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Characterization of jackfruit seed enriched pasta: product-functionality profile, secondary protein structures, bioactive composition and molecular morphology

Harmeet Singh[1], Rajan Sharma[1], Antima Gupta[1], Swati Joshi[1], B.N. Dar[2]*, Baljit Singh[1], Savita Sharma[1]*

[1]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, India; [2]Department of Food Technology, Islamic University of Science and Technology, Kashmir, India

***Corresponding authors:** B.N. Dar, Department of Food Technology, Islamic University of Science and Technology, Kashmir, India. Email: darnabi@gmail.com; Savita Sharma, Department of Food Science and Technology, Punjab Agricultural University, Ludhiana, India. Email: savitasharmans@yahoo.co.in

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Abstract

This study aims to investigate the potential of mixing jackfruit seed flour (JFSF) with pasta and its effects on techno-functional properties, cooking behavior, textural characteristics, morphology, macromolecular interactions, and secondary structure of proteins of pasta. The results showed with increase in the addition of JFSF from 6 to 24% caused significant ($P < 0.05$) improvement in the functional properties, decline in the minimum cooking time (7.07 to 6.20 min), and an increase in the cooking loss (5.13 to 11.26%) as well as firmness of the pasta. Organoleptic evaluations indicated the incorporation of JFSF up to 18% without affecting the flavor. Scanning electron microscopy revealed that after cooking bell-shaped starch granules were embedded in the protein matrix. Fourier transform infrared spectra analysis of the secondary structure of protein showed that the major protein fractions were β-sheets, followed by β helix. Positive correlations between cooking losses and water solubility index and several other parameters were established using principal component analysis. Therefore, incorporating JFSF into pasta could be a promising way for developing protein-rich, high-quality pasta with improved nutritional and functional properties.

Keywords: jackfruit seed flour; cooking quality; FTIR; SEM; principal component analysis

Introduction

Jackfruit (*Artocarpus heterophyllus* Lam.), also known as *kathal* in India (Butool and Butool, 2013), is a tree-borne fruit belonging to the family *Moraceae*. It is a multi-purpose fruit that provides food, fodder, fuel, and industrial and medicinal products (Sultana *et al.*, 2014). The demand for jackfruit pulp has led to increased utilization of its by-products such as seeds and rinds (Azeez et al., 2015). Jackfruit seeds contain a high level of nutrients, such as 14% protein, 80% carbohydrate, 2% ash, and 1% fat, and a sufficient amount of minerals, namely sodium (60.66 mg/kg), calcium (3087 mg/kg), potassium (14,781 mg/kg), manganese (1.12 mg/kg), and copper (10.45 mg/kg), and iron (130.74 mg/kg), and others such as nitrogen, phosphorus, magnesium, sulfur, and zinc (Maurya and Mogra, 2016). Its high protein content is due to amino acid score and protein efficiency ratio contributed by essential amino acids. It also contains phenols, saponins, alkaloids, tannins, and steroids (Shanmugapriya *et al.*, 2012) that possess bioactive properties. The presence of vitamins A, B, and C, as well as anti-carcinogenic properties and pectin compounds, aids in maintaining pancreatic health and improves hemoglobin levels thereby curing anemia. Jackfruit has been processed into a variety of food products like thermal processed and canned jackfruit (Babu *et al.*, 2022), jackfruit pectin (Lal *et al.*, 2021), and nonthermally processed jackfruit products (Nelluri *et al.*, 2022).

Pasta is becoming popular due to its low cost, composition, easy availability, ease of preparation and conveyance, and higher shelf life (Kaur *et al.*, 2012). It is made from durum wheat–semolina, which has low-quality protein, making improvement in this area necessary (Yıldırım *et al.*, 2019). Jackfruit seed flour (JFSF) has been used in cakes (Arpit and John, 2015), noodles (Nandkule *et al.*, 2015), and biscuits (Butool and Butool, 2013). The seed starch has been used as a thickening agent in sauces (Maduwage *et al.*, 2019) and the roasted seeds are used as a substitute for the cocoa aroma (Spada *et al.*, 2020). There have been a few instances of using jackfruit seeds in the development of extruded products and employing it as a source of enrichment for the production of nutrient-rich and convenient food products. Incorporating JFSF into pasta compositions could increase nutrition and reduce food waste. Both the World Health Organization (WHO) and the Food Agriculture Organization (FAO) recommended pasta as an effective medium for enriching various nutrients. Hence, this research investigates the effect of JFSF supplementation on the compositional, functional, textural, and structural characteristics of pasta.

