# A Study on the Effect of Passion Fruit Peel Powder Incorporation on Physical, Nutritional and Sensory Quality of Flat Noodles

**Rohan K.N[1], Prabhavathi S.N[2]**

[1]Research Scholar, Department of Food Science and Nutrition, University of Mysore.
[2]Associate professor, Department of Food Science and Technology,
Yenepoya (Deemed to be University, Mangaluru)
E-mail: prabhafsn1110@gmail.com and rohankompuli@gmail.com

**Abstract**

This study investigates the utilization of passion fruit peel powder (PFPP) in flat noodles as a means of improving their nutritional, physical, and sensory characteristics. Yellow passion fruit peels were processed into powder and incorporated into flat noodles at levels of 10% and 15%. The PFPP-enriched noodles exhibited higher dietary fibre, mineral content (iron and calcium), and acceptable sensory attributes. Although peel incorporation slightly affected colour and texture, it enhanced nutritional density and overall acceptability. The results suggest that PFPP can be an effective functional ingredient for developing fibre-enriched cereal-based products.

**Keywords:** Passion fruit peel powder, Flat noodles, Dietary fibre, Sensory evaluation, Nutritional enhancement.

## Introduction

Passion fruit (*Passiflora edulis*) is an economically important tropical fruit primarily valued for its aromatic pulp, which is widely utilized in juice manufacturing. In contrast, the peel—accounting for roughly 50–60% of the total fruit weight—is often discarded despite its richness in dietary fibre, pectin, and bioactive constituents such as polyphenols and carotenoids. Efficient utilization of this by-product could contribute to sustainable food production while simultaneously improving the nutritional profile of cereal-based foods (Zeriak et al., 2010). Among the *Passiflora* species, *P. edulis f. edulis* (purple type) and *P. edulis f. flavicarpa* (yellow type) are the most commercially significant, with the latter being cultivated more widely. During juice extraction, nearly half of the fruit mass—comprising mostly rind and seeds—is wasted (Lousada et al., 2006). The pith portion of the peel serves as a major source of fibre and pectin, which can be used as an ingredient in functional foods (Coelho et al., 2017).

Processing the dried and ground peel yields passion fruit peel flour (PFPF), a material noted for its health-promoting potential. PFPF is particularly rich in pectin, a soluble fibre consisting mainly of polygalacturonic acid and its methylated derivatives (Smith et al., 2012). Typically, PFPF contains about 10% moisture, 7.5% ash, 4% protein, 19% soluble fibre, 38% insoluble fibre, and 21% carbohydrates (Córdova et al., 2005; Pinheiro et al., 2008). The pectin concentration ranges from 12.6 to 18.2 g per 100 g dry matter (Freitas de Oliveira et al., 2016; Kliemann et al., 2009; Seixas et al., 2014). Studies have shown that the peel contains higher antioxidant activity than the pulp, with measurable levels of ascorbic acid (41.98 mg/100 g), polyphenols (482.56 mg GAE/100 g), and carotenoids (4.85 mg β-carotene/100 g) on a dry-mass basis (Hernández-Santos et al., 2015). These nutritional characteristics contribute to its physiological benefits, as the gel-forming nature of pectin can delay carbohydrate absorption, regulate glycaemic response, and potentially aid in diabetes management (Sachs, 2002). PFPF has also been associated with cholesterol reduction and improved intestinal function (Córdova et al., 2005; Centenaro et al., 2004). Additionally, the peel and seeds are abundant in nutraceutical compounds such as phenolic acids, flavonoids, anthocyanins, and carotenoids—particularly β-carotene, which exhibits provitamin-A activity (Morais et al., 2016). These bioactives possess antioxidant, anti-inflammatory, antiviral, and anticancer properties, which may contribute to lowering the risk of chronic diseases.

