

Research Article

Influence of Wheatgrass Juice on Techno-Functional Properties and Bioactive Characteristics of Pasta

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Received 18 June 2022; Revised 26 July 2022; Accepted 27 July 2022; Published 29 August 2022

Academic Editor: Addi Mohamed

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Pasta is an excellent source for fortification of ingredients and wheatgrass juice (WGJ) as a natural source of vital nutrients and antioxidants; the study was taken to develop WGJ-rich functional pasta. Wheatgrass juice (WGJ) was added at the rate of 33, 66, and 100% by replacing water during the mixing process of pasta. The samples were assessed by cooking quality, proximate composition, antioxidant properties, color, texture attributes, and sensory evaluation. Fourier transform infrared spectroscopy (FTIR) and scanning electron microscopy (SEM) were performed. Incorporation of WGJ significantly ($p < 0.05$) decreased the optimum cooking time of pasta, whereas water absorption capacity was increased. Cooking loss in pasta increased from 2.89 to 3.21% with increasing levels of WGJ from 33 to 100%. The addition of wheatgrass juice to pasta improved the nutritional and antioxidant profile significantly ($p < 0.05$), as evidenced by increases in protein, phenolics, flavonoids, chlorophyll, and antioxidant activities (FRAP, DPPH, and ABTS). The incorporation of wheatgrass juice reduced the L value, whereas a^* of the pasta enhanced gradually. With the addition of WGJ, the stiffness and hardness of the pasta changed dramatically. FTIR spectra validated the existence of bioactive compounds and chlorophyll pigments in pasta. Sensory data revealed that pasta containing 100% of WGJ was acceptable with the highest overall acceptability score of 7.72.

1. Introduction

Wheatgrass is a nutritious food made from the *Triticum aestivum* microgreens. Wheatgrass contains vitamins A, B, C, and E, as well as minerals, phenolic acids (ferulic, gallic, sinapic, syringic, and p-coumaric acids), flavonoids, chlorophylls, amino acids, and many other active enzymes [1]. The presence of phenolic compounds such as vanillic acid, luteolin, sinapic acid, and protocatechuic acid in WGJ provide desirable health benefits (cardioprotective,

antihyperlipidemic, antidiabetic, and anticancer) beyond basic nutrition to reduce the risk of major chronic diseases. WGJ has a significant chlorophyll level, and its structure is similar to that of haemoglobin (a protein present in red plasma platelets that carries oxygen from the lungs to your body's organs and tissues while somehow delivering CO₂ back into the lungs). Chlorophyll is a very well-known chemopreventive agent that is found in plant foods [2].

The lifestyle of people is altering at a faster pace due to globalization and urbanization. It becomes more sedentary

and stressful, which is one of the major reasons for the production of free radicals and oxidative stress [3]. The fast lifestyle forces people to opt for ready-to-eat food products. Smart consumers are strictly restricting foods loaded with chemicals and are demanding phytochemically rich and natural colored food products [4]. The bioactive components present in foods have the ability to scavenge the free radicals and thus prevent oxidative stress in the body. These compounds even present in small amount possess the ability to prevent or reduce the risk of degenerative diseases such as cardiovascular diseases, diabetes, hypertension, coronary disease, cancer, and so on [4–6]. Several studies, including Panghal et al. [7], Bawa et al. [8], Simonato et al. [9], and Majewska et al. [10], reported the successful enhancement of bioactive and antioxidant properties of food products with the increment of bioactive compound rich substances.

Pasta is one of the most popular foods in the world today because of its ease of preparation, storage stability, low cost, and nutritional properties [11]. Pasta consumption is expanding as a result of consumer demand for new meals, new flavors, and higher spending power. Pasta is suggested by the WHO and the FDA as an excellent transporter for bioactive compounds and micronutrient delivery [12, 13]. Pasta is a convenient food product having diverse shapes and sizes and is more popular because of its ease of preparation, palatability, and better nutrition. Wheat pasta mainly contains carbohydrates 74–77% and proteins 11–13% [7], but it is lacking in mineral content, vitamins, phenolics, and dietary fiber. Previous studies showed the incorporation of *Syzygiumcumini* L. pulp [7], red cabbage juice [14], beetroot juice and carrot juice [15, 16], raddish juice [17], and potato juice [18] into pasta for the enhancement of nutritional, antioxidant, and bioactive properties.

WGJ was also used as an ingredient of fortification in flavored milk, paneer, and enrobed paneer [19], for the increment of nutritional and phytochemical compounds. Currently, no studies are available on the utilization of WGJ in pasta, while in the previous studies, Bawa et al. [8] reported that wheatgrass powder can be successfully incorporated at a 9% level for the development of the pasta without compromising much of its technological properties and with higher bioactive potential and consumer acceptability. Taking into account that pasta is an excellent source for fortification of ingredients and WGJ as a natural source of vital nutrients and antioxidants, the goal of the study was to develop WGJ-rich functional pasta for the assessment of physico-functional properties, cooking characteristics, antioxidant properties, and textural and morphological attributes.

2. Materials and Methods

2.1. Preparation of Wheatgrass Juice. The wheat cultivar (*Unnat* PBW 550) was grown as per the methodology described by Bawa et al. [8]. Wheatgrass was picked after it reached a height of 7 inches. Wheatgrass was carefully harvested, cleaned manually, rinsed, and sliced into 1 cm

pieces. Afterwards, it was blended in a mixture with a little amount of water and strained through a muslin cloth. Prepared juice was stored in an airtight container in the refrigerator (4–7°C).

2.2. Preparation of Wheatgrass-Juice-Enriched Functional Pasta. WGJ was added at a level of 0, 33, 66, and 100% by replacing water added during the mixing process. In the pasta extruder's mixing chamber (Le Monferrina, Masoero Arturo, and C.S.N.C, Italy), the ingredients (semolina, water, and WGJ) were mixed properly to reach desired consistency. A pasta die (No. 225) having corrugated V type spots of 1.5 mm opening was used to make "fusilli" shaped pasta. Then the prepared pasta was dried hot air drier (45–50°C; Naarang Scientifics, New Delhi, India). The prepared pasta was put into HDPE bags and refrigerated at 4°C till further analyzed.

2.3. Cooking Quality of WGJ-Enriched Pasta. The AACC [20] standard procedures were used to determine the cooking parameters, namely, optimal cooking time (OCT), volume expansion, swelling index, water absorption capacity (WAC), and gruel solid loss of the developed pasta.