Material and Methods

Raw materials and pasta preparation

The semolina and jackfruit seeds, which contain protein (16.46%), ash (2.12%), crude fat (1.52%), and crude fiber (2.77%), were procured from the local market in Ludhiana, Punjab, India. The seeds were cleaned manually, dipped into 3% NaOH solution to remove the spermoderm, then dried at 60°C in a tray dryer, and then ground into flour. The particle sizes of semolina and JFSF were 250 and 175 micrometers respectively. Control samples with 100 percent semolina and pasta blends with JFSF at various concentrations of 0, 6, 12, 18, and 24% and semolina were prepared and passed through a sieve with a mesh size of 20.0 (840 μm) thrice for uniform mixing. The extrusion was performed using a fusilli-shaped die (No. 133) in a pasta extruder (Dolly La Monferrina, Italy). The samples were dried at temperature of 50°C for 4–5 h and were packed in polyethylene pouches for further examination (Surasani *et al.*, 2019).

Functional properties

Water absorption capacity and water solubility index

Water absorption capacity (WAC) and water solubility index (WSI) were determined using the method proposed by Ding *et al.* (2005). The sample (2.0 g) was taken in a pre-weighed centrifuge tube and 20 mL of distilled water was added. It was incubated for 30 min with intermittent shaking. The supernatant was collected and dried at 100 ± 2°C. WAC and WSI were calculated using the following formulae:

$$\text{WAC} = \frac{\text{Weight of the gel pellet after removal of supernatant (g)}}{\text{Weight of the sample (g)}}$$

$$\text{WSI} = \frac{\text{Weight of dry solids in the supernatant (g)}}{\text{Weight of the sample (g)}} \times 100$$

Oil absorption capacity

The oil absorption capacity (OAC) was calculated as suggested by Ding *et al.* (2005). To the sample (1 g) taken, 10 mL of cottonseed oil was added to a pre-weighed centrifuge tube. The tube was held for 30 min and shaken every 5 min during this time, followed by centrifugation at 3000 rpm for 15 min. The supernatant was decanted and the weight of the gel obtained after the removal of the supernatant was recorded. OAC is calculated as follows:

$$\text{OAC} = \frac{\text{Weight of the gel obtained after removal of supernatant (g)}}{\text{Weight of the sample (g)}}$$

Bioactive profile

The antioxidant was measured using the method proposed by Singh et al. (2019) with slight modification which requires the use of free radical 2,2-diphenyl-1-picrylhydrazyl (DPPH) in methanol. Total phenolic content (TPC) was measured using the Folin–Ciocalteu reagent and the results were expressed as mg of Gallic acid equivalents (GAE)/g on a dry weight basis. The total flavonoids were determined using the aluminum chloride method and were expressed as mg quercetin equivalent (QE)/100 g on a dry weight basis.

Cooking quality

To determine the cooking time, 10-g samples of pasta were cooked in 100 mL boiling distilled water and were removed after every 30-sec intervals and placed between a pair of glass plates (AACC 2000, pp. 66–50). The WAC of pasta was calculated as the increase in weight after cooking, expressed as a percentage of water absorption. The volume expansion was determined by measuring the difference in pasta volume between cooked and raw samples in a 250-mL measuring cylinder and expressed as mL/g. Cooking loss was calculated by drying a 50-mL aliquot from the cooking water in petri dishes at 105°C in the oven, with the solid residue weight expressed as percent loss. It is thus given as:

$$\text{Cooking loss (\%)} = \frac{\text{Wt. of residue (g)} \times \text{volume of cooking water}}{\text{Volume of aliquot} \times \text{Weight of raw sample}} \times 100$$

Color profile

The color of the sample was evaluated in terms of L, a*, and b* values with the Hunter Lab colorimeter (CR-300 Minolta Camera, Japan). The overall color change was calculated using the following equation:

$$\Delta E = \sqrt{\Delta a^2 + \Delta b^2 + \Delta c^2}$$

Texture analysis

After determining the minimum cooking time, 6 pieces of pasta were cooked and evaluated for texture analysis using a reliable micro system texture analyzer (Model: TA-XT plus, USA). The test speed was set at 0.1 mm/s and the probe was placed 3 mm away from the sample. Using a probe calibrated for a load cell of 250 kN, the pasta sample was placed transversely on the plate over a metal sheet support and compressed to determine its textural properties in terms of firmness and toughness (Surasani *et al.*, 2019).

