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ORIGINAL ARTICLE

Effect of guar gum and xanthan gum on pasting and noodle-making properties of potato, corn and mung bean starches

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Abstract The effect of xanthan and guar-gum on pasting and noodle-making properties of potato, corn and mung bean starches was studied. Mung bean starch showed the highest amylose content (43.4 %) followed by potato (23.2 %) and corn starch (15.5 %). Potato starch showed the highest swelling power (19.0 g/g) and solubility index (17.5 %) and exhibited the highest paste viscosities. Addition of both gums improved peak viscosity, hot paste viscosity and final viscosity for mung and corn starches; while for potato starch, guar gum increased peak and final viscosities and decreased hot paste viscosity while xanthan gum increased hot paste and final viscosities and decreased peak viscosity. The noodles made from mung bean starch showed the most desirable characteristics in terms of the lowest-cooking loss and adhesiveness. The gums increased noodle cooking time and decreased cooking loss, firmness and cohesiveness.

Keywords Gums · Noodle · Pasting · Starch · Texture

Introduction

Noodles are one of the many convenience foods which are generally prepared from wheat flour. These are important foods consumed in Asian countries and China is the largest producing and consuming country. Noodles are popular on the account of sensory appeal, low cost, ease of preparation and storage stability. Starch noodles have an edge over those made from wheat flour as these are gluten-free thus are safe for celiac patients who are allergic to gluten. The characteristic of starch noodles depends largely on the functional properties of starches used to prepare them. Physicochemical properties of starch play an important role in both noodle processing and quality (Chen et al. 2003). Excellent starch noodles are clear, transparent fine threads and have high tensile strength and low cooking loss (Collado et al. 2001). Textural characteristics are other important attributes of cooked noodles for the acceptance by consumers. Noodles should be firm, elastic and should have smooth surface (Edwards et al. 1996).

Traditionally, pulse starch is considered as the most suitable raw material for making starch noodles as it gives the best appearance and texture to the final product. Bean starch is regarded as ideal raw material for noodle production because of high amylose content, restricted swelling and high shear resistance (Lii and Chang 1981). However, apart from the pulse starches, potato and corn starches could be other important raw material for the production of noodles (Singh et al. 2002). Potato starch has unique desirable characteristics such as low gelatinization temperature, large granule size, high paste viscosity and formation of translucent paste (Singh et al. 2014) and has been used in production of several types of noodles. Potato noodles maintain a clear shiny appearance after cooking and have a smooth and slippery texture (Kim et al. 1996). Corn is the third most important cereal after rice and wheat (Shevkani et al. 2014a). Large quantities of corn are

Highlights Potato, corn and mung starches were evaluated for physicochemical, pasting and noodle-making properties
Guar and xanthan gums were used to improve noodle-making properties of the starches
The gums increased noodle cooking time and decreased cooking loss, firmness and cohesiveness

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processed to produce starch which is widely utilised in the food industry for preparation of a number of products, but the use of corn starch as a raw material for noodle preparation is limited as the noodles prepared from it have a low tensile strength. However, on incorporation of hydrocolloids the noodles with desirable tensile strength may be prepared from corn starch.

Gums/hydrocolloids are widely used in starch-based products mainly to improve stability, modify texture and facilitate processing. Hydrocolloids used in gluten-free formulations are derived from various sources like seeds, fruits, plant extracts, seaweeds and micro-organisms. The hydrocolloids protect the starch granules against shear during cooking and improve product texture. Pectin, carboxymethylcellulose, agarose gum, xanthan gum, β-glucan, hydroxypropylmethylcellulose, locust bean gum, guar gum and carageenan are some of the hydrocolloids used in food industry among which guar and xanthan gums are most widely used (Norton and Foster 2002). Guar gum is water soluble non-ionic polysaccharide obtained from the ground endosperm of guar (*Cyamopsistetra gonoloba*) seeds while xanthan gum is a polysaccharide secreted by *Xanthomonas campestris* and is commonly used as a thickening agent in various foods. Singh et al. (2015) reported that xanthan gum can improve appearance, technological and sensory characteristics of gluten-free muffins.

The objective of the present study was to evaluate potato, corn and mung bean starches for physicochemical, morphological, pasting and noodle-making properties.