Earlier investigations have demonstrated successful use of PFPF in bakery and snack items to enhance fibre content and antioxidant capacity (Ishimoto et al., 2007; Souza et al., 2008). More recently, there has been growing interest in adding PFPF to staple foods such as noodles and bread to improve their nutritional quality and functionality, while also reducing food industry waste. The seeds of the fruit are likewise an excellent source of insoluble fibre, beneficial for both intestinal and cardiovascular health (Chau et al., 2004). Building on these findings, the present study examines the influence of incorporating passion fruit peel powder (PFPP) into flat noodles on their physical, nutritional, and sensory properties.

## Materials and Methods

### Sample preparation and storage conditions

Yellow passion fruit was collected from Kodagu district. The passion peels were removed from the fruit and were sliced into small pieces and allowed to dry for 2 days at controlled temperature in oven at 60ºC. The dried samples were then ground into a fine powder with the help of electric grinder. The powdered samples were stored in zip pouches and kept in refrigerator for further analysis.

### Formulation of products

The ingredients used for preparing flat noodles were refined flour, salt, oil, omum seeds, garlic powder, onion powder, white pepper powder and refined oil were procured from the local market.The products were formulated by incorporating Passion fruit peel powder. The developed products were analysed for nutritional composition and sensory quality. All the control products were prepared according to the standard recipe. While, variations were prepared by incorporating Passion fruit peel powder and the level of incorporation was standardized to obtain a product having acceptable sensory quality. Flat noodles were prepared using refined flour with 0%, 10%, and 15% PFPP substitution. Standardized formulations included common seasonings and additives.

### Standardization of Recipe

**Ingredients:** Refined flour-100 g, Garlic powder-3 g, Onion powder-3 g, White pepper powder-2 g, Salt to taste and Water for making the dough. **Methods:** Refined flour, salt, and oil were thoroughly mixed. Small quantities of water were gradually added to form a smooth dough. The prepared dough was covered with a clean cloth and allowed to rest for 10–15 minutes. Subsequently, the dough was divided into small portions. Each portion was flattened, lightly dusted with refined flour, and folded to obtain a three-layer structure. The folded dough sheets were then rolled out and cut into strips. The strips were dusted with refined flour to prevent sticking, shade-dried, and stored in airtight containers for further use.

**Variation 1 (10 g Passion Fruit Peel Powder)**
In this formulation, 10 g of passion fruit peel powder was incorporated into the basic dough mixture prior to water addition. All subsequent preparation steps were performed following the standard procedure described above.

**Variation 2 (15 g Passion Fruit Peel Powder)**
In this formulation, 15 g of passion fruit peel powder was incorporated into the basic dough mixture prior to water addition. The dough was then prepared and processed using the same method as outlined for the basic formulation.

**Estimation of Functional properties**
The functional properties of passion fruit peel powder (PFPP), including bulk density, water absorption capacity (WAC), fat absorption capacity (FAC), and swelling index, were determined using standard analytical procedures. Bulk density reflects the compactness and particle arrangement of the powder, while WAC and FAC indicate the powder's ability to retain water and oil, respectively—key attributes influencing texture and stability in food formulations. The swelling index represents the degree of hydration and structural expansion upon contact with water, providing insight into the powder's functional performance in composite food systems.

**Nutrient analysis**
The proximate composition of passion fruit peel powder (PFPP) and PFPP-incorporated flat noodles was analyzed according to standard methods of the Association of Official Analytical Chemists (AOAC). Moisture content was determined by the gravimetric method (AOAC, 2005), lipids by Soxhlet extraction (Raghuramulu et al., 2003), and protein content by the Kjeldahl method using a conversion factor of 6.25. Ash content was measured in a muffle furnace at 600°C. Total dietary fiber was estimated by the enzymatic–gravimetric method, while iron content was determined colorimetrically (Raghuramulu et al., 2003). Calcium was quantified through precipitation as calcium oxalate, followed by dissolution in hot dilute $H_2SO_4$ and titration against standard potassium permanganate (Oscar, 1965). All results are expressed as percentages, and the values reported represent the averages of duplicate analyses.