2.4. Proximate Composition of WGJ-Enriched Pasta. The AOAC [21] standard procedures were used to calculate the proximate composition, namely, moisture content, protein content, lipid content, ash content, and fiber content of both raw and cooked pasta.

2.5. Phytochemical Analysis of WGJ-Enriched Pasta. The raw and cooked pasta samples were dried in a forced air oven at 45–50°C for 6–8 h till constant weight. The dried samples were then milled using a Supertec Mill 3303 (Perten Instruments, Sweden) and sieved through a 40 mm for evaluation of its phytochemical properties. The phytochemical compounds were extracted in acidified (0.1% Conc. HCl) aqueous methanol (80% v/v) by refluxing at 40°C. DPPH (2,2-diphenyl-1-picrylhydrazyl) antioxidant activity was calculated as per the methodology described by Brand-Williams et al. [22], ferric reducing antioxidant power (FRAP) assay by Tadhani et al. [23], and ABTS (2,2'-azino-bis(3-ethyl-benzothiazoline-6-sulfonic acid)) radical scavenging activity as per the method described by Re et al. [24]. Total phenolics content (TPC) was measured by using the method described by Singleton et al. [25], total flavonoid content was calculated by the method of Zhishen et al. [26], and chlorophyll content was estimated by protocol illustrated by Ranganna [27].

2.6. Color Characteristics of WGJ-Enriched Pasta. The ColorFlex meter (Hunter Lab Color Flex, Hunter Associates Inc., USA) was used to calculate the color characteristics (L , a^* , b^*) of both raw and cooked pasta [11]. The measurement of color psychophysical parameters such as hue angle (h^*)

and chroma (C^*) was obtained. Cartesian Coordinates (a^* and b^*) transformed to polar coordinates (h^* and C^*) according to the following equations:

$$\text{Hue Angle}(h^*) = \arctan\left(\frac{b^*}{a^*}\right), \quad (1)$$

$$\text{Chroma}(C) = (a2 + b2)^{1/2}.$$

Total color difference (ΔE) was calculated by the following formula:

$$\Delta E^* = \sqrt{(\Delta L)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}. \quad (2)$$

2.7. Texture Attribute of WGJ-Enriched Pasta. The textural characteristics, namely, Firmness and toughness of both raw and cooked pasta were evaluated by utilizing TA-XT plus texture analyzer by Stable Micro Systems, UK. A blade probe was used to cut the sample of 2.5 cm to a distance of 10 mm at a speed of 1 mms⁻¹. With pre- and post-test speeds of 2 mms⁻¹, a trigger force of about 10.0 g was used [28].

2.8. Sensory Evaluation of WGJ-Enriched Pasta. A panel of 20 semitrained people (ages 22 to 55) from the Department of Food and Nutrition, Punjab Agricultural University, Ludhiana, India, assessed the cooked pasta samples on a 9-point hedonic scale for the sensory quality parameters, namely, appearance, color, flavor, taste, texture, and overall acceptability.

2.9. Fourier Transform Infrared Spectroscopy (FTIR) Analysis of WGJ-Enriched Pasta. FTIR spectrophotometer (Alpha Bruker, USA) was used to analyze the FTIR spectra of pasta, taking into account the effect of WGJ addition on the functional group of pasta. The pasta sample was powdered and placed on the sample holder of FTIR. Different infrared spectrums were observed within a range of 500 to 4,000 cm⁻¹ wavelengths [29].

2.10. Microstructure Analysis of WGJ-Enriched Pasta. The micromorphological characteristics of raw and cooked pasta samples were studied using a scanning electron microscope (SEM; Model: Hitachi S 3400N, UK). The cross-sectional area of dry pasta is hauled into a retaining pan and sputtered plated with golden for 2 minutes using a vacuum evaporator. After that, the sample was placed on a microscopic level platform and tested at 15 kV at a 9.75 × 10⁻⁵ Pa vacuum.

2.11. Statistical Analysis. Analysis of variance was used with the help of Statistical Package for the Social Sciences (SPSS, [PASW version 18.0] Inc., USA). Results were expressed as the mean of three different observations and standard deviation to measure the differences among the treatments Tukey's test ($p < 0.05$) was performed.

3. Results and Discussion

3.1. Cooking Quality

3.1.1. Optimum Cooking Time. The optimum cooking time (OCT) is the amount of time requisite for the white core of pasta to completely disappear during the cooking process. A higher OCT value indicates the extended time required for pasta cooking. Increased replacement of WGJ from 0–100% with water significantly ($p < 0.05$) reduced OCT from 6.10 to 5.42 minutes (Table 1), while nonsignificant variation was observed at replacement levels 33 and 66%. The observed reduction in cooking time is due to an increase in acidity with the addition of ascorbic acid-rich WGJ [30]. This changes the crystalline structure of starch, and starch becomes corroded that destroys microcrystals in the starch and the glycoside bond hydrolyzed. Moreover, the molecular weight of starch decreases along with a decrease in amylopectin amount and the formation of more amylose bonds that have free hydroxyl groups [31]. These hydroxyl groups enhance the starch solubility in water that decreases the OCT. Similar results were found in beetroot juice added pasta where minimum cooking time was observed in pasta having the highest amount of beetroot juice [15].

3.1.2. WAC. WAC is the potential of pasta to interlock and retain water against the gravitational force. Starch and protein networks are the main factors that affect the water absorption tendency of pasta [32]. WAC of control and WGJ enriched pasta are presented in Table 1. WAC varied from 101.3–108.6% with the addition of WGJ from 0 to 100%. The slight increase in WAC is attributed to the changes made in starch structure by WGJ. The structure becomes porous and increases in the hydrophilic groups of starch that makes it absorb more water as compared with control pasta [31]. A study by Prerana and Anupama [33] also reported an increase in WAC with the addition of carrot puree in pasta. WAC of pasta is found positively correlated with swelling index (SI; $r = 0.100$; $p < 0.05$), volume expansion ($r = 0.992$; $p < 0.05$), gruel solid loss ($r = 0.959$; $p < 0.05$), and protein content ($r = 0.989$; $p < 0.05$).

