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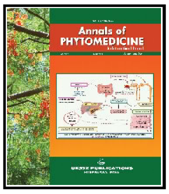

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Hull-less pumpkin seeds (*Cucurbita pepo* subsp. pepo var. styriaca) enriched functional pasta: Technofunctional, phytochemical, sensory, textural and structural characterization

Shivani Kumari*◆, Sonika Sharma*, Kiran Grover*, Ajmer Singh Dhatt, Shikha Mahajan*, Sanjula Sharma***, Khushdeep Dharni**** and Vikas Kumar*******

** Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141001, Punjab, India*
*** Department of Vegetable Science, Punjab Agricultural University, Ludhiana-141001, Punjab, India*
**** Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana-141001, Punjab, India*
***** School of Business Studies, Punjab Agricultural University, Ludhiana-141001, Punjab, India*
****** Department of Food Science and Technology, Punjab Agricultural University, Ludhiana-141001, Punjab, India*

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Abstract

Hull-less pumpkin seeds (PAU Magaz Kadoo 1), the first of their kind in Indian history, have not yet been evaluated for their nutritional composition and potential for making functional foods. The influence of semolina replacement with raw and roasted hull-less pumpkin seed powder (HPSP) at 10-30% level was evaluated for nutritional, technofunctional, phytochemical, textural, and structural characteristics of functional pasta. Results showed that incorporation of HPSP significantly ($p<0.05$) increased the protein (14.88%), fibre (5.08%), ash (2.72%), fat (9.87%) content, antioxidant activity (31.13%), total phenols, flavonoids and total carotenoid content. The mineral content, *i.e.*, iron (4.58%), zinc (5.04), calcium (39.21) and fatty acids like palmitic (2.96%), stearic (2.16%), oleic acid (15.14%) enhanced in HPSP supplemented pasta as compared to the control. Result of quality parameters revealed that the minimal cooking time, the pasta's capacity to absorb water, and its capacity to expand in volume were reduced when HPSP was added, but the cooking loss increased noticeably. Addition of HPSP significantly reduced the lightness (L*) and increase the greenness (a*) of the pasta owing to total chlorophyll pigment. Fourier transform infrared (FTIR) spectroscopy further confirmed the presence of flavonoids, phenols and chlorophyll in HPSP-incorporated pasta. Sensory data revealed that pasta containing 30% of HPSP was acceptable with the overall acceptability score of 8.8.

1. Introduction

Pumpkin seeds are rich in nutritional and medicinal properties. The hull-less pumpkin seed is a trait of pumpkin that lacks complete lignification's of testa. Pepitas, flat, green, and edible seeds, are the common name for pumpkin seeds. In addition to being healthy, pumpkin seeds make a tasty, chewy snack.

Indian pumpkin cultivar PAU Magaz Kadoo1 has edible seeds. Pumpkin seeds without hulls (PAU Magaz Kadoo 1). The first of their kind in Indian history, have not been studied for their nutritional profiles, the impact of processing on their nutritional component, or the creation of health foods. The advance breeding lines for hull-less pumpkin seed yield, growth, and quality features were examined by Kaur *et al.* (2017) at PAU, Ludhiana.

Pumpkin seeds which are produced and used worldwide provide a diverse range of nutritive components like 32.0%-35.5% protein, 30.2-50.8% fat, 3.07-6.5% fibre, 3.98% ash and 484-559 kcal energy (Nawirska-Olszañska *et al.*, 2013; Kim *et al.*, 2012). World Health Organisation recommends daily intake of pumpkin seeds as they are rich in proteins, unsaturated fatty acids, fiber, antioxidants and vitamins and have an important content of minerals especially zinc. Pumpkin seeds also provide vitamin E as gamma-and delta-tocopherol, carotenoids like lutein and zeaxanthin, and a range of minerals including manganese, phosphorus, magnesium, zinc and iron (Gupta *et al.*, 2015; Kim *et al.*, 2012). The amino acid profile is balanced and high in arginine, aspartate and glutamate. The oil fraction provides over 80% unsaturated fatty acids, mainly linoleic and oleic acid (Parthasarathy *et al.*, 2008). Omega-6 linoleic acid accounts for 36-60%, while oleic acid makes up 18-44% of the total fatty acids (Gupta *et al.*, 2015).

Minerals present in significant amounts include phosphorus, magnesium, manganese, zinc, copper and iron (Nawirska-Olszañska *et al.*, 2013). The tryptophan content supports serotonin synthesis which may promote sleep and calmness (Gupta *et al.*, 2015). Pumpkin seeds provide specific bioactives like phenolic acids, lignans, phytosterols, and cucurbitacins with functional benefits. Lignans in particular demonstrate antidiabetic, anti-inflammatory and anticancer potential (Nawirska-Olszañska *et al.*, 2013).

The antidiabetic effect results from inhibited alpha-glucosidase activity (Xanthopoulou *et al.*, 2009). Pumpkin seed oil exhibits antioxidant, antimicrobial and hypolipidemic properties as well (Gupta *et al.*, 2015). The existence of phenolics, flavonoids, and tannins highlights their capacity as powerful antioxidants, shielding against oxidative stress and damage from free radicals (Sunarharum *et al.*, 2019). With this diverse nutritional and phytochemical profile,

Corresponding author: Ms. Shivani Kumari
Department of Food and Nutrition, Punjab Agricultural University, Ludhiana-141001, Punjab, India
E-mail: shivanikomal1995@gmail.com
Tel.: +91-8264385956

hull-less pumpkin seed powder serves as an excellent functional food ingredient. Incorporating it into baked goods, snacks, beverages and other products could enhance protein, unsaturated fat, and micronutrient content, along with increasing bioactive compounds. Utilizing hull-less pumpkin seeds in functional foods offers a convenient and nourishing method for individuals to enhance their essential nutrient intake, potentially enhancing their overall health and well-being.

2. Materials and Methods

2.1 Procurement of sample

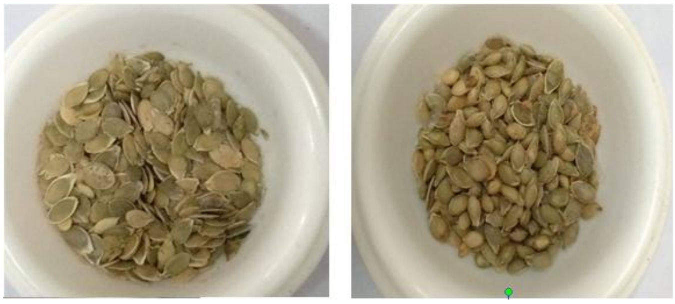
Pumpkin seeds (*Cururbita pepo*) without a hull were acquired from Vegetable Science Department, Punjab Agricultural University, Ludhiana (PAU Magaz Kadoo 1). Other ingredients (semolina and salt) were bought from the local market.

2.2 Processing of hull-less pumpkin seeds

The seeds were cleaned, sun dried, and then roasted for five minutes at 75°C. To create fine flour, hull-less pumpkin seeds were treated both raw and roasted. Healthy pasta has been developed using hull-less pumpkin seeds, both raw and roasted.