Sensory evaluation

The cooked pasta samples were evaluated for sensory attributes by 20 semi-trained panelists (age group 30–55 years; male to female ratio 2:3) in the Department of Food Science and Technology, PAU, Ludhiana, Punjab, India. On a 9-point hedonic scale, the panelists were asked to rank pasta samples according to flavor, appearance, texture, color, and overall acceptability.

Fourier Transform Infrared Spectra Analysis

Fourier transform infrared spectra (FTIR) spectra of pasta samples were obtained using an FTIR spectrometer (Thermo Scientific, Nicolet 6700) and analyzed with OPUS software v.7.0. Prior to the analysis, the pasta samples were kept in an oven at 30°C for 2 days to eradicate moisture. The moisture free sample was mixed with KBr (1:99) and pressed to form a pellet. The spectra were recorded in the 4000–5000 cm^1 at room temperature. For each sample, two batches of data were examined, and four spectra were recorded.

Scanning electron microscope

A scanning electron microscope (SEM) (Model: Hitachi S 3400 N, UK) was used to examine the structural morphology of raw and cooked pasta samples. The sputter-coated pasta sample was transported to the microscope and analyzed at a vacuum of 9.75×10^{-5} Pa and an accelerating voltage of 15 kV (Singh *et al.*, 2019).

Statistical Analysis

All the above experiments were conducted in triplicates unless stated otherwise. The obtained data were checked for variance using Tukey's post-hoc test to determine any significant differences among different variables. The maximum variance and dependence of different variables on each other was determined using principal component analysis (PCA). The results were further analyzed utilizing Statistical Package for Social Science v. 20.0 software (IBM). Pearson's correlation coefficient was calculated to establish a significant ($P < 0.05$) relation between the different variables, where P-value greater than 0.05 was considered to be significant.

Results and Discussion

Functional properties of pasta with incorporated JFSF

WAC increased significantly ($P < 0.05$) with an increase in the levels of JFSF (Table 1), thereby exhibiting a positive correlation with the fiber content ($r = 0.997$, $P < 0.05$). The presence of different protein compositions, degree of interaction with water, a loose association of amylose and amylopectin, and weak associative forces of the granular structure in starch granules influence the WAC of the flour. According to Devi (2015), higher WAC was observed in the extrudates prepared from jackfruit seed and bulb flour, ranging from 5.08 to 6.87%.

As Table 1 shows, the control pasta has 3.38% WSI which increased significantly ($P < 0.05$) with increased levels of JFSF from 6 to 24 g per 100 g, resulting in a rise in WSI from 3.56 to 4.90%. The increase in WSI of supplemented pasta is due to the ability of seed starch to absorb more water resulting in higher solubility. Food products with low WSI values digest slowly in the digestive tract and also have low glycemic index values (Michalak-Majewska *et al.*, 2020). WSI is positively correlated with minimum cooking time (MCT)($r = 0.951$, $P < 0.05$). The OAC increased proportionally from 1.89 to 1.92 g/g, with increased concentration of JFSF, due to the high OAC of JFSF compared to semolina.

Effect of JFSF on cooking quality of pasta

The MCT of JFSF-enriched pasta ranged from 6.20 to 7.02 min as indicated in Table 1. The increase in the JFSF concentration significantly decreased the MCT of pasta which could be attributed to the presence of A-type starch which has a close packing of double helices in amylopectin and indicates strong granule crystallinity. MCT showed a positive correlation with WAC ($r = 0.937$, $P < 0.05$). The results obtained are in line with previous research. Noodles extruded using 20% JFSF showed larger yields and took less time to cook (Kumari *et al.*, 2015). According to Devi (2015), the cooking time of pasta decreased as the particle size of the jackfruit seed grits decreased. As the JFSF concentration increased from 6 to 24%, the water absorption increased from 104.50 to 153.98%. Swathi *et al.* (2019) also reported an increase

Table 1. Functional properties and cooking quality of pasta prepared from JFSF and semolina.

