

PHYSICOCHEMICAL, COOKING AND FUNCTIONAL PROPERTIES OF SPINACH AND TANNER'S CASSIA FLOWER ENRICHED PASTA AS A FUNCTIONAL FOOD PRODUCT

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ABSTRACT

Traditional pasta made from refined wheat flour is low in fibre and bioactive compounds. Incorporating nutrient-rich spinach and tanner's cassia flower adds dietary fibre and antioxidants, enhancing its health benefits. The present study aimed to develop and evaluate the development and quality evaluation of fibre and antioxidant rich pasta formulated by incorporating spinach powder at varying levels (5-20%) and tanner's cassia flower extract (50-65 mL). The physicochemical, cooking quality, water activity and phytochemical characteristics of the control and treated samples (T_1 - T_4) were evaluated. Incorporation of spinach powder significantly altered the functional properties of pasta. Bulk density decreased with increasing spinach levels, whereas the water absorption index (WAI), oil absorption capacity (OAC) and water solubility index (WSI) showed a marked increase, indicating improved hydration and fat-binding capacities attributed to the presence of fibre, proteins and polysaccharides. Cooking quality was also affected, with optimum cooking time reduced from 8.50 minutes in control to 6.00 minutes in T_4 , while cooking loss and swelling index increased as a result of gluten dilution and weakened structural strength caused by high fibre incorporation. Water activity ranged from 0.570 to 0.602. Phytochemical analysis confirmed the presence of flavonoids, phenolic compounds, tannins, saponins and terpenoids in spinach, tanner's cassia extract and enriched pasta samples, whereas the control exhibited no detectable phytochemicals. Overall, the inclusion of spinach powder and tanner's cassia flower extract successfully enhanced the nutritional, functional and bioactive properties of pasta, demonstrating strong potential for developing value-added functional food products.

Keywords: Pasta, tanner's cassia, spinach, fibre, antioxidant.

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INTRODUCTION

Traditional pasta is produced from a non-fermented dough composed entirely

of durum wheat semolina, water and it is commonly consumed because it has a long shelf life at room temperature without losing nutritional or sensory quality (Iacobellis *et al.*, 2024). However, most commercially available pasta made from refined flour is low in dietary fibre and bioactive compounds

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like phenolics and flavonoids, but high in rapidly digestible carbohydrates. Regular consumption of pasta may contribute to elevated postprandial blood glucose levels, weight gain, and reduced gastrointestinal health. Several factors influence pasta quality, including raw material quality, ingredient composition, processing methods including extrusion or lamination, dough mixing and drying conditions (Dziki, 2021).

Iacobellis *et al.* (2024) reported that *Spinacia oleracea* L., a dark green leafy vegetable belonging to the Amaranthaceae family, is widely consumed due to its rich nutritional composition and strong antioxidant properties. It is also considered a reasonably priced source of dietary fibre. According to Ramu *et al.* (2016), spinach contains high levels of carotenoid compounds, particularly lutein and zeaxanthin, which play a protective role against various eye diseases. Its extracts and bioactive components may help delay or reduce age-related cognitive decline; it is recognized as a major antioxidative vegetable commonly consumed boiled, either from fresh or frozen leaves, with freshly cut leaves containing approximately 1,000 mg kg⁻¹ of total flavonoids.

Girme *et al.* (2018) reported that *Cassia auriculata* L. (Family: Caesalpinaceae), commonly known as tanner's cassia or Avaram, is a shrub with vibrant yellow blossoms widely distributed across central and western Asia and is valued for its rich phytochemical composition, including volatile oils, alkaloids, glycosides, tannins and saponins, which underpin its

therapeutic properties. Traditionally, it has been used to treat tumours, skin infections, asthma, ulcers, diarrhoea, Hansen's disease and various microbial infections (Sahoo, 2020).

Conventional solvent extraction methods such as reflux and Soxhlet extraction often result in reduced extract yields due to thermal degradation, oxidation and long processing times. To address these challenges, green extraction technologies have been developed. These methods require less time, energy and solvent, improve heat and mass transfer efficiency and better preserve the bioactivity of thermolabile compounds. Green extraction methods include mechanical pressing, microwave-assisted extraction, ultrasound-assisted extraction (UAE), supercritical fluid extraction and the instant controlled pressure drop (DIC) process (Sharmila *et al.*, 2016).