2.3 Preparation of functional pasta

The Punjab Agricultural University's, Food and Nutrition Department and Food Science and Technology Department in Ludhiana developed different percentage of healthy pasta using standardised recipes (Figure 1). Pumpkin seeds, both raw and roasted processed into flour were used in the development of functional pasta by substituting semolina. In three trial samples of pasta, hull-less pumpkin seed flour (HPSF) both in raw and roasted form was incorporated at levels of 10%, 20%, and 30% after replacing 100% semolina in control pasta sample.



Pumpkin seeds (raw) Pumpkin seeds (roasted)

Pasta (Control) HPS pasta (10%) HPS pasta (20%) HPS pasta (30%)

Figure 1: Pumpkin seed (raw and roasted) and HPS functional pasta with different levels of hull-less pumpkin seeds.

2.4 Quality parameter of raw and roasted hull-less pumpkin seeds developed functional pasta

2.4.1 Cooking quality of hull-less pumpkin seeds enriched pasta

The cooking parameters for the developed pasta, including minimal cooking time (MCT), volume expansion, water absorption capacity (WAC), and gruel solid loss, were calculated using the AACC standard procedures.

2.4.2 Color characteristics of hull-less pumpkin seeds enriched pasta

The colour properties (L, a*, and b*) of raw and roasted pasta were calculated using a Color flex metre (Hunter Lab Colour Flex, Hunter Associates Inc., USA). Colour psychophysical parameter such as chroma (C*) was measured. Cartesian coordinates (a* and b*) are converted to polar coordinates (C*) using the formulae below:

Chroma (C*) = $(a^2+b^2)1/2$

2.4.3 Texture attribute of hull-less pumpkin seeds enriched pasta

Textural properties, specifically hardness, springiness, cohesiveness, gumminess, chewiness and resiliency of both raw and roasted pasta were tested using a TA-XT plus texture analyzer from Stable Micro Systems, UK. A blade probe was used to cut the 2.5 cm sample to a distance of 10 mm at a speed of 1 mm/s. A trigger force of approximately 10.0 g was employed with pre- and post-test speeds of 2 mms1.

2.5 Nutritional profiling of raw and roasted hull-less pumpkin seeds developed healthy pasta

2.5.1 Proximate composition

The proximate composition, including moisture, crude protein, crude fat, total ash, crude fibre, total carbohydrate, and energy were analysed using AOAC, (2000), Utilizing the Kjekdhal technique and the

KELPLUS nitrogen estimation system, protein content was measured. Soxhlet extraction equipment was used to calculate the total fat content and to calculate total carbs, all proximate values-including moisture content, crude protein, crude fat, crude fibre, and total ash-were added together and deducted from 100. The Factorial approach was used to calculate energy.

2.5.2 "Fourier transform infrared spectroscopy (FTIR) analysis of HPS-enriched pasta

In order to account for the impact of HPS-addition on the functional group of pasta, the FTIR spectra of pasta were examined using an FTIR spectrophotometer (Alpha Bruker, USA). The powdered pasta both raw and roasted sample was put on the FTIR sample holder. Between 500 and 3,500 cm1 wavelengths, many infrared spectra were seen.

2.5.3 Estimation of antioxidant activity using DPPH method (Dehshahri *et al.*, 2012)

The DPPH method was used to estimate total antioxidant activity of hull-less pumpkin seeds enriched pasta:

AA% = (1-A/B × 100)

where, A = Sample absorbance, B = Blank absorbance

2.5.4 Mineral analysis (Charles and Fredeen, 2004)

Following wet digestion, the minerals, which included iron, zinc, calcium, magnesium, and potassium, were analysed by inductively coupled plasma-optical emission spectrometry (Perkin Elmer, Optima 2100 DV).

2.5.5 Estimation of total carotenoid content (Ranganna, 2002)

Acetone was used to grind five grammes of the sample in a pestle and mortar. After that, filter paper was used to refine it. Until the extract lost its colour, the extraction procedure was carried out two or three more times. The filterate was then transferred to a separating funnel, and 10-15 ml of petroleum ether and an equal amount of distilled water were added to it. The petroleum ether was then filled with the colours (aqueous phase). The petroleum ether extract was filtered through 5% anhydrous sodium sulphate after the aqueous phase had been removed from the separating funnel. Petroleum was used to create the volume of the filtered extract in a 25 ml volumetric flask. To determine the total carotenoid content, the absorbance at 452 nm was measured:

Carotenoid content (µg/g) = A × V(ml) × 104"

A1cm^1 % x P(g)

where A= Absorbance; V= Total volume of extract; P= Weight of the sample; A1cm^1%= 2592(β-carotene extinction coefficient in petroleum ether).

2.5.6 Estimation of fatty acid composition (Appleqvist, 1968)

Fatty acid composition of food samples was estimated using gas liquid chromatography (GLC). The EZ chrome elite software was used to compute the fatty acid composition are palmitic acid, stearic acid, oleic acid, linoleic acid.

2.6 Sensory evaluation

A semi-trained panel of 10 judges assessed the sensory qualities of healthy foods supplemented with raw and roasted hull-less pumpkin seeds flour at varying levels in pasta. One control and its test samples, was served to the judges. Using a 9-point Hedonic rating scale, judges were asked to rate the developed items on their general acceptability, look, colour, texture, taste, and flavour (Wichchukit and Mahon, 2015). To prevent any biassed evaluation, every sample was coded in this way. The judges assessed each pasta, and average ratings were computed for each.

2.7 Statistical analysis

With the use of statistical techniques like mean and standard deviation, the data were evaluated, and analysis of variance (ANOVA) was used to spot a significant difference between the experimental and control samples. To find the statistically significant difference, the Tukey-Post HOC test was used. Using JAM 10.0.1 software, the nutritional value of samples of raw and roasted pumpkin seeds enriched pasta was evaluated. Data were presented as the mean SD for at least three replicates. *p* values between 0.05 and 0.01 indicate a substantial difference.

3. Results

3.1 Effect of processing on quality parameter of hull-less pumpkin seeds (HPS) functional pasta

3.1.1 Cooking quality

3.1.1.1 Minimum cooking time

The minimum cooking time (MCT) refers to the duration required for the white core of pasta to cook completely. A higher MCT value indicates a longer cooking time. In comparing to control (semolina) pasta with hull-less pumpkin seed functional pasta (experimental), it was noted that the optimal cooking time for the control was marginally longer than Experimental pasta, though the difference was not statistically significant. The experimental pasta exhibited a decreased minimal cooking time, attributed to its high fiber content (table 1). The fiber altered the gluten matrix within the pasta, allowing for enhanced water penetration into the core and resulting in faster cooking.

Table 1: Cooking quality of hull-less pumpkin seeds HPS functional pasta

Quality parameter	Control pasta (CP)	Experimental (HPS) pasta	
		(Raw) P1	(Roasted) P2
Minimal cooking time (min)	5.82 ± 0.53^b	5.02 ± 0.12^c	5.04 ± 0.16^c
Water absorption capacity (%)	102.51 ± 2.32^a	94 ± 0.42^b	93 ± 0.32^b
Volume expansion (ml/g)	0.87 ± 0.02^b	0.86 ± 0.06^c	0.87 ± 0.11^c
Gruel solid loss (%)	2.82 ± 0.07^a	8.45 ± 0.14^b	8.65 ± 0.34^b

Values are expressed as Mean ± SD.

CP-control pasta (semolina); P1- Hull-less pumpkin seed pasta (Raw); P2- Hull-less pumpkin seed pasta (Roasted).