Samples	Water absorption capacity (g/g)	Water solubility index (%)	Oil absorption capacity (g/g)	Minimum cooking Time (min)	Water absorption (%)	Volume expansion (mL/g)	Gruel solid loss (%)
Control	2.08 ± 0.01^{d}	3.38 ± 0.07^{c}	1.26 ± 0.20^{d}	7.07 ± 0.01^{a}	104.50 ± 0.40^{e}	0.40 ± 0.06^{d}	5.13± 0.11^{d}
*JFSP6	2.25 ± 0.11^{cd}	3.56 ± 0.04^{b}	1.89 ± 0.65^{c}	7.02 ± 0.01^{b}	128.71 ± 0.51^{d}	0.62 ± 0.07^{c}	7.28 ± 0.33^{c}
*JFSP12	2.38 ± 0.19^{bc}	4.85 ± 0.06^{a}	1.90 ± 0.35^{b}	6.53 ± 0.02^{c}	130.88 ± 0.23^{c}	1.16 ± 0.08^{b}	8.19 ± 0.23^{b}
*JFSP18	2.59 ± 0.16^{ab}	4.86 ± 0.01^{a}	1.90 ± 0.28^{b}	6.47 ± 0.02^{d}	139.80 ± 0.75^{b}	1.13 ± 0.01^{b}	8.61 ± 0.12^{b}
*JFSP24	2.63 ± 0.09^{a}	4.90 ± 0.03^{a}	1.92 ± 0.39^{a}	6.20 ± 0.03^{e}	153.98 ± 0.93^{a}	1.51 ± 0.06^{a}	11.36 ± 0.45^{a}

*JFSP represents jackfruit seed flour pasta; 6, 12, 18, and 24 denote the concentration of JFSF; data is presented as mean ± standard deviation; means with different superscript letters in a column differ significantly at $P < 0.05$.

Table 2. Bioactive profile of pasta prepared from JFSF and semolina.

Samples	Total phenolic content (mg GAE/g)	Total flavonoid content (mg quercetin/100 g)	Antioxidant activity (% DPPH Radical Scavenging Activity)
Control	5.95 ± 0.04^{e}	3.57 ± 0.02^{e}	21.65 ± 0.02^{e}
*JFSP6	6.12 ± 0.02^{d}	4.13 ± 0.01^{d}	24.45 ± 0.04^{d}
*JFSP12	6.85 ± 0.02^{c}	5.12 ± 0.03^{c}	27.54 ± 0.02^{c}
*JFSP18	7.52 ± 0.05^{b}	5.87 ± 0.04^{b}	28.23 ± 0.03^{b}
*JFSP24	8.56 ± 0.03^{a}	6.45 ± 0.01^{a}	35.02 ± 0.05^{a}

*JFSP represents jackfruit seed flour pasta; 6, 12, 18 and 24 denote the concentration of JFSF; data is presented as mean ± standard deviation; means with different superscript letters in a column differ significantly at $P < 0.05$; GAE, Gallic acid equivalent; DPPH, 2,2-Diphenyl-1-picrylhydrazyl.

in the water absorption of pasta with the incorporation of jackfruit seed and bulb flour. The volume expansion increased from 0.62 to 1.51 mL/g with increasing JFSF concentration. Surasani *et al.* (2019) concluded that supplementing pasta with pangas protein isolate from 0 to 10.0 g/100 g resulted in a total rise in volume expansion of 60.54%. Volume expansion showed a positive correlation with MCT ($r = 0.932$, $P < 0.05$). The values of gruel solid loss, as shown in Table 1, indicate that an increase in JFSF concentration in pasta increased solids leaching. Swathi *et al.* (2019) reported a higher cooking loss in jackfruit pasta. Surasani *et al.* (2019) observed that the greater cooking loss of enriched pasta may be due to the weakening of gluten that inhibits the formation of the starch and gluten network.

Effect of JFSF on the bioactive composition of pasta

The addition of JFSF, instead of semolina, led to a significant increase in the TPC and total flavonoid content ranging from 6.12 mg GAE/g to 8.56 mg GAE/g and 3.57 to 6.45 mg quercetin/100 g, respectively (Table 2). This increase can be attributed to the higher phenolic content and total flavonoids present in jackfruit seeds (Gupta *et al.*, 2011; Swami *et al.*, 2012). In addition, jackfruit seed contains high β and α lutein, xanthin, and carotene. The results found were slightly different from those indicated by Sreeja Devi *et al.* (2021), where TPC ranged between 1.45 and 2.12 μg/mg. The DPPH activity also showed a significant increase when semolina was replaced with JFSF at different concentrations.

