

## Underutilized horse chestnut (*Aesculus indica*) flour and its utilization for the development of gluten-free pasta

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Received: 11 June 2021; Accepted: 18 September 2021; Published: 7 October 2021

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### Abstract

There has been a growing demand for the production of gluten-free products due to increased occurrence of celiac disease. Thus, different research groups have been investigating the use of various available materials for the development of these functional products to fulfill customer's needs. Horse Chestnut (*Aesculus indica*) seeds are underutilized, low-cost, and gluten-free, found in hilly areas of the Himalayan region of Kashmir valley, India. To determine their potential as an alternative to conventional food grains, an investigation was conducted to determine the physicochemical, functional, pasting, and thermal properties of Horse Chestnut (HCN) flour and its compatibility for the development of gluten-free pasta. HCN flour comprised 73.34% carbohydrate, 11.36% protein, 6.34% crude fiber, 3.27% fat, 3.16% ash, 3.15g/g oil absorption capacity, and 4.65% water absorption index. HCN flour showed 505 cp peak, 354 cp trough, 151 cp breakdown, 472 cp final viscosity, and 66.05°C pasting temperature. Transition temperatures (onset, peak, and conclusion) and enthalpy change ( $\Delta H$ ) were 60.12°C, 69.90°C, 81.53°C, and 10.56 J/g, respectively. Pasta prepared from HCN flour using guar gum (0, 0.5, and 1%) was analyzed for color, cooking qualities, and textural and sensory analysis. The present results showed that HCN flour possesses good nutritional quality and has properties comparable to conventional wheat flour. Therefore, HCN-flour-based pasta can act as a nutritious alternative to conventional gluten-free pasta and add variety to the diet of people suffering from celiac disease.

**Keywords:** celiac disease; cooking; horse chestnut; nonconventional; nutritional; pasta

### Introduction

Horse Chestnut (*Aesculus indica*) is abundantly found in hilly areas of the Himalayan region of Kashmir valley, India. The seeds of the tree are harvested during October and November. Horse Chestnut (HCN) seeds are mainly consumed by wild animals and many seeds are wasted. The seeds are kept in running water to reduce the bitterness attributed to the presence of anti-nutrients and then added in powdered form to wheat flour

for making *Halwa* (porridge) and *chapattis*, a traditional flatbread (Rajeasekaran and Joginder, 2009). HCN seeds can be used as nutritional supplements because they are nutritionally good and have a distinctive composition of carbohydrate, crude protein, fat, and ash. Oleic acid, linoleic acid, palmitic acid, linolenic acid, arachidic acid, and myristic acid are the major fatty acids present in the HCN seed. The chief minerals present in HCN include potassium, phosphorus, calcium, sulfur, iron, copper, zinc, and manganese (Majeed *et al.*, 2010). The seeds

also have several medicinal uses like in the treatment of fever, viral diseases, skin infections, and cardiovascular disorders (Kaur *et al.*, 2011). HCN seeds are rich in polyphenols, flavonoids, fiber, and essential minerals (Majeed *et al.*, 2010).

Pasta, a traditional delicacy, is a popular staple food used throughout the world because of its low cost, longer shelf life, and ease of preparation. Commonly, wheat flour is used in the preparation of pasta (Kaur *et al.*, 2012). Pasta food products are produced by extruding feed mixture in an extruder equipped with different dies that determine the shape of the final product. The pasta products are then dried and packed. It has been recognized as an ancient means of nourishment and versatile food from nutritive and gastronomic perspectives (Fuad and Prabhasankar, 2010). Pasta is considered a superior medium for the incorporation of nutrients as per the reports of Food and Drug Administration and World Health Organization (Pasqualone *et al.*, 2016). The selection of flour for pasta development depends on water absorption and water solubility indexes and the acceptability and cooking parameters of the developed pasta (Rudra *et al.*, 2020). The behavior of starch and protein in pasta during cooking is such that starch swells and solubilizes but protein gets coagulated during cooking (Hager *et al.*, 2012). Best-quality pasta has acceptable firmness with low solid loss, and stickiness (Phongthai *et al.*, 2017). Gluten as the structure builder promotes viscosity, elasticity, extensibility, and cohesiveness in pasta products (Lazaridou *et al.*, 2007). Gluten helps to maintain the shape of bakery products and pasta due to the extensibility and elastic dough behavior with resilience and textural properties acceptable to consumers (Phongthai *et al.*, 2017). However, due to the amplified dominance of celiac disease and other health issues such as gluten allergy, nonceliac gluten sensitivity, and other gluten-related disorders, demand for gluten-free pasta products has increased (Dib *et al.*, 2018; Ozgoren and Yapar, 2019). To avoid these disorders, grains other than wheat may be used, either individually or in combined formulation, to replace gluten in food products. The only possible treatment for individuals having celiac disease is to consume foods devoid of gluten (Witczak *et al.*, 2017). However, gluten-free products have low nutritional quality, and defective textural and sensory property due to crumbly and fragile dough formation (Cai *et al.*, 2016). Hence, to counterbalance the absence of gluten, fortification with gums, proteins, and different flours are considered (Foschia *et al.*, 2017; Padalino *et al.*, 2016). To replace gluten and to maintain the dough structure and texture of the final product, various types of protein and hydrocolloids are used in gluten-free products (Foschia *et al.*, 2017). Hydrocolloids, such as xanthan gum, guar gum, hydroxypropyl methylcellulose, and carboxymethyl cellulose used as an additive in gluten free products can

improve their textural characteristics (Lorenzo *et al.*, 2018; Palavecino *et al.*, 2017). To improve the quality attributes like mouthfeel, texture, consumer acceptability, and shelf-life of gluten-free products, diverse research has been done using alternative components like hydrocolloids, emulsifiers, starches, and nongluten proteins (Capriles *et al.*, 2016; Kumar *et al.*, 2019). The worldwide market for gluten-free food products increased up to 83% with an estimated annual growth rate of 12.3% for pasta products until 2022 (Chauvin, 2019). Gluten-free products are not only consumed by celiac patients but also by other individuals as well (Bresciani *et al.*, 2021). Researchers have been motivated by United Nations for the Agenda 2030 to research healthy formulations for bakery and pasta products and the use of functional agro-industrial by-products for fortification in foods (Simonato, 2021).

