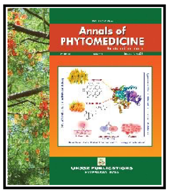
Annals of Phytomedicine 14(1): 959-969, 2025

DOI: http://dx.doi.org/10.54085/ap.2025.14.1.96

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885



Original Article : Open Access

Exploration of nutritional potential of unripe papaya (*Carica papaya* L.) powder in traditional Indian foods

Pushpinder Kaur◆, Neerja Singla, Jagbir Rehal* and Monika Gupta**

Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141004, Punjab, India
**Department of Food Science and Technology, Punjab Agricultural University, Ludhiana-141004, Punjab, India*
*** Department of Fruit Science, Punjab Agricultural University, Ludhiana-141004, Punjab, India*

Article Info

Article history
Received 26 February 2025
Revised 13 April 2025
Accepted 14 April 2025
Published Online 30 June 2025

Keywords
Antioxidant activity
Nutritional content
Organoleptic evaluation
Traditional foods
Unripe papaya powder

Abstract

Unripe papaya (*Carica papaya* L.) is an underutilized fruit, often discarded as a by-product of food processing industries. The present study aimed to analyze the nutritional and antioxidant properties of unripe papaya powder and evaluate its potential as a functional ingredient in traditional Indian foods such as chapatti, mathi, and besan chilla. Unripe papaya of the Red L.786 variety was processed into powder and assessed for its physical, functional, and nutritional properties. The composition of the powder was analyzed for proximate composition, total sugars, dietary fiber, vitamin C, potassium, magnesium and bioactive compounds including total phenols, flavonoids, and antioxidant activity. Traditional food products were prepared with varying levels of unripe papaya powder supplementation (10% in chapatti and mathi, 15% in besan chilla). Sensory acceptability, textural properties and nutritional enhancements were evaluated. Unripe papaya powder contained significant amounts of dietary fiber (24.00 g/100 g), potassium (514.50 mg/100 g), vitamin C (35.00 mg/100 g), total phenols (278.95 mg GAE/100 g), and flavonoids (336.15 mg QE/100 g), with an antioxidant activity of 26.44%. The developed food products were well accepted at the specified supplementation levels. Textural analysis revealed that supplemented products were softer than controls. Nutritional analysis showed a significant ($p \leq 0.05$) increase in dietary fiber, potassium, bioactive compounds, and antioxidant activity. It was concluded that incorporating unripe papaya powder into traditional Indian foods enhances their nutritional profile, particularly dietary fiber and antioxidants, promoting better health. Therefore, unripe papaya powder can be a functional ingredient in diet based interventions for metabolic disorders such as diabetes, obesity, and cardiovascular diseases.

1. Introduction

Food is essential for the body's proper growth and maintenance of a person's health (Gupta and Sarwat, 2022). Traditional foods hold significant cultural value and play a critical role in dietary habits, especially in countries like India, where they are part of daily meals. India depends on its traditional foods due to its affordability and ease of access. People are influenced from generation to generation because traditional meals are deficient in several nutrients (Divya, 2022). However, as nutritional science progresses, there is an increasing interest in enhancing these foods to meet modern health needs, such as higher dietary fiber content, increased bioactive compounds and antioxidant potential. This pursuit aligns with global efforts to address dietary deficiencies and promote functional foods, which provide health benefits beyond basic nutrition. The body's anti-inflammatory, anticholesterol, and antioxidant processes may be improved by regular consumption of functional foods (Sharma and Sarwat, 2022). Fruits' inherent antioxidant qualities have been linked to their contents, specifically vitamin C and flavonoids, which have been associated with health benefits (Chellammal, 2022).

The papaya is the most economically significant and widely grown fruit that comprises the botanical family *Caricaceae* and the genus *Carica* (Biswal *et al.,* 2022). Chuwa and Kamal (2022) stated that papaya is a powerhouse of nutrients because it contains a high concentration of nutrients, including total soluble solids (9.50ºB), reducing sugars (2.05%), total sugars (7.35%), titratable acidity (0.06%), crude fat (0.14%), crude protein (0.65%), total carbohydrates (8.51%), crude fiber (0.91%), ascorbic acid (59.26 mg per 100 g), β carotene (13.04 mg per 100 g), ash (0.72%) and total energy (34.26 kcal per 100 g). While ripe papaya is widely consumed for its sweet taste and nutrient density, the green unripe papaya is often overlooked, despite its superior fiber content and bioactive profile.

Unripe papaya contains papain, also known as vegetable pepsin, which can help dyspeptic individuals who are unable to digest the gliadin (wheat protein), but can digest it when treated with papain (Huet *et al.,*2006). Papain and chymopapain decay as the fruit ripens and are no longer present in the ripe fruit (Oloyede, 2005). Papayas are a significant source of fiber and adding them to food improves nutritional value as well as several of its functional qualities such as emulsification and increased ability to hold water and oil (Joymak *et al.*, 2021).

Corresponding author: Ms. Pushpinder Kaur
Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141004, Punjab, India
E-mail: kaurpushpinder2k@gmail.com
Tel.: +91-8284912336

Traditional foods such as chapatti, mathi, and besan chilla hold a central place in daily Indian diets. Therefore, one promising approach to boost the nutritional value of these staples is the inclusion of unripe papaya, a fruit rich in essential nutrients and bioactive compounds that are often underutilized in culinary applications. Incorporating dried papaya into food products not only extends its shelf life but also introduces a delightful twist to traditional recipes, showcasing the versatility of this tropical fruit. It can significantly increase the intake of these beneficial compounds without altering the food's basic texture and taste profile.

The present study investigates the nutritional enrichment of chapatti, mathi, and besan chilla with unripe papaya powder, focusing on enhancements in dietary fiber, bioactive compounds, and antioxidant capacity. By fortifying these traditional foods with unripe papaya, we aim to bridge the gap between cultural dietary habits and modern nutritional needs, presenting an innovative yet practical way to support public health. This research could not only expand the use of unripe papaya but also pave the way for nutrient-rich, functional food products that maintain the essence of traditional Indian cuisine.

2. Materials and Methods

2.1 Procurement of sample and preparation of powder

Unripe papaya [The Red Lady 786 hybrid papaya (Red L.786)] was procured from the Department of Fruit Science, Punjab Agricultural University, Ludhiana. This cultivar is distinguished by its early bearing, vigorous growth, and resistance to papaya ringspot virus, making it highly suitable for commercial cultivation. It is recommended for its high yield potential and superior fruit quality. The fruits exhibit short, oblong shapes on female plants and elongated forms on bisexual plants, typically weighing between 1.5 to 2 kg. They possess red flesh and exhibit good shelf-life characteristics. The fresh unripe papaya samples were washed with distilled water to remove soil and other impurities. Then samples were peeled and grated and grinded to powder after drying at 60ºC for 24 h in tray drier. Unripe papaya powder (UPP) was stored in sealed packet for further analysis and supplementation (Bokaria and Ray, 2016).