**Colour Measurement**
The colour characteristics of flat noodles incorporated with passion fruit peel powder (PFPP) were evaluated using the CIE L*, a*, b* system. Measurements were performed with a Miniscan XE Plus colorimeter (Model 45/0-S, Hunter Associates Laboratory, Inc., Reston, VA, USA) under D65 illuminant and a 10° standard observer. The instrument was calibrated using white and black standard ceramic tiles prior to analysis. The colour parameters were expressed as L* (lightness; representing whiteness or darkness), a* (redness/greenness), and b* (yellowness/blueness), providing a quantitative assessment of the impact of PFPP incorporation on the visual appearance of the noodles.

**Storage Studies**

The shelf-life quality of PFPP-incorporated noodles was assessed through free fatty acid (FFA) content in extracted oil, expressed as milligrams of potassium hydroxide required to neutralize FFA per gram of oil (AOAC, 2000), as an indicator of lipid deterioration.

**Physical Properties of Noodles**

Cooking characteristics, including cooking time, cooking loss, and swelling index, were evaluated following AACC (2000) methods. Cooking time was defined by the disappearance of the opaque core during boiling, and cooking loss (%) was calculated based on the dried residues in cooking water relative to uncooked noodle weight. Swelling index was measured to determine water uptake during cooking.

**Microstructural Analysis (SEM)**

Microstructural changes due to PFPP incorporation were examined using a Quanta 200 Environmental Scanning Electron Microscope (FEI, Hitachi, USA). Dried dough samples were defatted with petroleum ether and observed without coating at an accelerating voltage of 30 kV. SEM analysis provided insights into fiber-induced modifications in noodle texture and dough structure.

**Sensory Evaluation**

Sensory attributes of appearance, texture, taste, mouthfeel, and overall acceptability were evaluated by 30 semi-trained panelists using a descriptive score card. Samples were coded and presented with relevant carrier materials. Ratings were assigned on a 20-point scale: Poor (1–4), Fair (5–8), Satisfactory (9–12), Good (13–16), and Excellent (17–20).

**Statistical Analysis**

All experiments were conducted in duplicate. Data are expressed as mean ± standard deviation (SD). Analysis of variance (ANOVA) was performed to determine statistically significant differences between the PFPP-incorporated samples and control.

**Results and Discussion**

**Functional properties of PFPP**

The functional properties of passion fruit peel powder (PFPP) are summarized in Table 1. The bulk density of PFPP was 32.5 g/100 mL, water holding capacity (WHC) was 70 mL/100 g, fat absorption capacity (FAC) was 282.5 mL/100 g, and swelling index was 1.65 mL. The higher FAC indicates PFPP’s potential to retain oil, thereby enhancing flavor retention and sensory appeal in food products.

**Table 1. Functional properties of PFPP**

| Functional properties | Passion fruit peel powder |
|---|---|
| Bulk density (g/100ml) | 32.5 ± 0.5 |
| Water holding capacity (ml/100g) | 70.0 ± 10.0 |
| Fat absorption capacity (ml/100g) | 282.5 ± 5.5 |
| Swelling index (ml) | 1.65 ± 0.01 |

**Proximate Composition of PFPP and PFPP-Incorporated Flat Noodles**

The proximate composition of PFPP is presented in Table 2. PFPP was rich in dietary fiber (64%), predominantly insoluble (30.43 g/100 g) compared to soluble fiber (13.75 g/100 g). Protein, fat, and ash contents were 5.15, 0.7, and 7.0 g/100 g, respectively. Minerals such as iron (16.49 mg/100 g) and calcium (249.2 mg/100 g) were present at appreciable levels.

**Table 2. Nutritional composition of PFPP (g/100 g)**

| Nutrients | Passion fruit peel powder |
|---|---|
| Moisture (%) | 3.45 ± 0.05 |
| Fat (g) | 0.7 ± 0.1 |
| Total Ash (g) | 7.0 ± 0.33 |
| Protein(g) | 5.15 ± 0.15 |
| Insoluble Dietary Fibre (g) | 30.43 ± 0.07 |
| Soluble Dietary fibre (g) | 13.75 ± 0.04 |
| Iron (mg) | 16.49 ± 0.16 |
| Calcium (mg) | 249.2 ± 0.75 |

The nutritional profile of PFPP-incorporated flat noodles is summarized in Table 3. The incorporation of PFPP significantly enhanced dietary fiber, ash, iron, and calcium contents. Moisture and protein content were slightly reduced, while fat remained largely unchanged.