UAE has emerged as an effective technique for extracting plant bio actives due to its reliance on acoustic cavitation, which disrupts plant cell walls and enhances solvent penetration and mass transfer. The technique improves extraction yield, preserves phenolic integrity and is widely recognized for its efficiency and simplicity (Sharmila *et al.*, 2016).

In India, rising urbanization, evolving dietary habits and increased demand for ready-to-eat foods have contributed to the growing consumption of pasta and extruded products. However, pasta made from refined flour lacks essential nutrients

and dietary fibre, leading to potential health concerns such as elevated blood sugar, weight gain and poor digestive health. To address these limitations, the present study aims to enhance the antioxidant content, dietary fibre and overall nutritional profile of pasta by incorporating spinach powder and tanner's cassia flower extract.

MATERIALS AND METHODS

Processing of raw materials

The details of the processing of ingredients viz., spinach leaves powder and tanner's cassia flower extract are discussed below.

Preparation of spinach and tanner's cassia flower powder

The tanner's cassia flowers and fresh spinach leaves were procured from the local market and thoroughly washed with potable water to remove surface contaminants. The samples were shade-dried for one week, after which the dried leaves and flowers were ground and sieved (120 μ m) to obtain a fine powder. The resulting powder was stored in an airtight container for further research work (El-Sayed, 2020).

Tanner's cassia flower extract - ultrasound extraction

Tanner's cassia (*Cassia auriculata*) flower extract was prepared using a modified method of Sharmila *et al.* (2016). Two grams of dried flower powder were mixed with 100 mL of potable water and sonicated at 50°C for 30 minutes using an ultrasonic bath (20

kHz). After cooling, the mixture was filtered through muslin cloth and the resulting aqueous extract was collected and stored at 4°C for further analysis (Suvalakshmi *et al.*, 2025).

Pasta preparation

Fibre and antioxidant containing pasta in the shape of "Ziti" was produced on a laboratory scale at the College of Food and Dairy Technology, Chennai using a mini pasta maker (Dolly La Monferrina, Italy, 2017; 2.5 kg capacity, 80 rpm). Pasta was prepared according to Poorvitha (2024) by mixing of dry ingredients including refined flour, whole wheat flour and spinach powder (Table 1). Salt, refined oil and xanthan gum were added and moisture was adjusted with water and flower extract. The dough was kneaded, cold-extruded, steamed at 100°C then dried using solar-drying. Finally, the dried product was packed using LDPE packaging material and used for the further analysis.

Physicochemical characteristics

Bulk density

Bulk density of the extruded pasta was measured using the method of Dharmaraj *et al.* (2016). A 10 g sample of uncooked pasta was placed in a 100 mL measuring cylinder and tapped gently until the volume stabilized. The bulk density was then calculated using Equation 1.

Bulk density (g/cc) = (Weight of the sample)

(Volume occupied by the sample).....(eq 1)

Water absorption index and Water solubility index

The water solubility index (WSI) and water absorption index (WAI) of the extrudates were measured according to Zarzycki *et al.* (2017). One gram of powdered extrudate was dispersed in 15 ml of distilled water and allowed to stand for 30 minutes with intermittent shaking. The mixture was centrifuged at 3000 rpm for 15 minutes. The supernatant was dried at 105°C to constant weight and the remaining gel was weighted. Results were calculated using Equations 2 and 3.

$$\text{WAI (g/g)} = \frac{(\text{weight gain of gel})}{(\text{dry weight of extrudate})} \dots\dots\dots(\text{eq 2})$$

$$\text{WSI (\%)} = \frac{(\text{weight of dry solids in supernatant})}{(\text{dry weight of extrudate}) \times 100} \dots\dots(\text{eq 3})$$

Oil absorption capacity (OAC)

The oil absorption capacity (OAC) of the flours and powders was determined using the method of Onwuka and Onwuka (2005) with slight modifications. One gram of sample was mixed with 10 ml of soybean oil in a centrifuge tube and allowed to stand for 30 minutes. The mixture was then centrifuged at 3000 rpm for 20 minutes and the tube containing the retained oil was weighed. OAC was calculated using Equation 4.

$$\text{Oil Absorption Capacity (\%)} = \frac{(W_2 - W_1)}{W_s} \dots\dots(\text{eq 4})$$

Where, W_s – Weight of the sample (g),
 W_1 – Weight of tube with sample (g),
 W_2 – Weight of the tube with the Oil-absorbed samples (g).