Because of its good nutritional profile and gluten-free nature, HCN flour may represent a potential nonconventional alternative to conventional flours. Only limited information is available regarding HCN flour and there are no reports about the production of gluten-free pasta from HCN flour. Therefore, it is essential to characterize the flour to explore possible utilization in food industry and to optimize the ingredients for the development of quality pasta from HCN flour. So, in the present study, characterization of HCN flour with respect to physicochemical, functional, thermal, and pasting properties, and development and characterization of pasta were carried out.

## Materials and Methods

### Raw materials

Fully matured Horse Chestnut seeds were obtained from Horse chestnut trees located at Anantnag, Jammu & Kashmir, India, cleaned and stored at 5°C till used. Hard wheat was procured from Punjab Agriculture University (Ludhiana). The chemicals and reagents were procured from Sigma-Aldrich.

### Flour preparation

Horse Chestnut flour was prepared with slight modification to the method of Singh *et al.* (2013). The kernels obtained after manual dehulling of HCN seeds were sliced and then dried in a tray dryer at 60°C. The slices before drying were treated to reduce the anti-nutritional factors in the previous work of RAFIQ *et al.* (2016). The dried seed slices were ground in a laboratory-type grinder to obtain HCN flour. Both wheat and HCN flours were sieved using a 60-mesh sieve. HCN and wheat flour were then analyzed for various properties.

## Physicochemical characteristics of HCN flour

### Color analysis

Flour color analysis was done in triplicates, with Color Flex Spectro-colorimeter (D-25, Ruston, USA), and color values ( $L^*$ ,  $a^*$ , and  $b^*$ ) were determined.

### Proximate analysis

Standard methods were employed to analyze the flour samples for moisture, protein, ash, fiber, and fat content (AOAC, 2006), while the carbohydrate content was determined using the difference method.

### Bulk density

An accurately weighed sample was poured into a graduated cylinder. Tapping during the filling was done for uniform packing. Bulk density was calculated using the below equation:

$$\text{Bulk density (g/cm}^3\text{)} = \frac{\text{Weight of the sample (g)}}{\text{Volume of sample (cm}^3\text{)}}$$

### True density

The method followed by Raigar and Mishra (2015) was used to determine true density. An accurately weighed flour sample (1 g) was taken and poured into a burette filled with toluene. The equation given below was used to calculate true density:

$$\text{True density (g/cm}^3\text{)} = \frac{\text{Weight of flour sample (g)}}{\text{Rise in toluene level (cm}^3\text{)}}$$

## Functional properties

### Water absorption capacity

Water absorption capacity (WAC) of the flour was determined per Vázquez-Luna *et al.* (2019) with slight modifications. Approximately, 5 g of the sample was mixed with 70 mL of water for 1 min and then held at room temperature for 30 min, followed by centrifugation ( $3000 \times g$  for 15 min). After centrifugation, the sediment obtained was weighed and WAC was calculated:

$$\text{WAC(g/g)} = \frac{\text{Weight of sediment}}{\text{Weight of flour sample}}$$

### Oil absorption capacity

The method followed by Khan and Saini (2016) was used to determine the oil absorption capacity (OAC) of the sample. Five grams of flour and 75 mL of oil were mixed and agitated for 30 min and then centrifuged for 10 min at  $3000 \times g$ . Afterward, oil was drained while the retained

sample was weighed to calculate OAC as shown in the below equation:

$$\text{OAC (g/g)} = \frac{\text{Weight of residue}}{\text{Sample weight}}$$

### Emulsion properties

The emulsion activity and stability of samples were calculated by using the method of Du *et al.* (2014). Sample (3.5 g) and water (50 mL) were agitated for 30 s using the high setting homogenizer (Yorco, India). Afterward, groundnut oil (25 mL) was added and then again homogenized for 30 s, followed by another addition of 25 mL groundnut oil and then homogenized for 90 s. The emulsion obtained was then centrifuged for 5 min at  $1100 \times g$ .

#### Emulsion activity (%)

$$= \frac{\text{Volume of emulsified layer}}{\text{Emulsion volume before centrifugation}} \times \text{Emu}$$

After calculating the emulsion activity, emulsion stability was evaluated by heating the flour emulsion samples (15 min at  $85^\circ\text{C}$ ), then cooling, followed by centrifugation for 5 min at  $1100 \times g$ . The percent emulsion activity that remained after heating can be expressed as the emulsion stability.

### Foaming properties

The foaming properties, viz., foaming capacity (FC) and foaming stability (FS), were observed with minor modifications to the method followed by Jia *et al.* (2021). Sample (3 g) and distilled water (50 mL) were mixed, and the dispersion was homogenized for 3–5 min. The mixture was then instantly poured into the measuring cylinder and the increase in volume percent upon whipping was calculated. The percentage of volume increase was the foaming capacity and the change in the foam volume after 1 h of storage was recorded as the foaming stability.