**Table 3. Nutritional composition of PFPP-incorporated flat noodles (g/100 g)**

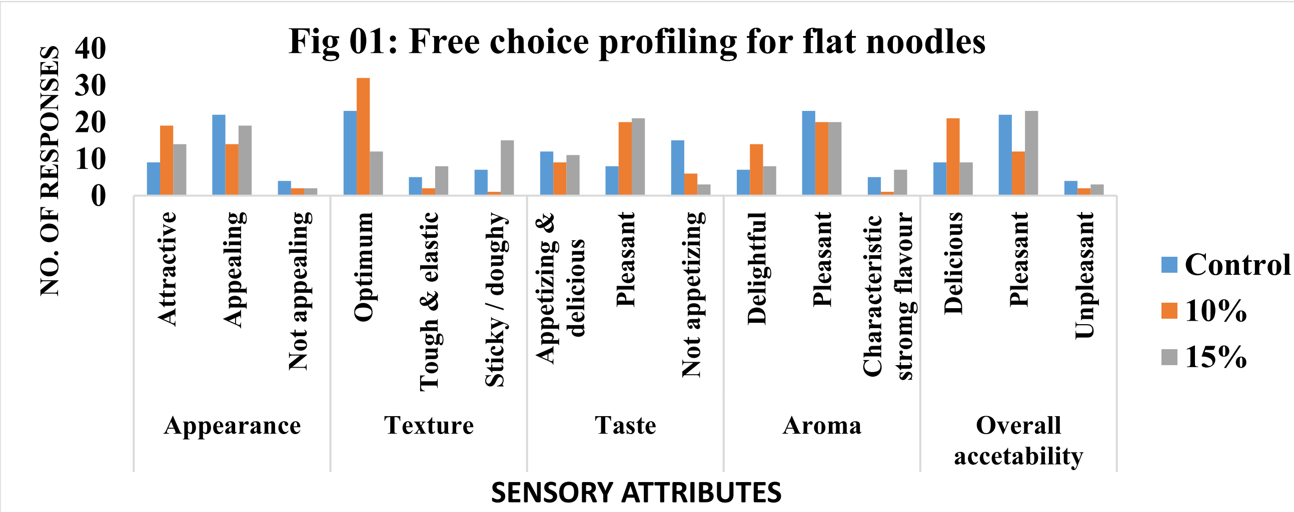
| Nutrients | Control | Variation 1 (10% PFPP) | Variation 2 (15% PFPP) |
|---|---|---|---|
| Moisture (%) | 5.7 ± 0.10 | 3.4 ± 0.20 | 3.8 ± 0.20 |
| Fat (g) | 5.1 ± 0.10 | 5.0 ± 0.30 | 5.1 ± 0.10 |
| Total ash (g) | 2.4 ± 0.16 | 4.0 ± 0.0 | 4.0 ± 0.0 |
| Protein (g) | 11.4 ± 0.02 | 10.2 ± 0.10 | 9.3 ± 0.20 |
| Insoluble Dietary fibre (g) | 5.15 ± 0.35 | 8.3 ± 0.1 | 12.8 ± 0.3 |
| Soluble Dietary fibre (g) | 1.15± 0.05 | 2.6 ± 0.1 | 3.5 ± 0.05 |
| Iron (mg) | 4.6 ± 0.1 | 7.25 ± 0.05 | 11.1 ± 0.3 |
| Calcium (mg) | 17.7 ± 0.2 | 55.7 ± 0.7 | 87.2 ± 1.2 |

**Sensory Evaluation**

Mean sensory scores of PFPP-incorporated noodles are shown in Table 4. Variation 1 (10% PFPP) consistently scored higher across appearance, taste, texture, mouthfeel, and overall acceptability. Variation 2 (15% PFPP) exhibited slightly lower scores for texture and aroma, likely due to the characteristic color and fiber content of PFPP. Free-choice profiling (Fig. 1) confirmed that panelists preferred the sensory attributes of variation 1 over control and variation 2.

