Effect of debittered fenugreek (Trigonella foenum-graecum L.) flour addition on physical, nutritional, antioxidant, and sensory properties of wheat flour rusk

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Abstract
Fenugreek (Trigonella foenum-graecum) is a unique legume crop having many pharmacological properties and health benefits attributed to its high soluble dietary fiber and phytochemicals. The main objective of this study was to evaluate selected functional and physical (color and pasting) properties of debittered fenugreek flour (DFF) and its addition on the nutritional value and acceptance of wheat flour rusk, prepared with 5%, 10%, 15%, and 20% DFF. The antioxidant potential and sensory attributes of DFF-added rusks were also analyzed. The results revealed that with successive increase of DFF level, the nutritional, mineral, dietary fiber, and bioactive contents of the rusks were significantly (p ≤ .05) enhanced. The progressive replacement at 0% to 20% level significantly (p ≤ .05) improved the total phenolic content (157.5 to 455.8 mg GAE per 100 g), total flavonoid content (5.5 to 8.2 mg CE per 100 g), and antioxidant activity (20.4% to 45.5%). DFF incorporation significantly (p ≤ .05) increased the water and oil absorption capacity, whereas peak viscosity, breakdown viscosity, final viscosity, setback viscosity, and peak temperature were decreased. The color of rusks became darker, the loaf weight and hardness increased, whereas loaf volume and specific loaf volume values were decreased with DFF addition. Sensory attributes of rusks were slightly affected with DFF incorporation, and rusks with 15% DFF were found most desirable with significantly (p ≤ .05) enhanced nutritional, antioxidant, and sensory characteristics. The results of the present study demonstrated that incorporation of DFF at acceptable level could be achieved successfully for preparation of bakery product with enhanced nutritional and sensory quality.

KEYWORDS
antioxidant, debittered fenugreek flour, dietary fiber, pasting properties, rusks

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1 | INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) is an important legume crop grown mainly in India and many parts of the world. It is unique among legumes because of its high soluble dietary fiber (SDF) and phytochemicals contributing many pharmacological effects such as hypoglycemia (Tavakoly, Maracy, Karimifar, & Entezari, 2018), hypocholesterolemia (Belguith-Hadriche et al., 2013), antimicrobial, carminative, galactagogue, anticarcinogenic, and anti-inflammatory (Pandey & Awasthi, 2015; Wani & Kumar, 2018). Fenugreek is rich in protein (25–35%), lysins (5.7 g/16 g N), SDF and insoluble dietary fiber (IDF; 20–25% and 25–30%, respectively), and fat (5.0–7.5%) besides being rich in calcium, iron, and beta-carotene (Naidu, Shyamala, & Naik, 2011). Fenugreek is recognized as health-promoting food due to the presence of functional compounds such as carotenoids, phenolics, flavonoids, free amino acids, and polyunsaturated fatty acids. Fenugreek gum as well as proteins interact with food ingredients to stabilize and emulsify them and thereby have potential use in different food products (Gadkari, Reaney, & Ghosh, 2019; Wani & Kumar, 2018).

The interest is increasing day by day in developing novel foods loaded with natural antioxidants derived from whole grains, oilseeds, fruits, vegetables, and their by-products (Dhull, Kaur, & Purewal, 2016). Composite flours, in addition to extending the availability of wheat flour (WF), also supply essential nutrients and possess many bioactive substances of food science and biological values (Kaur, Kaur, & Purewal, 2018). Considering the health benefits of fenugreek, their incorporation as composite blends in the preparation of different food products may enhance nutritional and health status of consumers. Fenugreek incorporation in different baked products such as biscuits (Hegazy & Ibrahim, 2009; Hooda & Jood, 2005) and bread (Afzal, Pasha, Zahoor, & Nawaz, 2016; Chaubey et al., 2018; María Man et al., 2019) has been reported for improving their nutritional profile, dietary fiber, and antioxidant profile.

Although fenugreek owing to excellent nutraceutical properties has received significant recognition in recent years, however, its bitter taste limits the acceptability in food products prepared with its addition. Appropriate mitigation of this biggest limitation is always a product development challenge for the food researchers and culinologists. Past research shows the use of different approaches (e.g., soaking, germination, and roasting) to address bitterness (Ertaş & Bilgiçli, 2012; Pandey & Awasthi, 2015). Further, the use of small amount of sugar (Sharafi, Hayes, & Duffy, 2013) and curd or yoghurt (Srinivasan, 2010) has been suggested to minimize the bitterness and pungent taste in traditional foods.

