Hindawi
Journal of Food Quality
Volume 2022, Article ID 4940343, 10 pages
https://doi.org/10.1155/2022/4940343

Research Article

The Influence of Fenugreek Seed Powder Addition on the Nutritional, Antioxidant, and Sensorial Properties of Value-Added Noodles

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Received 14 July 2022; Revised 30 August 2022; Accepted 6 September 2022; Published 16 September 2022

Academic Editor: Ravi Pandiselvam

The present study aimed at assessing the nutritional, antioxidant, and sensorial attributes of fenugreek seed powder (FSP) and supplemented functional noodles prepared by replacing wheat flour at 2–10% supplementation levels. Cooking losses of the value-added baked goods significantly ($p < 0.05$) declined from 2.4–1.2%. The results for water solubility, foaming capacity, and bulk density suggested significant ($p < 0.05$) increases from 8–10%, 77–87% and 0.51–0.70 g/mL, respectively, on replacing wheat flour with FSP in the value-added product. Dehydrated FSP addition caused significant ($p < 0.05$) improvement in ash (0.90–1.54%), proteins (10.4–13.7%), and crude fibers (0.9–1.9%) contents of the noodles. Maximum supplementation of FSP in supplemented noodles significantly ($p < 0.05$) improved the TPC, TFC, DPPH, and FRAP values from 111–310 mg GAE/100 g, 2.3–2.8 mg CE/g, 31–42%, and 215–460 umol/100 g, respectively. Sensory evaluation of supplemented noodles revealed the highest sensory acceptability of the value-added product at a 6% supplementation level. Conclusively, supplementing dehydrated FSP in the development of value-added foods could improve its functional features. It could also be considered as a plausible source of fibers and proteins, which might be helpful in mitigating malnutrition and a number of health maladies, such as cancer and diabetes.

1. Introduction

Fenugreek (*Trigonella foenumgraceum*), a dark green leafy vegetable that belongs to the family Fabaceae [1] is globally consumed, particularly in the Indo-Pak region, South Asia, Egypt, and Italy. The vegetable is considered a cheaper source of dietary proteins, vitamins, minerals, and elements including zinc, potassium, iron, potassium, manganese, and copper. Additionally, it is also referred to as an abundant source of folates, carotenoids, and chlorophyll, which elicits ameliorative effects against degenerative disorders, cancer, and diabetes [1, 2]. In the case of amino acids, fenugreek seeds contain higher amounts of L-tryptophan and lysine [3].

Fenugreek is considered an enriched source of bioactive health-promoting phytonutrients such as flavonoids, quercetin, kaempferol and vitexin, glycosides, and phenolics [4]. The phytochemical profile of fenugreek refers to its exhibiting an array of health-promoting bioactive compounds such as saponins (neotigogenin, yamogenin, diosgenin, and tigogenin), polyphenols (flavonoids), carotenoids (β-carotene), zeaxanthin, and lutein. The aforemetioned phytonutrients are known to possess antiflammatory, antidiabetic, antifungal, antioxidant, antiviral, antitumor, hepatoprotective, and hypocholesterolemic properties [2, 3, 5].

In the preview of its dietary significance, fenugreek has been exploited for many decades as a fresh vegetable, dehydrated ingredient [6], food additive [7], and a culinary spice of choice [8, 9]. Its industrial application involves steroidal hormone production [1, 3]. Earlier studies have suggested that baked and extruded goods are viable carriers of dehydrated vegetables to ameliorate nutritional insecurity challenges, micronutrient inadequacies, and malnutrition [4, 10]. Noodles are nutritionally enriched preferred staple foods in different regions of globe such as Japan, China, and Mediterranean regions over baked goods due to their ease of consumption, preparation, and cost effectiveness [2]. Consumer preference for noodles is increasing from day to day, as the annual noodle consumption has reached 95.4 billion servings/annum in more than 80 countries. Among the leading noodles consumers, China is ranked as first followed by Indonesia, Japan, and Vietnam [11].

Despite the wide phytonutrient composition and nutrient diversity of fenugreek, a meagre amount of literature is available in hand revealing the potential for exploitation of nutrient-rich dehydrated fenugreek seed powder (FSP) in value-added noodles in Asian and Western countries. Hence, the present study was conducted to evaluate the nutritional and antioxidant potential and sensorial acceptability of dehydrated FSP in the development of value-added noodles.

2. Materials and Methods

2.1. Raw Materials and Chemicals. Fresh insect-, pest-, and disease-free fenugreek seeds (*Qasoori methi*) (1 kg) and fine wheat flour (2 kg) were procured from local markets at Bahawalpur. Food additives and ingredients used in the development of the supplemented noodles were purchased from a local supermarket, Imtiaz-Bahawalpur, Punjab, Pakistan. All chemicals and reagents including DPPH (2,2-diphenyl-1-picryl-hydroxyl) reagent, sodium acetate buffer (pH = 3.6), Folin–Ciocalteu reagent (FCR), sodium carbonate (Na_2CO_3), ascorbic acid, gallic acid, and TPTZ (2, 4, 6-tri (2-pyridyl)-s-triazine) used in the study were of analytical grade and obtained from Sigma-Aldrich Inc., USA.

2.2. Preparation of Fenugreek Seed Powder (FSP). Freshly procured fenugreek seeds were first graded, sorted, washed, and cleaned well before drying. Then, the fenugreek seeds were solar dried under condition of controlled temperature, sunlight, and air currents to obtain favorable moisture below 15% using a solar dryer under low intensity of sunlight at $37 \pm 2^{\circ}C$. Solar-dried fenugreek seeds were converted into fine powder, that is, 72 mm mesh size, using a heavy-duty grinder machine. Subsequently, the FSP thus produced was packed in polyethylene bags (size—5.5 × 4 inches; thickness—0.4 mm) under airtight conditions. The powder was stored at its normal shelf life pending further appraisal [12].