Materials and methods

Materials

Potato and mung bean were procured from local market of Amritsar, India. Corn starch was provided by Sukhjit Starch and Chemicals Ltd., Phagwara, India. Potato starch was isolated following the method of Singh and Singh (2001) with a slight modification. Briefly, sliced potatoes were immersed in deionized water containing potassium meta-bisulphite (0.5 %) to avoid browning followed by grinding in a house-hold grinder (Sujata, India) to get fine slurry. This slurry was then filtered through nylon cloth and residue was washed 2–3 times with deionized water to recover maximum starch. The filtrate was collected and left over night for the starch to settle. Then, the supernatant was decanted and starch layer was washed repeatedly 4–5 times with deionized water until the supernatant became colourless. The starch cake was dried overnight in an oven at 40 °C until dry. The dried starch was ground to a fine powder using a mortar-pastel. Mung bean starch was isolated by the method of Schoch and Maywald (1968) with slight modification. Briefly, cleaned and soaked mung beans (overnight in deionized water at 40 °C) were ground using a house-hold grinder (Sujata, India). The slurry was filtered through a 60 mesh sieve till the residue retained on the sieve appeared to be free of starch. The slurry was then sieved through a muslin cloth and washed using deionized water to recover maximum starch. The filtrate obtained was left overnight for starch settling. The supernatant liquid was decanted and the starch layer was washed repeatedly with deionized water. Starch cake/slurry was then centrifuged at 3000 rpm for 10 min using a research centrifuge (Research Compufuge PR 24, Remi Electrotechnic, India) equipped with R-241 rotor (Remi Electrotechnic, India) to remove yellow protein layer. The starch cake obtained was finally dried at 40 °C and ground using a mortar-pastel. The dried starch was ground to a fine powder.

Physicochemical properties

Amylose content of the isolated starch was determined using method given by Williams et al. (1970). Swelling power and solubility was determined using method given by Leach et al. (1959). Briefly, a 2 % starch suspension was cooked at 95 °C for 30 min with constant stirring. The gelatinized starch paste was then centrifuged at 3000 rpm for 10 min. Supernatant was collected in pre-weighed aluminum dish. The supernatant in the pre-weighed aluminum dishes was dried in an oven at 110 °C for 24 h. Swelling power (g/g) was determined as weight of paste (remained as pallet in the tube) per gram of the starch while solubility (%) was determined as percent solids in the supernatant.

Syneresis (%) of the starches was measured as expulsion of liquid from starch gels under refrigerated storage for four days using 5 % starch suspension. Starch suspensions were heated at 90 °C for 30 min in a water bath. The starch gel thus obtained were cooled rapidly to room temperature using an ice-water bath. The starch gels were stored at 4 °C for 4 consecutive days and syneresis was measured as the percentage of water released after centrifugation at 3000 rpm for 15 min using aforementioned centrifuge.

Crystalline structures in the starches were determined using a FTIR spectrometer (Vertex 70, Bruker Optics, Germany). All the samples were kept in dessicator over P_2O_5 for at least 2 weeks until constant weights were obtained before spectra were taken. Spectra of an empty cell were taken as background using wavelength from 800 to 2000^{-1} cm with 4 cm^{-1} resolution using OPUS software. All spectra were the averages of 200 scans. The absorbance of the bands at 1047, 1035, and 1022 cm^{-1} were used to evaluate the crystalline structures of starches (van Soest et al. 1995).

Granular size determination

Granular size distribution of the starches were determined using laser-light particle size analyzer (S3550, Microtrac Inc., USA) equipped with delivery system for wet samples (Microtrac SDC, Microtrac Inc., USA).

Scanning electron microscopy (SEM)

Morphological property of starches was evaluated by using a digital scanning electron microscope, (Model EVOLS10, ZEISS, Oberkochen, Germany). The starch granules previously dehydrated in ethanol were sprayed on a metal plate covered with a double sided adhesive tape and taken to a Metalizer (Model SCD 050, Balzers, Liechtenstein) for application of a 20 nm silver layer. The starches were then observed with the digital scanning microscope.