Considering the health benefits, low price, and ready availability of fenugreek, its incorporation as composite blends in the preparation of different food products may enhance its economic potential and consumption as well as nutritional and health status of consumers. Though there are a number of previously published studies on the incorporation of raw fenugreek in different bakery products, studies regarding the use of debittered fenugreek in rusk preparation appear to be rather limited. Therefore, this study was undertaken with the main objective to investigate the effect of incorporation of debittered fenugreek flour (DFF) at 5%, 10%, 15%, and 20% levels on the nutritional, antioxidant, and sensory characteristics of rusks. The development of such nutritious bakery products would help to raise the availability of natural antioxidants and dietary fiber with demonstrated health benefits for the consumers.

2 | MATERIALS AND METHODS

Fenugreek seed cultivar HM-57 was purchased from Chaudhary Charan Singh Haryana Agriculture University, Hisar. Whole WF, curd, vegetable oil, sugar, and dry yeast were procured from a local market. Standard gallic acid and 2,2-diphenyl-1-picrylhydrazyl (DPPH; Sigma-Aldrich, Steinheim, Germany) and other chemicals and reagents (HiMedia, India) used were of analytical grade.

2.1 | Debittering of fenugreek seeds and preparation of blends

Fenugreek seeds were debittered using curd (1:1 in water) as per the procedure described by Chaubey et al. (2018), with a slight modification. After soaking in diluted curd for 12 hr, thoroughly washed and dried seeds were ground using a benchtop mill (Khera Mill, India) and passed through 70 mesh sieve to obtain DFF. The control consisted of 100% WF, whereas composite flour blends consisted of 5%, 10%, 15%, or 20% DFF in WF (these treatments were designated DFF-5, DFF-10, DFF-15, and DFF-20).

2.2 | Rusk formulation and preparation

The method described by Yaseen (2000), with some modifications, was used for preparation of rusks (with and without DFF). WF/DFF-added flour blends (100 g, passed through 60 BSS sieve), dry yeast (1.0 g), sugar (20 g), salt (1.0 g), vegetable oil (10 g), and fennel (0.5 g) were mixed in a pin mixer (12 min) with an adequate amount of water for preparing rusk dough. The dough was allowed to rest for 30 min, followed by fermentation of dough pieces (150 g, as per pan size) at 30°C for 90 min. The fermented loaves were then baked at 220°C for 25 min in revolving reel oven (National Mfg. Co., Lincoln, NE, USA) and then thoroughly cooled for easy slicing. The slices of about 1-cm thickness were then cut mechanically followed by roasting (200°C, 15 min) in an oven.

2.3 | Proximate composition, dietary fiber, and mineral estimation

The flour and rusk samples were analyzed for moisture, ash, fat, crude fiber, and protein (N x 6.25) contents using standard methods (AOAC,
The samples were analyzed for SDF and IDF according to AOAC Methods 993.19 and 991.42, respectively (AOAC, 2005). Calcium (Ca), iron (Fe), zinc (Zn), and copper (Cu) contents were estimated in atomic absorption mode, whereas sodium (Na) and potassium (K) contents of seeds were estimated in emission mode using atomic absorption spectrophotometer (Model AA-7000, Shimadzu, Tokyo, Japan; AOAC, 2005).

### 2.4 Functional properties

Bulk density was calculated as weight per unit volume of sample (g/ml) using a 10-ml graduated cylinder. Briefly, sample was filled in the cylinder and was gently tapped until no further diminution of the sample after filling to the 10-ml mark. Water absorption capacity (WAC) was measured by following the methods described by Sosulski (1962). Briefly, 0.5 g of sample was dispersed in 25 ml of distilled water, held for 30 min, and centrifuged (3,000 \( \times \) g, 25 min), and supernatant was decanted. The sediment was weighed to calculate WAC, and results were presented as %. Oil absorption capacity (OAC) was measured by the method of Lin, Humbert, and Sosulski (1974). Briefly, 0.5 g of sample and corn oil (6 ml) was mixed, held for 30 min, and centrifuged (3,000 \( \times \) g, 25 min), the separated oil was removed with a pipette, and the sediment was then reweighed. The flour samples were analyzed for their sedimentation value by following the method of Gupta, Bawa, and Semwal (2011). A 5-g portion of sample and 50-ml distilled water were mixed in a 100-ml stoppered graduated cylinder, shaken horizontally for 30 s initially followed by shaking at regular time intervals of 2 and 4 min. Then 50 ml of sodium dodecyl sulfate–lactic acid reagent was added, inverting the cylinder four times and further repetition of the inversion at 6-, 8-, and 10-min intervals. Finally, the contents were allowed to settle for 20 min, and the sedimentation values (ml) were recorded.