Values having different superscripts are significantly (p<0.05) different.

Control- product developed with standard recipe using semolina.

Experimental-product developed by incorporating raw and roasted hull-less pumpkin seeds powder into standard recipe.

3.1.1.2 Water absorption capacity

The addition of HPS to pasta resulted in a significantly reduced water absorption capacity of 94% compared to the control pasta, which exhibited a water absorption capacity of 102.51% (Table 1). This decrease in water absorption capacity in the HPS-enriched pasta (P1) was attributed to its higher fiber content.

3.1.1.3 Volume expansion

The control pasta showed a slightly higher volume expansion of 0.87 ml/g compared to the HPS-supplemented pasta at 0.86 ml/g, with no significant difference observed between them (Table 1).

3.1.1.4 Gruel solid loss

The HPS functional pasta showed a significantly higher gruel solid loss of 8.45% compared to the control pasta, which only had a gruel solid loss of 2.82% (Table 1). This higher cooking loss in the HPS pasta was attributed to the dilution of the gluten matrix caused by the presence of fiber particles in the HPS fortified pasta.

3.1.2 Color characteristics of hull-less pumpkin seeds functional pasta

Product colour indicates the origin and quality of a food product's constituents and determines consumer acceptability. Colour is represented by L* a* b* values in the CIELAB colour space. L* represents perceptual lightness, a* the red/green value, and b* the blue/yellow value. In the present study, after pasta fortification with hull-less pumpkin seed (raw and roasted), the L* value decreased. The results showed significant difference (p<0.05) with increasing the HPS flour integration from control (semolina) to 30% (raw and roasted) reduced the L value of uncooked raw and roasted pasta from 53.05 to 34.37 (raw) and 30.85 (roasted) with no significant difference. This is because the chlorophyll content of the product increases as HPS is added, which improves the greenness shade as the amount of HPS flour inclusion increases.

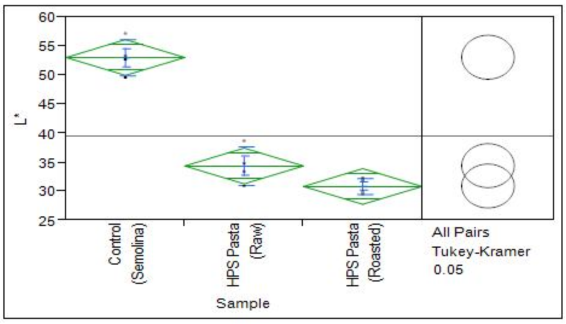
Table 2: Color characteristics of hull-less pumpkin seeds HPS functional pasta

Pasta	L*	a*	b*	C*
Control (CP)	53.05 ± 3.10 ^{a}	0.215 ± 0.193^{a}	5.52 ± 0.62^{ab}	5.52 ± 0.63^{ab}
HPS pasta (raw) P1	34.37 ± 3.25 ^{b}	-0.222 ± 0.102 ^{b}	3.48 ± 0.37^{bc}	3.49 ± 0.37^{bc}
HPS pasta (roasted) P2	30.85 ± 1.38 ^{b}	-0.252 ± 0.168^{b}	2.62 ± 0.21^{bc}	2.63 ± 0.21^{bc}

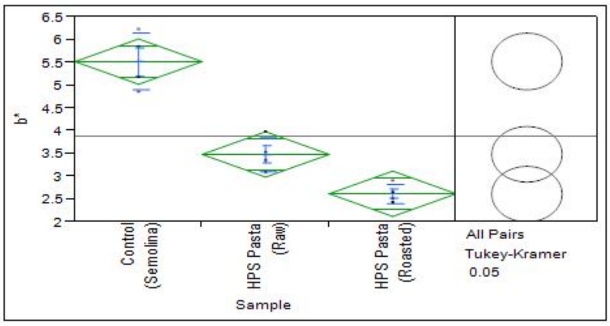
L*- lightness; a*- redness; b*- yellowness; C*- chroma value; CP-control pasta (semolina); P1- Hull-less pumpkin seed pasta (Raw); P2- Hull-less pumpkin seed pasta (Roasted).
Values are expressed as Mean ± SD.
Values having different superscripts are significantly (p<0.05) different.
Control- product developed with standard recipe using semolina.
Experimental-product developed by incorporating raw and roasted hull-less pumpkin seeds powder into standard recipe.

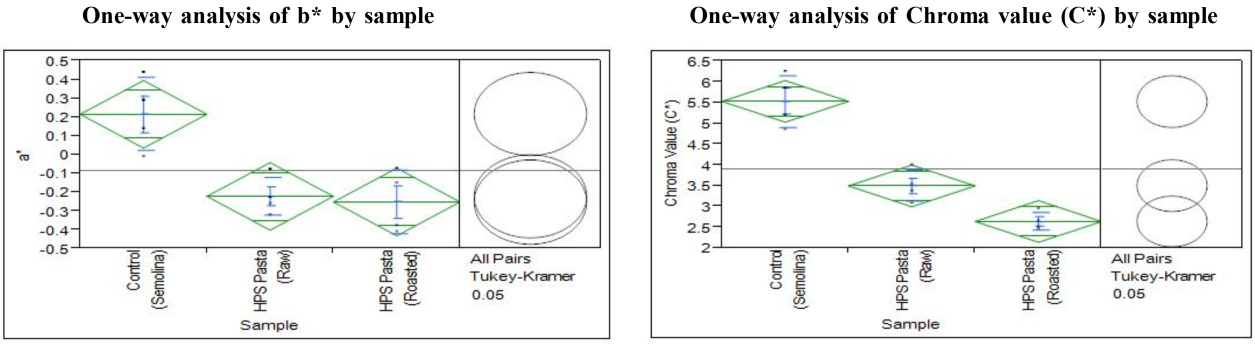
The pasta's L" value was adversely correlated with its total chlorophyll content. A positive a* value indicates red colour, while a negative value indicates green colour. With the addition of HPS (30%) in control (semolina), a value in the uncooked pasta increased considerably (p<0.05) from 0.215 to -0.222 (raw) and -0.252 (roasted); the increase in the negative value indicates that the intensity of the green colour increased. While, HPS pasta - (raw)and (roasted) showed non-significant difference (Table 2). The C* values varied significantly (p < 0.001) from control (semolina) 5.52 to 30% incorporation of raw (3.49) and roasted (2.63) HPS; that showed non- significant difference. The colour may be the consequence of modifications in bioactive substances, which can happen as a result of either their breakdown or their leaching into the cooking water.

One-way analysis of L*by sample



One-way analysis of a* by sample




One-way analysis of b* by sample

One-way analysis of Chroma value (C*) by sample

Figure 2: Color characteristics of HPS functional pasta.

3.1.3 Textural attributes of hull-less pumpkin seeds functional pasta

The texture of pasta is crucial for determining its overall quality. In contrast to subjective sensory evaluation, using a texture analyzer provides more accurate and relevant data. By analysing force-time curves, textural parameters such as cohesiveness, springiness, and hardness can be quantified. Cohesiveness represents the strength of the internal bonds within the product, springiness measures the product's ability to return to its original shape after compression, and hardness indicates the force required to achieve a specific deformation (Szczesniak, 1963; Bourne, 1978). Resilience, defined as the energy absorbed by the sample during compression and released during the first compression, was calculated using force-deformation curves. This calculation involved measuring the area enclosed by the hysteresis loop, which represents the amount of energy stored in the sample allowing for some recovery of its original shape (Voisey *et al*., 1975)."