3.1.3. Swelling Index and Volume Expansion. The swelling index (SI) signifies the relative volume change in the raw and cooked pasta. The data of SI for control and WGP enriched pasta are shown in Table 1. Significant ($p < 0.05$) increase was found in SI of pasta from 1.13 to 1.25 g/g with the incorporation of WGJ from 0–100%, whereas 66% and 100% WGJ-incorporated pasta SI varied nonsignificantly. This increase in SI was contributed to the fine particles existing in WGJ, which break the gluten matrix and allow water to easily infiltrate. As a result of the weaker gluten network, solids disintegrate, increasing the swelling index [7]. Simonato et al. [9] reported an increase in SI from 184 to 1.92 g/g when olive pomace was added to pasta at a rate of 5–10%. Volume expansion shows a similar trend as SI. Volume expansion was found parallel to the water absorption property because volume expansion depends on the

TABLE 1: Cooking quality of cooked wheatgrass-juice-incorporated pasta.

Level WGJ	Optimal cooking time (min)	Water absorption capacity (%)	Swelling index (g/g)	Volume expansion (mL/g)	Gruel solid loss (%)
Control	6.10 ± 0.07 ^a	101.3 ± 1.00 ^c	1.13 ± 0.01 ^c	0.95 ± 0.02 ^c	2.89 ± 0.04 ^d
33%	5.50 ± 0.02 ^b	103.8 ± 1.08 ^b	1.17 ± 0.02 ^c	0.99 ± 0.03 ^c	2.94 ± 0.02 ^c
66%	5.45 ± 0.02 ^b	106.0 ± 1.32 ^a	1.21 ± 0.01 ^b	1.06 ± 0.02 ^b	3.15 ± 0.02 ^b
100%	5.42 ± 0.03 ^c	108.6 ± 0.55 ^a	1.25 ± 0.01 ^a	1.13 ± 0.02 ^a	3.21 ± 0.03 ^a

Value represents mean ($n=3$) ± SD. Values having different superscripts from a to f show significant variation among the level of enrichment.

WAC. The volume of pasta varied from 0.95 to 1.13 mL/g with an increase in the incorporation of WGJ from 0–100%. SI is positively correlated with volume expansion ($r=0.993$; $p<0.05$), gruel solid loss ($r=0.966$; $p<0.05$), and protein content ($r=0.992$; $p<0.05$; Table 2).

3.1.4. Gruel Solid Loss. In the control pasta, minimum gruel solid loss (2.89%; Table 1) occurred, which signifies that the control pasta had a strong gluten matrix. A significant increase ($p<0.05$) was observed in gruel solid loss from 2.94 to 3.21% with an increase in substitution level of WGJ from 33 to 100%. The increase in the gruel solid loss is due to the weakening of the gluten matrix by the fine particles present in the WGJ. The amount of gruel solids lost has increased from 4.21 to 5.2%, according to Panghal et al. [7] with the addition of *Syzygium cumini* L. from 0 to 40%, due to a decrease in gluten network strength by pulp fiber. A study by Carini et al. [34] also notified an increment in gruel solid loss with the incorporation of carrot juice into pasta. Gruel solid loss of the pasta is positively correlated with fiber content ($r=0.952$; $p<0.05$) of the pasta and WAC ($r=0.959$; $p<0.05$; Table 2).

3.2. Proximate Composition. Results of the proximate composition of WGJ pasta were given in Table 3. The addition of WGJ into pasta marginally impacted the proximate composition of the pasta. Results showed that with an increase in the level of WGJ from 0 to 100%, there was a significant ($p<0.05$) increase in the protein and ash content of the pasta from 12.41 to 14.10% and 0.55 to 0.73%, respectively. Similar findings were reported by Wang et al. [14], who found that replacing water with spinach juice in the making of pasta increased the protein content of the pasta from 12.49 to 12.76%. An increase in ash content of pasta from 0.68–0.89% with the incorporation of spinach juice and from 0.68 to 0.78% with the incorporation of red cabbage juice in replacement with water was observed by Wang et al. [14]. A high proportion of amino acids such as aspartic acid, alanine, glutamic acid, serine, and arginine in the WGJ and a plethora of minerals such as calcium, magnesium, alkaline Earth metals, phosphorus, potassium, boron, zinc, and molybdenum could be accountable for the enhancement of protein and ash content of WGJ pasta [35]. Fat, fiber, and moisture did not show significant variation by the replacement of WGJ with water in semolina pasta. Proximate compositions of the pasta, namely, protein and ash, are positively correlated with level of WGJ addition ($r=0.992$ and $r=0.991$; $p<0.05$; Table 2). All of the

parameters were found to be nonsignificantly lower in cooked pasta than in raw pasta. After cooking, a 1.9–9.9% reduction was observed in protein content and 9.9–23.6% in ash content in cooked pasta in comparison with raw pasta. The reduction is mainly attributed to the loss of dry matter in the cooking water. During cooking, starch granules rooted in the protein frameworks to wallow and gelatinize, causing the protein structure to loosen and soluble dry matter particles to leak out into the cooking water [10].

3.3. Antioxidant Activities and Bioactive Compounds. The antioxidant and bioactive potential of pasta was significantly enhanced when WGJ was added to it. Incorporation of WGJ from 0–100% significantly ($p<0.05$) enhanced the radical scavenging activity from 21.76 to 36.37% DPPH RSA, 39.54 to 135.2 mg FeSO₄ FRAP value, and 19.20 to 35.74% ABTS radical cation scavenging activity in the raw pasta (Table 4). The increment in the antioxidant potential of pasta is attributed to the increment of bioactive compound-rich WGJ. Studies reported high content of apigenin, quercetin, and luteolin bioactive compounds in WGJ. The presence of 70% of chlorophyll content in WGJ was also responsible for the increased antioxidant activity of the pasta [30]. Coherent results of increment of antioxidant potential were observed by the study by Devi et al. [19] with the incorporation of WGJ into milk, paneer, and enrobe paneer. Similarly, Panghal et al. [7] also found that incorporating *Syzygium cumini* L. pulp in pasta increased the antioxidant activity of pasta. The antioxidant activities of the pasta, namely, DPPH, FRAP, and ABTS, are positively correlated with level of WGJ addition ($r=0.1000$, $r=0.997$, and $r=0.994$, respectively; $p<0.05$), TPC ($r=0.966$, $r=0.963$, and $r=0.959$, respectively; $p<0.05$), total flavonoid content ($r=0.990$, $r=0.985$, and $r=0.979$, respectively; $p<0.05$), and total chlorophyll content ($r=0.995$, $r=0.994$, and $r=0.992$, respectively; $p<0.05$; Table 2) of the pasta. Furthermore, in the uncooked pasta, TPC, total flavonoid content, and total chlorophyll content were increased from 31.13 to 85.28 mg GAE/100 g, 44.26 to 77.18 mg QAE/100 g, and 1.06 to 17.88 mg/100 g, respectively, with the incorporation of WGJ from 0–100% (Table 4). This is due to the addition of phytochemical-rich WGJ. A study by Kumar et al. [35] reported a high amount of apigenin, luteolin, and quercetin bioflavonoids in the WGJ. Chauhan [36] reported that 70% of a total chemical constituents of WGJ were chlorophyll. Several other authors also reported an increase in the total phenolic content of pasta with the addition of fruit and vegetable juices. Coherent results of an increase in bioactive compounds were also

TABLE 2: Correlation matrix of selected properties of uncooked pasta.