FC and FS were calculated using the below mentioned formulas:

$$\text{FC(\%)} = \frac{V_2 - V_1}{V_2} \times 100$$

$$\text{FS(\%)} = \frac{V_3}{V_2 - V_1} \times 100$$

where,  $V_1$  = volume prior to whipping (mL),  $V_2$  = foam volume after whipping (mL), and  $V_3$  = foam volume (mL) after holding

### Least gelation concentration (LGC)

The method of Khan and Saini (2016) was used to determine the gelation properties of the flour samples. Two

percent, 4, 6, 8, 10, 12, 14, 16, 18, and 20% (w/v) of flour suspensions in 5 mL of water were boiled for 1 h, cooled in cold water, and kept at 4°C for 2 h.

### Pasting characteristics

Rapid Visco Analyzer (TecMaster, Warriewood, Australia) was used for the determination of the pasting profile. A programmed heating and cooling cycle (taking sample 3 g, 14% mb; and distilled water 25 mL) was used for generating the viscosity profile. Experimental conditions include holding the samples for 1 min at 50°C, heating to 95°C at 12°C/min cooling rate, holding for 2.5 min at 95°C, cooling to 95 to 50°C at 12°C/min heating rate, and then holding for 2 min at 50°C.

### Thermal properties

A differential scanning calorimeter (DSC821, Mettler Toledo, Switzerland) was involved in determining thermal properties of the sample. The samples were prepared with flour (3mg, dwb) and water (7 µl), sealed, and kept undisturbed at room temperature for 1 h. The sample was heated at 20–120°C at a rate of 10°C/min.

### Pasta preparation

Different pasta formulations (control sample (durum wheat); native sample (HCN flour + 0% gum); pasta formulation containing HCN flour and 0.5 and 1% guar gum, respectively) were mixed using Hobart benchtop mixer (5KPM50, USA) for 1 min at low speed followed by conditioning for 5 min with distilled water (30 mL). The sample was fed to a single screw extruder (Model: Dolly La Monferrina Italy) of 7 mm die diameter. Pasta was then transferred to cabinet drier for 4 h set at 60°C, reducing the moisture content to 8%, and then packed in high-density polyethylene pouches.

### Characterization of pasta

#### Color parameters

Color parameters of pasta were determined using a color spectrophotometer (CM-3600d, Konica Minolta, Bremen, Germany). Color analysis was done in terms of  $L^*$ ,  $a^*$ , and  $b^*$  values.

#### Cooking properties

Cooking time was evaluated by using the AACC (2000) method. Pasta sample (10 g) was cooked in water (300 mL). The optimum time of cooking is the point of disappearance of the inner white core of pasta and was

observed by squeezing the pasta between glass plates. The weight of the cooked pasta after being drained for 2 min was taken as the cooked weight (g). The cooking loss was calculated by evaporation of cooking water to dryness at 110°C overnight.

#### Water uptake

Water uptake is the difference between the weight of cooked and uncooked samples, and is expressed as uncooked pasta weight percentage (Çabuk and Yilmaz, 2020). The investigation indicated the absorption of water during the cooking process.

#### Cooking loss

The method followed by Teterycz *et al.* (2020) was employed for cooking loss determination. Sample (10 g) was cooked in boiling water (300 mL) and then cooking water was dried overnight (105°C). The residue left after drying was weighed and then cooking loss was calculated.

#### Texture

For determination of texture, the samples were cooked till optimum cooking time, and then drained with 10 min rest time. Four pasta strands were taken and placed under the compression plate of pasta firmness/stickiness rig. The resulting force-time curve was used to determine firmness, cohesiveness, springiness, adhesiveness, chewiness, and gumminess.

#### Sensory evaluation

Panel comprising 12 trained members have done the sensory evaluation of pasta samples; evaluated the attributes like firmness, slipperiness, chewiness, surface adhesiveness, appearance; and determined the total score for each pasta sample. Perceived intensities were scored on a 5-point scale.

### Statistical analysis

The experimental data was statistically analyzed by One-way ANOVA using triplicate readings for all experiments except sensory evaluation where 12 observations were averaged.

## Results and Discussion

### Physiochemical properties of HCN flour

The desired color characteristics for the flour are low chroma ( $a^*$ ) value and high lightness ( $L^*$ ) value to meet the consumer preference. The color parameters and nutritional composition of HCN and wheat flour are given in Table 1. Results showed that the  $L^*$  value of the flours was almost similar; however, significant difference

Table 1. Physicochemical characteristics.