### 2.5 Pasting properties

A starch cell of Modular Compact Rheometer (Anton Paar MCR-52, Austria) was used to measure the pasting properties of flour samples (Kaur & Singh, 2016). In an aluminum canister, flour sample (3.5 g) was mixed with 25-ml distilled water to measure the viscosity profile of the flour samples. All parameters, that is, the pasting temperature, peak viscosity, breakdown, setback, and final viscosity, were calculated from recorded data, using three replicates.

### 2.6 Physical properties

After first baking and cooling, loaf weight and loaf volume (rapeseed displacement method) were measured. Specific loaf volume (ml/g) was calculated by dividing loaf volume with weight.

### 2.7 Hardness

The rusk samples were analyzed for their hardness using TA-XT2 Texture Analyzer (Stable Micro Systems, Haslemere, England), and hardness was determined from force–time curves of the texture profile analysis using the method described by Baik, Powers, and Nguyen (2004).

### 2.8 Color properties

Color measurement of flours was calculated using a Hunter Colorimeter fitted with optical sensor (Hunter Associates Laboratory Incorporation, Reston, VA, USA) on the basis of \( L^* \), \( a^* \), and \( b^* \) color system. Total color difference (\( \Delta E \)) was calculated by using the following equation:

\[
\Delta E = \left( (dL^*)^2 + (da^*)^2 + (db^*)^2 \right)^{1/2}.
\]

### 2.9 Antioxidant properties

#### 2.9.1 Total phenolic content

Total phenolic content (TPC) of the extracts was determined using Folin–Ciocalteu reagent, as described by Salar and Purewal (2017). Absorbance of the extracts was recorded at 765 nm against a blank, and the results were expressed as gallic acid equivalent (GAE) from the standard calibration curve.

#### 2.9.2 Total flavonoid content

Total flavonoid content (TFC) was measured by the colorimetric assay developed by Zhishen, Mengcheng, and Jianming (1999), and absorbance of the mixture was determined at 510 nm versus water blank. TFC of extract was expressed on a fresh weight basis as mg/g catechin equivalents (CE).

#### 2.9.3 DPPH assay

The DPPH radical scavenging capacity of the extracts was measured as described by Yen and Chen (1995) with some modifications. Briefly, 3 ml of 100-\( \mu \)M DPPH was added to 100 \( \mu \)l of extract, and the changes in absorbance were recorded after 30 min at 517 nm. Percent (\%) DPPH scavenging activity was calculated using the absorbance of control (\( A_C \)) and extracts (\( A_E \)):

\[
\text{DPPH Scavenging Activity (\%)} = \left( \frac{A_C - A_E}{A_C} \right) \times 100.
\]

### 2.10 Sensory properties

A semitrained panel evaluated the prepared rusk samples for various sensory characteristics such as color, aroma, taste, texture, and overall acceptability. A 9-point hedonic rating scale (9 = like extremely, 5 = neither like nor dislike, and 1 =
dislike extremely; Meilgaard, Civille, & Carr, 1999 was used by the panel of 32 judges in the age group of 20 to 35 years, comprising students and faculty members of the department.

2.11 | Statistical analysis

The data recorded in triplicate values for all the quality parameters were analyzed by applying one-way analysis of variance (Snedecor & Cochran, 1994). Statistical analysis was carried out using statistical software package SPSS V.23 program.