**Table 4. Sensory scores of PFPP-incorporated flat noodles**

| Attributes | Control | Variation 1 | Variation 2 | P –value |
|---|---|---|---|---|
| Appearance | 14.0 ± 2.80 | 15.7 ± 2.32 | 15.2 ± 3.03 | 0.02* |
| Taste | 14.4 ± 3.11 | 16.4 ± 2.22 | 15.1 ± 2.47 | 0.009** |
| Texture | 15.0 ± 2.89 | 16.6 ± 2.22 | 14.5 ± 2.99 | 0.006** |
| Mouthfeel | 15.3 ± 2.37 | 16.6 ± 2.02 | 14.6 ± 2.82 | 0.002** |
| Aroma | 14.7 ± 2.64 | 15.9 ± 2.70 | 14.5 ± 2.67 | 0.06ns |
| Overall acceptability | 15.4 ± 2.47 | 17.1 ± 2.15 | 15.5 ± 2.51 | 0.006** |




## Colour Analysis

Colour parameters (L*, a*, b*) of noodles are presented in Table 5. PFPP incorporation decreased lightness (L*), increased redness (a*), and enhanced yellowness (b*), reflecting the influence of fiber and pigments in the peel powder on noodle appearance. It can be concluded that the incorporation of any fibre source at any level resulted in an increase in the b* value, meaning more yellowish hue in fibre-enriched products compared to the control.

**Table 5. Colour analysis of PFPP-incorporated flat noodles**

| Samples | *L** | *a** | *b ** |
|---|---|---|---|
| Control | 70.81 ± 0.17 | 1.65 ± 0.05 | 19.30 ± 1.29 |
| Variation 1 | 69.86 ± 4.34 | 3.35 ± 0.21 | 21.78 ± 0.46 |
| Variation 2 | 67.50 ± 5.38 | 5.91 ± 1 | 27.67 ± 2.45 |

## Cooking Characteristics

Cooking time, cooking loss, and swelling index of noodles are shown in Table 6. Control noodles cooked faster (14 min) than PFPP-enriched variations (15.5–16 min) due to less cross-linking in starch. Cooking loss increased with PFPP incorporation (14.93–19.83%), indicating disruption of the starch-protein matrix, while swelling index slightly increased with higher fiber content. This suggests that increased amount of fibre in the dough matrix had disrupted the protein starch network, causing starches to leach out during the cooking, and consequently resulting in a decrease in cooking quality.

**Table 6. Cooking properties of PFPP-incorporated flat noodles**

| Properties | Control | Variation 1 | Variation 2 |
|---|---|---|---|
| Cooking time (min) | 14 | 15. 30 | 16 |
| Cooking loss (%) | 7.05 ± 0.01 | 14.93 ± 0.03 | 19.83 ± 0.01 |
| Swelling index (ml) | 0.95 ± 0.01 | 0.92 ± 0.01 | 1.02 ± 0.01 |

**Storage Stability**

Free fatty acid (FFA) content of noodles during storage (0–20 days) is presented in Table 7. Initial FFA levels were low in all samples. Over 20 days, FFA increased in all samples, but PFPP-incorporated noodles exhibited lower FFA accumulation (variation 2: 5.4%) compared to control (9.4%), suggesting improved lipid stability due to fiber content.