2.2 Analysis of physical and functional characteristics of unripe papaya powder

Unripe papaya powder (UPP) was analyzed for physical characteristics including particle size and colour and functional properties including bulk density, water absorption capacity (WAC), water swelling power (WSP), water solubility index (WSI) and oil absorption capacity (OAC).

2.2.1 Particle size

The Ro-Tap Shaker was used to measure particle size with a sieve stack (5.6 mm to 180 µm and a pan). A 100 g sample was shaken for five minutes, and residue on each sieve was collected. Particle size was determined by weighing the retained sample.

2.2.2 Colour

Color analysis of unripe papaya powder was conducted using a Hunter Lab colorimeter. The device was calibrated with black and white plates before measurement. Three exposures were taken at different positions using a 90-degree angle. Hunter L*, a*, and b* values were recorded for color quantification.

Hue Angle $(h^*) = \arctan (b^*/a^*)$

Chroma $(C) = \sqrt{a^2 + b^2}$

2.2.3 Bulk density (AOAC, 2001)

An exact 1 g flour sample was weighed and put into a graduated 10 ml cylinder. After that, the cylinder was tapped until the flour being settled and the volume occupied was measured. The mass to volume ratio was used to indicate density.

$$\text{Bulk density (g/ ml)} = \frac{\text{Mass}}{\text{Volume}}$$

2.2.4 Water absorption index (Elkhalifa and Bernhardt, 2010)

The sample was vortexed for 1 min, rested for 30 min, and centrifuged (3000 rpm, 30 min). The supernatant was decanted, and the tubes were inverted for 5 min. The gain in sample weight was used to determine water absorption capacity.

Water absorption capacity (g/g)

$$= \frac{\text{increase in weight of the sample (g)}}{\text{Initial weight of the sample (g)}}$$

2.2.5 Water solubility index (Elkhalifa and Bernhardt, 2010)

The supernatant obtained after water absorption of the flour sample was collected in a pre-weighed petri-plate and weighed. Then, to determine its solid content, the excess water was evaporated by drying the supernatant in a hot air oven at 105ºC and the weight of dry solids was recorded and the water solubility index (WSI) was calculated in per cent as follows:

$$\text{WSI (\%)} = \frac{\text{weight of dry solids (g)}}{\text{weight of sample (g)}}$$

2.2.6 Oil absorption capacity (Elkhalifa and Bernhardt, 2010)

A 1 g flour sample and 10 ml oil were added to pre-weighed tubes, vortexed for 1 min, and rested for 30 min. After centrifugation (3000 rpm, 30 min), the separated oil was removed, tubes were inverted for draining and reweighed to determine oil absorption capacity.

$$\text{OAC (g/ g)} = \frac{\text{weight of sediment}}{\text{Initial weight of flour}}$$

2.3 Nutritional evaluation of unripe papaya powder

Unripe papaya raw samples were further analyzed for nutritional parameters including proximate composition, total sugars, reducing and non-reducing sugars, dietary fiber, potassium and magnesium, vitamin C, total phenols, total flavonoids, total antioxidant activity by DPPH and FRAP assay.

2.3.1 Proximate composition (AOAC, 2012)

The proximate composition of the samples was analyzed using standard AOAC (2012) methods. Moisture content was determined by drying a homogenized sample in a hot air oven at 105ºC for eight hours and weight loss was recorded. Crude protein was estimated using the Macro Kjeldahl method with the KEL PLUS Automatic Nitrogen System, where organic nitrogen was converted to ammonium sulfate, distilled and titrated using 0.1 NH_2SO_2. A conversion factor of 6.25 was applied. Crude fat was extracted using petroleum ether in an automated Soxhlet system and the extracted fat was weighed after evaporation. Ash content was determined by igniting the sample in a muffle furnace at 550ºC until only inorganic residue remained. Crude fiber was estimated by sequential acid and alkali digestion, followed by incineration in a muffle furnace. Carbohydrate content was calculated by subtracting the sum of moisture, protein, fat, fiber and ash from 100 per cent.

2.3.2 Total sugars, reducing and non-reducing sugars (Sadasivam and Manickam, 2016)

Sugars were extracted by refluxing 200 mg of finely ground sample sequentially with 80% and 70% isopropyl alcohol in a hot water bath. The resulting extract was concentrated, diluted with distilled water and subsequently treated with lead acetate to precipitate proteins. Excess lead ions were removed by the addition of sodium oxalate, followed by filtration to obtain a clear extract. Total sugar content was determined by reacting 0.2 ml of the extract with phenol and concentrated sulfuric acid, and measuring the absorbance at 490 nm. Reducing sugars were quantified by reacting the extract with alkaline copper tartrate, followed by heating in a boiling water bath and subsequent addition of arsenomolybdate reagent. Absorbance was measured at 620 nm. The concentration of non-reducing sugars was calculated by subtracting the amount of reducing sugars from the total sugar content.

2.3.3 Dietary fiber (soluble and insoluble) (AOAC, 2000)

Dietary fiber content was determined using fat-free samples. Crucibles were pre-ashed, cleaned and coated with Celite to facilitate filtration. The samples underwent sequential enzymatic digestion involving α-amylase (98-100°C), protease (60°C), and amyloglucosidase (60°C), with appropriate pH adjustments between each step. Following digestion, the insoluble dietary fiber fraction was separated by filtration, thoroughly washed, dried and weighed. Protein and ash contents in the residue were subsequently determined using the Kjeldahl method and muffle furnace incineration, respectively, to apply necessary corrections. The soluble dietary fiber was precipitated from the filtrate using preheated ethanol, then filtered through Celite, washed sequentially with ethanol and acetone, dried, and weighed. Corrections for residual protein and ash were also applied. Total dietary fiber was calculated by summing the corrected values of soluble and insoluble fractions, with final values adjusted for blank determinations.

2.3.4 Minerals (potassium and magnesium)

1 g of the sample was subjected to overnight digestion in concentrated nitric acid, followed by further digestion with perchloric acid at 250-300°C until a clear solution was obtained. The digested solution was then diluted to a known volume with deionized water and analyzed for mineral content using atomic absorption spectrophotometry (AAS). Mineral concentrations were quantified by comparison with standard calibration curves and expressed in milligrams per 100 g of sample, based on the absorbance readings, dilution factor and initial sample weight.