The DPPH activity of enriched samples ranged between 24.45 and 35.02% compared to 21.65% in the control group. Similar antioxidant activity was identified for bioactive peptide (JFS-2) whereas protein protection potentiality was recognized in two peptides JFS-1 and JFS-2 (Chai *et al.*, 2021).

Color profile and texture of enriched pasta as affected by different levels of JFSF

As Table 3 shows, the addition of JFSF to the pasta led to a significant decrease in the L* due to the increase in the darkness quotient. The enriched pasta showed a higher a* value, varying from −0.26 to 0.98, with 24% JFSF-enriched pasta being the highest. The b* value also significantly increased with increased pasta enrichment. Hasan *et al.* (2010) reported that biscuits prepared from 50% JFSF showed desirable light brown color while biscuits made up of 80% seed flour exhibited dark color. Similar results have been reported by (Babiker *et al.* 2020; Veena et al. 2015). The ΔE value of the control sample was 15.90, which increased with an increase in the level of supplementation in pasta. Both firmness and toughness were negatively correlated with the MCT (firmness: $r = 0.905$, $P < 0.05$; toughness: $r = 0.906$, P < 0.05), with the JFSF-enriched pasta showing significant differences (P < 0.05) compared to the control sample (firmness =0.09 N; toughness =0.41 N). These characteristics increased with an increase of JFSF concentration in the samples, which could be due to rapid starch gelatinization and low water-holding capacity of flour. Desai *et al.* (2018) found a similar trend in fish powder–enriched pasta, where the higher protein contributed to a better protein matrix binding starch molecules very strongly, attributing to the increase in the hardness (Kaur *et al.*, 2013).

Influence of different levels of JFSF on sensory properties of pasta

The pasta enriched with 18% JFSF received the highest overall acceptability score of 8.4, which was comparable to the control pasta. On the other hand, the lowest overall acceptability was observed in the pasta enriched at a 24% level (Table 3). The acceptability dropped to 6.4 at the level above 18% due to the sticky, gritty, and chewy texture that resulted from the increased JFSF concentration. Hossain *et al.* (2014) found that, with a mixture of 15 and 20% JFSF, the flavor of the jackfruit seed was easily detectable in pasta. Biscuits and bread manufactured with less than 30% JFSF had excellent overall acceptability, but as the JFSF concentration increased, the overall acceptability decreased (Butool and Butool, 2015).

Morphological changes during enrichment of pasta with JFSF using Scanning Electron Microscopy

As seen in Figure 1C, the SEM results of the 18% JFSF pasta showed small, round to bell-shaped JFSF starch granules along with spherical semolina starch. Similar bell-shaped and smooth-surfaced JFSF starch molecules ranging in size from 7 to 11 μm were observed in the studies conducted by Chen *et al.* (2016). This is could be due to the swelling up of starch granules as a result of gelatinization due to high moisture and temperature during cooking. Further, the crystallinity of starch molecules is lost during the process leading to a compact and uniform protein matrix with embedded swollen starch granules in the cooked sample (Figure 1D). This resulted in a decrease in the number of pits and hollow spaces due to gelatinization forming a dense matrix and compact texture. Similar results were observed by Luo *et al.* (2015) in steamed noodles, which showed a compact structure and smooth surface.

Macromolecular interactions and secondary protein fractions as affected by JFSF using FTIR

The representative spectrum of JFSF-enriched pasta over 650 to 4000 cm^{-1} is shown in Figure 1. The strong broad bands near 3400 cm^{-1} in the spectrum indicated the presence of hydroxyl stretching in H-bonds (Setiawan *et al.*, 2016). The peaks lying between 2928 and 2926 cm^{-1} indicate the presence of alkane group with C-H stretching. The Amide I band (1600–1700 cm^{-1})was studied in detail using second derivative Gaussian deconvolution along with the modifications in the secondary protein structure. Frequencies of 1600–1640 and 1670–1680 cm^{-1} denoted β-sheet; while frequencies of 1640–1650 cm^{-1} represented random coils; and frequencies of 1650–1660 cm^{-1}, 1660–1670, and 1680–1700 cm^{-1} denoted α-helix and β-turn, respectively (Marzieh *et al.*, 2020). The results showed that the major protein fractions had β-sheet (49.08–64.59%) and β-turn (29.80 and 43.68%) structures, followed by random coils (5.59 and 7.23%) and minor portions of α-helix. Further, the incorporation of JFSF led to a decline in the β-turns and an increase in the protein fractions with β-sheet and random coils. The decline in β-turns improves *the vitro* protein digestibility, thereby providing better absorption and utilization of protein in the body.