	LWJ	OCT	WAC	SI	VE	GR L	A	Pr	Fb	DPPH	FRAP	ABTS	TPC	TFC	T CHL	L	A*	B*	HUE	CHR	DE	FIR	TOU
LWJ	1																						
OCT	-0.832	1																					
WAC	1.000*	-0.835	1																				
SI	1.000*	-0.834	1.000*	1																			
VE	0.993*	-0.763	0.992*	0.966*	1																		
GR L	0.966*	-0.743	0.959*	0.966*	0.974*	1																	
A	0.998*	-0.804	0.997*	0.998*	0.997*	0.978*	1																
Pr	0.992*	-0.771	0.989*	0.992*	0.998*	0.987*	0.998*	1															
Fb	0.945	-0.606	0.942	0.944	0.977*	0.952*	0.999*	0.994*	1														
DPPH	1.000*	-0.832	0.999*	1.000*	0.993*	0.972*	0.999*	0.994*	0.945	1													
FRAP	0.997*	-0.832	0.995*	0.998*	0.991*	0.980*	0.998*	0.995*	0.943	0.999*	1												
ABTS	0.994*	-0.830	0.990*	0.994*	0.987*	0.985*	0.996*	0.994*	0.939	0.996*	0.999*	1											
TPC	0.967*	-0.945	0.969*	0.968*	0.931	0.900	0.952*	0.932	0.831	0.966*	0.963*	0.959*	1										
TFC	0.992*	-0.881	0.995*	0.992*	0.974*	0.931	0.983*	0.969*	0.904	0.990*	0.985*	0.979*	0.987*	1									
T CHL	0.994*	-0.885	0.993*	0.994*	0.975*	0.956*	0.988*	0.978*	0.906	0.995*	0.994*	0.992*	0.987*	0.994*	1								
L	-0.966*	0.673	-0.967*	-0.965*	-0.986*	-0.934	-0.972*	-0.974*	-0.988*	-0.962*	-0.955*	-0.947	-0.877	-0.943	-0.932	1							
A*	0.917	-0.983*	0.918	0.919	0.866	0.851	0.898	0.874	0.738	0.918	0.919	0.918	0.986*	0.947	0.955*	-0.788	1						
B*	0.996*	-0.880	0.996*	0.996*	0.978*	0.954*	0.990*	0.979*	0.911	0.996*	0.994*	0.991*	0.986*	0.997*	1.000*	-0.939	0.950*	1					
HUE	-0.864	0.997*	-0.867	-0.867	-0.802	-0.790	-0.841	-0.812	-0.655	-0.866	-0.867	-0.867	-0.962*	-0.905	-0.914	0.713	-0.993*	-0.908	1				
CHR	0.994*	-0.887	0.994*	0.995*	0.975*	0.952*	0.988*	0.977*	0.905	0.994*	0.993*	0.990*	0.988*	0.996*	1.000*	-0.933	0.955*	1.000*	-0.914	1			
DE	0.996*	-0.866	0.998*	0.996*	0.982*	0.943	0.989*	0.978*	0.919	0.995*	0.990*	0.985*	0.982*	0.999*	0.995*	-0.953*	0.938	0.998*	-0.893	0.997*	1		
FIR	0.975*	-0.716	0.977*	0.974*	0.987*	0.927	0.976*	0.973*	0.975*	0.970*	0.961*	0.952*	0.903	0.961*	0.946	-0.997*	0.821	0.954*	-0.752	0.948	0.968*	1	
TOU	0.997*	-0.849	0.995*	0.998*	0.987*	0.975*	0.996*	0.991*	0.933	0.999*	0.999*	0.999*	0.971*	0.988*	0.997*	-0.948	0.931	0.997*	-0.882	0.996*	0.992*	0.957*	

Significance level is 0.05*, significance at a 5% level of significance. LWJ is percentage of WGJ, OCT – optimal cooking time, WAC – water absorption capacity, SI – swelling index, VE – volume expansion, GR L – gruel solid loss, a – ash content, P – protein content, Fb – fiber content, DPPH – radical scavenging activity, FRAP – ferric reducing power, ABTS – radical scavenging activity, TPC – total phenolic content, TFC – total flavonoid content, T CHL – total chlorophyll, L – lightness, A* – redness greenness balance, B* – yellowness blueness balance, HUE – hue angle, CHR – Chroma, DE – delta E, FIR – firmness of pasta, and TOU – toughness of pasta.

TABLE 3: Proximate composition of uncooked and cooked wheatgrass-juice-incorporated pasta.

Uncooked Level WGJ	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fiber (%)
Control	9.78 ± 0.21 ^a	0.55 ± 0.04 ^d	12.41 ± 0.50 ^{bc}	2.08 ± 0.02 ^a	1.18 ± 0.02 ^a
33%	9.96 ± 0.03 ^a	0.60 ± 0.05 ^c	12.78 ± 0.30 ^b	2.06 ± 0.03 ^a	1.18 ± 0.04 ^a
66%	10.16 ± 0.17 ^a	0.67 ± 0.04 ^b	13.55 ± 0.26 ^a	2.04 ± 0.06 ^a	1.20 ± 0.04 ^a
100%	10.35 ± 0.05 ^a	0.73 ± 0.06 ^a	14.10 ± 0.26 ^a	2.04 ± 0.05 ^a	1.22 ± 0.03 ^a
Cooked					
Control	9.91 ± 0.07 ^a	0.42 ± 0.02 ^d	11.17 ± 0.85 ^c	1.96 ± 0.02 ^a	1.10 ± 0.02 ^a
33%	10.07 ± 0.10 ^a	0.56 ± 0.01 ^{bc}	12.36 ± 0.47 ^{bc}	1.92 ± 0.01 ^b	1.10 ± 0.03 ^a
66%	10.31 ± 0.06 ^a	0.58 ± 0.04 ^{ab}	13.11 ± 0.20 ^{ab}	1.85 ± 0.02 ^c	1.09 ± 0.10 ^a
100%	10.46 ± 0.06 ^a	0.61 ± 0.05 ^a	13.83 ± 0.62 ^a	1.83 ± 0.02 ^c	1.06 ± 0.05 ^a

Value represents mean ($n = 3$) ± SD. Values having different superscripts from a to f show significant variation among the level of enrichment.