2.3.5 Vitamin C (AOVC, 1996)

5 g of unripe papaya were homogenized with metaphosphoric acid and subsequently filtered to obtain a clear extract. The filtrate was reacted with an acetate buffer and 2,6-dichlorophenol indophenol dye, facilitating the reduction of the dye by ascorbic acid. The resulting solution was then extracted with xylene to isolate the colored complex. Absorbance of the xylene layer was measured at 500 nm using a spectrophotometer. Vitamin C concentration was calculated by referencing a standard of ascorbic acid and a blank.

2.3.6 Total phenols (Singleton *et al*., 1999)

Total phenols were determined using the Folin-Ciocalteu method. Methanolic extracts were mixed with Folin reagent, followed by sodium carbonate and incubated in the dark for two hours. The absorbance was measured at 765 nm against a blank. Total phenols were expressed as mg gallic acid equivalent (GAE) per 100 g.

2.3.7 Total flavonoids (Zhischen *et al*., 1999)

Total flavonoid content was determined using the aluminium chloride colorimetric method. The methanolic extract was mixed with aluminium chloride, potassium acetate and distilled water, then incubated for 30 min. Absorbance was measured at 415 nm. The flavonoid content was expressed as mg quercetin equivalent (QE) per 100 g.

2.3.8 Total antioxidant activity by DPPH (Brand-Williams *et al*., 1995)

The methanolic extract was mixed with DPPH solution and incubated in the dark for 30 min. Absorbance was measured at 517 nm. The percentage of DPPH inhibition was calculated using the formula:

Per cent inhibition = [(Absorbance of blank – Absorbance of sample) / Absorbance of blank] × 100.

2.3.9 Total antioxidant activity (Benzie and Strain, 1999)

The ferric reducing antioxidant power (FRAP) assay measures antioxidants' ability to reduce the ferric complex (Fe^3z -TPTZ) to a blue-colored ferrous complex (Fe^2z -TPTZ) at low pH. The sample was mixed with FRAP reagent and incubated at 37ºC for 10 min. Absorbance was recorded at 593 nm against a blank.

2.4 Organoleptic evaluation and nutritional analysis of products

Then unripe papaya powder was supplemented with traditional foods like chapatti, mathi, and besan chilla. Recipes of all these products were standardized using control ingredients and unripe papaya powder at different levels. All the prepared products were evaluated for their sensory attributes using a 9-point Hedonic rating scale by a panel of semi-expert judges. The highly acceptable food products were evaluated for textural analysis and nutritional analysis using the same parameters as raw samples.

2.5 Statistical analysis

For statistical analysis of data, SPSS 16 (Statistical Package for the Social Sciences) was used. Mean and standard deviation was calculated for each parameter. Furthermore t-test was used to determine the significant difference between nutritional profile of control and most acceptable products.

3. Results

The results of this study present the findings on the physical, functional, and nutritional properties of unripe papaya powder (UPP) and its impact on supplemented traditional foods.

Table 1: Physical and functional properties of unripe papaya powder (mean ± SD)

Characteristic	Parameters	Unripe papaya powder
Particle size distribution		
Size of sieve pores	1.4 mm	-
	710 µm	00.13 ± 0.02
	355 µm	17.54 ± 0.73
	180 µm	50.69 ± 0.63
	Pan	31.08 ± 0.25
Colour analysis		
Colour values	L*	72.68 ± 0.96
	a*	07.27 ± 0.03
	b*	21.84 ± 0.72
	Hue value (radians)	1.249 ± 0.009
		71.6°
	Chroma value	23.01 ± 0.70
Functional properties	Bulk density (g/ml)	00.61 ± 0.01
	Water absorption capacity (g/g)	04.48 ± 0.30
	Swelling power (g/g)	04.80 ± 0.03
	Water solubility index (%)	09.28 ± 0.09
	Oil absorption capacity (g/g)	01.21 ± 0.04

Table 2: Nutritional profile of unripe papaya (per 100 g, dry weight basis) (mean ± SD)

Parameter	Unripe papaya
Moisture (%)	091.30 ± 0.06
Crude protein (%)	000.72 ± 0.01
Crude fat (%)	000.22 ± 0.02
Crude fiber (%)	001.30 ± 0.14
Ash (%)	000.55 ± 0.03
Carbohydrates (%)	005.90 ± 0.22
Total sugars (g)	001.13 ± 0.01
Reducing sugars (g)	000.93 ± 0.01
Non-reducing sugars (g)	000.20 ± 0.02
Total fibre (g)	024.01 ± 1.41
Insoluble fiber (g)	017.55 ± 1.06
Soluble fiber (g)	006.45 ± 0.35
Vitamin C (mg)	035.02 ± 1.41
Potassium (mg)	514.50 ± 9.19
Magnesium (mg)	085.50 ± 2.12
Total phenols (mg GAE/100 g)	278.95 ± 5.8
Total flavonoids (mg QE/100 g)	336.15 ± 8.16
DPPH (% inhibition)	026.44 ± 2.57
FRAP (µmol Fe^{2+}/100 g)	273.03 ± 19.74

3.1 Physical and functional properties of unripe papaya powder

The physical characteristics of UPP indicate a fine texture with a yellowish-green hue, while its functional properties demonstrate high water absorption and swelling capacities, suggesting good hydration potential (Table 1).

3.2 Nutritional profile of unripe papaya

Nutritional analysis (Table 2) reveals that unripe papaya contains 91.30 per cent moisture, 0.72 per cent protein, 0.22 per cent fat, 1.30 per cent crude fiber, 0.55 per cent ash, and 5.90 per cent carbohydrates. It has 1.13 g total sugars, including 0.93 g reducing and 0.20 g non-reducing sugars. Total fiber is 24.01 g, with 17.55 g insoluble and 6.45 g soluble fiber. It provides 35.02 mg of vitamin C, 514.50 mg of potassium and 85.50 mg of magnesium. Total phenols and flavonoids are 278.95 mg GAE and 336.15 mg QE per 100 g, respectively. Antioxidant activity includes 26.44% DPPH inhibition and 273.03 µmol $Fe^{2}z$ /100 g FRAP. This profile highlights unripe papaya's nutritional and bioactive potential.

3.3 Organoleptic evaluation of food products supplemented with UPP

The study explores the incorporation of UPP into traditional Indian foods, namely chapatti, mathi, and besan chilla. As per the results of the sensory evaluation (Figure 1), it was found that all the products were acceptable at different levels. Chapatti was acceptable at a 10 per cent level of supplementation of UPP with the highest overall acceptability scores (7.74). Mathi with a 10 per cent level of supplementation obtained the highest acceptability scores for all the parameters with an overall acceptability of 7.87. Besan chilla were acceptable at a 15 per cent level of supplementation of UPP with the highest scores for all the parameters ranging between 8.00 to 8.20 and overall acceptability of 8.12.