Cooking Quality Parameters of control and fibre, antioxidant rich pasta

Cooking time

Pasta samples (10 g) were cooked in 200 mL of boiling water following AACC (2000). At 30 seconds intervals, pieces were examined and the optimum cooking time was recorded when the white core disappeared.

Cooking loss

Cooking loss was measured using the AACC (2000) method. A 20 mL portion of the cooking water was collected in a pre-weighed petri dish and dried at 105°C. The resulting residue was weighed and expressed as the percentage of cooking loss (Eq. 5).

$$\text{Cooking loss (\%)} = \frac{(\text{Weight of dry solids} \times \text{Volume of cooking water})}{\text{Aliquot taken} \times \text{Weight of raw sample}} \times 100 \dots\dots(\text{eq 5})$$

Swelling index

The swelling index was determined according to the method described by AACC (2000) and calculated using the following procedure (Eq 6).

$$\text{Swelling index (g/g)} = \frac{(\text{Weight of the cooked product} - \text{Weight of dried pasta})}{(\text{Weight of dried pasta})} \dots\dots\dots(\text{eq 6})$$

Water activity

The water activity of the developed pasta was determined using an electrical dew point water activity meter, following the method described by Vimercati *et al.* (2020).

Phytochemical analysis

The extraction procedure was modified from Derakhshan *et al.* (2018). The principal modification involved the use of 80% ethanol instead of methanol as the extraction solvent. Briefly, 100 g of dried powdered sample was extracted with 80% ethanol (1000 mL) at 25°C for 48 h, followed by double filtration. The filtrate was stored at 4°C until further chemical analysis.

Flavonoids

To identify the presence of flavonoids, 5 mL of ammonia solution was added to a sample of extract, followed by strong sulfuric acid. The presence of flavonoids was indicated by the appearance of yellow coloration that disappeared with standing (Vijayalakshmi *et al.*, 2011).

Phenols

The lead acetate test was used to detect the presence of phenols. The plant extract was diluted with 5 mL of distilled water before adding 3 mL of a 10% lead acetate solution. The formation of white precipitate suggested the presence of a phenolic compound (Shaikh and Patil, 2020).

Tannins

The lead sub-acetate test was used to detect the presence of tannins. This procedure involves treating 1 mL of the extract with 3 drops of lead sub-acetate solution (10%). The presence of a creamy gelatinous precipitate indicated that the extract contained tannins (Shaikh and Patil, 2020).

Saponins

To identify the presence of saponins, 0.5 mL of extract was mixed with 0.5 mL of distilled water and vortexed for 10 minutes. The formation of foams indicates the presence of saponins (Vijayalakshmi *et al.*, 2011).

Terpenoids

To determine the presence of terpenoids, 5 mL of extract was added with 2 mL of chloroform and 3 mL of concentrated sulphuric acid was carefully added to form a layer. A reddish-brown coloration at the interface indicates the presence of terpenoids (Vijayalakshmi *et al.*, 2011).

RESULTS AND DISCUSSION

Physicochemical analysis

The physicochemical analysis of control and fibre, antioxidant rich pasta (T_1 , T_2 , T_3 and T_4) are given in Table 2. The functional properties of pasta samples varied significantly ($P < 0.01$) with the incorporation of spinach powder. Bulk density dropped progressively from 0.38

g/ml (control) to 0.36 g/ml (T_1), 0.35 g/ml (T_2), 0.33 g/ml (T_3) and 0.32 g/ml (T_4). This reduction is attributed to the high fibre and low starch contents of spinach powder, reducing particle compactness and improving porosity. These results were found to be comparable with Anitha, (2023) who showed decreased bulk density in carrot-based pasta due to increased fibre content.