3 | RESULTS AND DISCUSSION

3.1 | Proximate composition of flours

The results of proximate analysis are summarized in Table 1. WF showed 10.52% moisture, 12.60% protein, 2.91% fat, 1.70% ash, and 1.22% crude fiber on dry weight basis (dwb). Punia, Sandhu, and Siroha (2017) also reported values of different wheat varieties for protein, fat, and ash that were in the range of our results. The moisture, protein, fat, ash, and crude fiber contents of DFF were 7.55%, 30.0%, 4.05%, 3.8%, and 6.95%, respectively. In a previous study, soaked fenugreek was found to have 35.1% protein, 41.7% total dietary fiber, 4.6% fat, and 4.0% ash (Pandey & Awasthi, 2015). DFF was found to be a potential source of SDF (18.2%), IDF (25.7%), Fe (236.3 mg/kg), Ca (1590.0 mg/kg), Na (558.2 mg/kg), and K (5821.8 mg/kg; data for minerals not shown).

3.2 | Proximate composition and mineral content of rusks

The DFF-added rusks were evaluated for their chemical composition, dietary fiber, and mineral content in comparison with their control rusk (Table 1). The addition of DFF to WF enhanced the nutritional profile of DFF-added rusks owing to high protein, SDF, IDF, and minerals in fenugreek (Naidu et al., 2011). The results clearly revealed that with successive increase in DFF concentration, a significant (p ≤ .05) linear increase in moisture (2.50% to 3.05%), ash (1.52% to 1.97%), fat (4.50% to 6.27%), protein (8.20% to 15.50%), crude fiber (1.82% to 3.50%), SDF (1.35% to 4.02%), and IDF (9.37% to 12.75%) content of DFF-added rusks compared with control was observed (Table 1). Hooda and Jood (2005) also showed an increase in protein, ash, total dietary fiber, SDF, and IDF of wheat biscuits supplemented with fenugreek flour.

Micronutrient density in grains has nutritional significance as minerals play various fundamental roles in the human metabolism. The results of present study showed that addition of DFF significantly (p ≤ .05) enhanced the micronutrient status of DFF-added rusks, which could be attributed to higher mineral content of DFF (data not shown). The concentrations of the major elements, that is, Ca, K, and Na of supplemented rusk with 5% to 20% DFF compared with control, increased from 369 to 673 mg/kg, 1,755 to 2,250 mg/kg, and 20.81 to 185.35 mg/kg, respectively. The values of the trace elements, that is, Fe and Cu, were also increased from 35.66 to 92.44 mg/kg and from 4.19 to 5.24 mg/kg, respectively. Hooda and Jood (2005) observed a slight increase in the Ca, Fe, and Zn contents of biscuits supplemented with 10% fenugreek flour.

3.3 | Antioxidant properties

Phenolics can act as antioxidant by inhibiting formation of free radicals, chelating metal ions, affecting the activity of prooxidative and antioxidant enzymes and inhibiting the autoxidation chain reactions inside the body (Carocho & Ferreira, 2013). The results presented in Table 2 showed that DFF has higher total phenolics (4032.8 mg GAE per 100 g), total flavonoids (18.5 mg CE per 100 g), and antioxidant activity (86.7% DPPH scavenging activity) as compared with WF. DFF incorporation in rusk at 0% to 20% level significantly (p ≤ .05)
improved the TPC (157.5 to 455.8 mg GAE per 100 g), TFC (5.5 to 8.2 mg CE per 100 g), and antioxidant activity (20.4% to 45.5%; Table 2). The control sample exhibited lowest TPC, TFC, and antioxidant activity (5.5% to 8.2%, and 20.4%, respectively, in comparison with all DFF-added rusks). This significant (p ≤ .05) increase in the antioxidant potential of DFF-added rusks was due to increase in polyphenolic and flavonoid-rich flour supplementation and melanoids formation by browning reaction.

Some previous studies on supplementation of WF with fenugreek flour also reported increase in TPC and antioxidant potential of different products such as biscuits (Hooda & Jood, 2005) and bread (Chaubey et al., 2018; Maria Man et al., 2019). Phenolic compounds possessing antioxidant properties can delay or prevent food deterioration, maintain nutritional value, and help in protecting tissues from oxidative damage (Oomah & Sitter, 2009). Antioxidant activity for DFF-added rusks was significantly (p ≤ .01) positively correlated with TPC (r = .964) and TFC (r = .976; Table S1). This could be owed to the reducing properties of polyphenolic compounds in DFF, confirming their antioxidant potential.