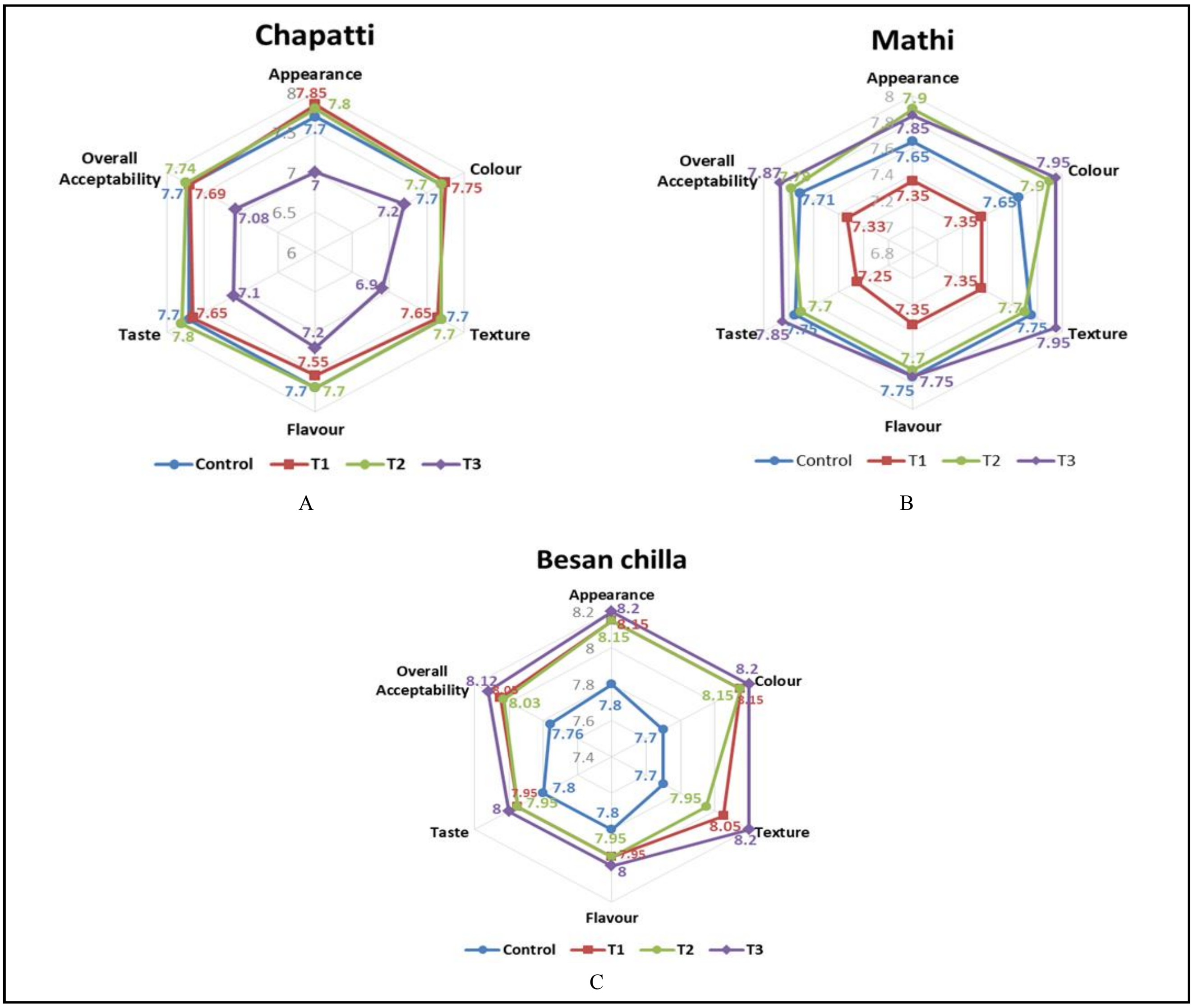


Figure 1: **Organoleptic acceptability scores of products supplemented with UPP: A. Chapatti, B. Mathi, and C. Besan chilla. For Chapatti and Besan Chilla, T_1, T_2 and T_3 indicate 5, 10 and 15% and for Mathi, 5, 7.5 and 10%. UPP supplementation, respectively.**

3.4 Nutritional evaluation of acceptable food products

Nutritional analysis of supplemented foods reveals improvements in dietary fiber, mineral content, and bioactive compounds. The fiber content in all products increases significantly ($p<0.05$), aligning with the high fiber content of UPP. Additionally, vitamin C, potassium and antioxidant properties are enhanced, indicating the functional benefits of UPP supplementation. The protein and fat content in supplemented products show slight reductions. The antioxidant activity of the developed products assessed using DPPH and FRAP assays, shows a significant increase ($p\leq0.05$).

Table 3: Nutritional analysis of chapatti supplemented with unripe papaya powder (per 100 g) (mean ± SD)

Parameters	Control	Supplemented	t-value
Moisture (%)	003.83 ± 0.05	004.00 ± 0.01	4.408*
Crude protein (%)	010.80 ± 0.69	009.75 ± 0.19	2.049^{NS}
Crude fat (%)	000.38 ± 0.01	000.37 ± 0.04	0.350
Crude fibre (%)	002.02 ± 0.07	003.30 ± 0.27	6.453*
Ash (%)	001.76 ± 0.05	002.31 ± 0.12	5.677*
Carbohydrates (%)	081.21 ± 0.71	080.27 ± 0.1	1.854
Total sugars (g)	002.26 ± 0.11	02.40 ± 0.06	1.565
Reducing sugars (g)	000.92 ± 0.05	01.06 ± 0.10	1.853
Non-reducing sugars	001.35 ± 0.06	01.34 ± 0.16	0.042*
Total fibre (g)	010.70 ± 0.42	013.65 ± 0.35	7.551*
Soluble fibre (g)	002.70 ± 0.28	003.65 ± 0.07	4.612*
Insoluble fibre (g)	008.00 ± 0.71	010.00 ± 0.28	3.711
Vitamin C (mg)	000.27 ± 0.06	006.25 ± 0.78	39.256*
Potassium (mg)	318.65 ± 1.13	403.21 ± 2.83	16.284*
Magnesium (mg)	024.50 ± 0.71	028.42 ± 0.57	6.09*
Total phenols (mg GAE)	144.38 ± 1.66	162.15 ± 3.04	7.263*
Total flavonoids (mg QE/100 g)	252.69 ± 3.26	324.27 ± 9.96	9.655*
DPPH (% inhibition)	028.22 ± 1.13	037.38 ± 1.52	6.858*
FRAP (µmol Fe^{2+}/100 g)	568.74 ± 16.04	744.94 ± 25.91	8.179*

*Significant at 5% level of significance ($p\leq0.05$) ** significant at 1% level of significance ($p\leq0.01$).