Pasting properties

Evaluation of the pasting properties of starches and starch-hydrocolloid (0.25 and 0.35 %) blends was done using a rheometer (MCR-301, Anton Paar, Austria) equipped with starch cell (C-ETD 160) and stirrer probe (ST 24-2D/2 V/2 V-30). Starch or starch-hydrocolloid suspensions (10 %) were held at 50 °C for 1 min then heated from 50 to 95 °C at a rate of 12.16 °C/min, held at 95 °C for 2.5 min, cooled from 95 to 50 °C at a rate of 11.84 °C/min, and held at 50 °C for 2 min. Parameters recorded were pasting temperature, peak viscosity, hot paste viscosity, final viscosity, breakdown viscosity and setback viscosity.

Starch noodle preparation

Starch and hydrocolloid dough was prepared by slightly modifying the method proposed by Silva et al. (2013). Starch suspension (10 %) and the hydrocolloids were pregelatinized by mixing in a boiling water bath till a homogenous mixture was obtained. The rest of the starch was gradually added to the suspension at 40 °C with constant stirring until uniform dough was obtained. The dough ball after a resting time of 5 min was extruded into noodles using cylindrical hand extruder (0.3 mm orifice) and dried at 40 °C in an oven.

Table 1 Physico-chemical properties of potato, corn and mung bean

Starch source	Amylose content (%)	Swelling power (g/g)	Solubility (%)	Ratio of absorbance between 1047 and 1022 cm^{-1}
Potato	23.22±0.40	19.02±0.38	17.50±0.56	0.33±0.02
Corn	15.54±0.23	8.63±0.44	11.33±0.16	0.67±0.08
Mung bean	43.43±1.01	10.97±0.27	13.42±0.62	0.73±0.05

Values are mean ± SD

Noodle cooking properties

Noodles were evaluated for cooking time and loss of solids during cooking. Noodles (2.5 g) were cooked in 300 ml boiling deionized water. Cooking time was determined as the time required for the disappearance of white core as judged by squeezing the noodle between two glass slides. For the determination of loss of solids during cooking, 10 g noodle were cooked in 500 ml boiled deionized water for the minimum cooking time. The cooked noodles were drained and rinsed with deionized water (100 ml) in a Buchner Funnel. Solid losses were determined by evaporating and drying the cooking water to dryness in pre-weighed petri-plates in an oven at 110 °C for 12 h.

Textural properties

Cooked noodle strands (4 cm long) were placed on platform of texture analyzer (TA/TX2 plus, Stable Micro systems, Surrey, England). Texture profile analysis was done using 70 % compression with the P/75 probe at a test speed of 0.5 mm/s using 1 kg load cell. Various textural parameters obtained were firmness, cohesiveness and adhesiveness (Kaur et al. 2005).

Statistical analysis

The data reported is mean of at least triplicate values. The data was subjected to analysis of variance using Minitab Statistical Software (Minitab Inc., State College, PA, USA).

Results and discussion

Physicochemical characteristics

Amylose content of starches varied between 15.5 and 43.4 %. Mung bean starch showed the highest amylose content (43.4 %) followed by potato (23.2 %) and corn starch (15.5 %). Earlier, amylose content was reported to vary in the range of 16.4 to 20.6 % for potato (Singh et al. 2008) and 16.9 to 21.3 % for corn starches (Sandhu and Singh 2007). The variations in amylose content may be due to the different botanical source of the starch as well as different climatic conditions and soil type during growth (Singh et al. 2003).

Swelling power and solubility of starches from potato, corn and mung bean starches are shown in Table 1. Potato starch

Table 2 Syneresis (%) of potato, corn and mung bean starch gels during storage at 4 °C for four days

Starch source	0 day	1st day	2nd day	3rd day	4th day
Potato	74.96±0.36	75.32±0.07	76.08±0.34	76.59±0.20	77.09±0.19
Corn	44.58±1.37	60.99±0.35	65.59±1.96	70.75±2.08	79.02±0.23
Mung bean	62.70±4.05	64.38±3.31	70.17±0.10	75.98±0.55	83.66±0.90

Values are mean ± SD

showed the highest swelling power (19.0 g/g) and solubility index (17.5 %) while corn starch showed the least (8.6 g/g and 11.3 % respectively). The highest swelling power and solubility of potato starch may be attributed to the presence of negatively charged phosphate groups on adjacent chains which increased hydration of starch granules (Swinkels 1985). Mung bean starch showed higher swelling power and solubility than corn starch (Table 1) which may be attributed to the strongly associated amylopectin chains within crystalline regions in mung bean than in corn (Hoover et al. 1997). Corn starch showed the lowest swelling power and solubility index which might be attributed to the presence of lipids which complex with amylose and reduces granular swelling (Shevkani et al. 2011).