The WAI increased from 4.10 g/100 g (control) to 4.47 g/100 g (T_1), 4.54 g/100 g (T_2), 4.52 g/100 g (T_3) and 4.74 g/100 g (T_4), indicating that spinach powder improved water-holding capacity due to the presence of hydrophilic compounds like fibre and polysaccharides.

The oil absorption capacity (OAC) increased from 1.33 ± 0.006 g/g (control) to 1.34 g/g (T_1), 1.36 g/g (T_2), 1.41 g/g (T_3) and 1.47 g/g (T_4). Water solubility index (WSI) increased from 12.3 g/100 g (control) to 12.6 g/100 g (T_1), 13.6 g/100 g (T_2), 13.9 g/100 g (T_3) and 14.5 g/100 g (T_4).

The WAI and OAC increased with increase in the addition of spinach powder. These results due to spinach powder has hydrophilic and hydrophobic compounds like protein, fibre and polysaccharides, which is responsible for high water-holding capacity and oil absorption capacity followed by Anitha, (2023) reported that WAI increased with incorporation of carrot powder in pasta when compared to control pasta due to the fibre content present in the treated samples.

The WSI also increased because incorporating of a high amount of fibre content from spinach powder, dilutes gluten forming protein and cannot effectively entrap starch granules, leading to greater starch leaching into the cooking water. Similarly, Iacobellis *et al.* (2024) found that higher values of WAI in PSP25 followed by PSP12 with increasing the addition of spinach content in pasta formulation, while control had lower values.

Cooking quality parameters

Table 3 presents the cooking quality parameters of control and fibre, antioxidant rich pasta (T_1 - T_4) using spinach and tanner's cassia flower extract. Adding spinach powder substantially altered the optimal cooking time, cooking loss and swelling index of pasta samples ($P < 0.01$). The optimal cooking time reduced from 8.50 ± 0.014 min for the control to 7.47 min (T_1), 7.02 min (T_2), 6.33 min (T_3) and 6.00 min (T_4) due to increasing in fibre content affecting the structure of pasta. Similar results were reported by Aravind *et al.* (2012), the optimum cooking time decreased with increasing level of semolina substitution with inulin, which can be attributed to gluten dilution in pasta.

The cooking loss exhibited a significant increase, rising from 6.95% in the control sample to 8.80% (T_1), 9.93% (T_2), 10.55% (T_3) and 11.60% (T_4). This result indicates that increasing levels of spinach substitution impaired the structural integrity of the pasta matrix, thereby promoting

higher leaching of solids during the cooking process. Similar results were observed by Ramu *et al.* (2016) for instant noodles with the addition of spinach paste in wheat flour as a fibre source. The addition of spinach paste in the noodles may have caused an increase in cooking loss due to weakening of the protein network.

The swelling index also showed a gradual increase from 0.75 g/g (control) to 1.02 g/g (T_1), 1.16 g/g (T_2), 1.21 g/g (T_3) and 1.42 g/g (T_4). This could be related to the inclusion of spinach powder as a fibre source caused strong water-holding capacity and starch granule disruption in the pasta as per reported by Iacobellis *et al.* (2024) the SI was lowest in control pasta and followed by 12% and 25% spinach powder added pasta.

Water activity analysis

The water activity of control and fibre, antioxidant rich pasta was analysed and the results are summarized in Table 4. The water activity (aw) values of pasta samples showed a highly significant difference. The control sample recorded an aw of 0.591, while the spinach incorporated samples showed 0.570 for T_1 , 0.573 for T_2 , 0.601 for T_3 and 0.602 for T_4 . The water activity of pasta sample increased with addition of spinach powder because of high fibre content and weakened gluten network, which binds and retain more moisture aligning with the findings of Iacobellis *et al.* (2024), where spinach powder increased water activity (aw) of pasta.

Phytochemical analysis

The qualitative phytochemical analysis (Table 5) revealed that spinach, tanner's cassia flower extract and the T_2 pasta sample included bioactive components such as flavonoids, phenols, tannins, saponins and terpenoids, which were not present in the control. Spinach and tanner's cassia extract both had positive responses to all studied phytochemicals, with the flower extract exhibiting greater strength, notably for flavonoids and phenols (++).