TABLE 4: Antioxidant properties and bioactive compounds of uncooked and cooked wheatgrass-juice-incorporated pasta.

Uncooked Level WGJ	DPPH (%) RSA	FRAP (mg FeSO ₄ equivalent/100 g)	ABTS (%) RSA)	Total phenolic content (mg GAE/100 g)	Total flavonoid content (mg QE/100 g)	Chlorophyll a (mg/100 g)	Total chlorophyll (mg/100 g)
Control	21.76 ± 1.46 ^d	39.54 ± 1.52 ^d	19.20 ± 1.23 ^d	31.13 ± 1.05 ^d	44.26 ± 1.80 ^d	0.88 ± 0.08 ^d	1.06 ± 0.11 ^d
33%	26.63 ± 1.08 ^c	69.78 ± 1.16 ^c	24.31 ± 1.67 ^c	61.60 ± 3.18 ^c	58.56 ± 1.47 ^c	4.97 ± 0.60 ^c	8.08 ± 0.54 ^c
66%	32.01 ± 1.01 ^b	108.7 ± 1.80 ^b	31.72 ± 1.32 ^b	72.31 ± 1.93 ^b	65.71 ± 1.38 ^b	8.78 ± 0.92 ^b	13.49 ± 0.55 ^b
100%	36.74 ± 1.52 ^a	135.2 ± 3.84 ^a	35.74 ± 1.36 ^a	85.28 ± 3.39 ^a	77.18 ± 1.87 ^a	13.03 ± 0.63 ^a	17.88 ± 1.01 ^a
Cooked							
Control	17.57 ± 1.00 ^d	24.23 ± 1.23 ^d	15.08 ± 3.15 ^d	20.52 ± 0.76 ^d	27.78 ± 1.16 ^d	0.89 ± 0.05 ^d	0.75 ± 0.20 ^d
33%	21.36 ± 1.06 ^c	42.26 ± 1.57 ^c	17.85 ± 1.00 ^c	37.91 ± 1.03 ^c	35.20 ± 1.07 ^c	4.86 ± 0.15 ^c	8.77 ± 0.24 ^c
66%	26.85 ± 1.11 ^b	72.88 ± 2.70 ^b	24.96 ± 1.01 ^b	51.85 ± 1.96 ^b	42.78 ± 2.50 ^b	9.69 ± 0.80 ^b	15.17 ± 1.08 ^b
100%	30.37 ± 1.21 ^a	86.77 ± 1.93 ^a	28.96 ± 0.76 ^c	63.79 ± 1.69 ^a	49.65 ± 0.70 ^a	13.26 ± 0.70 ^a	20.51 ± 0.74 ^a

Value represents mean ($n = 3$) ± SD. Values having different superscripts from a to f show significant variation among the level of enrichment.

reported by Sipos et al. [15] and Mridula et al. [16] in beetroot juice and carrot juice containing pasta, respectively. Except for the chlorophyll level in cooked pasta, all parameters showed a significant ($p < 0.05$) decrease. After cooking, DPPH radical scavenging activity decreased by 16.1–19.7%; FRAP value decreased by 32.9–39.4%; ABTS radical cation scavenging activity decreased by 18.9–26.5%; TPC decreased by 25.1–38.4%; and total flavonoid content decreased by 34.8–39.8%, respectively, in the cooked pasta (Table 4). The bioactive compounds are not heat stable; they gets degraded during heating and also leach out into cooking water during the boiling of food product [37, 38]. Total phenols and flavonoids present in WGJ are not heat-stable, and moreover, during looking, these compounds are lost in cooking water resulting in a decrease of these compounds after cooking. Similar results of the loss of bioactive and antioxidant properties were reported in olive pomace [9] and grape pomace [39] incorporated pasta.

3.4. Color Characteristics. Product color gives an indication of the nature and quality of ingredients of food product and also influences consumer acceptability [7]. The results showed that by increasing the level of WGJ integration from 0 to 100%, the uncooked pasta's L^* value declined from 89.16 to 84.26 (Table 5). This is due to an increase in the chlorophyll content of the product as WGJ is added, which enhances the greenness shade as the amount of WGJ

incorporation is increased. The pasta's L^* value was adversely correlated with its total chlorophyll content ($r = 0.967$; $p < 0.05$). In the cooked pasta, L^* value was reduced from 17.5 to 20.9% as compared with uncooked pasta. This may be due to the reason that the pigment chlorophyll was released more after cooking [8], which darkens the cooked pasta's color. Coherent results of a decrease in L^* value were reported by Jeong et al. [17] in radish-juice-incorporated pasta. Positive a^* value signifies red color, and negative a^* value signifies green color [40]. With the addition of WGJ from 0 to 100%, a^* value significantly ($p < 0.05$) increased from -0.10 to -3.27 (Table 5) in the uncooked pasta; the increment in the negative value of a^* signifies that the intensity of the green color increased. In the cooked pasta, as compared to uncooked pasta, a 15.9–23.0% reduction was found in a^* value after cooking. The a^* value of pasta was positively correlated with the concentration of TPC ($r = 0.986$) and total chlorophyll ($r = 0.955$; $p < 0.05$; Table 2) content of pasta. Poonsri et al. [41] also reported a similar trend of a^* value with the addition of cassava leaves in rice noodles. The b^* value of the uncooked pasta increased significantly ($p < 0.05$) from 12.53 to 16.32 (Table 5) with an increase in the level of inclusion of WGJ. In the cooked pasta, as compared to uncooked pasta, a 5.4 to 25.9% reduction was observed after cooking. The change in b^* value in cooked pasta is possibly related to pasta swelling and pigment conversion after cooking [42]. Overall color difference (ΔE) of the pasta enhanced significantly ($p < 0.05$) from 2.79 to

TABLE 5: Color characteristics of uncooked and cooked wheatgrass-juice-incorporated pasta.