**Table 7. Free fatty acid content of PFPP-incorporated flat noodles (%)**

| Samples | Day 0 | Day 10 | Day 20 |
|---|---|---|---|
| Control | 0.94 ± 0.03 | 8.0 ± 0.3 | 9.4 ± 0.1 |
| Variation 1 | 0.70 ± 0.01 | 5.85 ± 0.25 | 6.25 ± 0.25 |
| Variation 2 | 0.59 ± 0.01 | 4.00 ± 0.1 | 5.40 ± 0.1 |

**SEM Analysis**

SEM micrograph revealed that PFPP incorporation altered noodle microstructure. Control noodles displayed a continuous gluten network with partially exposed starch granules. PFPP addition reduced starch exposure, disrupted the protein network, increased matrix porosity, and enhanced water retention, indicating improved elasticity and structural integrity. Higher PFPP levels (15%) caused more pronounced disruption but retained uniform particle size and smooth surfaces.

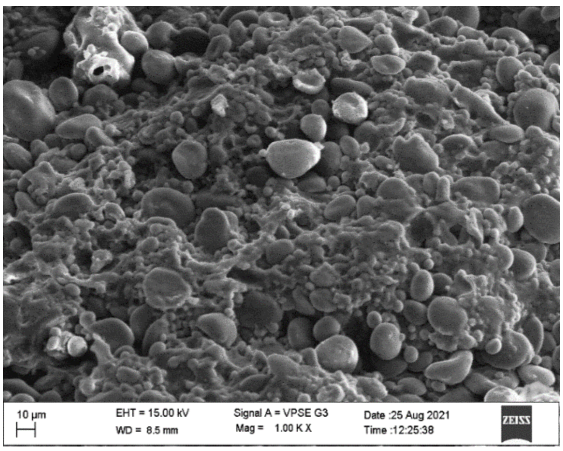



**Figure (2). Standard flat noodles (Control)**

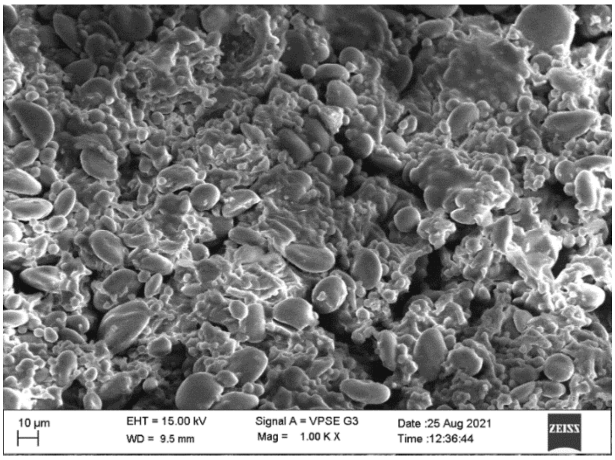



**Figure (3). Flat noodles with 10% PFPP**

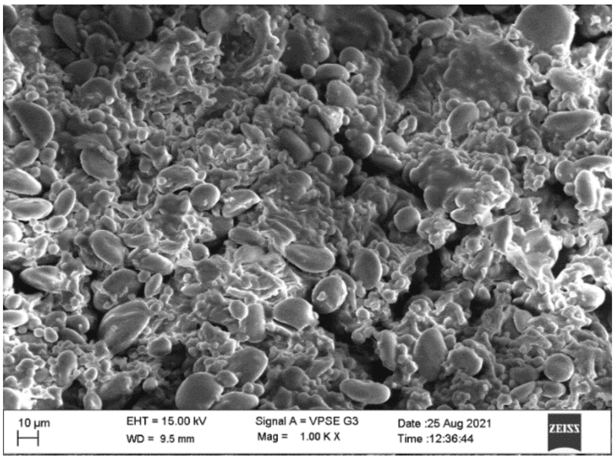



**Figure (4). Flat noodles with 15% PFPP**

## Conclusion

PFPP incorporation in flat noodles enhanced dietary fiber, minerals (iron, calcium), and overall nutritional quality. Sensory evaluation indicated that 10% PFPP-enriched noodles were most preferred. Although higher PFPP levels slightly affected texture and color, all products remained acceptable. PFPP represents a promising functional ingredient for increasing the nutritional density of cereal-based products without compromising sensory quality. Future studies could explore techniques to further optimize texture and sensory attributes in fiber-enriched foods.

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