3.4.1 Chapatti

Table 3 presents the nutritional analysis of chapatti supplemented with unripe papaya powder compared to the control. The supplemented chapatti showed significant ($p\leq0.05$) increases in moisture, crude fibre, ash, total and soluble fibre, vitamin C, potassium, magnesium, total phenols, flavonoids, and antioxidant activity (DPPH and FRAP), indicating enhanced nutritional and functional properties. Protein and fat content showed slight, non-significant changes. The increase in antioxidant compounds and fibre highlights the potential health benefits of incorporating unripe papaya powder into traditional foods.

3.4.2 Mathi

Table 4 presents the comparative nutritional profile of control and unripe papaya powder-supplemented mathi per 100 g. The supplemented sample showed a significant ($p\leq0.05$) increase in moisture (4.89%), crude fibre (2.56%), ash (2.58%), total fibre (4.63 g), and both soluble and insoluble fibre fractions. Notably, vitamin C content increased substantially from 0.39 mg to 7.35 mg, along with a marked rise in antioxidant components such as total phenols (168.4 mg GAE) and flavonoids (140.38 mg QE/100 g). Antioxidant activity also improved, indicated by higher DPPH inhibition (33.34%) and FRAP values (717.55 µmol Fe²z /100 g). Additionally, enhanced mineral content was observed, particularly in potassium and magnesium. While crude protein and fat content slightly decreased, the overall nutritional enhancement especially in fibre, antioxidants, and vitamin C demonstrates the functional benefits of incorporating unripe papaya powder into traditional mathi.

3.4.3 Besan chilla

Table 5 presents the nutritional analysis of besan chilla supplemented with unripe papaya powder, revealing significant improvements in dietary fibre, micronutrients and antioxidant properties. The supplemented product exhibited a marked increase in crude fibre (3.04%), total fibre (16.70 g), ash (6.02%), and vitamin C (15.09 mg), alongside elevated levels of total phenols, flavonoids, and antioxidant activity (DPPH and FRAP). Potassium content also increased significantly ($p\leq0.05$), enhancing the mineral profile. While reductions in crude protein and fat were observed.

Table 4: Nutritional analysis of mathi supplemented with unripe papaya powder (per 100 g) (mean ± SD)

Parameters	Control	Supplemented	*t-value*
Moisture (%)	004.12 ± 0.1	004.89 ± 0.15	6.062*
Crude protein (%)	006.83 ± 0.13	005.81 ± 0.35	3.927
Crude fat (%)	021.97 ± 0.2	019.10 ± 0.64	6.090*
Crude fibre (%)	000.34 ± 0.04	002.56 ± 0.31	10.017*
Ash (%)	001.48 ± 0.12	002.58 ± 0.35	4.158*
Carbohydrates (%)	065.25 ± 0.26	065.06 ± 1.79	0.149
Total sugars (g)	002.09 ± 0.10	002.29 ± 0.06	2.481
Reducing sugars (g)	000.81 ± 0.02	001.10 ± 0.03	11.80**
Non-reducing sugars	001.29 ± 0.12	001.19 ± 0.09	0.913
Total fibre (g)	002.78 ± 0.04	004.63 ± 0.06	37.006**
Soluble fibre (g)	000.53 ± 0.09	001.29 ± 0.11	7.663*
Insoluble fibre (g)	002.26 ± 0.13	003.35 ± 0.05	10.772**
Vitamin C (mg)	000.39 ± 0.02	007.35 ± 0.21	59.470**
Potassium (mg)	348.20 ± 12.26	433.34 ± 8.32	8.125*
Magnesium (mg)	022.50 ± 0.71	030.03 ± 1.41	6.71*
Total phenols (mg GAE)	130.70 ± 2.76	168.40 ± 3.59	11.767**
Total flavonoids (mg QE/100 g)	102.69 ± 3.26	140.38 ± 3.26	11.549**
DPPH (% inhibition)	022.67 ± 0.13	033.34 ± 0.22	59.682**
FRAP (µmol Fe^{2+}/100 g)	675.16 ± 65.38	717.55 ± 34.54	19.936**

* Significant at 5% level of significance ($p \leq 0.05$) ** significant at 1% level of significance ($p \leq 0.01$).

Table 5: Nutritional analysis of besan chilla supplemented with unripe papaya powder (per 100 g) (mean ± SD)

Parameters	Control	Supplemented	*t-value*
Moisture (%)	005.10 ± 0.02	005.81 ± 0.11	8.784*
Crude protein (%)	013.74 ± 0.12	012.13 ± 0.11	13.750**
Crude fat (%)	003.70 ± 0.22	002.67 ± 0.4	3.154
Crude fibre (%)	000.84 ± 0.08	003.04 ± 0.03	36.870**
Ash (%)	003.78 ± 0.2	006.02 ± 0.05	15.501**
Carbohydrates (%)	072.86 ± 0.25	070.33 ± 0.43	7.145*
Total sugars (g)	001.95 ± 0.06	002.18 ± 0.04	4.610*
Reducing sugars (g)	000.61 ± 0.09	000.85 ± 0.06	3.328
Non-reducing sugars	001.34 ± 0.14	001.33 ± 0.01	0.100
Total fibre (g)	013.40 ± 1.13	016.70 ± 0.15	4.082
Soluble fibre (g)	003.80 ± 0.14	004.50 ± 0.42	2.214
Insoluble fibre (g)	009.60 ± 0.99	012.20 ± 0.28	3.571
Vitamin C (mg)	004.69 ± 0.13	015.09 ± 1.03	19.694**
Potassium (mg)	372.92 ± 7.66	469.05 ± 2.26	17.024**
Magnesium (mg)	075.04 ± 4.24	062.11 ± 1.41	4.11
Total phenols (mg GAE)	088.91 ± 3.87	145.35 ± 3.04	16.232**
Total flavonoids (mg QE/100 g)	154.62 ± 2.72	202.69 ± 0.5	25.000**
DPPH (% inhibition)	021.41 ± 0.35	029.35 ± 0.04	32.125**
FRAP (µmol Fe^{2+}/100 g)	347.49 ± 40.27	581.82 ± 19.74	7.390*

* Significant at 5% level of significance ($p \leq 0.05$) ** significant at 1% level of significance ($p \leq 0.01$).