Uncooked Level WGJ	L^*	a^*	b^*	Hue angle ($^\circ$)	Chroma	ΔE
Control	89.16 \pm 0.19 ^a	-0.10 \pm 0.04 ^d	12.53 \pm 0.09 ^d	89.54 \pm 0.21 ^a	12.53 \pm 0.09 ^d	—
33%	88.49 \pm 0.24 ^b	-2.30 \pm 0.05 ^c	14.09 \pm 0.41 ^c	80.72 \pm 0.17 ^b	14.27 \pm 0.41 ^c	2.79 \pm 0.25 ^c
66%	86.92 \pm 0.68 ^c	-2.93 \pm 0.07 ^b	15.23 \pm 0.24 ^b	79.10 \pm 0.38 ^c	15.51 \pm 0.23 ^b	4.53 \pm 0.40 ^b
100%	84.26 \pm 0.41 ^c	-3.27 \pm 0.01 ^a	16.32 \pm 0.08 ^a	78.66 \pm 0.07 ^c	16.64 \pm 0.08 ^a	6.96 \pm 0.29 ^a
Cooked						
Control	73.55 \pm 0.37 ^a	-0.95 \pm 0.14 ^d	13.25 \pm 0.77 ^c	85.89 \pm 0.74 ^a	13.28 \pm 0.47 ^d	—
33%	70.72 \pm 0.77 ^b	-2.91 \pm 0.08 ^c	18.85 \pm 0.49 ^b	81.20 \pm 0.31 ^b	19.08 \pm 0.49 ^c	6.62 \pm 0.18 ^c
66%	69.01 \pm 0.75 ^c	-3.58 \pm 0.06 ^b	20.56 \pm 0.28 ^a	80.10 \pm 0.17 ^c	20.87 \pm 0.28 ^b	9.00 \pm 0.62 ^b
100%	66.63 \pm 0.48 ^d	-3.89 \pm 0.08 ^a	21.39 \pm 0.04 ^a	79.67 \pm 0.20 ^c	21.74 \pm 0.05 ^a	11.09 \pm 0.33 ^a

Value represents mean ($n = 3$) \pm SD. values having different superscripts from a to f show significant variation among the level of enrichment.

TABLE 6: Textural attributes of uncooked and cooked wheatgrass-juice-incorporated pasta.

Uncooked Level WGJ	Firmness (kg)	Toughness (kg.s)
Control	1.08 \pm 0.03 ^c	0.89 \pm 0.04 ^b
33%	1.17 \pm 0.06 ^c	0.98 \pm 0.03 ^b
66%	1.28 \pm 0.05 ^b	1.08 \pm 0.02 ^a
100%	1.51 \pm 0.03 ^a	1.15 \pm 0.06 ^a
Cooked		
Control	0.30 \pm 0.03 ^a	1.69 \pm 0.05 ^a
33%	0.28 \pm 0.02 ^a	1.42 \pm 0.06 ^b
66%	0.26 \pm 0.02 ^a	1.30 \pm 0.05 ^{bc}
100%	0.24 \pm 0.02 ^a	1.24 \pm 0.05 ^c

Value represents mean ($n = 3$) \pm SD. Values having different superscripts from a to f show significant variation among the level of enrichment.

6.96 (Table 5) with an increment of WGJ from 0 to 100%. After cooking, there was a 37.2 to 57.8% increase in ΔE value in the cooked pasta in comparison to uncooked pasta. This increase was attributed to an increase in chlorophyll content after cooking as shown in Table 4. Overall color difference (ΔE) was positively correlated with TPC ($r = 0.982$; $p < 0.05$), total flavonoid content ($r = 0.999$; $p < 0.05$), and total chlorophyll content ($r = 0.995$; $p < 0.05$; Table 2) of the pasta. This difference in color difference may be due to changes occurring in bioactive compounds, which can occur as a result of either breakdown or leaching these compounds into the cooking water [43].

3.5. Textural Attributes. The texture of the pasta is a key factor in judging the overall quality of the pasta. When compared to the sensory approach of texture, the texture analyzer is more relevant and recommended [11, 44, 45]. In uncooked pasta, firmness increased significantly ($p < 0.05$) from 1.08 to 1.51 kgf (Table 6) as the incorporation level of WGJ enhanced from 0 to 100%. This rise is ascribed to the addition of WGJ to the pasta, which increased the protein level that in turn influences the firmness of the pasta resulting in a dense protein matrix within the pasta samples [46]. Jeong et al. [17] reported similar results of firmness with the incorporation of radish juice into pasta. After cooking, cooked control pasta exhibited maximum firmness value (0.30 kgf; Table 6), and it declined nonsignificantly ($p < 0.05$) from 0.28 to 0.24 kg (Table 6) with an increased inclusion level of WGJ from 33 to 100%. This may be ascribed to the gluten network's dilution due to the addition of

WGJ that leads to weakness in the pasta structure after cooking [9]. Similar results of the decline in firmness after cooking were testified by Najeeb et al. [47] with the inclusion of fenugreek leaves (*Trigonella foenum-graecum* L.) puree in pasta. The value of toughness for uncooked pasta was increased nonsignificantly ($p < 0.05$) from 0.89 to 1.15 kg.s (Table 6) with an increment of WGJ from 33 to 100%. The increase in the toughness value is attributed to the more firmness of the pasta because a stronger force is needed to rupture the firmer pasta. Najeeb et al. [47] showed similar findings for uncooked pasta toughness with the addition of fenugreek leaves (*T. foenum-graecum* L.) puree. The toughness value for control cooked pasta was 1.69 kg.s, while the toughness value decreased from 1.42 to 1.24 kg.s as the level of WGJ incorporation rose (Table 6). This confirms that more energy is needed to rip up the control pasta's structure as compared to other pasta because the gluten network was weak in WGJ-incorporated pasta after cooking. The gluten network weakens because WGJ addition increases the acidity that makes starch structure porous [48] and thus absorbs more water, which in turn decreases water availability for gluten matrix development.