3.4 | Functional properties of flours

Various functional properties of WF and DFF-added flour blends are summarized in Table 3. The bulk density of the composite flour decreased progressively with increase in the level of DFF from 5% to 20%, the highest value (0.80 g/ml) was observed for the control (WF) sample. The results for WAC of WF and DFF-added flours showed increase in values with the increase in DFF level. The blend with 20% DFF showed the highest WAC of 168%. This increase in WAC may be due to the high amount of dietary fiber and gum present in fenugreek (Rashid, Hussain, & Ahmed, 2018). OAC involves physical entrapment of oil droplets and plays an important role in improving the mouthfeel and retaining the flavor. It was also increased with increasing level of DFF; the highest (150%) and lowest (140%) values were observed for 20% DFF-added flour and control, respectively. Dhull and Sandhu (2018) also reported that WAC and OAC were increased with incorporation of fenugreek flour in WF used for noodle preparation. Sedimentation value is normally used to assess the bread making and gluten quality of WF (Gupta et al., 2011). The highest value for sedimentation value of 62.67 ml was exhibited by WF, decreased with increase in the level of DFF from 5% to 20%. The decrease in the concentration of gluten with increasing level of DFF could be attributed for this reduction in sedimentation test value.

3.5 | Pasting properties

The pasting properties of WF and DFF-added flours blends are summarized in Table 4 (Figure S1). These properties are generally associated with absorption of water, swelling, and further rupturing of starch granules in any system. Significant (p ≤ .05) difference in pasting properties of control (WF) and DFF-added flours were observed. DFF incorporation at 0% to 20% level significantly (p ≤ .05) decreased PV (573 to 469 mPa.s), breakdown viscosity (194 to 60 mPa.s), final viscosity (842 to 732 mPa.s), setback viscosity (463 to 323 mPa.s), and peak temperature (78.2°C to 66.2°C). PV is regarded as maximum viscosity attained by system after free swelling of starch granules before physical breakdown (Jan, Saxena, & Singh, 2016). Therefore, the decrease in PV could be attributed to the dilution of starch due to DFF addition. The decrease in breakdown viscosity showed that the

| TABLE 2 | Total phenolic content (TPC), total flavonoid content (TFC), and DPPH scavenging activity of wheat flour (WF), debittered fenugreek flour (DFF), and rusks made with WF and added DFF |
|---|---|---|---|
| Sample | TPC (mg GAE per 100 g) | TFC (mg CE per 100 g) | DPPH scavenging activity (%) |
| Flour | 209 ± 2.0ₐ | 7.5 ± 0.05ₐ | 20.9 ± 1.0ₐ |
| DFF | 4,032.8 ± 1.5ₙ | 18.5 ± 0.02ₙ | 86.7 ± 1.2ₙ |
| Rusk | 157.5 ± 1.₅ₐ | 5.5 ± 0.01ₐ | 20.4 ± 1.₅ₐ |
| Control | 221.7 ± 1.₀ₐ | 6.0 ± 0.02₀ | 29.0 ± 1.₁₀ |
| DFF-5 | 312.9 ± 1.₇ₐ | 6.9 ± 0.0₃₇ | 35.5 ± 1.₂₇ |
| DFF-10 | 381.5 ± 1.₂₉ | 7.5 ± 0.0₃₇ | 38.2 ± 1.₄₉ |
| DFF-20 | 455.8 ± 4.₅₉ | 8.2 ± 0.0₅₉ | 45.5 ± 1.₀₉ |

Note. Control represents rusks with 100% WF. DFF-5, DFF-10, DFF-15, and DFF-20 represent rusks made with 5%, 10%, 15%, and 20% DFF, respectively. The values are expressed as mean ± standard deviation (n = 3). The values with different subscripts in a column differ significantly at level p ≤ .05.

| TABLE 3 | Functional properties of wheat flour (WF) and debittered fenugreek flour (DFF)-added flour blends |
|---|---|---|---|---|
| Flour sample | Bulk density (g/ml) | WAC (%) | OAC (%) | Sedimentation value (ml) |
| WF | 0.80 ± 0.01ₐ | 135 ± 0.03ₐ | 140 ± 0.01ₐ | 62.67 ± 0.58ₐ |
| DFF-5 | 0.78 ± 0.00ₐ | 141 ± 0.0₁ₐ | 142 ± 0.03ₐ | 61.96 ± 0.4₃ₙ |
| DFF-10 | 0.75 ± 0.01ₐ | 150 ± 0.0₂₉ | 145 ± 0.0₃ₙ | 60.25 ± 0.3₅₉ |
| DFF-15 | 0.74 ± 0.0₀ₐ | 159 ± 0.0₃₉ | 148 ± 0.0₁₄ | 58.85 ± 0.6₅₉ |
| DFF-20 | 0.72 ± 0.0₁ₐ | 168 ± 0.0₃₉ | 150 ± 0.0₂₉ | 56.92 ± 0.5₅₉ |