Table 3: Textural attributes of hull-less pumpkin seeds HPS functional pasta

Pasta	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
CP	2.36 ± 0.728^{a}	0.25 ± 0.15^{ac}	0.40 ± 0.02^{ab}	0.80 ± 0.33^{a}	0.42 ± 0.081^{ab}	0.19 ± 0.020^{b}
P1	1.10 ± 0.081^{b}	0.41 ± 0.02^{bc}	0.50 ± 0.01^{bc}	0.28 ± 0.07^{b}	0.12 ± 0.037^{bc}	0.13 ± 0.04^{b}
P2	0.86 ± 0.025^{b}	0.60 ± 0.18^{bc}	0.55 ± 0.01^{bc}	0.47 ± 0.01^{b}	0.187 ± 0.044^{bc}	0.16 ± 0.003^{b}

CP- Control pasta (semolina); P1- Hull-less pumpkin seed pasta (raw); P2- Hull-less pumpkin seed pasta (roasted).
Values are expressed as Mean ± SD.
Values having different superscripts are significantly (p<0.05) different.

The findings represent the mean of at least 10 reproducible runs for each sample in a batch. Typically, the texture assessment procedure involves compressing samples of cooked pasta, returning to the initial contact point, and repeating the cycle once more (Bustos *et al*., 2015). One-way ANOVA was conducted to determine the effect of pasta sample (Control-semolina, HPS raw, HPS roasted) on, various texture attributes like hardness, springiness, cohesiveness *etc*. The analysis found significant differences (p<0.01) between the samples for most of the texture attributes. The HPS-roasted pasta showed the lowest hardness (0.86 ± 0.025) compared to control (2.36 ± 0.728) and HPS-raw pasta (1.10 ± 0.081), respectively (Table 3). This large difference indicates roasting of hull-less pumpkin seed powder incorporation in pasta, greatly reduced the pasta hardness. Similarly, roasting improved cohesiveness for HPS roasted (0.55 ± 0.01) vs control pasta (0.40 ± 0.02). In contrast, there were significant (p<0.001) differences between the control semolina pasta, raw HPS pasta, and roasted HPS pasta in gumminess and chewiness were highest for control pasta (0.80 ± 0.33 and 0.42 ± 0.081) and lowest for HPS raw (0.28 ± 0.07 and 0.12 ± 0.037). So, incorporation of HPS in pasta helped to reduce gumminess and chewiness. The effect on springiness was also significant (p<0.05) were lowest in control pasta (0.25 ± 0.15) and highest in HPS pasta roasted (0.60 ± 0.18). One attribute that did not differ significantly between samples was resilience. In terms of specific differences between samples, the control semolina pasta exhibited the highest values for hardness, gumminess and chewiness compared to both types of HPS pasta, indicating it was tougher and more difficult to chew (Figure 3). On the other hand, roasted HPS pasta had the highest springiness and cohesiveness, making it more elastic and cohesive. Raw HPS pasta tend to have intermediate texture properties, but had the lowest gumminess indicating it was the least tough sample. These results demonstrate that incorporating HPS into pasta alters many aspects of its chewy, elastic texture compared to traditional semolina pasta. Further processing of hull-less pumpkin seed by roasting had an impact on the pasta's overall textural attributes.

3.2 Sensory evaluation of hull-less pumpkin seeds developed pasta

The hull-less pumpkin seeds and its flour (raw and roasted), which were added to pasta in various amounts to replace the main ingredient, were added in accordance with normal procedures. Figure 4 displays the average results of a panel of 10 semi-trained judges' organoleptic assessment of healthy foods using a 9-point Hedonic scale.

The pasta supplemented with raw and roasted hull-less pumpkin seed flour, three test samples were developed and one control. For control, semolina was used as base ingredient and for experimental samples, raw and roasted hull-less pumpkin seed flour was incorporated at different levels, *i.e*., 10%, 20% and 30%. The results showed that highest scores were obtained by the pasta supplemented with 30% of raw and roasted hull-less pumpkin seed flour, followed by supplementation of 20% of raw and roasted hull-less pumpkin seed flour. Both the treatments with 30% incorporation of raw and roasted seed flours acquired higher scores than control in appearance, colour, texture, flavor and taste.

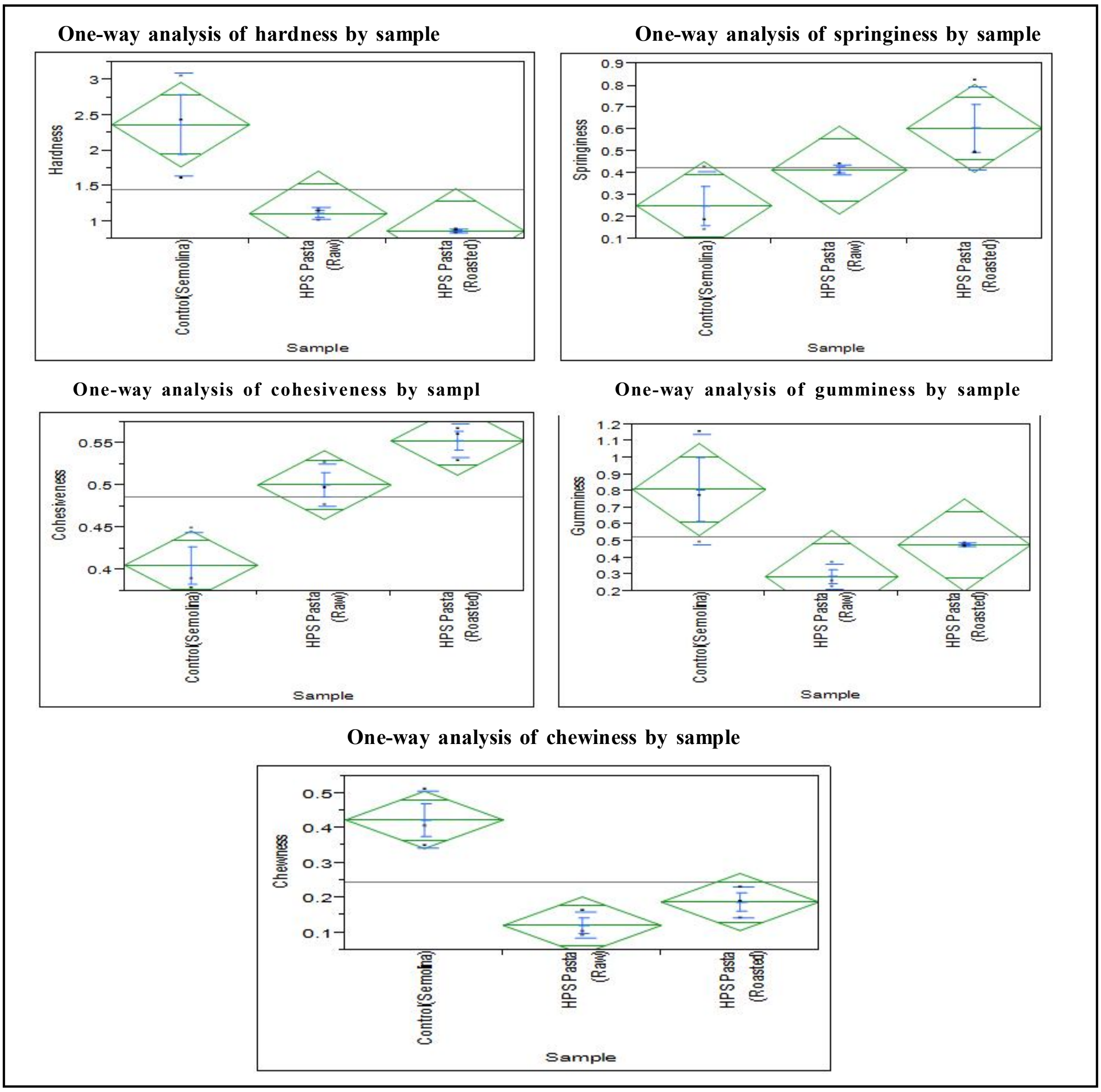
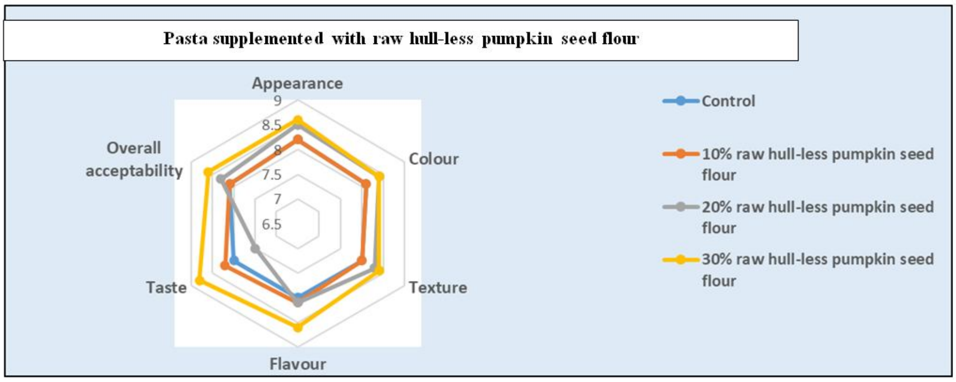