Physicochemical	Horse Chestnut flour	Wheat flour
<i>Color</i>		
L*	92.07 ± 0.49 <sup>a</sup>	92.85 ± 0.28 <sup>a</sup>
a*	3.47 ± 0.21 <sup>a</sup>	2.03 ± 0.07 <sup>b</sup>
b*	13.70 ± 0.26 <sup>a</sup>	9.69 ± 0.15 <sup>b</sup>
Moisture content (%)	9.71 ± 1.23 <sup>b</sup>	11.35 ± 0.54 <sup>a</sup>
Protein (%)	7.78 ± 1.19 <sup>b</sup>	11.36 ± 1.10 <sup>a</sup>
Crude fat (%)	3.27 ± 0.39 <sup>a</sup>	1.40 ± 0.57 <sup>b</sup>
Crude fiber (%)	6.34 ± 0.22 <sup>a</sup>	1.67 ± 0.14 <sup>b</sup>
Ash (%)	3.16 ± 0.05 <sup>a</sup>	0.88 ± 0.03 <sup>b</sup>
Carbohydrate (%)	69.74 <sup>b</sup>	73.34 <sup>a</sup>
Energy value (Cal/100g)	327.51 <sup>b</sup>	346.84 <sup>a</sup>
Bulk density (g/mL)	0.64 ± 0.12 <sup>a</sup>	0.51 ± 0.10 <sup>a</sup>
True density (g/mL)	1.25 ± 0.24 <sup>a</sup>	1.42 ± 0.12 <sup>a</sup>

Results presented are mean values and the superscripts significantly differ in row (P < 0.05).

was observed in a\* and b\* values. This variation in the color parameters may be ascribed to a difference in the natural pigment content inherent to HCN and wheat flours depending on the origin of the plant (Drakos *et al.*, 2017). Nutritional composition of HCN and wheat flour also varied significantly (Table 1). Moisture content of HCN flour was low (9.71%) compared to wheat flour (11.35%). Similarly, protein and carbohydrate content of HCN flour was lower than wheat flour. However, HCN flour showed significantly higher values for ash, fat, and crude fiber content than wheat flour. High ash content of HCN flour could be related to high mineral content of the HCN seeds being rich in nitrogen, potassium, phosphorus, sulfur, calcium, iron, etc. (Majeed *et al.*, 2010). The bulk density did not differ significantly in both the flours (Table 1). Similar results were observed for the true density of HCN flour (1.25 g/mL) and wheat flour (1.42 g/mL).

### Functional properties of HCN flour

#### Water absorption capacity

WAC describes the interaction of flour and water under a limited quantity of water. The WAC of flour plays a significant part in food research as it affects other determining properties of food material. HCN flour showed significantly lower values of WAC, 2.21 g/g as compared to wheat flour, 4.65 g/g (Table 2). Hydrophilic behavior and gel-forming ability of starch, and protein quality are the determining factors that affect the WAC of flour (Al-Farga *et al.*, 2016). Higher number of hydrophilic components in flour is responsible for its elevated WAC (Njintang *et al.*, 2008). The variation in the WAC

Table 2. Functional characteristics.

Properties	HCN flour	Wheat flour
WAC (g/g)	2.22 ± 0.12 <sup>b</sup>	4.65 ± 0.08 <sup>a</sup>
OAC (g/g)	3.24 ± 0.15 <sup>a</sup>	1.10 ± 0.05 <sup>b</sup>
Foaming capacity (%)	20.2 ± 1.17 <sup>b</sup>	31.40 ± 0.71 <sup>a</sup>
Foaming stability (%)	22.32 ± 2.41 <sup>b</sup>	54.05 ± 5.52 <sup>a</sup>
Emulsion activity (%)	58.69 ± 0.31 <sup>b</sup>	61.01 ± 1.33 <sup>a</sup>
Emulsion stability (%)	62 ± 0.27 <sup>b</sup>	68.32 ± 0.12 <sup>a</sup>

WAC, Water absorption capacity; OAC, Oil absorption capacity. Results presented are mean values and the superscripts significantly differ in row (P < 0.05).

behavior of the flours could be related to difference in the composition of the flour.

#### Oil absorption capacity

OAC capacity is an important property of the flour, which defines its application in various food formulations and determines its capacity to entrap oil which affects flavor retention and mouthfeel of the developed product (Khatab and Arntfield, 2009). OAC of flour is important for new product development and storage stability. Significantly higher values of OAC of 3.15 g/g in HCN flour than 1.10 g/g in wheat flour was observed (Table 2). Interaction of nonpolar side chains present in the flour with oil through hydrocarbon side chains affect their OAC (Adebowale and Lawal, 2004). Flour particle size, starch content, and occurrence of nonpolar amino acids are other factors that affect the OAC of flour (Chau *et al.*, 1997; Ofori *et al.*, 2020). Also, the protein type and content contribute to oil-retaining properties of the foods (Ravi and Sushelamma, 2005).

#### Foaming properties

The foaming properties are essential parameters for the formulation of food products. Results related to foaming capacity and stability of HCN, and wheat flour is given in Table 2. Carbohydrate and protein content play an important role in determining the foaming properties of flour (Sreerama *et al.*, 2012). Formation of interfacial layer by proteins is responsible for foaming, keeps air bubbles in suspension, and slows down coalescence rate (Adebowale and Lawal, 2004). HCN flour and wheat flour showed foaming capacity of 20.20 and 31.40%, respectively. Low-protein and high-fat content of HCN flour is responsible for lower foaming capacity of HCN flour (Siddiq *et al.*, 2010). Formation of the protein-fat complex may influence the foaming properties. Foam stability for Horse Chestnut flour (22.32%) was also lower than wheat flour (54.05%). Good foam stability is most likely associated with soluble proteins' surface activity

in continuous water phase while the presence of highly ordered globular proteins in the flour which resist surface denaturation could be related to low foamability (Du *et al.*, 2014).