2.3. Preparation of FSP-Supplemented Noodles. Methods of Yu and Ngadi [13] and Dhull and Sandhu [6] were followed for preparation of the fine wheat flour and FSP-based noodles. Noodles were prepared using FSP (0, 2, 4, 6, 8, and 10% *w*/*w*, i.e., 2–10% FSP supplementation exhibited better textural features in preliminary lab trials) in fine wheat flour (100, 98, 96, 94, 92, and 90% *w*/*w*), mixed with 2% sodium chloride (NaCl) and 0.1% sodium hydrogen carbonate ($NaHCO_3$). To develop a dough of the desired consistency, about 100.0 g of each premix/blend was mixed with clean drinking water (i.e., 35.0 mL) in a laboratory dough mixer. Thereafter, each dough was extruded using manual extruder and dried at $40 \pm 2^{\circ}C$ for 12 h using polyethylene sheets. The developed fine wheat flour–FSP-supplemented noodles were stored at normal room temperature ($25 \pm 2^{\circ}C$) for further analysis.

2.4. Cooking Qualities Determination of FSP-Supplemented Noodles. Yadav et al.'s [14] method was followed to estimate the cooked weight of FSP-supplemented noodles. Preweighed raw extruded noodles were cooked in 250 mL clean drinking water until the center of the noodles was fully cooked and turned brown. The following formula was used to estimate the cooking weight of noodles as

$$\text{cooking weight} = \frac{\text{weight of cooked supplemented noodles}}{\text{weight of raw noodles}} \times 100. \quad (1)$$

Following cooking, the noodles were kept in a hot air oven at 105°C for evaporation until final drying and cooking losses were estimated in accordance with the method documented by Shere et al. [15]. For cooking time, about 250 g of FSP-supplemented noodles were cooked in a stainless steel bowl using 250 mL boiling water (100°C). Every 60 s, the doneness of noodles was assessed using a stick. Cooking time was estimated as the appearance of a brown tinge with the disappearance of white color from the central strand of supplemented noodles upon gently pressing between plastic paper. Cooking losses of noodles were estimated using the formula mentioned hereunder:

$$\text{cooking losses of noodles} = \frac{\text{weight of dried residues in cooking water}}{\text{weight of noodles before cooking}} \times 100, \quad (2)$$

2.5. Functional Properties of Fine Wheat Flour, Fenugreek Seed Powder, and Supplemented Noodles

2.5.1. Swelling Power (SP). Rashid et al.'s [16] and Shere et al.'s [15] methods were adopted to determine the swelling power of FSP and supplemented noodles with slight modifications. Accurately measured 1 g of each sample was taken in a beaker and was mixed with 25 mL distilled water followed by vigorous shaking for 5 min and allowed to rest for 24 h at room temperature (25 ± 2°C). The swelling index of each sample was estimated using the formula given as follows:

$$\text{swelling power}\,(\%) = \frac{\text{weight of cooked noodles} - \text{weight of noodles after drying}}{\text{weight of noodles after drying}} \times 100. \tag{3}$$

2.5.2. Water Solubility (Sol.). Waseem et al.'s [12] method was used to quantify the water solubility of FSP and supplemented noodles. Precisely measured 0.5 g of each sample was vigorously mixed with 10 mL of clean distilled water and centrifuged (Hermle Z236 K) at 4,000 rpm for 30 min. The supernatant was dried in a hot-air oven (Memmert) at 55°C until completely dry. The supernatant and the sediment were weighed using a digital weighing balance. Water solubility (%) was calculated using the formula mentioned hereunder:

$$\text{water solubility}\,(\%) = \frac{\text{weight of supernatant}}{\text{weight of dry sample}} \times 100. \tag{4}$$

2.5.3. Foaming Capacity (FC). Rashid et al.'s [16] method was adopted to assess the foaming capacity of FSP and its supplemented noodles with slight modifications. Accurately measured 2.5 g of each sample was mixed for 2 min in 100 mL clean distilled water at room temperature (25 ± 2°C). The increase in volume of admixture was assessed as an index of foaming, and the foaming capacity values were calculated using the following formula:

$$\text{foaming capacity} = \frac{\text{final foam volume}}{\text{initial foam volume}} \times 100. \tag{5}$$

2.5.4. Bulk Density (BD). FSP and supplemented noodles' bulk densities were estimated using Jan et al.'s method [17]. About 100 g of each sample was taken in a graduated cylinder (500 mL), and the bottom of the cylinder was tapped numerous times to remove the air spaces and for homogeneity. The bulk densities of the samples were estimated using the formula mentioned as follows:

$$\text{bulk density}\,(g/\text{mL}) = \frac{\text{weight of sample (g)}}{\text{volume of sample (mL)}} \times 100. \tag{6}$$

2.6. Nutritional Composition of Fine Wheat Flour, FSP, and Supplemented Noodles. Nutritional composition, that is, moisture (AOAC method No. 925.10), crude ash (AOAC method No. 923.03), crude fat (AOAC method No. 920.85), crude fiber (AOAC method No. 32–10), crude protein (AOAC method No. 920.87), and carbohydrates (100−(% moisture + % ash + % protein + % fat + % fiber)), of all samples including fine wheat flour, FSP, and supplemented noodles was determined using the standard protocols as outlined by Association of Official Analytical Chemists (AOAC) [18].