Figure 3: Textural attributes of HPS pasta.



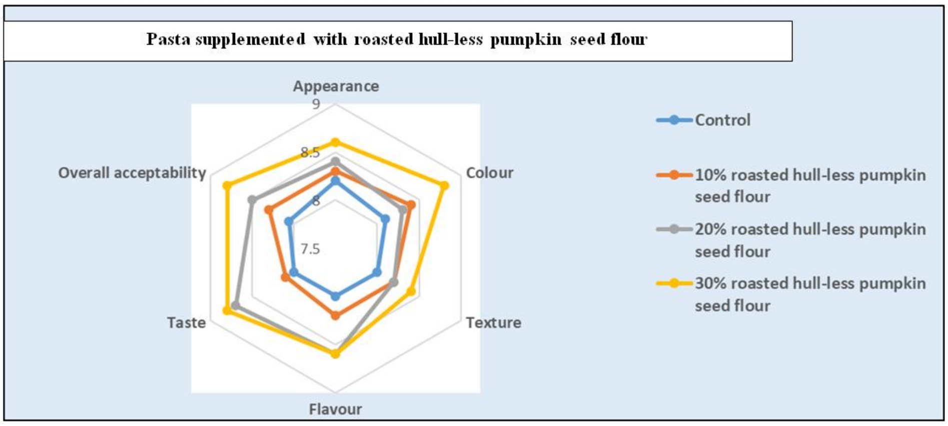


Figure 4: Organoleptic evaluation of raw and roasted hull-less pumpkin pasta.

Table 4: Nutritional profile of hull-less pumpkin seeds HPS functional pasta

Nutritional profile	Control pasta (CP)		Experimental (HPS) pasta	
			(Raw) P1	(Raw) P2
Moisture (%)	0.56^b ± 0.05		1.52^a ± 0.11	1.44^a ± 0.14
F-value (*p*-value)		405.33 (<0.0001)		
Crude protein (%)	10.67^c ± 0.5		14.88^b ± 0.6	15.40^a ± 0.7
F-value (*p*-value)		2018 (<0.0001)		
Crude fat (%)	0.85^c ± 0.15		9.87^b ± 0.07	11.15^a ± 0.08
F-value (*p*-value)		49760.21 (<0.0001)		
Crude fibre (%)	1.08^c ± 0.17		5.08^a ± 0.14	4.80^b ± 0.09
F-value (*p*-value)		9158.2 (<0.0001)		
Crude Ash (%)	1.08^c ± 0.1		2.72^b ± 0.16	3.04^a ± 0.17
F-value (*p*-value)		2314 (<0.0001)		
Carbohydrates (%)	85.16^a ± 4.3		67.83^b ± 3.6	65.59^c ± 4.3
F-value (*p*-value)		2107.1 (<0.0001)		
Energy (kcal)	386^b ± 2.7		420^a ± 1.4	424^a ± 4.5
F-value (*p*-value)		539.75 (<0.0001)		
Iron (mg/100 g)	1.48^c ± 0.05		4.58^b ± 0.09	4.69^a ± 0.08
F-value (*p*-value)		22991.77 (<0.0001)		
Zinc (mg/100 g)	1.96^c ± 0.08		5.04^b ± 0.08	5.10^a ± 0.07
F-value (*p*-value)		290244 (<0.0001)		
Magnesium (mg/100 g)	22.24^c ± 1.6		115.79^b ± 1.3	116.74^a ± 1
F-value (*p*-value)		98237.53 (<0.0001)		
Potassium (mg/100 g)	186.78^b ± 5.1		471.17^a ± 7.9	472.32^a ± 8.1
F-value (*p*-value)		28864.71 (<0.0001)		
Calcium (mg/100 g)	17.86^b ± 1.4		39.21^a ± 1	39.82^a ± 0.5
F-value (*p*-value)		2307.73 (<0.0001)		
Total carotenoid content mg/100 g)	0.30^c ± 0.07		0.69^a ± 0.04	0.61^b ± 0.03
F-value (*p*-value)		293.77 (<0.0001)		

Total antioxidant activity (%)	$24.03^{c} \pm 1.5$		$30.13^{b} \pm 1.4$	$41.75^{a} \pm 0.5$
F-value (*p*-value)		801.5 (<0.0001)		
Palmitic Acid (%)	$0.17^{c} \pm 0.1$		$2.96^{b} \pm 0.08$	$3.07^{a} \pm 0.1$
F-value (*p*-value)		60773 (<0.0001)		
Stearic acid (%)	$1.04^{c} \pm 0.05$		$2.16^{b} \pm 0.11$	$2.29^{a} \pm 0.13$
F-value (*p*-value)		817.44(<0.0001)		
Oleic acid (%)	$0.21^{c} \pm 0.08$		$15.14^{b} \pm 0.13$	$15.41^{a} \pm 0.08$
F-value (*p*-value)		27253.38 (<0.0001)		
Linoleic acid (%)	$0.78^{c} \pm 0.08$		$12.02^{a} \pm 0.15$	$10.54^{b} \pm 0.12$
F-value (*p*-value)		90723.8 (<0.0001)		

Values are expressed as Mean ± SD.
Values having different superscripts are significantly ($p < 0.05$) different.
CP-control pasta (semolina); P1- hull-less pumpkin seed pasta (raw); P2- hull-less pumpkin seed pasta (roasted).