#### Emulsion properties

The ability of protein to form a stable emulsion is known as emulsion activity, and it gives information about the ability of protein to occupy the interfacial layer of oil–water emulsion while the emulsion stability is related to the strength of an emulsion to stress, provided by the proteins (Singh *et al.*, 2010). Emulsion capacity and stability values of HCN and wheat flour are significantly different (Table 2). Emulsion activity and stability of HCN flour was lower (58.69 and 62%) than wheat flour (61.01 and 67.87%), which might be related to the difference in quality and content of protein. Proteins having several polar side chains make them more hydrophilic, thereby increasing the protein–water interactions, and thus affecting their emulsification properties (Yan *et al.*, 2020). The high emulsion stability depends on the globular nature of proteins in the flour. The emulsifying properties of different foods vary due to varied composition and processing conditions and the capacity of protein to form and stabilize emulsions (Adebowale *et al.*, 2005).

#### Least gelation concentration

LGC is expressed as the quantity of flour required per volume to obtain a gel. Results related to LGC of flour samples are presented in Table 3. Flour which has lower value of LGC has greater ability to form gels and low concentration of flour is required for gel formation. Higher concentration (6 g/100 mL) of HCN flour was required for initial gel formation than wheat flour (4 g/100 mL). A firm gel was obtained when using 12% of HCN flour and 10% of wheat. The difference in the gel-forming ability among various types of flours is related to different ratios of components like carbohydrates, proteins, and lipids (Drakos *et al.*, 2017). The lower LGC value of wheat flour might be related to high protein and starch content, which are responsible for gel formation (Joshi *et al.*, 2015).

#### Pasting characteristics

Pasting profile of wheat and HCN flour is depicted in Figure 1. Pasting properties play a significant part in the selection of raw materials for industrial use as a thickener, binder, etc. Rigidity of starch granules which affects swelling of starch granules and leaching of amylose in solution determine the pasting properties of the flour (Leewatchararongjaroen and Anuntagool, 2016). Compared to wheat flour (pasting temperature: 83.36°C), the pasting temperature of HCN flour was low (66.05°C). It could be the starch in HCN flour that is less resistant

**Table 3. Least gelation concentration.**

Concentration	HCN Gel	Wheat Gel
2%	No	No
4%	No	Weak
6%	Weak	Weak
8%	Weak	Weak
10%	Weak	Firm
12%	Firm	Firm
14%	Firm	Firm
16%	Firm	Hard
18 %	Hard	Hard
20%	Hard	Hard

to swelling that is responsible for the low PT of Horse Chestnut flour. The pasting temperature has also been related to the amount of protein present. Shevkani *et al.* (2015) have reported high pasting temperature with higher amount of protein in rice flour. Peak viscosity (PV) which indicates the degree of granule swelling was 505 cP for HCN flour and 1215 cP for wheat flour. The low peak viscosity could be due to high fat content in HCN flour that produces more fluid system and subsequently low viscosity. Trough viscosity was 354 cP (HCN flour) and 1005 cP (wheat flour) and depicts a decline following PV owing to swollen starch granules disruption upon high temperature and shear. Breakdown viscosity was 151 cp for HCN flour and 210 cp for wheat flour. The low breakdown viscosity indicates higher resistance to shearing at high temperature. Final viscosity (FV) was 472 cP for HCN flour and 1560 cP for wheat flour. Besides this, setback viscosity (SBV) of HCN flour (118 cp) was considerably lower than that of wheat flour (301 cP). The important factors that affect setback and final viscosities are polymerization or reordering of leached amylose and linear amylopectin (Abu *et al.*, 2006). The difference in pasting parameters of the flours could be linked to the occurrence of components such as proteins, minerals, lipids, etc., which can bind with starch, thereby affecting the pasting parameters of the flour (Ocheme *et al.*, 2018). The protein and lipid components of the flour affect the pasting properties through amylose–protein and amylose–lipid interactions (Yu *et al.*, 2012). Due to the protective effect of protein molecules on the integrity of starch granules, viscosity of corn starch paste decreased (Singh *et al.*, 2014). Difference in the viscosity of wheat flour pastes is correlated to variation in the proportion of polymeric or monomeric proteins among wheat flours (Singh *et al.*, 2016).

#### Thermal properties of HCN flour

Thermal properties are related to gelatinization behavior described as granular disruption, loss of