2.7. Antioxidants Properties of FSP-Supplemented Noodles

2.7.1. Total Phenolic Contents (TPCs). Pandey and Awasthi's [19] method was adopted to determine the total phenolic contents of FWF, FSP, and supplemented noodles. Accurately measured 0.3 g of sample was amalgamated with 0.5 mL Folin–Ciocalteau reagent. Thereafter, 7.5 mL distilled water was added into the sample mixture, and the reaction mixture was allowed to settle for 20 min at room temperature (25 ± 2°C). Afterward, about 1.5 mL sodium bicarbonate (conc. 7.5%) solution was poured into the reaction amalgam. Thereafter, the test tubes with the reaction mixture were again rested at 40°C for 20 min in the water bath. Now, precisely measured 0.5 mL of solution was added to 2 mL distilled water. Spectrophotometric absorbance of each sample and control was recorded using a UV/Vis spectrophotometer (CECIL, CE7200) at 755 nm. Total phenolic contents in samples were computed against the gallic acid standard curve and expressed as mg GAE/100 g.

2.7.2. Total Flavonoid Contents (TFC). The TFC of FWF, FSP, and supplemented functional noodles were estimated using the protocol adopted by Chaubey et al. [20] with slight modifications. Precisely measured 2 g of sample was mixed with 5 mL distilled water in a 10-mL volumetric flask. Thereafter, 0.3 mL $NaNO_2$ (conc. 5%) was added. Subsequently, 0.6 mL aluminum chloride ($AlCl_3$) (conc. 10%) was poured and rested for 5 min under in the dark at room temperature (25 ± 2°C). Now, 2 mL sodium hydroxide (NaOH) (conc. 1 M) was mixed into the reaction mixture, and the final volume was adjusted to 10 mL using clean deionized water. Afterward, about 1 mL of this reaction mixture was diluted using 9 mL deionized water. Final absorbance was measured using a spectrophotometer at 510 nm using catechin equivalents (CE) as a standard, and total flavonoid contents were expressed as mg CE/100 g.

2.7.3. DPPH (2,2-Diphenyl-1-picrylhydrazyl) Activity Determination. Man et al.'s [21] protocol was followed to determine the DPPH free-radical scavenging activities in fine wheat flour, FSP, and supplemented noodles. About, 1 mL DPPH reagent was amalgamated into 4 mL sample extract. The samples containing DPPH reagent were mixed and allowed to incubate for 30 min at room temperature (25 ± 2°C) in the dark. Double-distilled water was used as reagent blank. The absorbance of each sample was recorded spectrophotometrically at 520 nm against the reagent blank (i.e., double-distilled water) and control (i.e., a sample without any DPPH reagent) at 520 nm. The DPPH free-radical scavenging activity (%) or percent inhibition was computed using the following mentioned hereunder:

$$\text{free} - \text{radical scavenging activity}\,(\%) = \frac{\text{AB} - \text{AA}}{\text{AB}} \times 100. \qquad (7)$$

(i) AB = Absorbance of reagent blank (at 0 min)

(ii) AA = Absorbance of sample extract (after 30 min of stay)

2.7.4. Ferric-Reducing Antioxidant Power (FRAP) Determination. Benzie and Strain's [22] protocols were used to determine the ferric-reducing antioxidant power of FWF, FSP, and supplemented noodles. About 0.5 mL of each sample was amalgamated with 1.25 mL, 0.2 M phosphate buffer of 6.6 pH, and 1.25 mL, 1% potassium ferricyanide. The reaction mixture was rested for incubation at room temperature (25 ± 2°C), and 1.25 mL trichloroacetic acid (TCA) (conc. 10%) with 0.1% ferric chloride were added to it and incubated again for 10 min at room temperature (25 ± 2°C). The absorbance of samples and control were recorded on a UV/Vis spectrophotometer at 700 nm. Standard curves were developed using ferrous sulfate (100–1000 μM). Results of samples and control were expressed as μM of Fe (ferrous ions to ferric ions conversion) per 100 g.

2.8. Sensory Evaluation of Noodles. Sensory evaluation of FSP-based noodles was carried out by a sensory expert panel at the Department of Food Science and Technology, The Islamia University of Bahawalpur, Pakistan, using a 9-point hedonic scale at 0th, 15th, 30th, and 45th days of storage. Before sensory evaluation, the FSP-supplemented noodles were randomly coded with different letters to avoid bias. The sensory acceptability scale ranged varied between 1—dislike extremely, 5—neither like nor dislike, and 9—like extremely. The noodles prepared using fine wheat flour without FSP (control) and with FSP were assessed for various physical attributes, including physical appearance, physical color, texture, taste, and overall acceptability [12].

2.9. Statistical Analysis. All experiments were replicated thrice, and means were computed as means ± *S*. D. Data obtained from the physic-chemical analysis of FSP, fine wheat flour, and supplemented noodles were statistically evaluated using an analysis of variance (ANOVA) using the Statistics 8.1 software (Tallahassee, FL). Means were evaluated using the least significance difference (LSD) at $p < 0.05$ [23].

3. Results and Discussion

3.1. Cooking Qualities of FSP-Supplemented Noodles. The cooking properties of FSP-supplemented noodles prepared by replacing fine wheat flour with FSP were assessed. The results of the present study revealed a significant ($p < 0.05$) effect of cooking on the weight, cooking losses, and cooking time (Table 1). The findings for cooking weight exhibited a linear increase in weight from 26–38 g for $T_0 - T_4$ (2–10%). Maximum weight gain was observed in T_4, that is, 38 g, while the least weight was recorded for control (T_0), that is, 26 g. Dhull and Sandhu [6] elucidated comparable findings for the cooking weight of supplemented noodles, which increased from 27–40 g at 2–10% supplementation. Significant ($p < 0.05$) increase in cooking weight of the noodles could be attributed to their higher water absorption capacity on cooking due to their water-absorbing food constituents, that is, crude fibers and proteins. Higher water absorption is a result of higher hydration attributes, which significantly influence the edible quality of noodles [14].