3.3 Nutritional profiling of developed HPS enriched pasta

The best hull-less pumpkin flour-based functional pasta, whether it is raw or roasted. Using standardized procedures, the proximate composition, mineral content, total antioxidant potential, and fatty acid composition of pasta (30%), were assessed (Table 4).

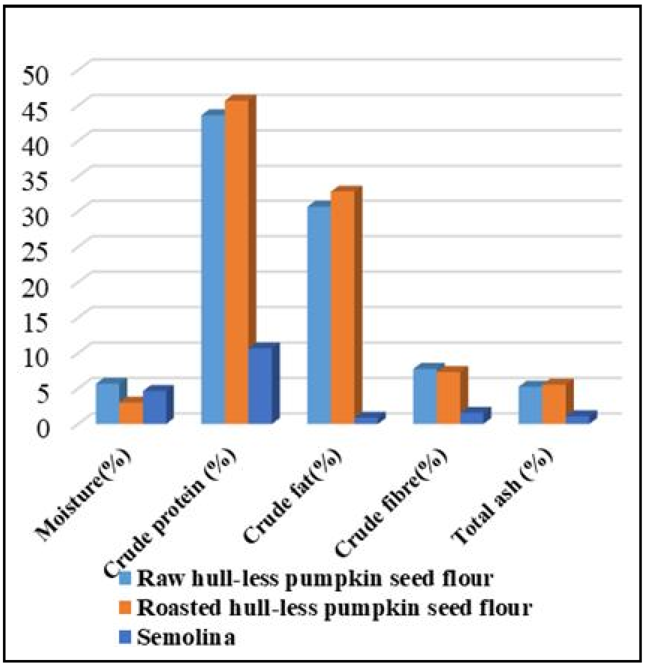
The results have been evaluated per 100 g of prepared pasta on dry matter basis and then compared to their respective control samples prepared with 100% of semolina and hull-less pumpkin seed pasta-raw and roasted incorporated at 30% level. It was observed that pasta supplemented with raw and roasted hull-less pumpkin seeds and flour were significantly higher (p<0.001) in all the parameters, *i.e*., proteins, fat, fibre and ash content than control samples (without supplementation). Further, a significant increase in crude protein, crude fat, total ash and energy content was observed in pasta supplemented with roasted hull-less pumpkin seeds/flour as compared to raw hull-less pumpkin seeds/flour. By substituting raw and roasted hull-less pumpkin seed flour for semolina in pasta functional pasta was developed. Figure 5 compares the nutritional profiles of substitute flours used to create healthy pasta with raw and roasted hull-less pumpkin seed flour in terms of proximate composition, mineral content, total carotenoid concentration, and total anti-oxidant activity.

From the results it was concluded that crude protein, crude fat, total ash and crude fibre of raw and roasted hull-less pumpkin seed flour was significantly higher (p<0.0001) than the semolina flours that were replaced to develop functional pasta.

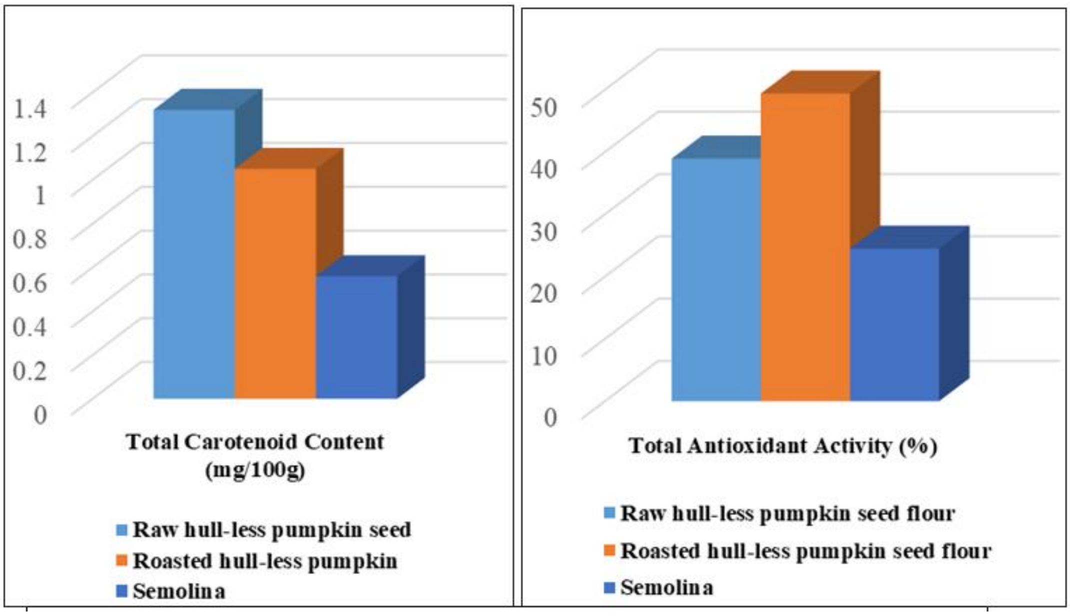
In the present study, a significant increase(p<0.0001) was observed in the mineral content, *i.e.,* iron, zinc, potassium, magnesium and calcium of highly acceptable hull-less pumpkin seeds functional pasta compared to their respective control sample (Table 2). The comparison of mineral composition of different flours replaced with raw and roasted hull-less pumpkin seed flour for the development of pasta is given in the Figure 3. From the results it was concluded that significantly higher (p<0.0001) content of minerals was observed in raw and roasted hull-less pumpkin seed flour in comparison to semolina.

The antioxidant capacity of pasta was noticeably boosted by adding hull-less pumpkin seeds in raw and roasted form in comparison to control samples (semolina). As hull-less pumpkin seed flour had a much greater content of total antioxidant activity and carotenoid content than the flours replaced in the preparation of pasta, it significantly increased the DPPH scavenging activity and total carotenoid content of HPS functional pasta. Sunarharum *et al*. (2019) found that roasting significantly enhances antioxidant activity in both Arabica and Robusta coffee varieties. This suggests that the roasting process plays a crucial role in improving the antioxidant potential of coffee products.

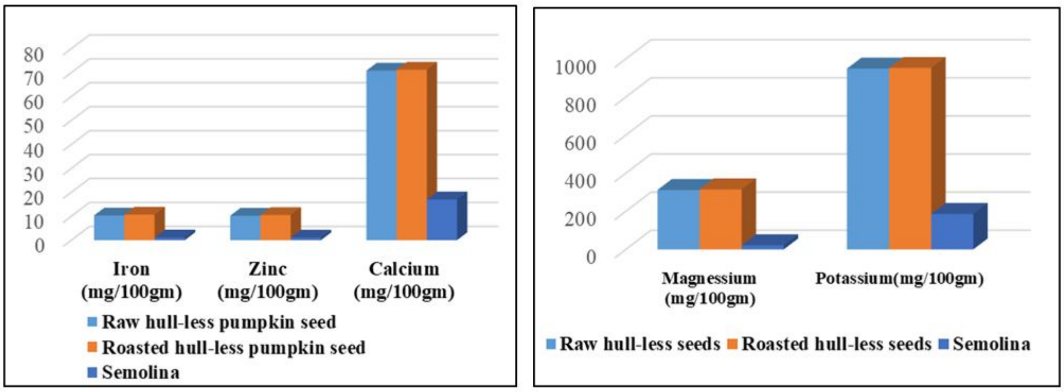
The addition of hull-less pumpkin seeds significantly (p<0.0001) improved the fatty acid composition of developed pasta mainly palmitic, stearic, oleic and linoleic acid content (Table 3). Thus, supplementation of hull-less pumpkin seed flour in both raw and roasted forms improved the nutritional profile of the developed health foods.