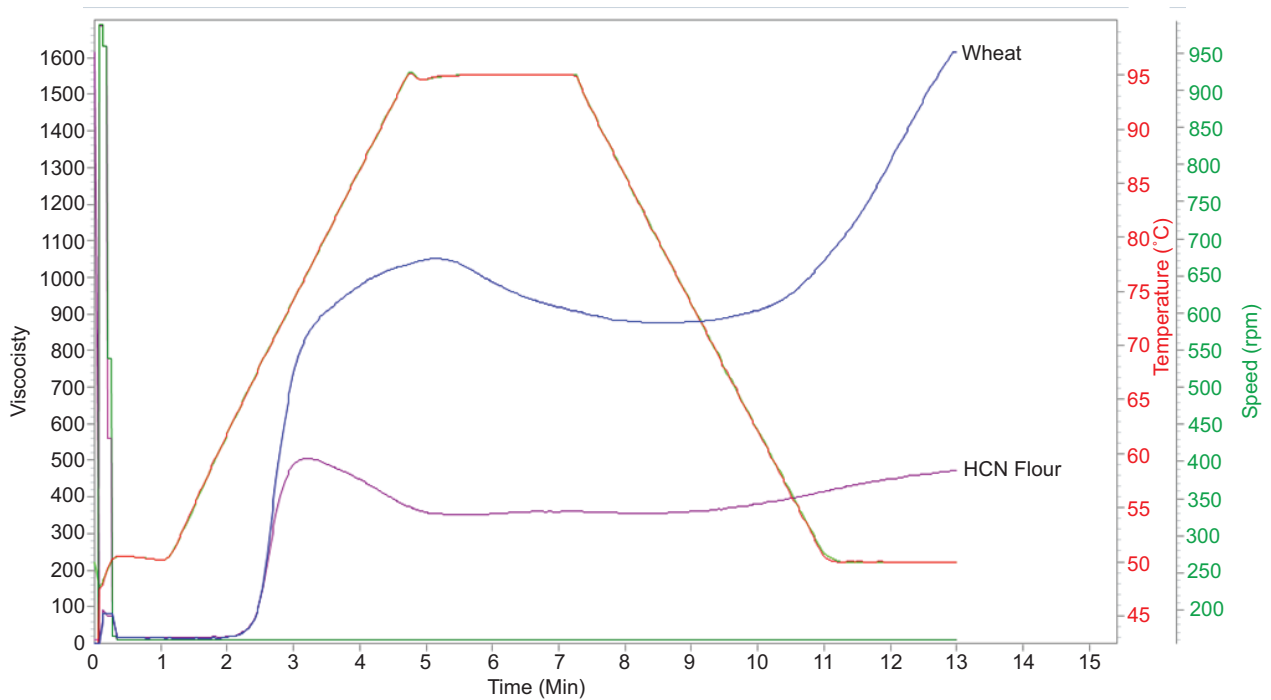


Figure 1. Pasting profile of wheat and HCN flour.

double helical and crystalline structure of starch (Rincón-Londoño *et al.*, 2016). Table 4 shows the results related to onset, peak, and conclusion temperatures, and enthalpy of gelatinization ( $\Delta H$ ) of HCN and wheat flour. Transition temperatures for HCN flour were  $T_o = 60.12$ ,  $T_p = 69.90$ , and  $T_c = 81.53$  °C while for wheat flour transition temperatures were high ( $T_o = 78.32$ ,  $T_p = 81.12$ , and  $T_c = 86.34$  °C). Starch granule size, their form and distribution, and the bonding between micellar network of the granule and other flour components are responsible for variation in transition temperatures of flours (Xu *et al.*, 2019). Enthalpy of gelatinization of 10.56 J/g was observed for HCN flour while for wheat flour, it was 13.21 J/g. Variation in the shape of starch granules, and proportion of large and small granules are the factors that affect the enthalpy of gelatinization (Kaur and Singh, 2005). The decreased gelatinization enthalpy can also be due to the disruption of crystalline regions upon depolymerization of amylose and breakdown of amylopectin.

### Color characteristics of pasta

Customer acceptance depends on the color of the product and the most desirable attribute of pasta quality is the bright yellow color (Petitot *et al.*, 2010). Color values ( $L^*$ ,  $a^*$ , and  $b^*$ ) of raw and cooked Horse Chestnut pasta, and control were significantly different (Table 5). The  $L^*$  value for Horse Chestnut pasta was less than the control pasta sample. The differences in color parameters between

Table 4. Thermal characteristics.

Parameters	Horse Chestnut flour	Wheat flour
Onset Temp. (°C)	60.12 ± 0.11 <sup>b</sup>	78.32 ± 0.98 <sup>a</sup>
Peak Temp. (°C)	69.90 ± 0.23 <sup>b</sup>	81.12 ± 0.12 <sup>a</sup>
Conclusion Temp. (°C)	81.53 ± 0.17 <sup>b</sup>	86.34 ± 0.18 <sup>a</sup>
$\Delta H$ (J/g)	10.56 ± 0.41 <sup>b</sup>	13.21 ± 0.63 <sup>a</sup>

Results presented are mean values and the superscripts significantly differ in row ( $P < 0.05$ ).

control and HCN pasta samples could be related to the inherent color of the flour and the pigments present. The addition of gum in pasta formulation at different levels showed no significant effect on pasta color. Similar effect of hydrocolloids on color characteristics of developed noodles was observed by Shere *et al.* (2020) Color values of cooked and uncooked pasta were significantly different which could be related to the leaching of pigments on cooking.

### Cooking characteristics of pasta

The cooking characteristics of pasta are influenced by numerous phenomena taking place during cooking, viz., hydration, starch gelatinization, and interaction with nonstarchy constituents. Cooking parameters for the pasta samples including cooked weight, water uptake, solid loss, and cooking time are given in Table 6. The

**Table 5. Color characteristics of raw and cooked pasta**

Sample	Raw pasta			Cooked Pasta		
	L*	a*	b*	L*	a*	b*
A	75.40 ± 2.05 <sup>a</sup>	1.30 ± 0.34 <sup>b</sup>	20.73 ± 1.2 <sup>a</sup>	70.60 ± 1.68 <sup>a</sup>	0.04 ± 0.01 <sup>a</sup>	19.34 ± 0.76 <sup>a</sup>
B	62.85 ± 1.36 <sup>b</sup>	1.49 ± 0.40 <sup>a</sup>	18.09 ± 1.83 <sup>b</sup>	55.84 ± 1.46 <sup>b</sup>	0.04 ± 0.03 <sup>a</sup>	16.10 ± 0.70 <sup>b</sup>
C	61.41 ± 1.90 <sup>b</sup>	1.35 ± 0.32 <sup>b</sup>	17.49 ± 1.31 <sup>c</sup>	56.17 ± 2.01 <sup>b</sup>	0.03 ± 0.03 <sup>a</sup>	15.50 ± 0.72 <sup>c</sup>
D	61.82 ± 1.41 <sup>b</sup>	1.38 ± 0.29 <sup>ab</sup>	18.88 ± 0.53 <sup>b</sup>	56.65 ± 1.61 <sup>b</sup>	0.02 ± 0.02 <sup>a</sup>	15.20 ± 1.61 <sup>c</sup>

Results presented are mean values and the superscripts significantly differ in column ( $P < 0.05$ ).  
Sample A: control (durum wheat); Sample B: HCN seed flour; Sample C: HCN seed flour + 0.5% gum addition; Sample D: HCN seed flour + 1% gum addition.