Amorphous structure is related to infrared absorbance band at 1047 cm^{-1} whereas short-range order was related to infrared absorbance band at 1022 cm^{-1} (van Soest et al. 1995). The IR absorption bands at 1047 cm^{-1} and 1022 cm^{-1} were related to crystalline and amorphous structure, respectively. The ratio of intensities at 1047 cm^{-1} and 1022 cm^{-1} describes relative crystallinity in the starches (van Soest et al. 1995). Mung bean starch showed the highest ratio of the intensities at 1047 and 1022 cm^{-1} (0.73) indicating the highest crystallinity followed by corn (0.67) and potato starches (0.33). Earlier ratio between intensities at 1047 and 1022 cm^{-1} in the range of 0.72 to 0.75 was reported for native kidney bean starches (Kaur et al. 2013). Differences in crystallinity have been attributed to the difference in amylose content, amylopectin chain length distribution, genotype and botanical sources of the starches (Singh et al. 2003, 2010; Shevkani et al. 2011).

Syneresis increased with storage duration and depended on starch source (Table 2). Mung bean starch showed the highest syneresis (83.7 %) after 4 days of refrigerated storage followed by corn (79.0 %) and potato starch (77.1 %). Syneresis is caused mainly by retrogradation in starch gels which include recrystallization of gelatinized starch chains and release of water. During retrogradation, amylose forms double helical associations of

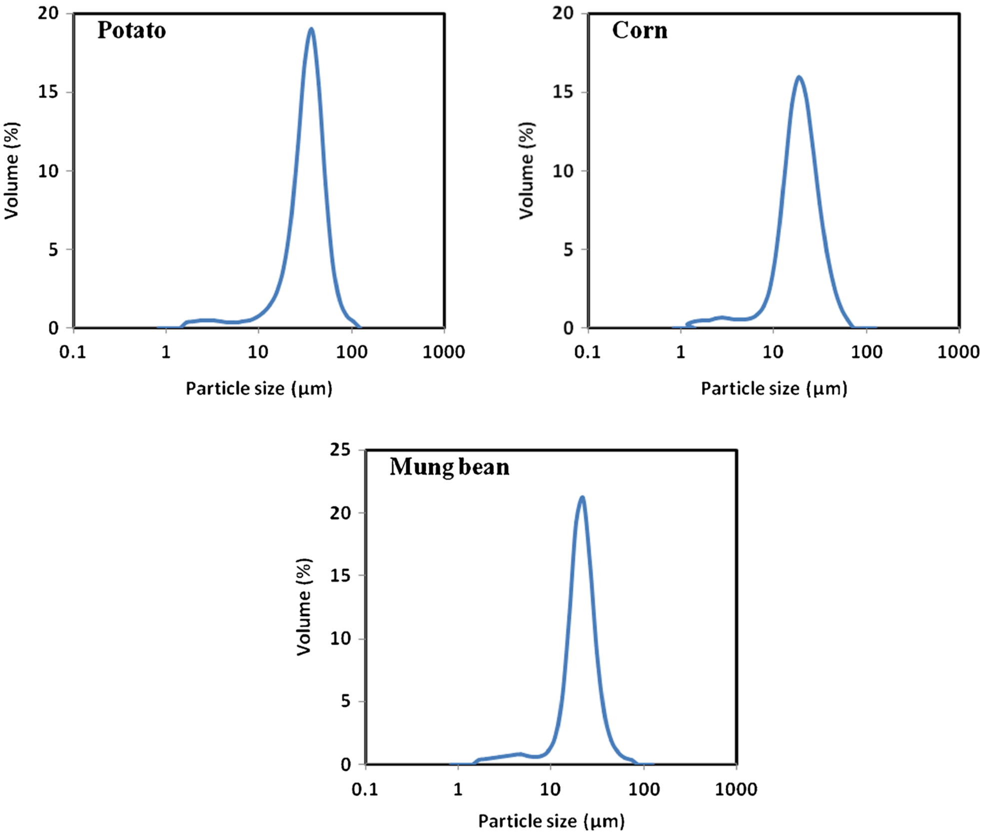
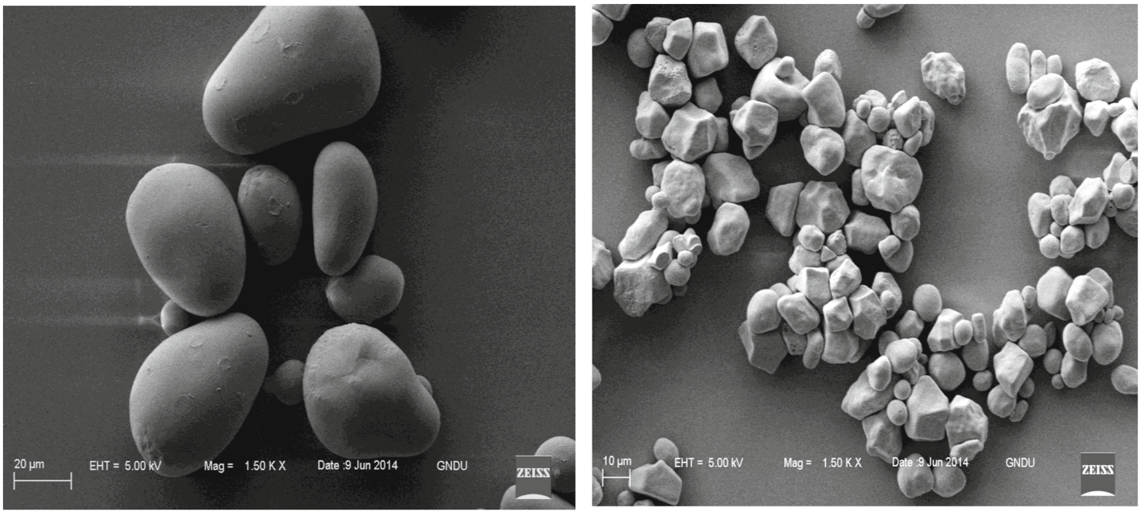