Proximate composition of different flours



Antioxidant Potential of different flours



Mineral content of different flours

Figure 5: Nutritional profile of different flours.

3.3.1 Fourier transform infrared spectroscopy (FTIR) analysis of hull-less pumpkin seeds functional pasta

FTIR analysis offers spectra profiles serving as molecular fingerprints, facilitating the detection and analysis of various bioactive components. It proves highly effective in identifying functional groups within a sample. Upon examining the FTIR spectra of different pasta samples, no impact on the arrangement of functional groups due to the enrichment of HPS (hull-less pumpkin seeds) was observed. Transmittance bands were predominantly observed in specific areas, such as 700, 900, 1000, 1200, 1650, 2350, 2360, 2450, 2600, 2850, 3200, and 3300 cm^{-1}. A broad band with a peak around 3100 to 3275 cm^{-1} indicated the presence of OH groups, signifying interactions between water molecules and pasta components, as well as water-water interactions through hydrogen bonding. Among the three formulations, the flour exhibited the highest intensity of the OH band. The FTIR spectra revealed bands associated with the most common types of organic molecules. The absorbance peaks at around 2350, 2360, and 2950 cm^{-1} corresponded to CN and N-H bond stretching vibrations present in HPS pasta compared to the control, respectively. Additionally, the peak at 3289 cm^{-1} indicated NH and OH bond stretching vibrations. Semolina pasta displayed a small peak at 2930 cm^{-1}, representing the C=H stretching of aliphatic groups. The intensity of this doublet was higher in the control sample, indicating a greater amount of lipids compared to HPS pasta (Figure 6). The HPS pasta exhibited multiple peaks at approximately 1745 cm^{-1}, which were attributed to the C=O stretching of esters. Notably, this peak was smaller in the control pasta formulation. Additionally, a prominent peak at 1647.5 cm^{-1} was observed in HPS pasta, confirming C=O stretching and indicating the presence of chlorophyll content and phenolic compounds. The presence of phenolic compounds was also evident from unique peaks associated with C-H, C-O, and C=C bonds in both raw and roasted pasta samples. Vibrations related to the antisymmetric deformation of CH_3 groups were observed around 1450 cm^{-1}. The amidic band II at 1545 cm^{-1} was caused by the C=O stretching in the amides I, II, and III, while the bending vibrations of the N-H groups, resulting from the increased protein content in HPS-added pasta, also contributed to this band. Characteristic bands of proteins were centered at approximately 1640 and 1540 cm^{-1}, corresponding to the amide I and amide II groups, respectively. These bands reflect the carbonyl stretch of CO with a minor contribution from out-of-plane CN stretching vibration and NH bonding, as well as the CH stretching of proteins. The spectral region associated with polysaccharides, such as starch, falls within the range of 800-1200 cm^{-1}, indicating the backbone vibrations of CO, CN, and CC bonds. The peak at around 700 cm^{-1} (COH) was attributed to the above-plane bending of hydroxyl groups, often associated with free water molecules. Moisture, proteins, and starch are the primary components of pasta and play a crucial role in its quality and texture. Therefore, further analysis of the OH, amide I, and starch bands will provide insights into the roles of these main pasta components.

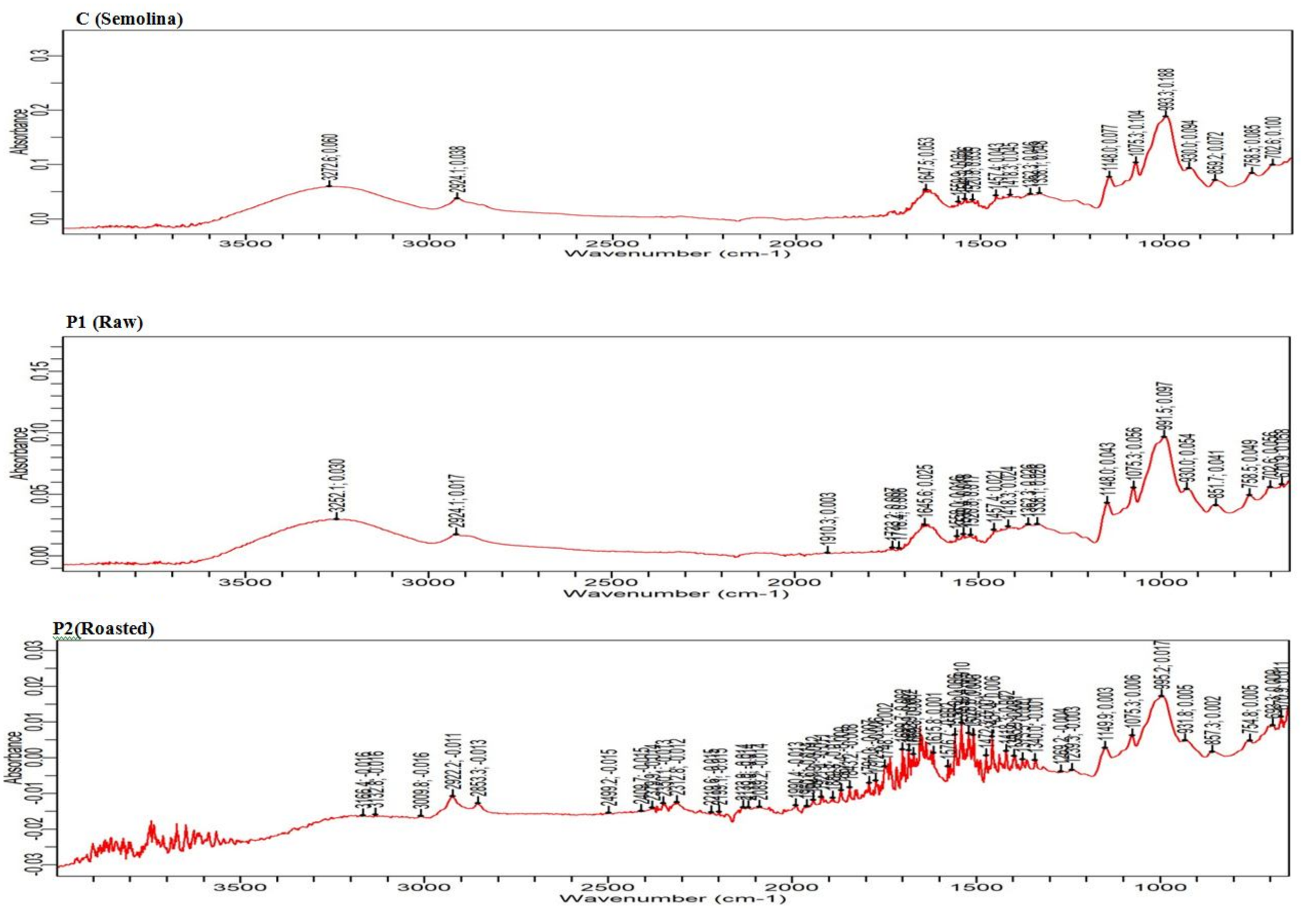


Figure 6: Fourier transform infrared spectroscopy (FTIR) analysis of hull-less pumpkin seeds functional pasta.

