibrous components. The work for plunger away the probe from bread was increased as the amount of adhesive materials in bread were increased. Springiness defined as “the rate at which a deformed material goes back to its undeformed condition after the deforming force is removed”. No significant difference (P > 0.01) was found between the springiness and cohesiveness values of bread samples. However, an increasing trend in chewiness was observed with the inclusion of PSF, as was also observed in crumb firmness. Chewiness of PSF containing breads gradually increased with the addition of higher levels of PSF. The negative impact of green tea powder on hardness and chewiness of whole-wheat flour pan bread have been also reported by Ning, Hou, Sun, Wan, and Dubat (2017).

3.3.3. Sensory evaluation of breads

The sensory attributes of the control and PSF enriched breads were scored for loaf volume, crust color, crumb color, crust appearance, chewiness, smell, taste/flavor and affordability (Figure 2). The results revealed that the breads enriched by a PSF were taken significantly low sensory scores than the control bread with increasing PSF content. But crumb color scores of them were found slightly little than the control bread. In terms of crust color, smell, taste/flavor and affordability breads with 5% PSF were preferred than others. Therefore, we suggest that the fiber-enriched bread can be prepared with 5% PSF in order to increase the intake of protein and dietary fibers and maintain the sensory acceptability for the consumers.

4. Conclusion

In today’s global economy, consumers are more health conscious than before and therefore they are becoming increasingly interested in the health aspects of bakery products. This leads producers to make an effort to produce products which contain a value-added factor, such as dietary fiber which is considered as more healthy. In the present study, PSF, functional by-product of pomegranate processing plants, was added in bread to evaluate its

| Table 3. Textural properties of breads. |
| --- |
| **Table 3. Propiedades texturales de los panes.** |
| Addition level of PSF (%) | Firmness (g) | Adhesiveness (g s) | Springiness | Cohesiveness | Chewiness |
| --- | --- | --- | --- | --- | --- |
| 0 | 2488.7d | −9.02a | 0.97a | 0.60a | 1445.6c |
| 5 | 3877.3c | −14.77a | 0.95a | 0.57a | 2117.4b |
| 7.5 | 4980.8b | −40.07bc | 0.93a | 0.55a | 2577.3a |
| 10 | 5311.1a | −41.20c | 0.93a | 0.55a | 2693.5a |

Mean values in the table in the same column followed by different letter are significantly different (P < 0.01).

Los valores medios en la misma columna de la tabla seguidos de distintas letras son significativamente diferentes (P < 0.01).
effect on dough and bread quality. At the 5% level PSF substitution to wheat flour, dough rheological properties, loaf volume, crumb hardness and sensory scores of breads showed slight decrease compared to the control group; however, dough and bread quality was negatively affected from higher addition levels (7.5% and 10%) of PSF. Addition of PSF significantly increased the dietary fiber content though there were no substantial increase in the TP content and antioxidant activity of the breads. Phytochemicals of the breads may be increased by adding PSF more than 10%. In this case, further studies need to be conducted to overcome the deleterious or harmful effects of PSF on bread quality so that higher quantities can be incorporated in bread. Further experiments with animals are planned to better understand the nutritional value of PSF-enriched breads.

In conclusion, we recommend that the PSF can be incorporated in breads up to 5% level without changing the technological and sensory quality of bread drastically. From industrial and economical perspective, these findings can be important as these breads can be labeled as ‘source of fiber’ and marketed to more health conscious consumers while cutting the costs of the bread producers with the addition of PSF.

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No potential conflict of interest was reported by the authors.

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