Whereas, the results for cooking losses of FSP-supplemented noodles elucidated a significant ($p < 0.05$) decrease from 2.4 to 1.2% with the increase of FSP supplementation from 2 to 10% supplementation (Table 1). The significant ($p < 0.05$) decrease in cooking solid losses of the functional noodles could be attributed to the greater magnitudes of crude fibers and starch in FSP to comprehend tight bonding with the gluten proteins of wheat [14]. A study by Dhull and Sandhu [6] revealed close corroboration in cooking losses of noodles wherein a linear decline in cooking losses was observed from 2.2–1.3% at 2–10% supplementation. Lower cooking loss of the noodles is an indicator of the resistance of noodles to cooking, that is, desirable. However, solid cooking losses of supplemented noodles were within the acceptable range for losses that is, <10 g/100 g.

Likewise, the time required for functional cooking of the noodles showed significant ($p < 0.05$) increase from 6.3 to 9 min on successive addition of FSP at 2 to 10% substitution with wheat flour. The cooking time of FSP noodles was greater than that of the noodles prepared as control (Table 1). Dhull and Sandhu [6] elucidated a linear increase in cooking time of supplemented noodles, which was enhanced from 7.5–9 min at 2–10% supplementation. The decrease in the cooking time of the noodles could be attributed to higher levels of gelatinizable starch.

3.2. Functional Properties of Fine Wheat Flour, FSP, and Supplemented Noodles. The results for the comparative assessment of functional properties of FSP with fine wheat flour revealed the FSP to exhibit higher magnitudes of water solubility (31.2%), foaming capacity (155.0%), and bulk density (1.2 g/mL), whereas the fine wheat flour showed lower concentrations of these components (Table 2). In Table 1 and Table 2, the data suggest that FSP, FWF, and FSP-supplemented noodles can be distinguished as three different food commodities. SP, Sol, and FC contents of fine wheat flour and noodles (baked goods) cannot be intermingled with each other since noodles have different recipes

Table 1: Cooking quality attributes of fenugreek seed powder (FSP)–supplemented composite noodles.

Treatment	Cooking weight (g)	Cooking loss (%)	Cooking time (min)
T_0	25.70 ± 1.04^{d}	2.42 ± 0.03^{a}	6.33 ± 0.08^{g}
T_1	27.20 ± 0.5^{d}	2.14 ± 0.02^{b}	6.97 ± 010^{f}
T_2	29.60 ± 0.64^{c}	1.96 ± 0.02^{c}	7.45 ± 0.06^{e}
T_3	32.80 ± 0.75^{b}	1.67 ± 0.04^{d}	7.88 ± 0.20^{d}
T_4	34.40 ± 1.04^{b}	1.23 ± 0.03^{e}	8.56 ± 0.16^{bc}
T_5	37.90 ± 0.87^{a}	1.18 ± 0.03^{e}	8.97 ± 0.13^{a}

Values are presented as means ± SD ($n = 3$). Values having similar lettering in each column show non-significance at $p > 0.05 T_0 = 100\%$ fine wheat flour–based noodles (control), $T_1 = 2\%$ FSP-supplemented noodles, $T_2 = 4\%$ FSP-supplemented noodles, $T_3 = 6\%$ FSP-supplemented noodles, $T_4 = 8\%$ FSP-supplemented noodles, $T_5 = 10\%$ FSP-supplemented noodles.

Table 2: Functional properties of fine wheat flour (FWF), fenugreek seed powder (FSP), and supplemented composite noodles (g/100 g).

Treatment	SP (%)	Sol (%)	FC (%)	BD (g/mL)
FWF	210.80 ± 4.7^{a}	18.60 ± 0.8^{b}	92.25 ± 1.3^{b}	0.58 ± 0.01^{b}
FSP	105.35 ± 3.4^{b}	31.20 ± 0.9^{a}	155.00 ± 5.3^{a}	1.23 ± 0.07^{a}
T_0	144.00 ± 6.07^{a}	7.99 ± 0.40^{de}	77.60 ± 2.66^{b}	0.51 ± 0.02^{d}
T_1	142.50 ± 6.07^{a}	$8.43 \pm 0.26^{c\text{-}e}$	78.30 ± 2.77^{b}	0.59 ± 0.02^{c}
T_2	141.25 ± 4.77^{a}	$8.86 \pm 0.37^{b\text{-}d}$	79.40 ± 3.58^{ab}	0.62 ± 0.02^{bc}
T_3	139.75 ± 4.77^{a}	$9.22 \pm 0.39^{a\text{-}c}$	81.50 ± 1.27^{ab}	$0.65 \pm 0.01^{a\text{-}c}$
T_4	137.00 ± 5.78^{a}	9.54 ± 0.40^{ab}	84.20 ± 2.25^{ab}	0.67 ± 0.02^{ab}
T_5	135.00 ± 6.36^{a}	9.93 ± 0.39^{a}	87.10 ± 4.10^{a}	0.70 ± 0.02^{a}

Values are presented as means ± SD ($n = 3$). Values having similar lettering in each column show non-significance at $p > 0.05$. $T_0 = 100\%$ fine wheat flour (FWF) based noodles (control), $T_1 = 2\%$ FSP-supplemented noodles, $T_2 = 4\%$ FSP-supplemented noodles, $T_3 = 6\%$ FSP-supplemented noodles, $T_4 = 8\%$ FSP-supplemented noodles, $T_5 = 10\%$ FSP-supplemented noodles. SP = swelling power, Sol = water solubility, FC = foaming capacity, BD = bulk density.

and compositions. Considering SP as one parameter, FWF shows its contents as the highest, that is, 210.8%, while FSP shows its lower contents, that is, 105.4%, while control noodles (T_0) showed its estimated contents of about 144.0%.