Principal component analysis

The PCA plot in Figure 3 shows a data variance of 92.98%. The variance is represented majorly by two factors

Table 3. Color and texture analysis and sensory evaluation of JFSF-enriched pasta.

Samples	L	a*	b*	Hue angle (°)	Chroma	Firmness	Toughness	Overall acceptability
Control	42.67 ± 0.38^{a}	−1.17 ± 0.02^{a}	5.57 ± 0.54^{c}	66.14 ± 0.61^{a}	5.70 ± 0.57^{c}	0.09 ± 0.01^{d}	0.41 ± 0.04^{d}	7.4 ± 0.38^{b}
*JFSP6	38.04 ± 1.22^{b}	−0.26 ± 0.02^{d}	5.37 ± 0.74^{c}	66.03 ± 0.32^{ab}	5.87 ± 0.72^{c}	0.13 ± 0.01^{c}	0.42 ± 0.01^{d}	7.3 ± 0.27^{b}
*JFSP12	34.45 ± 1.21^{c}	0.05 ± 0.01^{e}	7.02 ± 0.10^{b}	65.91 ± 0.05^{b}	7.06 ± 0.09^{b}	0.14 ± 0.01^{bc}	0.48 ± 0.12^{c}	7.2 ± 0.31^{b}
*JFSP18	37.44 ± 0.86^{b}	0.90 ± 0.02^{c}	9.03 ± 0.03^{a}	65.77 ± 0.09^{b}	9.08 ± 0.06^{a}	0.15 ± 0.03^{b}	0.60 ± 0.08^{b}	8.4 ± 0.32^{a}
*JFSP24	33.53 ± 0.40^{c}	0.98 ± 0.02^{b}	9.54 ± 0.39^{a}	65.12 ± 0.018^{c}	9.59 ± 0.38^{a}	0.18 ± 0.04^{a}	0.78 ± 0.01^{a}	6.4 ± 0.25^{c}

*JFSP represents jackfruit seed flour pasta; 6, 12, 18, and 24 denote the concentration of JFSF; data is presented as mean ± standard deviation; means with different superscript letters in a column differ significantly at P < 0.05.