3.6. FTIR Analysis of Wheatgrass-Juice-Incorporated Pasta. FTIR analysis results are shown in Figure 1. FTIR spectra profile is the molecular fingerprint of the sample that is used to screen and scan many different components. It is one of the effective methods to detect functional groups present in the sample [49–51]. FTIR spectroscopy of different pasta samples showed that WGJ enrichment did not significantly

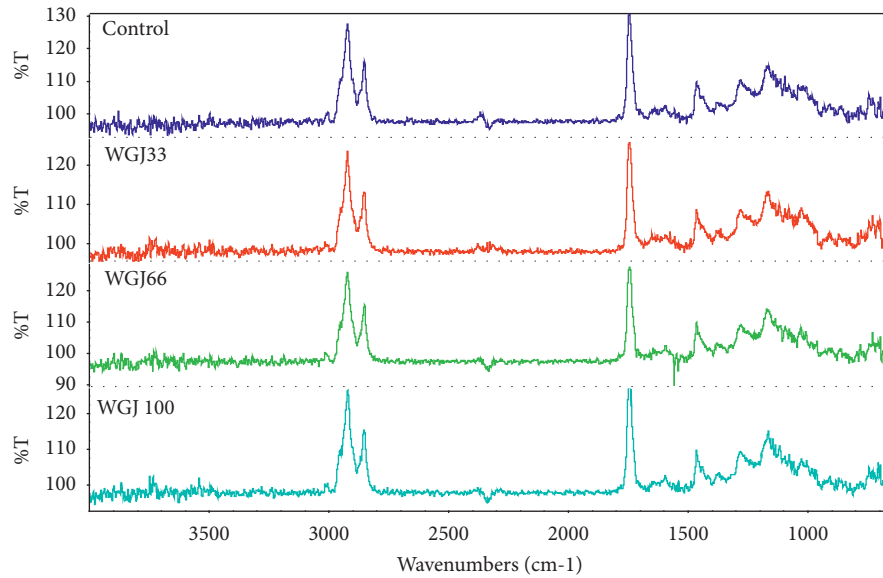


FIGURE 1: FTIR spectra of wheatgrass-juice-incorporated pasta (0, 33, 66, and 100%).

affect the configuration of functional groups. Most of the transmittance bands were nearly observed at 1,000, 1,650, 2,350, 2,360, 2,950, 3,500, 3,650, 3,750, and 3,950 cm^{-1} regions in most samples. For all of the samples, distinctive peaks of C–H, C–O, and C=C bonds indicate the existence of phenolic chemicals. Peaks at 1,000 cm^{-1} areas, which essentially correspond to the stretching of C–O–H vibrations, were detection of the amorphous condition of starch granules [52]. The peaks near 1,650 cm^{-1} were mostly an indication of the presence of peak concentration of the amide I band area that was caused by the increased protein matter of WGJ included pasta [53]. The absorbance peaks near 2,350, 2,360, and 2,950 cm^{-1} correspond to CN and N–H bond stretching vibrations. Peaks between 3,200 and 3,650 cm^{-1} were linked to the stretching vibration of the O–H bond, whereas peaks relating 3,700 and 3,900 cm^{-1} indicate the presence of the O–H group. In WGJ-containing samples, a strong peak at 1,662.7 cm^{-1} was seen, indicating C=O stretching, which suggested the presence of chlorophyll content, as well as infrared absorption of phenolics [54].

3.7. Microstructure Analysis. A scanning electron microscope (SEM) uses a focused electron beam over the sample surface to get a clear image of the microstructure. These electrons interact with the sample, resulting in a variety of signals in order to gather information about the sample's surface composition and whole chorography [55]. The microstructure of control and WGJ pasta samples (uncooked and cooked) was studied using the SEM, and alterations were observed in protein network and starch granules in samples with the increment of WGJ (Figure 2). Nearly in all uncooked pasta sample's similar structure was observed, circular starch granules merged in the smooth protein matrix. Irregularities were noticed in protein-merged starch granules in 33%, 66%, and 100% WGJ-

containing pasta samples (Figures 2(c), 2(e), and 2(g)) as compared to control (Figure 2(a)) that showed a more distinct image. Due to interference in structure caused by WGJ addition, SEM images of WGJ included (Figures 2(c), 2(e), and 2(g)) samples revealed a higher uneven and irregular surface matrix with a large number of holes and cracks in comparison to control sample (Figure 2(a)), but generally, the matrix seems smooth. Shrinkage during the extrusion process, as well as an increase in surface tension during drying, resulted in cracks and small holes in the matrix [33]. Due to these irregularities, the structure of pasta becomes brittle, and moreover, the cracks increase the water absorption capacity of pasta [8]. Kowalczewski et al. [18] on the addition of potato juice into pasta noticed disruptions in the protein matrix of SEM pictures. The swollen and gelatinized starch granules were seen in cooked pasta (Figures 2(b), 2(d), 2(f), and 2(h)). Cooked control pasta showed a well-developed gluten network with embedded gelatinized starch granules and a smooth surface (Figure 2(a)) in comparison to others. This could be owing to the fact that pasta strands expand during cooking, causing stress to be conveyed to the enclosing protein film, which smooths the pasta surface [33]. The uneven shape of cooked pasta containing 33, 66, and 100% WGJ could be attributed to gluten matrix rupture and WGJ particle interference in starch swelling (Figures 2(d), 2(f), and 2(h)) [56].

3.8. Sensory Attributes. Sensory characteristics are important aspects of consumer acceptance of a product. Nine-point hedonic scales are considered as the best method for sensory evaluation because of their reliable and valid results [57]. On a nine-point hedonic scale, the prepared food product was rated. In comparison to control pasta, the appearance, color, flavor, taste, texture, and general acceptability of the wheatgrass juice enhanced pasta were evaluated. Control pasta showed sensory score of