Note. 100% WF. DFF-5, DFF-10, DFF-15, and DFF-20 represent flour blends made with 5%, 10%, 15%, and 20% DFF, respectively. The values are expressed as mean ± standard deviation (n = 3). The values with different subscripts in a column differ significantly at level p ≤ .05. Abbreviations: OAC, oil absorption capacity; WAC, water absorption capacity.
TABLE 4  Pasting properties of wheat flour (WF) and debittered fenugreek flour (DFF)-added flour blends

| Flour sample | Peak viscosity (mPa s) | Trough viscosity (mPa s) | Breakdown viscosity (mPa s) | Final viscosity (mPa s) | Setback viscosity (mPa s) | Peak temperature (°C) |
|--------------|------------------------|-------------------------|-----------------------------|------------------------|----------------------------|-----------------------|
| WF           | 573 ± 6.1a             | 379 ± 3.3ab             | 194 ± 5.5a                  | 842 ± 5.2d             | 463 ± 2.5c                 | 78.2 ± 0.11d          |
| DFF-5        | 528 ± 4.2c             | 371 ± 4.5a              | 157 ± 6.7d                  | 710 ± 3.1ab            | 339 ± 3.1b                 | 67.4 ± 0.24c          |
| DFF-10       | 525 ± 5.5c             | 387 ± 4.1b              | 138 ± 5.8c                  | 703 ± 3.2a             | 316 ± 3.3a                 | 67.4 ± 0.19c          |
| DFF-15       | 497 ± 6.5b             | 398 ± 5.2c              | 99 ± 4.9b                   | 715 ± 3.7b             | 317 ± 4.2a                 | 65.1 ± 0.25a          |
| DFF-20       | 469 ± 4.7c             | 409 ± 4.2d              | 60 ± 4.2a                   | 732 ± 5.1c             | 323 ± 3.5a                 | 66.2 ± 0.19b          |

Note. 100% WF. DFF-5, DFF-10, DFF-15, and DFF-20 represent flour blends made with 5%, 10%, 15%, and 20% DFF, respectively. The values are expressed as mean ± standard deviation (n = 3). The values with different subscripts in a column differ significantly at level p ≤ .05.

starch molecules in DFF blends were not fully ruptured during shearing at high temperature. It could be attributed to the increase in fiber content of the composite flour, competing with starch molecules in water binding and hence resulting in delayed gelatinization of starch molecules. Trough viscosity indicates the ability of starch to withstand breakdown during cooling. Trough viscosity (379 to 409 mPa-s) of DFF-added flours was increased with progressive increase in replacement of WF with DFF from 0% to 20% level (Table 4). As the starch molecules were gelatinized at high temperature and further disrupted using mechanical stress, the viscosity was enhanced during cooling.