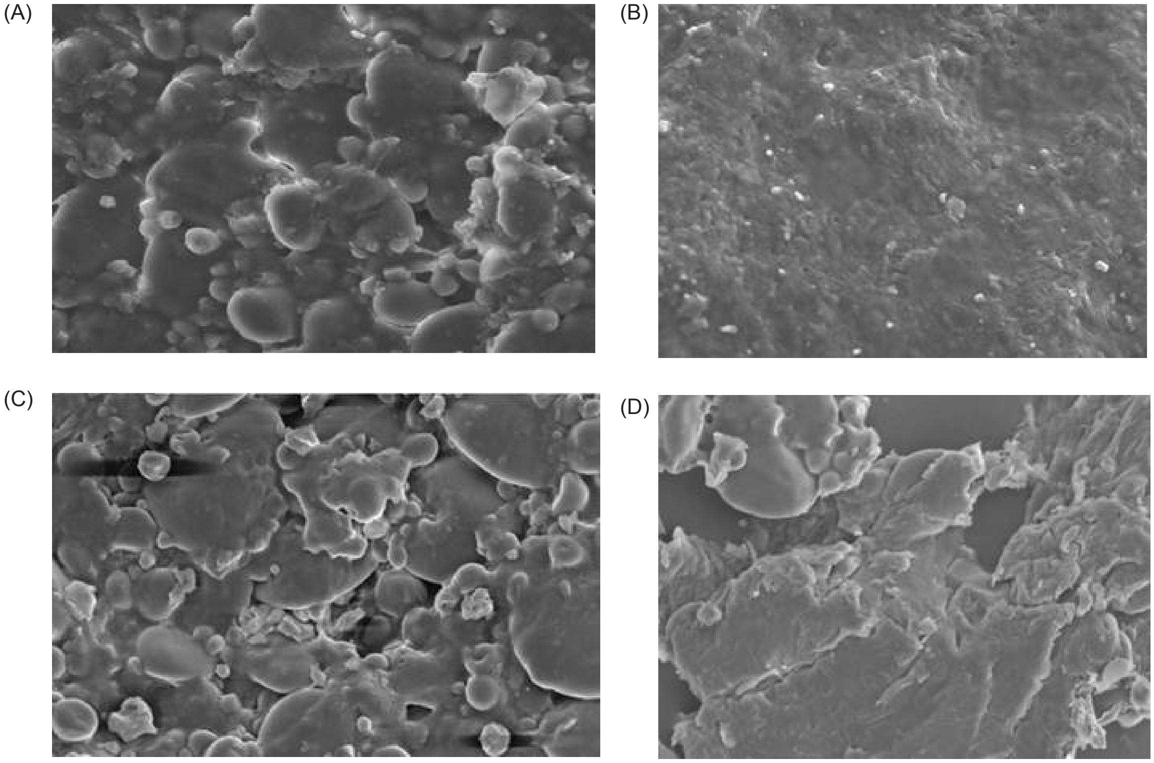

Figure 1. Scanning Electron Microscopic images of raw and cooked pasta. (A) Raw durum wheat semolina pasta; (B) Cooked durum wheat semolina pasta supplemented at 18.0 g/100g level; (C) Raw JFSF pasta enriched at 18.0 g/100 g and (D) Cooked JFSF pasta enriched at 18.0 g/100 g level; circles represent the intact starch granules and arrows denote the gelatinized starch granules embedded uniformly in the protein matrix.

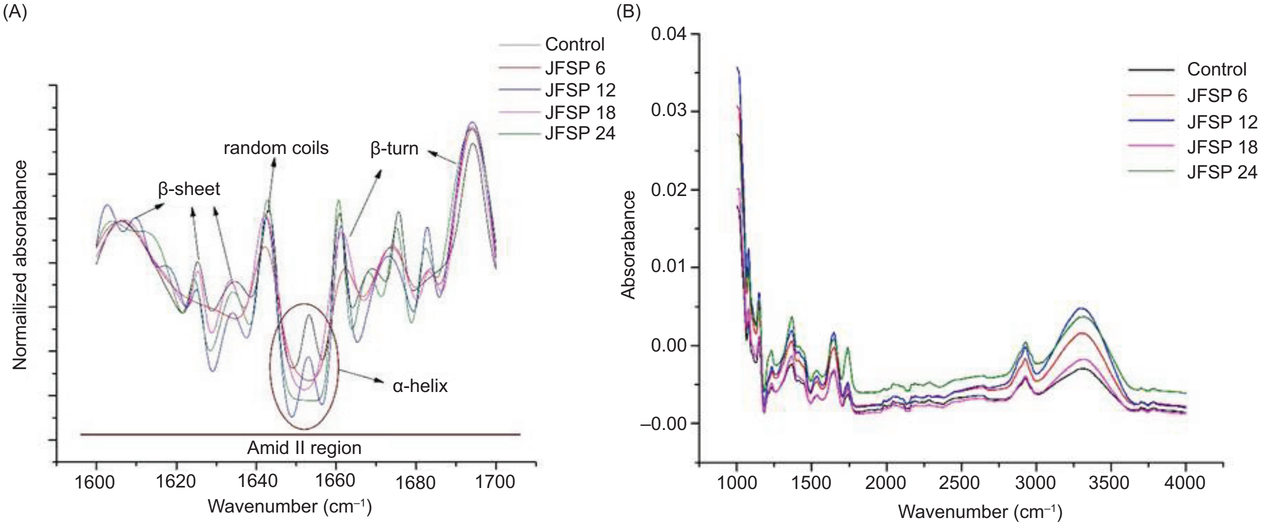

Figure 2. (A) Effects of JFSF on the secondary structure of proteins using second derivative Gaussian deconvolution between 1600 and 1700 cm-1 wavenumbers and (B) FTIR spectra of jackfruit seed enriched pasta. JFSP represents jackfruit seed flour pasta and 6, 12, 18, and 24 represent the concentration of JFSF in pasta.