3.5 Textural analysis of products supplemented with UPP

The results are compared between control and experimental (supplemented) samples of chapatti, mathi, and besan chilla (Table 6). The hardness values for chapatti and mathi did not show significant differences, with chapatti control at 37.75 N and experimental at 29.09 N and mathi control at 4.53 N and experimental at 3.70 N. For besan chilla, the control had a hardness of 12.26 N compared to 9.04 N for the experimental group, though this difference also lacked statistical ($p \leq 0.05$) significance.

Table 6: Textural analysis of food products supplemented with unripe papaya powder

Treatments	Hardness (Force) (N)		
	Chapatti	Mathi	Besan chilla
Control	37.75 ± 4.05	4.53 ± 0.49	12.26 ± 1.21
Supplemented	29.09 ± 2.20	3.70 ± 0.21	09.04 ± 1.00
t-value	2.652^{NS}	2.153^{NS}	2.901^{NS}

^{NS}Non significant

4. Discussion

The present study explored the nutritional enhancement of traditional Indian foods through the supplementation of unripe papaya powder (UPP), focusing on its impact on dietary fiber, bioactive compounds, and antioxidant activity. The findings indicate that UPP supplementation improved the nutritional profile of chapatti, mathi, and besan chilla while maintaining their organoleptic acceptability. These results align with existing literature that emphasizes the nutritional potential of unripe papaya in functional food development (Joymak *et al*., 2021; Rajput *et al*., 2019).

4.1 Physical and functional properties of unripe papaya powder

Usually, the first thing that people notice about a food product's look is its colour. Customers will see the goods as inferior if the colour does not live up to their expectations (Endrizzi *et al*., 2015). Therefore, color estimation of unripe papaya powder was carried out to assess its visual appeal and potential impact on the appearance of food products developed with its incorporation to ensure that the addition of papaya powder does not negatively affect the overall appeal of the final products. The results of the study indicated a fine texture with a yellowish hue of UPP which can be used in the development of traditional Indian foods.

The functional properties of UPP, such as bulk density, water absorption capacity, and oil absorption capacity, revealed its potential as a functional ingredient in food formulations. The bulk density (0.58 g/ ml) observed in the present study was consistent with Joymak *et al.* (2021), who reported similar values for papaya peel powder. The high bulk density of UPP can be attributed to its porous nature and irregular shape, which influences its flow properties and stability in food matrices (Rajput *et al*., 2019). The swelling power of UPP was found to be favorable, attributed to its high fiber content, which influences water retention properties. This is supported by Silva *et al.* (2009), who highlighted the role of dietary fiber in enhancing water absorption capacity in food matrices. Additionally, the high water-holding capacity of UPP can be explained by the presence of hydrophilic groups in soluble fiber, which can form hydrogen bonds with water molecules, thus improving hydration properties. Unripe papaya powder had a good swelling capacity which might be due to the low fat content present. According to Sowbhagya *et al.* (2007), the residual oil trapped inside the fiber matrix of the sample will restrict the entry of water molecules and therefore lead to a lower swelling capacity. The flour particle size affects the oil absorption capacity, where the smaller particles have a higher capacity due to their larger surface areas.

4.2 Nutritional composition of unripe papaya powder

In the present study, the nutritional profile of unripe papaya was analyzed as presented in Table 2 and found that it contained 91-92 per cent moisture, which was by the values found by Puwastein *et al.* (2000) where the moisture content of unripe papaya was reported as 92.6 per cent. All the nutrient composition values of unripe papaya without peel were consistent with the values reported by Pahari *et al.* (2022) for fresh unripe papaya. It was found that peel unripe papaya had significantly higher values for crude fiber and ash. Proximate analysis revealed that the raw unripe fruit pulp was high in moisture and crude fiber moderate in protein, carbohydrate, and ash, but low in crude fat. These findings corroborate those of other studies (Nwofia *et al.,* 2012) that *C. papaya* pulp is high in moisture which indicates that the raw fruit pulp may not be preserved for a long period without spoilage, as the high moisture makes it susceptible to microbial attack. However, as shown in the results, the moisture content reduced significantly when dried, and powdered/ dried pulp can keep longer without spoilage.

Potassium and magnesium, two important minerals analyzed in the present study were found in reasonable amount in the unripe papaya. The values are in alignment with the results reported by Umoh (2005). The good concentration of these could be useful because it is known that certain inorganic minerals play a significant function in the maintenance of proper glucose tolerance and the release of insulin from the pancreas' beta cells by acting as cofactor for different enzymatic reactions (Stone *et al.,* 2016).

Rajput *et al.* (2019) reported papaya fruit contained a good number of phenols (5.6 mg GAE/ g in pulp and 4 mg GAE/ g in the peel) and flavonoids (9.6 mg QE/ g in pulp and 9.2 mg QE/ g in the peel) which were aligned with the results obtained in the present study. The presence of significant amounts of bioactive compounds such as phenolics and flavonoids suggests that UPP could contribute to reducing oxidative stress and promoting overall health. The observed high dietary fiber content may also play a role in glycemic control, satiety enhancement, and improved digestive health, making it a valuable ingredient for functional foods.

4.3 Organoleptic and nutritional evaluation of unripe papaya powder-supplemented food products

The incorporation of unripe papaya powder into traditional foods presents an innovative approach to enhancing the nutritional profile of commonly consumed items. Composite flour formulation is essential for the formulation of value-added products because of their superior nutritional quality in addition to consumer acceptance (Mounika and Hymavathi, 2021). The organoleptic evaluation of the developed functional foods was carried out to assess their sensory attributes, including appearance, taste, texture, and overall acceptability. The panelists evaluated the products based on a 9-point Hedonic scale and the highly acceptable ones were selected for further nutritional evaluation (Figure 1).

4.3.1 Chapatti

Chapatti, a staple food in many regions, was enhanced with papaya flour to increase its functional properties. The chapatti made with 10 per cent unripe papaya powder supplementation obtained the best acceptability scores and had a higher fiber content (13.65%) compared to wheat chapatti (10.90%), making it a healthier alternative. Additionally, the chapatti exhibited improved softness and pliability, making it easier to roll and cook. UPP-added chapattis had lower protein percentage because fruit pulp and peel are composed of lower nitrogenous matter in comparison with control chapatti.

4.3.2 Mathi

Mathi, a traditional savory snack, was enriched with unripe papaya flour to improve its fiber content and nutritional value. The texture of the mathi was slightly altered, becoming crisper with a denser mouthfeel, but the flavor remained appealing. The sensory properties of mathi, such as crispiness and flavor, were retained despite the inclusion of papaya flour. This suggests that unripe papaya can be successfully integrated into traditional snack foods without compromising consumer acceptance (Rao and Yadav, 2018).