4. Discussion

The HPS pasta, resulted in a reduction in minimum cooking time (MCT). These findings are consistent with Biernecka *et al.* (2017), who have developed pasta enriched with carob fiber, observing a reduction in cooking time with increased carob fiber levels, with control pasta requiring the longest cooking time.

The addition of HPS to pasta led to a decrease in water absorption capacity, primarily due to its higher fiber content. This finding contrasts with studies involving other sources of dietary fiber, such as wheat bran, which have shown similar decreases in water absorption capacity but attributed them to cooking loss (Lei *et al.*, 2021; Bustos *et al.* 2015). The volume expansion and gruel solid loss, two parameters that reflect changes in pasta structure during cooking. The addition of HPS resulted in a slightly lower volume expansion compared to the control pasta, indicating potential differences in texture and mouthfeel. Additionally, the HPS-enriched pasta exhibited a significantly higher gruel solid loss, suggesting a greater degree of disintegration during cooking. These findings highlight the complex interplay between fiber content and pasta properties, underscoring the need for comprehensive analysis to assess overall quality. Altiner and Hallac, (2020); Voisey *et al.* (1975), reported that the addition of soy flour and fiber-rich carob flour led to a reduction in volume expansion.

The HPS functional pasta showed a significantly higher gruel solid loss, which was similar to the results reported by Tolve *et al.* (2020), that the addition of grape pomace powder to pasta at concentrations of 5% to 10% resulted in an increase in gruel solid loss from 8.18% to 9.48%. The reason for this increase was also attributed to the disruption of the gluten matrix due to the higher fiber content.

Texture profile analysis provides reliable instrumental measurement of texture attributes that correlate well with sensory evaluations (Bourne, 1978; Szczesniak, 1963). This study revealed the complex effects of dietary fiber on pasta texture. Increased water absorption due to fiber altered texture qualities beyond just firmness. Higher levels of hull-less pumpkin seed (HPS) powder increased pasta hardness and reduced adhesiveness. This aligns with previous findings showing fortification with pumpkin seed flour increased hardness and chewiness but decreased adhesiveness in cooked pasta, attributed to disruption of the gluten network by the higher protein and fiber content (Kumar *et al*., 2022; El-Soukkary, 2001). These results highlight the multifaceted impacts of ingredients like HPS powder on overall pasta texture.

In the present study, after pasta fortification with hull-less pumpkin seed (raw and roasted), the L* value decreased. Jeong *et al.* (2016) revealed coherent results of a reduction in L value in radish-juice-incorporated pasta. A negative a* value indicates green colour in the present study which was similar to the results reported Poonsri *et al.* (2019) with the addition of cassava leaves to rice noodles. The study demonstrates that supplementing pasta with raw and roasted hull-less pumpkin seeds and flour significantly enhances its nutritional profile compared to traditional semolina-based pasta. Sultan *et al.* (2020) evaluated semolina and wheat pasta supplemented with buckwheat at different levels and reported nutritional composition of developed pasta as fibre content (2.64%), ash content (1.722%), protein content (8.93%) and fat content (3.093%). Monika *et al.* (2023) reported the seeds of Fenugreek demonstrated enhanced proximate composition and mineral content (ash content at 3.55%, crude fat at 7.77%, crude fiber at 9.25%, crude protein at 25.57%). The developed millet-based biscuits incorporated with amaranth seeds were nutritionally superior in ash, fat, crude protein, crude fiber and iron (Sushree, and Gitanjali, 2023). Naumova *et al.* (2017) analyzed mineral elements of pasta products supplemented with ground chia seeds and found that iron, zinc, magnesium and calcium content of developed pasta was 12.15, 11.47, 392.38 and 157.13 mg/kg which was found to be significantly higher than the control.

Additionally, the antioxidant capacity and carotenoid content of the pasta are notably elevated, contributing to improved health benefits. The results from antioxidant tests showcased robust antioxidant activity in the examined extracts, highlighting their ability to act to varying extents as scavengers of free radicals. Notably, the study revealed that the seed extract exhibited a higher IC_{50} value compared to the standard ascorbic acid (Divya *et al*., 2023).

Jyoti *et al.* (2022) reported no significant difference in the metal chelating activity between the two varieties of mustard seeds, with values ranging from 18.07% to 25.72%. Furthermore, the fatty acid composition of the pasta is enriched, with increased levels of beneficial fatty acids such as oleic and linoleic acids. Hashempour- Baltrok *et al.* 2018; Appleqvist (1968) made puffed corn snacks incorporating powder of sesame seeds and analysed fatty composition of developed products. It was reported that palmitic, stearic, oleic and linoleic acids of developed puffed corn snacks were found to be 11.12%, 4.053%, 34.94% and 46.043% which were more than the control product.

The FTIR analysis of pasta samples enriched with hull-less pumpkin seeds (HPS) revealed distinct spectral profiles indicative of various organic molecules. While HPS enrichment did not affect the arrangement of functional groups, differences in absorbance peaks highlighted variations in bioactive components. Notably, peaks corresponding to C=O stretching, chlorophyll, phenolic compounds, and protein content were prominent in HPS pasta, suggesting potential nutritional benefits and flavor enhancements. These findings highlight the potential of incorporating hull-less pumpkin seeds into pasta formulations to create healthier and more nutritious products. Moond *et al.* (2023) revealed the presence of phenolics, flavonoids, tannins, and antioxidants in fenugreek seeds, affirming their status as a rich source of bioactive compounds with potential for free radical scavenging. This underscores their nutritional value. Comparisons with prior studies further validate the effectiveness of this method in augmenting the nutritional profile of pasta.

5. Conclusion

The incorporation of hull-less pumpkin seeds (HPS) in pasta formulations significantly impacts various quality parameters. The reduction in minimum cooking time (5.02 ± 0.12^c) and water absorption capacity (94 ± 0.42^b as compared with the control (Semolina) pasta minimum cooking time (5.82 ± 0.53^b) and water absorption capacity (102.51 ± 2.32^a). Additionally, the changes in color characteristics attributed to chlorophyll content highlight the visual impact of HPS enrichment. Furthermore, texture analysis revealed better firmness with HPS incorporation. These findings collectively demonstrate the potential of HPS as a functional ingredient in pasta production, offering opportunities for enhancing cooking properties, texture, and visual appeal.

HPS functional pasta is nutritionally enhanced as compared to semolina pasta available in the market. Further roasting of hull-less pumpkin seeds significantly increased the amount of crude protein, iron, zinc, calcium, magnesium, potassium, and total antioxidant activity as well as the composition of fatty acids. Raw and roasted hull-less pumpkin seeds can be added to daily diets to improve their nutritional value. Thus, raw and roasted hull-less pumpkin seeds could be processed in the powder and included in various health foods.

Conflict of interest

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

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