**Table 6. Cooking properties of pasta.**

Parameters	Sample (g)	Cooking time (min)	Cooked wt. (g/100g)	Solid loss (g/100g)	Water uptake (g/100g)
Sample A	5	5.1 ± 0.20 <sup>a</sup>	13.49 ± 0.86 <sup>a</sup>	6.9 ± 0.42 <sup>c</sup>	137 ± 7.21 <sup>a</sup>
Sample B	5	4.2 ± 0.25 <sup>bc</sup>	8.57 ± 0.12 <sup>c</sup>	16.8 ± 1.43 <sup>a</sup>	115 ± 2.65 <sup>c</sup>
Sample C	5	4.5 ± 0.40 <sup>ac</sup>	10.30 ± 0.90 <sup>b</sup>	10.6 ± 0.52 <sup>b</sup>	125 ± 3.61 <sup>bc</sup>
Sample D	5	4.8 ± 0.56 <sup>ab</sup>	12.39 ± 0.38 <sup>a</sup>	8.13 ± 0.45 <sup>c</sup>	132 ± 6.56 <sup>ab</sup>

Sample A: control durum wheat; Sample B: native Horse Chestnut flour; Sample C: 0.5% gum addition; Sample D: 1% gum addition. Results presented are mean values and the superscripts significantly differ in column ( $P < 0.05$ ) ( $n = 6$ ).

cooking time, cooked weight, and water uptake increased linearly ( $P < 0.05$ ) with gum addition in pasta formulation. Results observed are in accordance with findings of Sozer *et al.* (2007). The enhancement in water uptake with the addition of gum might be related to the accessibility of carboxyl and hydroxyl groups in gum structure, thereby increasing the water uptake of the pasta sample (Gull *et al.*, 2018). In addition, higher water uptake occurs during extended cooking time, as extra water diffuses and interacts with both protein and starch matrices. Besides this, increased affinity for water occurs because of a surge in polar amino-acid groups during cooking owing to protein denaturation (Alonso *et al.*, 2000), leading to subsequent increase in water uptake for pasta. The cooked weight of HCN pasta samples increased from 9.57/5 g to 12.39g/5 g with an increase in the concentration of gum used. The rise in cooked weight may be related to water-binding and water-holding capacity of the gum used for the preparation of pasta (Widelska *et al.*, 2019). Cooking loss is regarded a vital indicator of pasta quality. Cooking loss of pasta samples significantly decreased ( $P < 0.05$ ) with an increase in the addition of gum concentration from 0 to 1% in the pasta formulation. The decrease in cooking loss might be due to the addition of guar gum, which improved the protein network, formed a matrix with the proteins where starch granules get entrenched, and thus decreased the tendency of solid loss (Chauhan *et al.*, 2017; Martin-Esparza *et al.*, 2018). HCN pasta made with 1% gum showed comparable cooking parameters to that of the control sample. For good-quality pasta, an acceptable cooking loss is around 8% (Dick and Youngs, 1988). Hence, the HCN-flour-based pasta

containing 1% gum has a cooking loss in the acceptable range and could be considered as good quality. A desirable firmness and cooking resistance, low cooking loss, and stickiness are characteristics of high-quality pasta (Lucisano *et al.*, 2012). Studies have shown lowest cooking loss with improved physical and textural properties of gluten-free pasta prepared with 0.6% of xanthan gum concentration (Milde *et al.*, 2020). Kamsiati and Herawati (2019) observed cooking loss of 5.060% and hardness of 27.530N in cassava macaroni with guar gum addition of 0.25%.

### Textural properties of pasta

The textural assessment of pasta is an important criterion to estimate its quality and acceptance by consumers (Milde *et al.*, 2020). Textural attributes of the developed pasta are presented in Table 7. The use of gum showed significant effects ( $P < 0.05$ ) on the various textural attributes of the tested pasta samples. Firmness of the native HCN pasta sample (5.44N) was lower than the control sample (2.307N). Moreover, with the addition of gum, the firmness of HCN pasta samples increased from 2.307N to 4.297N, which might be related to an increase in the binding between protein and starch (Duda *et al.*, 2019). Adhesiveness of HCN pasta (native) was higher than control pasta while adhesiveness of HCN pasta prepared with 1% gum addition was comparable with control. Pasta adhesiveness decreased significantly ( $P < 0.05$ ) with increased gum concentration in the pasta formulation. The adhesiveness is associated with the amount of starch