4.3.3 Besan chilla

Besan chilla (Pancakes), a kind of bread made on a frying pan, are one of the most popular breakfasts worldwide. In the present study, besan chilla was prepared using Bengal gram flour and supplemented with UPP. Supplementation at the level of 15 per cent gave the best sensory results and the texture became soft and appearance also improved with the increasing percentage of UPP. Joymak *et al.* (2021) also prepared the pancakes using UPP at 5, 10, and 15 per cent levels and reported that the replacement of wheat flour with UPP increased the hardness of pancakes, which is in contradiction with the present study. The addition of unripe papaya powder into different food products increased the moisture content. This might be due to the higher water absorption capacity in the unripe papaya powder, which was high in fiber compared to wheat flour (Sunday and Dickson, 1992).

UPP-added products had lower protein percentages because fruit pulp and peel are composed of lower nitrogenous matter in comparison with wheat flour. Shih *et al.* (2005) reported that pancakes supplemented with sweet potato flour were relatively low in protein. The protein content of rice-potato pancakes ranged from 6 to 7 percent, whereas it was about 9 percent for the conventional wheat pancake. The low-fat content in supplemented products was due to the low-fat content of unripe papaya powder as agreed by Champagne *et al.* (2011). Dietary fiber content was significantly increased in all the supplemented products. Elleuch *et al.* (2011) reported that UPP contains higher total dietary fiber content than other by-product processing such as wheat and rice. Therefore, dietary fiber content was higher in supplemented products. The use of UPP in products will reduce the total carbohydrate of the product, as it is replaced in part by the fiber content thus also reducing the total calories of the product.

Supplemented products contained higher amounts of potassium and magnesium as compared to control products. Bioactive compounds and antioxidant activity were also higher in supplemented products. Joymak *et al.* (2021) observed that total phenolic content and FRAP value of pancakes supplemented with 10 and 20 per cent UPP was markedly increased. Bokaria and Ray (2016) reported that 5 per cent formulated papaya peel flour-based cookies had better antioxidant activity in comparison to control cookies.

The increased fiber content in supplemented products ($p \leq 0.05$) significantly enhanced their nutritional value without compromising sensory attributes, supporting the concept that fiber-rich functional foods can be integrated into daily diets without affecting consumer preference. The increased softness in chapatti and besan chilla could be attributed to the water-holding properties of dietary fiber, which promotes moisture retention during cooking and storage. The increase in potassium and magnesium content enhances the nutritional profile of these foods, making them beneficial for cardiovascular health, electrolyte balance, and blood pressure regulation. The role of antioxidants in reducing oxidative stress and inflammation suggests that regular consumption of UPP-enriched products may contribute to long-term health benefits.

4.4 Textural analysis of products supplemented with UPP

The present study (Table 6) reported that textural characteristics of products supplemented with unripe papaya powder (UPP) improved as compared to their control counterparts. The textural analysis highlighted that UPP reduces the hardness of chapatti, while the texture of mathi remains crisp, and besan chilla becomes softer. These modifications enhance the mouthfeel of the products without compromising their traditional appeal.

Chauhan *et al.* (2015) substituted amaranth flour in cookies and observed that the hardness of cookies decreased with the addition of amaranth flour at a 60 per cent level showing the least force (72.4 N) compared to control (145 N).

The chapatti enriched with unripe papaya flour exhibited a softer texture than traditional chapatti, which contributed to its ease of consumption. Dar *et al.* (2013) observed that the cutting force (N) of various bran-enriched chapattis varied from 5.30 N to 6.56 N. Cutting force decreased due to the presence of more fibers at higher enrichment levels. Shih *et al.* (2005) prepared gluten-free pancakes using rice flour and sweet potato flour and found that the textural properties of cooked pancakes such as hardness and chewiness decreased with increased sweet potato flour replacement.

5. Conclusion

The proximate composition analysis of unripe papaya revealed its high moisture content (91.3%) and the presence of crude protein (0.72%), crude fat (0.22%), crude fiber (1.30%), ash (0.55%), and carbohydrates (5.90%). The physical properties of unripe papaya powder (UPP) indicated a fine texture with a yellowish color and good functional properties. Sensory evaluation of UPP-incorporated traditional food products showed acceptable supplementation levels of 10 per cent in chapatti and mathi and 15 per cent in besan chilla. The formulated products exhibited significantly ($p \leq 0.05$) higher crude fiber, ash, mineral content (potassium and magnesium), vitamin C, and bioactive compounds (phenolics and antioxidants) than control samples. Among the three traditional foods supplemented with unripe papaya powder (UPP), besan chilla emerged as the best product, showing the highest overall acceptability score (8.12) at 15% supplementation. It exhibited the most significant nutritional improvements, including enhanced fiber content (16.70 g), vitamin C (15.09 mg), and antioxidant activity. These findings highlight besan chilla as the most nutritionally enriched and sensorily accepted UPP-based product developed in this study. Therefore, UPP is a valuable source of dietary fiber and bioactive compounds, contributing to the development of functional food products with enhanced nutritional benefits.

Acknowledgments

We sincerely acknowledge the contributions of all authors to this research. Neerja Singla conceptualized and designed the study, developing the overall research plan and overseeing its execution. Pushpinder Kaur played a crucial role in conducting the research, including hands-on experimentation and data collection, performing the statistical analysis and data interpretation, and contributing to the meaningful insights derived from the study. Jagbir Rehal and Monika Gupta provided essential materials required for the study, ensuring the availability of key resources. Additionally, all authors collaborated in drafting and critically revising the manuscript, with Pushpinder Kaur having primary responsibility for the final content. Their collective efforts have been instrumental in the successful completion of this research.

Conflict of interest

The authors declare no conflict of interest relevant to this article.

References

AOAC (2000). Official Methods of Analysis. Association of Official Analytical Chemists. Washington DC.

AOAC (2001). Official methods of analysis. Association of Official Analytical Chemists". 17th ed. Gaithersburg, USA.

AOAC (2012). Official Methods of Analysis. Association of Official Analytical Chemists". Gaithersburg: AOAC International.

AOVC (1996). Methods of vitamin assay. Association of Vitamin Chemists Inc. (Ed.) Interscience Publishers, pp:306-12.

Benzie, I.F. and Strain, J.J. (1999). Ferric reducing/antioxidant power assay: Direct measure of total antioxidant activity of biological fluids and modified version of simultaneous measurement of total antioxidant power and ascorbic acid concentration. Meth. Enzymol., **299**:15-27.