Meena *et al.* (2019) showed that *cassia auriculata* flower extract had significant amount of phytochemicals such as flavonoids, phenols, tannins, terpenoids and saponins. Olagoke, (2018) analysed phytochemical content of spinach powder and result revealed the presence of phenols, flavonoids, tannins, saponins and terpenes. Marzocchi *et al.* (2025); Wang *et al.* (2022) reported that integration of bioactive compounds rich ingredients in pasta formulation significantly enhances the TPC and TFC content of pasta when compared to the control.

CONCLUSION

The results of this study clearly demonstrate that the inclusion of spinach powder and tanner's cassia flower extract in pasta formulation enhances its physicochemical, cooking properties and nutritional qualities. Increasing levels of spinach powder led to reduced bulk

density and optimal cooking time, while significantly improving hydration properties such as WAI, OAC and WSI. Although cooking loss and swelling index increased, this behaviour is consistent with fibre induced weakening of the gluten network. Water activity values also increased with higher spinach incorporation, reflecting its superior moisture-retention capacity; however, all recorded values remained within the safe and acceptable range for storage stability. Importantly, enriched pasta samples exhibited the presence of key phytochemicals such as flavonoids, phenols, tannins, saponins and terpenoids, that were absent in the control, indicating a substantial improvement in bioactive compounds. Thus, the incorporation of spinach powder and

tanner's cassia flower extract successfully produced a fibre and antioxidant rich pasta with enhanced functional properties and improved health promoting attributes. This value-added product holds promising potential for consumers seeking nutritionally fortified alternatives to conventional refined-flour pasta. This research offers significant market relevance by supporting the growing demand for nutritionally enhanced, fibre-rich pasta products, demonstrating a safe, stable and commercially viable formulation aligned with current functional food innovations. Future studies will be conducted to evaluate the shelf life and economic feasibility of the developed pasta through shelf-life assessment and cost analysis.

Table.1. Standardization of fibre and antioxidant rich pasta

Ingredient (100g)/ Treatment	Control	T₁	T₂	T₃	T₄
Maida (g)	96	61	56	51	46
Wheat Flour (g)	-	30	30	30	30
Spinach powder(g)	-	5	10	15	20
Refined oil (ml)	8	8	8	8	8
Salt (g)	2	2	2	2	2
Xanthan gum (g)	2	2	2	2	2
Water (mL)	40	-	-	-	-
flower extract (mL)	-	50	55	60	65

Table.2. Physicochemical analysis of developed pasta (Mean± SE)

Sample	Bulk Density (g/cc)	Water absorption index (WAI) (g/100g)	Oil absorption capacity (OAC) (g/g)	Water solubility index (WSI) (g/100g)
Control	0.38 ^d ±0.004	4.10 ^a ±0.08	1.33 ^a ±0.006	12.3 ^a ±0.052
T1	0.36 ^c ±0.003	4.47 ^b ±0.026	1.34 ^{ab} ±0.003	12.6 ^b ±0.046
T2	0.35 ^b ±0.002	4.54 ^b ±0.023	1.36 ^b ±0.008	13.6 ^c ±0.067
T3	0.33 ^{ab} ±0.002	4.52 ^b ±0.007	1.41 ^c ±0.009	13.9 ^d ±0.081
T4	0.32 ^a ±0.002	4.74 ^c ±0.029	1.47 ^d ±0.008	14.5 ^e ±0.148
F value	32.921**	26.807**	66.536**	108.829**

@Average of six trials; Non significant – P>0.05; *Significant – 0.01<P≤0.05; **Highly significant - P≤0.01

Control – 100% Maida

T1 – 5% SP and 50 ml TCFE

T2 – 10% SP and 55 ml TCFE

T3 – 15% SP and 60 ml TCFE

T4 – 20% SP and 65 ml TCFE

Table.3. Cooking quality parameters of developed pasta(Mean± SE)