3.6  Physical characteristics and hardness of rusks

Physical characteristics such as loaf volume, loaf weight, and specific loaf volume are significantly important parameters in defining the suitability of the raw materials used in rusk preparation. Loaf weight of breads prepared from WF and DFF-added flours at different levels, that is, 5%, 10%, 15%, and 20%, was recorded (Table 5). The loaf weight of DFF-added flour blended from 160 to 168.2 g, the highest was of 20% DFF-added loaf, and the lowest was of control sample. A significant (p ≤ .05) increase in loaf weight was observed with each increment of non-WF (i.e., DFF), indicating that an extra amount of water was retained in breads after baking (Hooda & Joo, 2005). Also, increased weight of DFF-added loaf might be because of less retention of gas in the blended dough, hence providing a dense texture. The results were comparable with the values reported in previous studies for fenugreek flour-added WF breads (Chaubey et al., 2018) and flaxseed flour-added WF rusks (Kaur et al., 2018). A significant (p ≤ .05) linear decrease in loaf volume of DFF-added rusks was observed with increase in DFF level from 5% to 20% (Table 5). The highest loaf volume (519.0 ml) was of control, whereas the lowest value (494.1 ml) was observed for 20% DFF-added loaf. It could be attributed to the dilution effect on gluten with the addition of non-WF to WF (Sivam, Sun-Waterhouse, Waterhouse, Quek, & Perera, 2011), and less retention of CO₂ gas caused the depression in loaf volume (Sharma & Chauhan, 2002) in rusk prepared from DFF-added flour. Specific loaf volume was obtained by dividing the loaf volume by the loaf weight, and results indicated a decrease in specific loaf volume on increasing levels of DFF compared with the control (Table 5). The poor quality and quantity of gluten in cereal-pulse blended products may be responsible for dense structure of the fermented dough, resulting in low specific loaf volume. Some previous studies also reported a decrease in loaf volume for fenugreek flour-added bread (Chaubey et al., 2018) and flaxseed flour-added rusks (Kaur et al., 2018). The loaf weight was found positively correlated with WAC (r = .978, p ≤ .01). However, the loaf volume of DFF-added rusk was significantly (p ≤ .01) negatively correlated with WAC (r = −.975) but positively correlated with sedimentation volume (r = .993, Table S2), which confirmed the role of gluten in loaf volume. The viscoelastic properties of dough, which determines the size, shape of bread crumb, and its loaf volume, can be positively affected by protein addition (Aamodt, Magnus, & Færgestad, 2004).

The crumb hardness, that is, the force required to compress the sample, was measured using Texture Analyzer (the texture profile analysis is depicted in Figure S2), and the values are summarized in

TABLE 5  Physical characteristics of loaf and hardness and color properties of rusks made with WF and added DFF

| Sample | Loaf weight (g) | Loaf volume (ml) | Specific loaf volume (ml/g) | Hardness (g) | L* | a* | b* | ΔE |
|--------|----------------|-----------------|-----------------------------|--------------|----|----|----|----|
| Control| 160.0 ± 1.0a   | 519.0 ± 2.0b    | 3.24 ± 0.02b                | 8,419.8 ± 11.2a | 38.52 ± 1.15a | 5.50 ± 0.40a | 5.72 ± 0.20a | 40.15 ± 1.20a |
| DFF-5  | 161.6 ± 0.5a   | 513.4 ± 1.0d    | 3.20 ± 0.01b                | 8,860.3 ± 10.5b | 36.24 ± 1.11d | 6.03 ± 0.50b | 6.40 ± 0.45b | 37.85 ± 1.15d |
| DFF-10 | 163.5 ± 1.0b   | 502.2 ± 2.5c    | 3.03 ± 0.02a                | 8,902.1 ± 14.5c | 31.15 ± 1.23c | 7.18 ± 0.30c | 7.18 ± 0.55c | 33.54 ± 1.11c |
| DFF-15 | 167.7 ± 1.5c   | 499.8 ± 1.0b    | 3.00 ± 0.01a                | 9,013.2 ± 20.2d | 26.57 ± 1.15b | 7.30 ± 0.40b | 7.30 ± 0.40b | 28.50 ± 1.25b |
| DFF-20 | 168.2 ± 0.5c   | 494.1 ± 2.0a    | 2.99 ± 0.00a                | 9,824.9 ± 25.1a | 23.25 ± 1.12c | 7.95 ± 0.70c | 7.55 ± 0.50c | 25.15 ± 1.10c |

Note. Control represents rusk with 100% WF. DFF-5, DFF-10, DFF-15, and DFF-20 represent rusks made with 5%, 10%, 15%, and 20% DFF, respectively. L* = lightness; a* = redness; b* = yellowness; ΔE = difference in color. The values are expressed as mean ± standard deviation (n = 3). The values with different subscripts in a column differ significantly at level p ≤ .05.
thereby affecting the firmness. Scoponic compounds may affect starch gelation and retrogradation, as evident from the values of positive correlation with the WAC ($r = .915, p \leq .05$) because hygroscopic compounds may affect starch gelation and retrogradation, thereby affecting the firmness.