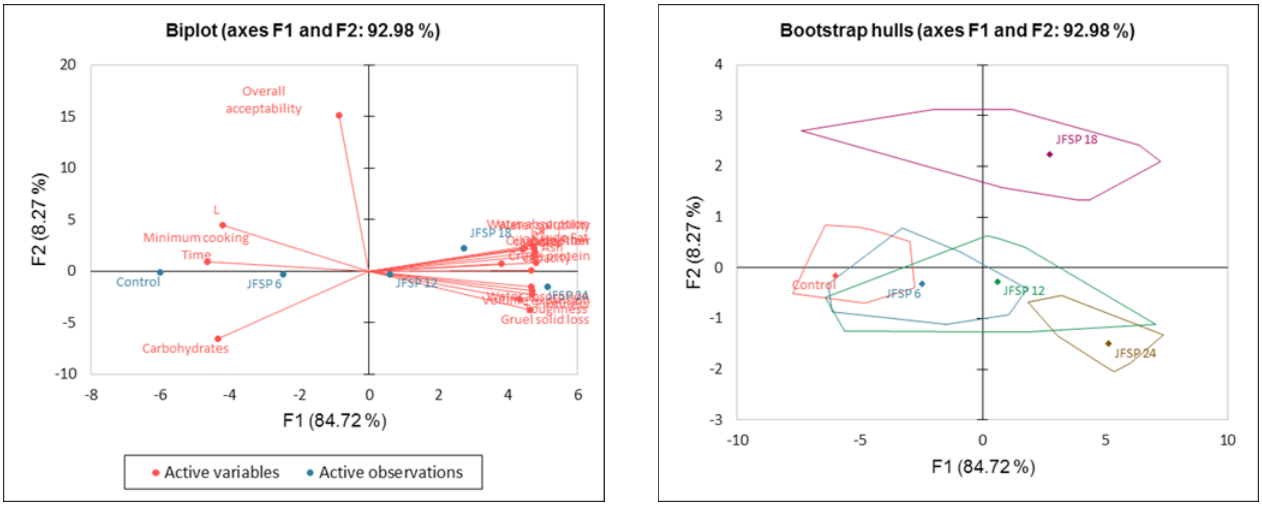

Figure 3. Principal component analysis plot denoted by F1 and F2 with data variance of 92.98%. Active variables represent different techno-functional properties and active observations denote different levels of JFSF-incorporated in pasta.

(F1 [84.72%] and F2 [8.27%]). Most of the samples, denoted by active observations, were represented by the F1 factor. All the active observations except 12% JFSF pasta were characterized by F1. The majority of active variables such as water absorption, oil absorption, minimum cooking time, gruel solid loss, volume expansion, and color values were characterized by the F1 dimensional factor. The active observations that are adjacent to each other had a close relationship, such as water absorption and volume expansion, while the observations opposite to each other had a negative correlation with each other, such as toughness and minimum cooking time. Water absorption, volume expansion, toughness, and gruel solid loss had a strong correlation, as indicated by 24% JFSF pasta. Also, WSI and oil absorption were closely associated with 18% JFSF pasta, while the minimum cooking time and L values were found closely linked to 6% JFSF pasta.

Conclusion

Pasta has become a widely accepted convenience food product around the world. Therefore, its supplementation with nutrient-dense, nonconventional ingredients such as JFSF aids to meet the nutritional requirements of the growing population. The addition of JFSF improved the techno-functional properties, such as WAC, WSI, and OAC, leading to pasta with desirable texture and mouthfeel. The developed JFSF-enriched pasta had high protein and crude fiber content which could reduce protein deficiency. The incorporation of JFSF at the rate of 18.0/100 g levels produced the best pasta with optimal protein and crude fiber content, optimum cooking time, water absorption, color, firmness, and sensory profile.

In conclusion, the addition of JFSF to pasta is a promising solution for producing high-quality, low-cost pasta with improved functional and nutritional properties. The valorization of food waste like jackfruit seeds into nutritionally rich, value-added food products presents a wider scope for reducing food losses and addressing hidden hunger in the future. This study could serve as a starting point for further advanced research based on food waste utilization, sustainable food patterns, and food insecurity in the upcoming years.

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Conflict of interest

The authors declare no conflict of interest.

Ethical approval

Ethical approval was not required for this research.

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