FWF holds higher SP, Sol, and FC due to the presence of higher magnitudes of carbohydrates and starches, which decreased in control noodles (T_0) due to the interaction of carbohydrates with other food components on heating and release of water on break down of bonds during noodles' development. As earlier, a study by David et al. [24] reported swelling power as an important functional property of carbohydrates, proteins, and starches derived from flours of numerous origins. Increased swelling power and water solubility index (WSI) have also been attributed to higher starch contents [25].

However, a gradual increase in the solubilization properties and FC of functional noodles T_0–T_5 (0–10%) might be linked to the reduction of electrostatic repulsions, protein aggregations, protein precipitations on isoelectric point (~4.6), and hydration of charged residues. The increase in a net charge of proteins results in a reduction of the hydrophobic interactions, which is thereby associated with the increase of SP, Sol, and protein flexibility of the successive products [26]. Improved water solubility and foaming properties of FSP could be considered a viable parameter which decides the quality of finished cereal and baked goods including soups, gravies, dough, breads, cakes, and spaghetti, which could be attributed to a wide array of amino acid composition, fiber composition, surface polarity, and hydrophilic nature of amino acids [26]. An earlier study by Feyzi et al. [26] has revealed comparable findings for the foaming capacity of fenugreek, that is, 31–137% to our research, which could be attributed to the appropriate balance between surface hydrophobicity and water solubility of proteins and balance in water–air interface. A study by El-Nasri and El-Tinay [27] reported comparable bulk density of fenugreek, that is, bulk density (0.6 g/mL). Whereas, the foaming capacity is generally considered a significant parameter in the quality determination of baked and confectionery products, that is, cakes, whipped cream, breads, toppings, chiffon desserts, and ice cream [27]. The ability to adsorb at the air–water interface, rapid conformational changes, and rearrangement at the interface are the key features of proteins which are useful in foaming and water solubility [28].

However, the findings for FSP-supplemented noodles showed significant ($p < 0.05$) improvement in water solubility, foaming capacity, and bulk density from 8–10%, 78–87%, and 0.5–0.7 g/mL, respectively, for T_0–T_5 (Table 2). The successive increase in solubilization properties and foaming capacities of the value-added functional noodles could be linked with the reduction of electrostatic repulsions, protein precipitations at isoelectric point (4.6), protein aggregations, and hydration of charged residues. The increase in net charge of proteins results in a reduction of hydrophobic interactions, which is thereby linked with the enhancement of protein flexibility and water solubility [26].

3.3. Nutritional Composition of Fine Wheat Flour, FSP and Supplemented Noodles. Dehydrated FSP was reported to contain a significant amount of ash (3.2%), crude fibers (7.6%), and proteins (44.3%) when compared with the fine wheat flour, which exhibited significantly ($p < 0.05$) lower magnitudes of ash, crude fibers, and proteins, that is, 0.9%, 0.4%, and 10.6%, respectively (Table 3). Greater variability in

Table 3: Proximate composition of fine wheat flour (FWF), fenugreek seed powder (FSP), and supplemented composite noodles (g/100 g).

Treatment	Moisture	Ash	Fat	Fiber	Protein	NFE†
FWF	12.1 ± 0.25^{a}	0.90 ± 0.04^{b}	1.07 ± 0.04^{b}	0.35 ± 0.04^{b}	10.6 ± 0.13^{b}	74.98 ± 3.47^{a}
FSP	9.98 ± 0.49^{b}	3.12 ± 0.14^{a}	4.17 ± 0.21^{a}	7.45 ± 0.39^{a}	44.32 ± 2.55^{a}	30.96 ± 1.82^{b}
T_0	9.16 ± 0.13^{a}	0.94 ± 0.03^{jk}	$1.29 \pm 0.05^{l\text{-}n}$	0.97 ± 0.01^{f}	10.42 ± 0.44^{f}	77.22 ± 4.41^{a}
T_1	8.89 ± 0.21^{ab}	1.07 ± 0.05^{i}	$1.41 \pm 0.02^{i\text{-}k}$	1.22 ± 0.04^{e}	11.18 ± 0.26^{ef}	76.23 ± 5.70^{b}
T_2	$8.73 \pm 0.22^{a\text{-}d}$	$1.26 \pm 0.03^{f\text{-}h}$	1.54 ± 0.04^{gh}	1.37 ± 0.07^{d}	$11.96 \pm 0.49^{c\text{-}e}$	75.14 ± 3.22^{c}
T_3	$8.59 \pm 0.19^{a\text{-}d}$	1.33 ± 0.04^{ef}	1.68 ± 0.08^{ef}	1.49 ± 0.02^{c}	$12.44 \pm 0.46^{b\text{-}d}$	74.47 ± 3.75^{d}
T_4	$8.42 \pm 0.41^{b\text{-}d}$	$1.47 \pm 0.03^{a\text{-}c}$	$1.81 \pm 0.05^{b\text{-}d}$	1.62 ± 0.09^{b}	13.02 ± 0.53^{ab}	73.66 ± 4.67^{e}
T_5	8.14 ± 0.31^{d}	1.54 ± 0.03^{a}	1.95 ± 0.08^{a}	1.88 ± 0.08^{a}	13.69 ± 0.39^{a}	72.80 ± 3.40^{f}

Values are presented as means ± SD ($n = 3$). Values having similar lettering in each column show non-significance at $p > 0.05$. $T_0 = 100\%$ fine wheat flour (FWF) based noodles (control), $T_1 = 2\%$ FSP-supplemented noodles, $T_2 = 4\%$ FSP-supplemented noodles, $T_3 = 6\%$ FSP-supplemented noodles, $T_4 = 8\%$ FSP-supplemented noodles, $T_5 = 10\%$ FSP-supplemented noodles. †Nitrogen-free extract = 100−(Moisture + Protein + Fat + Ash + Fiber).