### 3.7 Color properties of rusks

The results for different color characteristics of control and DFF-added rusk samples are summarized in Table 5. The results showed that a progressive increase in the substitution of WF with DFF significantly ($p \leq .05$) affected the color of the rusk samples (Figure 1), which is evident from the values of $L^*$ (lightness), $a^*$ (redness), $b^*$ (yellowness), and $\Delta E$ (total color difference) for control and DFF-added rusks (Table 5). There was a significant ($p \leq .05$) decrease in the value of $L^*$ from 38.52, 36.24, 31.15, 26.57, and 23.25 with progressive increment of DFF level (0%, 5%, 10%, 15%, and 20%, respectively). DFF-added rusk was observed. This increase could be attributed to flour ingredients or Maillard browning reactions between amino acids and reducing sugars during baking (Walker, Tseng, Cavender, Ross, & Zhao, 2014). The $b^*$ and $\Delta E$ values of control rusk were 5.72 and 40.15, respectively. But with increase in level of DFF in WF, the values of $b^*$ and $\Delta E$ progressively decreased from 5.85 to 3.12 and from 37.85 to 25.15, respectively. One previous study also reported a decrease in $L^*$ and $b^*$ values whereas increase in $a^*$ values with addition of debittered and germinated fenugreek flour in bread (Chaubey et al., 2018). Color is an important quality parameter that is directly related to type and amount of raw material and processing conditions applied and influence the acceptability of final product.

Some previous studies on beetroot pulp-added noodles (Chhikara, Kushwaha, Jaglan, Sharma, & Panghat, 2019) and black rice bran-added noodles (Kong et al., 2012) observed the effect of polyphenolic compounds on color characteristics. This could be due to formation of melanoids during processing as well as reaction of polyphenol oxidase with phenols leading to increased antioxidant activity (Chhikara et al., 2019). TPC, antioxidant activity, and TFC were negatively correlated with the lightness ($r = -.980, r = -.992,$ and $r = -.961, p \leq .01$, respectively), yellowness ($r = -.959, p \leq .01; r = -.948$ and $r = -.948, p \leq .05$, respectively), and color difference ($r = -.971$ and $r = -.994, p \leq .01; r = -.957, p \leq .05$, respectively) and positively correlated with redness ($a^*; r = -.985, p \leq .01; r = -.937, p \leq .05$; and $r = -.967, p \leq .01$, respectively; Table S2). The increase in TPC, TFC, and antioxidant potential resulted in dark-colored rusk samples.

### 3.8 Sensory properties of rusks

The replacement of WF with DFF at level of 5% to 20% significantly ($p \leq .05$) affected the sensorial properties of rusks, and the results for appearance, aroma, taste, texture, and overall acceptability (OA) are reported (Figure 2). All the sensory attributes of DFF-added rusk were negatively impacted with increasing level of DFF. Control (WF) rusk showed the highest values for all the sensory properties. Rusk with 20% DFF showed the lowest score for appearance (5.5), taste (6.5), aroma (5.0), and texture (6.0), thus the lowest OA score (5.5). The lowest sensory score for 20% DFF-added rusks may be due to its dark color, bitter taste, dense, and hard texture. The rusks with DFF at 15% level were found with desirable sensory score for appearance (8.5), aroma (8.0), taste (7.5), texture (8.0), and OA (8.0; Figure 2).
**CONCLUSIONS**

Partial replacement of WF with DFF had an impact on rusk quality and sensory characteristics. Rusks made with 15% DFF level had good nutritional and antioxidant profile with only minor reductions in sensory quality compared with a 100% WF control rusk. However, rusks made with 20% DFF were found more negatively affected. As DFF level increased, nutritional, dietary, mineral, and phytochemical profile of rusks was found to increase. At different levels of DFF inclusion (5%, 10%, 15%, and 20%), loaf volume and specific loaf volume were decreased, whereas loaf weight and hardness of DFF-added rusks were increased. All the pasting properties of DFF-added flours were negatively impacted as shown by higher degree of difference scores from the WF (control). The color of rusks became darker with the increase in the level of DFF. Of all the rusks made with DFF-added flour, the rusks made with 15% DFF had the most acceptable sensory and rusk quality characteristics.

**CONFLICT OF INTEREST**

The authors declare no conflict of interests.

**DATA AVAILABILITY STATEMENT**

The data that support the findings of this study are available from the corresponding author upon reasonable request.

**COMPLIANCE WITH ETHICAL REQUIREMENTS**

This article does not contain any studies with human and animal subjects.

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