Biswal, A.K.; Alakonya, A.E.; Mottaleb, K.A.; Hearne, S.J.; Sonder, K.; Molnar, T.L. and Prasanna, B.M. (2022). Maize lethal necrosis disease: Review of molecular and genetic resistance mechanisms, socio-economic impacts, and mitigation strategies in sub-Saharan Africa. BMC Plant Biology, **22**(1):1-21.

Bokaria, K. and Ray, S. (2016). Development of papaya peel flour based cookies and evaluation of its quality. J. Multidiscip. Eng. Sci. Technol., **3**(12):6393-6396.

Brands-Williams, W.; Cuvelier, M.E. and Berset, C.L. (1995). Use of a free radical method to evaluate antioxidant activity. LWT-Food sci. Tech., 28(1): 25-30. Brand-Williams B W, Cuvelier M E and Berset C L W T. Use of a free radical method to evaluate antioxidant activity. LWT-Food Sci. Tech., **28**:25-30.

Champagne, C.M.; Broyles, S.T.; Moran, L.D.; Cash, K.C.; Levy, E.J.; Lin, P.H. and Myers, V.H. (2011). Dietary intakes associated with successful weight loss and maintenance during the weight loss maintenance trial. J. Am. Diet. Assoc., **111**(12):1826-1835.

Chauhan, A.; Saxena, D.C. and Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. Cogent. Food Agric., **2**(1):1125773.

Chuwa, C. and Kamal, S. (2022). Effect of processing methods on the nutritional quality and utilization of ripe papaya (*Carica papaya* L.). J. Sci. Res. Rep., **28**(1):54-67.

Dar, B.N.; Sharma, S.; Singh, B. and Kaur, G. (2013). Quality assessment and physicochemical characteristics of bran enriched chapattis. Int. J. Food Sci., **1**:689729.

Elkhalifa, A.E. and Bernhardt, R. (2010). Influence of grain germination on functional properties of sorghum flour. Food Chem., **121**(2):387-392.

Elleuch, M.; Bedigian, D.; Roiseux, O.; Besbes, S.; Blecker, C. and Attia, H. (2011). Dietary fibre and fibre-rich by-products of food processing: characterisation, technological functionality and commercial applications: A review. Food Chem., **124**(2):411-421.

Endrizzi, I.; Torri, L.; Corollaro, M.L.; Demattè, M.L. and Aprea, E.(2015). A conjoint study on apple acceptability: Sensory characteristics and nutritional information. Food qual. Prefer., **40** :39-48.

Giami, S.Y. and Bekebain, D.A. (1992). Proximate composition and functional properties of raw and processed full fat fluted pumpkin (*Telfairia occidentalis*) seed flour. J. Sci. Food Agri., **59**(3):321-325.

Huet, J.; Looze, Y.; Bartik, K.; Raussens, V.; Wintjens, R. and Boussard, P. (2006). Structural characterization of the papaya cysteine proteinases at low pH. Biochem. Biophysical Res. Commun., **341**(2):620-626.

Joymak, W.; Ngamukote, S.; Chantarasinlapin, P. and Adisakwattana, S. (2021). Unripe papaya by-product: From food wastes to functional ingredients in pancakes. Foods, **10**(3):165-177.

Mounika, M. and Hymavathi, T.V. (2021). Nutrient and phytonutrient quality of nutricereals incorporated flour mix suitable for diabetics. Ann. Phytomed., **10**(1):132-140.

Nwofia, G.E.; Ojimelukwe, P. and Eji, C. (2012). Chemical composition of leaves, fruit pulp and seeds in some *Carica papaya* (L) morphotypes. Int. J. Med. Arom. Plants, **2**:200-206.

Oloyede, O.I. (2005). Chemical profile of unripe pulp of *Carica papaya*. Pak. J. Nutr., **4**(6):379-381.

Pahari, A.; Thapa, P.; Thagunna, B.; Kusma, R. and Kaur, J. (2022). Preparation and quality evaluation of underutilized unripe papaya candy. Malays. J. Halal Res., **5**(2):40-45.

Puwastien, P.B.; Burlingame, M.; Raroengwichit and Sungpuag, P. (2000). ASEAN Food Composition Tables of Nutrition, Mahidol University, Thailand.

Rajput, P.; Desai, K.; Khan, N.; Rajput, P. and Dasgupta, S. (2019). Antioxidant analysis of different parts of raw *Carica papaya*. Int. Arch. Appl. Sci.; **10**:119-122.

Rao, M. and Yadav, N. (2018). Development of traditional snacks with added functional ingredients: The case of papaya mathi. Ind. Food J., **22**:88-94.

Sadasivam, S. and Manickam, A. (2016). Biochemical Methods. New Age International (P) Limited, Publishers, pp:5-6.

Shih, F.F.; Truong, V.D. and Daigle, K.W. (2006). Physicochemical properties of gluten free pancakes from rice and sweet potato flours. J. Food Qual., **29**(1):97-107.

Silva, M.C.D.; Carvalho, C.W. and Andrade, C.T. (2009). The effects of water and sucrose contents on the physicochemical properties of non-directly expanded rice flour extrudates. Food Sci. Technol., **29**:661-666.

Singleton, V.L.; Orthofer, R. and Lamuela-Raventós, R.M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of folin-ciocalteu reagent. Meth. Enzymol., **299**:152-178.

Sowbhagya, H.B.; Suma, P.F.; Mahadevamma, S. and Tharanathan, R. N. (2007). Spent residue from cumin–a potential source of dietary fiber. Food Chem., **104**(3):1220-1225.

Stone, M. S.; Martyn, L. and Weaver, C. M. (2016). Potassium intake, bioavailability, hypertension and Glucose. control. Nutrients, **8**(7): 444.

Tester, R.F.; Karkalas, J. and Qi, X. (2004). Starch-composition, fine structure and architecture. J. Cereal Sci., **39**(2):151-165.

Umoh, I. B. (2005). Chemical composition of the very ripe, just ripe and unripe pawpaw fruits (*Carica papaya* L.). J. Food Sci. Technol., **34**(2):45-52.

Zhishen, J.; Mengcheng, T. and Jianming, W. (1999). The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. Food Chem., **64**(4):555-559

Citation **Pushpinder Kaur, Neerja Singla, Jagbir Rehal and Monika Gupta (2025). Exploration of nutritional potential of unripe papaya (*Carica papaya* L.) powder in traditional Indian foods. Ann. Phytomed., 14(1):959-969. http://dx.doi.org/10.54085/ap.2025.14.1.96.**