Sample	Optimum Cooking Time (min)	Cooking Loss (%)	Swelling Index (g/g)
Control	8.50 ^c ±0.014	6.95 ^a ±0.284	0.75 ^a ±0.011
T1	7.47 ^d ±0.013	8.80 ^b ±0.106	1.02 ^b ±0.011
T2	7.02 ^c ±0.007	9.93 ^c ±0.044	1.16 ^c ±0.010
T3	6.33 ^b ±0.038	10.55 ^d ±0.030	1.21 ^d ±0.009
T4	6.00 ^a ±0.018	11.60 ^e ±0.054	1.42 ^e ±0.020
F value	2183.707**	161.039**	348.610**

@Average of six trials; Non significant – P>0.05; *Significant – 0.01<P≤0.05; **Highly significant - P≤0.01

Control – 100% Maida

T1 – 5% SP and 50 ml TCFE

T2 – 10% SP and 55 ml TCFE

T3 – 15% SP and 60 ml TCFE

T4 – 20% SP and 65 ml TCFE

Table.4. Water activity analysis of developed pasta (Mean± SE)

Sample	Water activity (aw)
Control	0.591 ^b ±0.0003
T1	0.570 ^a ±0.0003
T2	0.573 ^a ±0.0001
T3	0.601 ^c ±0.0006
T4	0.602 ^c ±0.0004
F value	1349.717**

@Average of six trials; Non significant – $P>0.05$; *Significant – $0.01<P\leq0.05$; **Highly significant – $P\leq0.01$

Control – 100% Maida

T1 – 5% SP and 50 ml TCFE

T2 – 10% SP and 55 ml TCFE

T3 – 15% SP and 60 ml TCFE

T4 – 20% SP and 65 ml TCFE

Table.5. Phytochemical analysis of raw ingredients and developed pasta (Mean $\pm$ SE)

Parameters	Spinach Powder	Tanner's Cassia Flower Extract	Control	T2
Flavonoids	++	++	-	+
Phenols	+	++	-	++
Tannins	+	+	-	+
Saponins	+	+	-	+
Terpenoids	++	+	-	+

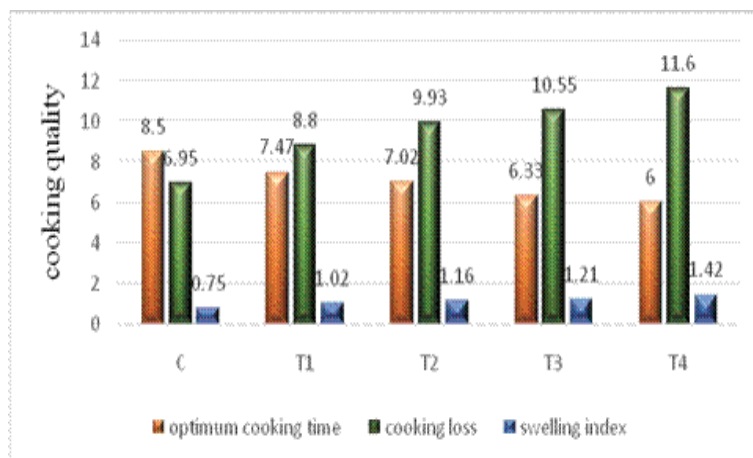


Fig.1. Cooking quality parameters of developed pasta

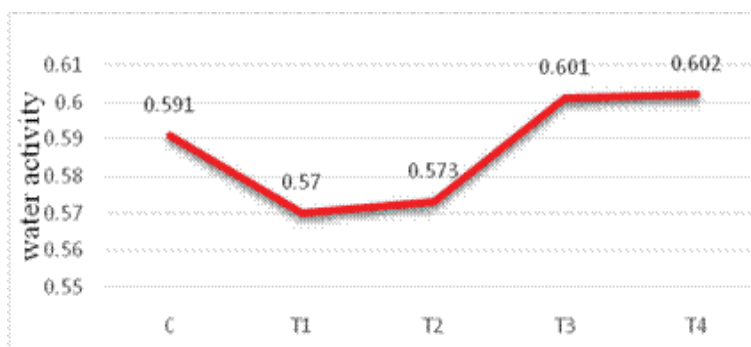


Fig.2. Water activity analysis of developed pasta

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