proximate contents of dehydrated FSP have also been revealed in earlier studies wherein the ash (3.3–4.2%), crude fibers (7.7–9.3%), and protein (22.7–28.4%) contents of FSP showed a wide array of difference in mean values of the these contents as mentioned, when compared to the retrospective studies [7, 27]. Plant proteins are considered crucial food constituents, which are helpful in improving the functional stability, texture, and nutritional quality of value-added products [29]. However, the variation observed in the present study could be attributed to various factors including geographical conditions, varietal status, and total solid content/extent of dehydration of plant material. The addition of nutrient-dense FSP in fine wheat flour may result in improvement of the nutritional potential of value-added finished goods (Table 3).

However, significant ($p < 0.05$) increments in ash, fiber, and protein contents of FSP-enriched noodles were witnessed with the values varying from 0.9 to 1.5%, 0.9 to 1.9%, and 10 to 14%, respectively. Significant ($p < 0.05$) improvement in ash, crude fiber, and protein content in FSP-supplemented noodles could be ascribed to the presence of these constituents in higher magnitudes in the FSP itself. A significant ($p < 0.05$) decrease in moisture content of the noodles could be attributed to the lower water-holding ability of the FSP when compared with the fine wheat flour. Earlier studies by El Nasri and El Tinay [27] have reported the substitution of wheat flour with FSP to show comparatively higher amounts of ash, fibers, and protein contents in composite biscuits, that is, 0.4%–0.8%, 1.6%–2.1%, and 9.2%–10.2%, respectively, whereas the relatively lower amounts of aforementioned constituents were observed for FSP-supplemented noodles as mentioned above. Supplementation of FSP in fine wheat flour to develop the value-added noodles means improving the nutritional quality of plant proteins as it enhances the provision of the limiting amino acids in fine wheat flour.

3.4. Antioxidant Profiling of FSP-Supplemented Noodles. Phenolic compounds present in fenugreek are considered to provide antioxidant activities; hypothesized to possess anticancer properties. The results for total phenolic content exhibited the highest concentrations for fenugreek seed powder, i.e., 697.50 mg GAE/100 g. The results elucidated that the replacement of fine wheat flour with FSP at varied levels of supplementation from 2–10% resulted in a significant ($p < 0.05$) improvement of the total phenolic content of the noodles. The findings anticipated the highest concentrations of total phenolics at maximum supplementation of 10%, that is, 310 mg GAE/100 g when compared to control (T_0), which showed the lower values of total phenolic compounds, that is, 111 mg of GAE/100 g. Among treatments, the lowest amounts of total phenolic content were recorded in T_1, that is, 165 mg GAE/100 g (Table 4). Higher concentrations of the phenolics in the FSP-based noodles could be attributed to the presence of naturally occurring bioactive compounds such as orientin, apigenins, rutin, tannins, and quercetin in fenugreek seeds [7, 30]. Our results for total phenolics are in line with Man et al. [21] wherein the total phenolics in wheat–fenugreek premixes and fenugreek-fortified bread developed at 2–8% supplementation ranged from 136–380 and 105–349 mg GAE/100 g, respectively. Likewise, comparable findings for total phenolics were reported by Afzal et al. [7] wherein the fenugreek seed enrichment in wheat flour at $T_0 - T_3$ (i.e., supplementation at 5–15%) in composite breads revealed the phenolic contents in the baked product between 117–450 mg GAE/100 g.

Flavonoids are considered a diverse group of polyphenolic compounds which exhibit an array of activities such as anti-inflammatory, free-radical scavenging, and antimicrobial properties [31]. The findings elucidated higher contents of total flavonoid contents for FSP, that is, 4.92 CE/g than FWF. The results for flavonoid content significantly ($p < 0.05$) differed (i.e., 2.3–2.8 mg CE/g) for all treatments, that is, T_0–T_4 (0–10% supplementation). The highest flavonoid contents were observed in T_4 (i.e., 10% supplementation), that is, 2.8 mg CE/g followed by the lowest flavonoid contents in the control (T_0), that is, 2.3 mg CE/g (Table 4). A study by Ishtiaque et al. [32] reported the addition of FSP to wheat flour to alleviate the total flavonoid content of the baked product. The results for total flavonoid content are in close harmony with an earlier study by Afzal et al. [7] wherein total flavonoids were recorded between 2.4–3.1 mg CE/g in fortified composite leavened breads developed by supplementing FSP at 5–15%.

Table 4: Antioxidant activities of fenugreek seed powder (FSP) supplemented composite noodles.

Treatments	TPC (mg GAE/100 g)	TFC (mg CE/g)	DPPH (% inhibition)	FRAP (μmol/100 g)
FWF	137.50 ± 3.54^{b}	2.40 ± 0.02^{b}	39.72 ± 0.40^{b}	224.00 ± 1.41^{b}
FSP	697.50 ± 3.54^{a}	4.92 ± 0.10^{a}	75.50 ± 0.71^{a}	557.50 ± 3.54^{a}
T_0	111 ± 3.47^{f}	2.28 ± 0.07^{e}	31.00 ± 1.16^{e}	215 ± 5.78^{f}
T_1	165 ± 7.51^{e}	2.35 ± 0.06^{d}	33.22 ± 1.03^{de}	277 ± 4.05^{e}
T_2	195 ± 5.78^{d}	2.51 ± 0.08^{c}	35.47 ± 1.30^{cd}	327 ± 4.62^{d}
T_3	230 ± 5.78^{c}	2.62 ± 0.11^{bc}	37.18 ± 0.63^{bc}	380 ± 7.51^{c}
T_4	270 ± 4.05^{b}	2.69 ± 0.09^{b}	39.55 ± 0.95^{ab}	415 ± 3.47^{b}
T_5	310 ± 5.78^{a}	2.80 ± 0.08^{a}	41.97 ± 0.76^{a}	460 ± 15.03^{a}