**Table 7.** Textural properties of cooked pasta.

Parameters	Sample A	Sample B	Sample C	Sample D
Hardness (N)	5.44 ± 0.63 <sup>a</sup>	2.307 ± 0.10 <sup>d</sup>	3.139 ± 0.22 <sup>c</sup>	4.297 ± 0.42 <sup>b</sup>
Adhesiveness (Ns)	-0.390 ± 0.02 <sup>c</sup>	-0.202 ± 0.07 <sup>a</sup>	-0.354 ± -0.27 <sup>b</sup>	-0.398 ± 0.09 <sup>c</sup>
Cohesion	0.699 ± 0.07 <sup>a</sup>	0.470 ± 0.02 <sup>c</sup>	0.584 ± 0.07 <sup>b</sup>	0.695 ± 0.08 <sup>a</sup>
Springiness %	85.572 ± 2.34 <sup>a</sup>	53.558 ± 1.92 <sup>b</sup>	84.577 ± 3.45 <sup>a</sup>	88.060 ± 3.71 <sup>a</sup>
Gumminess	387.654 ± 4.23 <sup>a</sup>	110.460 ± 3.65 <sup>d</sup>	187.047 ± 4.27 <sup>c</sup>	304.454 ± 2.81 <sup>b</sup>
Chewiness	331.724 ± 4.45 <sup>a</sup>	59.160 ± 3.45 <sup>d</sup>	158.199 ± 2.45 <sup>c</sup>	268.101 ± 4.45 <sup>b</sup>

Sample A: control durum wheat; Sample B: native Horse Chestnut flour; Sample C: 0.5% gum addition; Sample D: 1% gum addition. Results presented are mean values and the superscripts significantly differ in row ( $P < 0.05$ ) ( $n = 6$ ).

**Table 8.** Sensory evaluation of pasta.

Parameters	Sample A	Sample B	Sample C	Sample D
Slipperiness	3.67 <sup>a</sup> ± 0.82	1.83 <sup>c</sup> ± 0.98	3.00 <sup>b</sup> ± 1.10	3.53 <sup>a</sup> ± 1.75
Firmness	4.00 <sup>a</sup> ± 1.26	1.50 <sup>c</sup> ± 0.84	2.50 <sup>b</sup> ± 1.22	3.33 <sup>a</sup> ± 0.82
Chewiness	3.50 <sup>a</sup> ± 1.97	2.67 <sup>b</sup> ± 1.52	3.00 <sup>a</sup> ± 1.51	3.57 <sup>a</sup> ± 1.26
Surface adhesiveness	3.50 <sup>a</sup> ± 1.22	1.13 <sup>c</sup> ± 1.03	2.50 <sup>b</sup> ± 1.52	3.40 <sup>a</sup> ± 1.02
Appearance	4.33 <sup>a</sup> ± 0.82	2.67 <sup>c</sup> ± 1.51	3.17 <sup>b</sup> ± 1.60	4.00 <sup>a</sup> ± 1.67
Overall sensory score	4.5 <sup>a</sup> ± 0.26	1.63 <sup>c</sup> ± 0.13	2.94 <sup>b</sup> ± 0.10	4.43 <sup>a</sup> ± 0.17

Sample A: control durum wheat; Sample B: native Horse Chestnut flour; Sample C: 0.5% gum addition; Sample D: 1% gum addition. Mean ± S.D. with different superscripts in a row differ significantly ( $P < 0.05$ ) ( $n = 12$ ).

and gelatinization of starch. Besides, addition of gum results in the development of continuous protein network, which reduces pasta adhesiveness. Padalino *et al.* (2013) and Widelska *et al.* (2019) also observed that the hydrocolloid addition to the gluten-free pasta formulation led to the decrease in adhesiveness. Other textural attributes including cohesiveness, springiness, gumminess, and chewiness also increased with the addition of gum in pasta formulation. Mirhosseini *et al.* (2015) observed a similar kind of improvement in textural attributes with the addition of polysaccharide gums to gluten-free pasta formulations. HCN-flour-based pasta made with 1 % gum show comparable textural properties with that of the control sample.

### Sensory quality of pasta

The prepared pasta samples were evaluated for appearance, firmness, chewiness, surface adhesiveness, and slipperiness by sensory panellists using a 5-point scale. The mean values of sensory attributes for pasta samples are shown in Table 8. Sensory score of native HCN pasta (Sample B) was significantly low compared to control sample (sample A), which could be related to the difference in composition and properties of their corresponding flours (Bolarinwa and Oyesiji, 2021). Among

the HCN-flour-based pasta samples, Sample B (0% gum) showed a minimum score for sensory attributes (appearance, firmness, chewiness, slipperiness, and adhesiveness) while sample D (1% gum) showed the highest score. No significant difference was observed in the sensory parameters of Sample A (control) and Sample D. Overall, sensory score of Sample D was comparable with that of the control sample. Enhancement in the textural properties of pasta with the addition of gums in pasta formulation led to an improvement in sensory quality. Shere *et al.* (2020) also observed that gum addition enhanced the overall sensory quality of the developed instant noodles.

### Conclusions

The results provide an insight about the physicochemical, functional, pasting, and thermal properties of HCN flour, and the quality characteristics of pasta made from HCN flour. The results showed significant difference between the various properties of wheat and HCN flour. Difference in the ratio of flour constituents (protein, starch, etc.) could be the reason for the difference in properties of the two flours. Cooking, textural, and sensory characteristics of HCN-flour-based pasta samples showed that good-quality pasta comparable with commercial

wheat-based pasta could be prepared from HCN flour. The study would serve as a template about the derived properties of HCN flour. Furthermore, gluten-free pasta could be made from HCN flour using appropriate proportion of gum in the production process. In addition, the study suggests that HCN flour could be used as a substitute for conventional flours for the development of gluten-free pasta. Further research should be carried out to determine the possible utilization of HCN flour in the development of other food products.

## Acknowledgments

The first author is thankful to the UGC for Maulana Azad National Fellowship.

## Conflict of Interest

The authors state no conflict of interest.

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