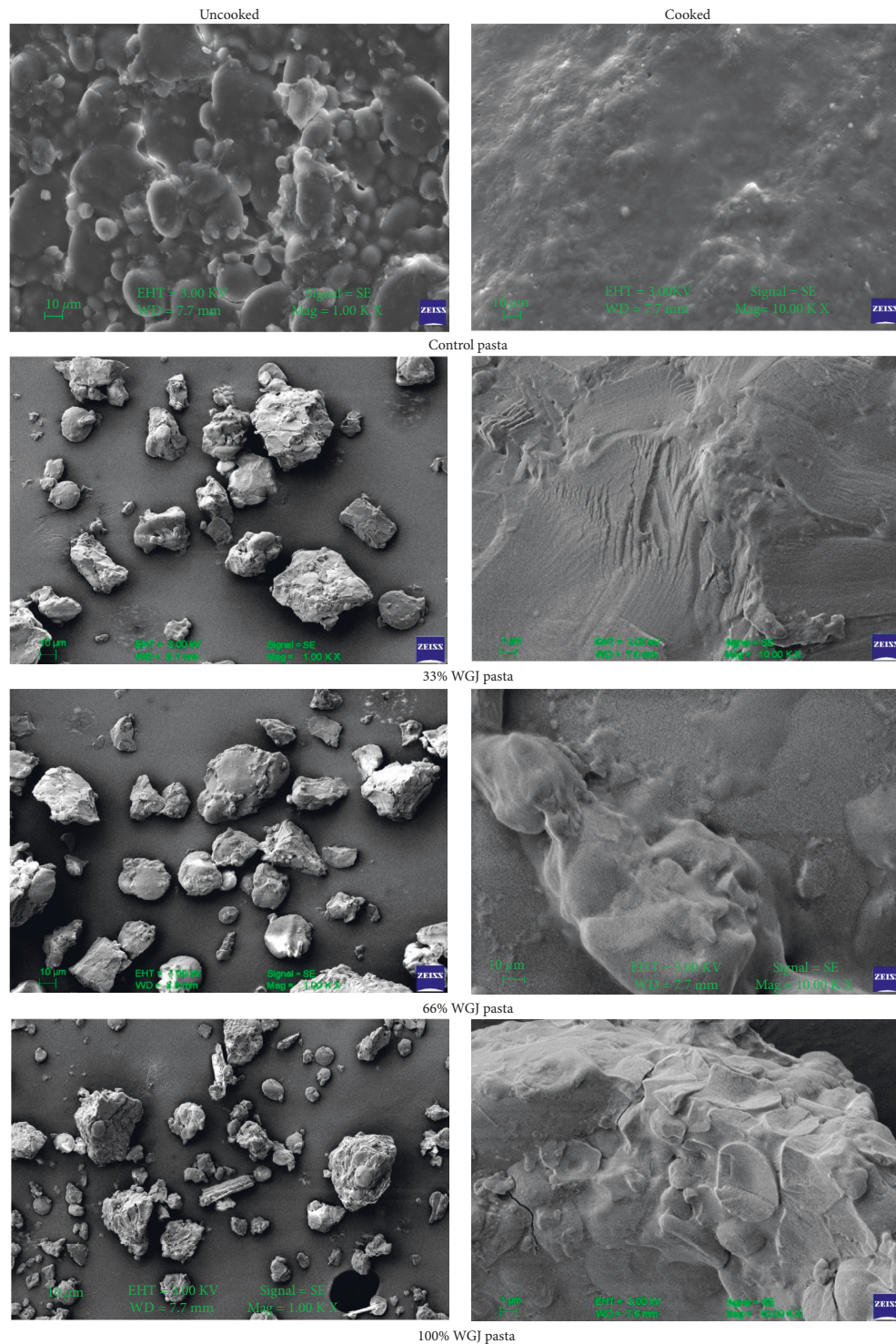


FIGURE 2: Microstructure of wheatgrass juice incorporated pasta.

appearance (7.42 ± 0.50), color (7.50 ± 0.52), flavor (7.50 ± 0.52), taste (7.43 ± 0.51), texture (7.50 ± 0.52), and overall acceptability (7.50 ± 0.52 ; Figure 3). Results do not vary significantly in all sensory scores as compared to control pasta, but pasta containing WGJ was found better as compared to control pasta in terms of all parameters. The best score for all the parameters was found in 100% of WGJ-

containing pasta with sensory scores for appearance (7.64 ± 0.49), color (7.64 ± 0.63), flavor (7.71 ± 0.46), taste (7.64 ± 0.49), texture (7.71 ± 0.46), and overall acceptability (7.66 ± 0.39 ; Figure 3). Coherent results for sensory evaluation are observed by Devi et al. [19] with an increase of WGJ in milk (0–9% WGJ) and by Sipos et al. [31] with an incorporation of beetroot juice into pasta (8–16%).

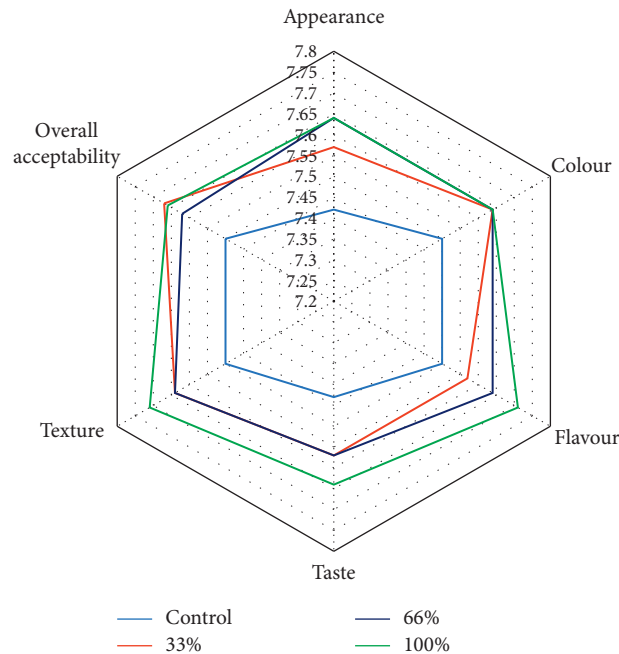


FIGURE 3: Sensory evaluation scores of wheatgrass-juice-incorporated pasta.

4. Conclusion

On the basis of the study, it is recommended that functional pasta enriched with wheatgrass juice (100%) can be successfully prepared without compromising the technical quality characteristics of pasta and with better consumer acceptability. From its findings, it can be concluded that adding 100% WGJ to pasta instead of water increased the firmness, volume expansion, antioxidant components, and water absorption capacity. However, this also increased the cooking loss, which is still within acceptable bounds. The structural analysis of the samples shows that the porosity of pasta samples increased with an increasing amount of WGJ. Overall, WGJ-incorporated pasta is a very good option of low-cost nutritional and bioactive compound-rich functional food. There is a need to shift consumer trends towards the utilization of food products with functional food ingredients, helping to modulate their dietary pattern.

Data Availability

The data that support the findings of this study are available from the corresponding authors upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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