Values are presented as means ± SD ($n = 3$). Values having similar lettering in each column show non-significance at $p > 0.05$. $T_0 = 100\%$ fine wheat flour–based noodles (control), $T_1 = 2\%$ FSP-supplemented noodles, $T_2 = 4\%$ FSP-supplemented noodles, $T_3 = 6\%$ FSP-supplemented noodles, $T_4 = 8\%$ FSP-supplemented noodles, $T_5 = 10\%$ FSP-supplemented noodles. TPC = total phenolic contents, TFC = total flavonoid contents, DPPH = 2, 2-diphenyl-1-picrylhydrazyl, FRAP = ferric reducing antioxidant power.

The DPPH assay is linked to the free-radical scavenging impact of natural antioxidants. The results reported a significant ($p < 0.05$) effect of FSP supplementation on the free-radical scavenging properties of supplemented noodles (Table 4). The highest free-radical scavenging activities were observed in FSP, that is, 75%, while the FWF showed the lowest DPPH activities, that is, 40%. The % DPPH free-radical scavenging activity of FSP-supplemented noodles prepared at T_0–T_4 varied between 31–42%. The highest DPPH free-radical scavenging activity (i.e., 42%) among all treatments was recorded for T_4 (i.e., 10% supplementation). The higher DPPH free-radical scavenging activities of T_4 (supplementation at 10%) could be correlated with their higher phenolic content as compared to the control. A study by Man et al. [21] reported comparable findings for DPPH free-radical scavenging properties in wheat flour–fenugreek treatment blends and fenugreek-supplemented leavened breads prepared at 2–8% supplementation varied from 33–54% and 29–55%, respectively. Likewise, another study by Afzal et al. [7] also suggested the significant ($p < 0.05$) improvement of DPPH free-radical scavenging activities from 35–58% in the FSP-supplemented leavened breads prepared at maximum 15% supplementation levels.

Ferric reducing power antioxidant compounds neutralize electron donor attributes of free radicals and neutralize these by developing stable end products [33]. The findings reported higher FRAP values in FSP, that is, 557.5 μmol/100 g than fine FWF, that is, 224.0 μmol/100 g. A significant ($p < 0.05$) drift in ferric reducing antioxidant power of the noodles prepared with the supplementation of the FSP from T_0–T_5 (0–10%) supplementation was noticed. The results also suggested the highest ferric reducing antioxidant power at maximum supplementation (T_5) with 460 μmol/100 g, while the lowest ferric reducing antioxidant power was noted in T_0, that is, 215 μmol/100 g (Table 4). The lower ferric reducing antioxidant power of the only wheat flour-based (T_0) supplemented noodles could be linked with the meager concentrations of naturally occurring antioxidant compounds present in fine wheat flour. The significant ($p < 0.05$) elevation of flavonoids in noodles could be attributed to the tannins, alkaloids, quercetin, and saponins compounds in fenugreek seeds [34]. Comparable findings for ferric reducing antioxidant power have been also noticed by Afzal et al. [7] wherein the researchers revealed the ferric reducing antioxidant power varying between 222–501 μmol/100 g in the leavened composite bread prepared with supplementing the FSP at 5–15%.

3.5. Sensory Acceptability of FSP-Supplemented Noodles. Sensorial attributes are considered incumbent quality parameters which decide the edibility and acceptability of the value-added finished goods. Sensory data on the appearance of FSP-supplemented noodles revealed the highest sensory acceptability score of 8.8 for control followed by a sensory score of 8.5 for the noodles prepared at 0 day, T_3 (i.e., 6% supplementation). Color, being a significant quality parameter that attracts consumers and improves eye appeal and acceptability of value-added product, was scored the highest (8.8) for control, followed by T_3 (i.e., 6% supplementation) on the 30th day on supplementation of FSP in wheat flour in developed functional noodles (Figure 1). Replacement of fine wheat flour with FSP at a maximum 10% was observed to drastically affect all sensorial features of the noodles. Taste sensory score declined on supplementation of FSP in noodles by 8% which could be linked to the presence of an array of astringent compounds such as galacato-mannans, sapogenin, trigonelline, choline, tannins, and alkaloids [20, 35]. The study revealed overall product acceptability against various sensory variables up to 0 day at 6% supplementation (T_3) of FSP in noodles. The results also demarcated a significant ($p < 0.05$) decrease in sensory scores with enhancing the levels of FSP enrichment. However; 8 to 10% replacement of fine wheat flour with FSP portrayed undesirable sensory appeal in comparison with the control. Fenugreek-based finished baked goods, that is, gluten-free breads and composite biscuits, have already been known for sensorial acceptability, wherein the pool of researchers indicated good consumer-sensory acceptability scores at 6% FSP supplementation [35]. Other studies by group of researchers including Afzal et al. [7], Chaubey et al. [20], and Man et al. [21] reported the sensorial acceptability of fortified bread, muffins, pizza, biscuit, and cakes developed at 6% FSP supplementation.

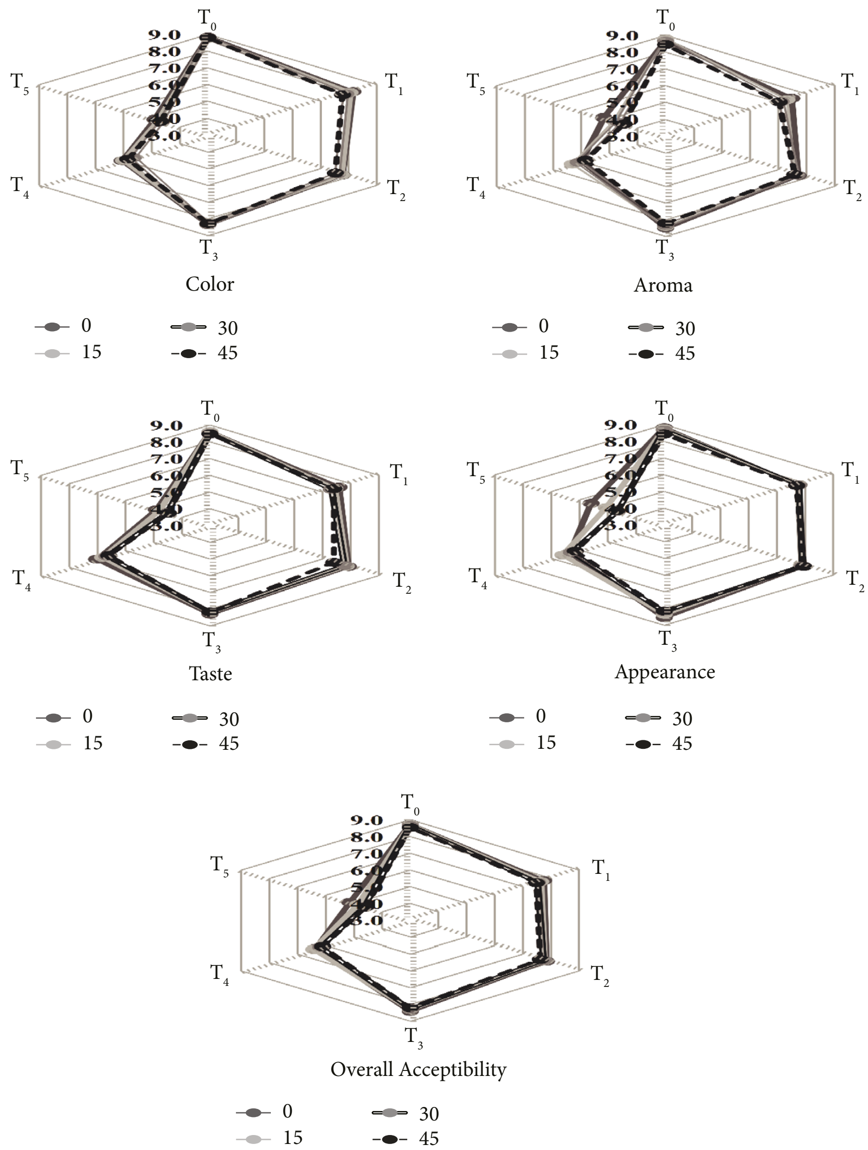

Figure 1: The effect of storage (0, 15, 30, and 45 days) on the sensory attributes of fenugreek seed powder–supplemented noodles.

4. Conclusions

Growing protein energy deficiencies, micronutrient malnutrition, and food insecurity in the underdeveloped and developing countries are the leading causes of disease burden among vulnerable population groups. Novel interventions to ameliorate these severe health challenges are imperative. Ample dietary intake of fresh vegetables is now transiting to novel approaches to nurture their augmented consumption. Hence, the use of dehydrated greens is now being extensively practiced in diverse food formulations and novel food recipes. Fenugreek seed powder (FSP) is referred to a remarkable source of micronutrients, proteins, crude fibers, and bioactive phytonutrients that can help prevent numerous maladies and nutritional health challenges. The study also reveals FSP and supplemented noodles to exhibit good antioxidant potential. The present study validates the supplementation of FSP in fine wheat flour to develop functional noodles at 8% supplementation rendered undesirable sensory appeal, while the study elucidated the highest sensorial acceptability of value-added functional noodles among all other treatment groups up to 0 day, for T_3 (i.e., 6%). Conclusively, the findings also suggested that the use of dehydrated green leafy vegetable seeds in powder premixes could be helpful in abridging the food insecurities challenges, nutritional deficiencies, and protein energy malnutrition issues among impoverished population groups.

Data Availability

The data supporting the conclusions of this article are included in the manuscript.

Additional Points

Fenugreek seed powder is widely available in Pakistan as a functional food ingredient. Moreover, fenugreek is recognized globally to impart flavor to several conventional foods. Fenugreek is also a rich source of bioactive compounds with a significant role in disease prevention and health promotion. Flour comprising fenugreek seed powder has good attributes for formulating bakery products, and nowadays several bakery items have been supplemented for achieving better results in development of functional foods. The current study was aimed at the evaluation of nutritional, antioxidant, and sensorial characteristics of noodles supplemented with fenugreek seed powder as functional ingredient.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Zulfiqar Ahmad contributed to conceptualization, supervision, project administration, and funding acquisition; Muhammad Ilyas was involved in investigation, formal analysis, methodology, original draft preparation, conceptualization, and review and editing; Muhammad Waseem contributed to finalizing the draft, methodology, results, and discussion; Muhammad Asif Khan contributed to introduction and methodology; Kashif Ameer contributed to review and editing, data interpretation, results, and discussion; Faiz-ul-Hassan Shah contributed to tabulation of data, results, and discussion; Tahir Mehmood contributed to statistics and figure manufacturing; Muhammad Adil Rehman contributed to formal analysis and methodology.

Acknowledgments

The authors are grateful to the Chairman, Department of Food Science and Technology, the Islamia University of Bahawalpur, for the generous support and laboratory facilitation for conducting this research.

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