Fig. 1 Particle size distribution of potato, corn and mung bean starches

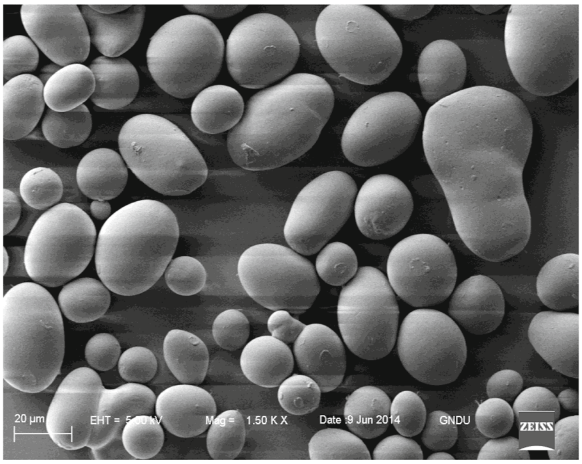
glucose units whereas amylopectin crystallization occurs by reassociation of the outermost short chains (Ring et al. 1987). The highest syneresis for mung starch may be due to the presence of the highest content of amylose while the lowest syneresis for potato starch might be attributed to the excessive branching of amylopectin which caused high water holding capacity, resulting in lower rate of retrogradation (Srichuwong and Jane 2007). Singh et al. (2010) also related variation in retrogradation amongst wheat starches to their amylose content and amylopectin chain length distribution.

Granular characteristics

Laser light diffraction analysis of starches revealed the presence of granules of sizes in the range of 1.9 to 124.5 μm for potato, 1.6 to 74.0 μm for mung bean and 1.1 to 62.2 μm for corn. It was observed that potato starch granules were the largest in size (average particle size=37.4 μm) followed by mung bean and corn starch granules (average particle size was 19.1 and 17.4 μm, respectively). Potato, mung bean and corn starches showed a bimodal granular size distribution with peaks <10 μm and >10 μm (Fig. 1). The proportion of <10 μm granules were 4.3 %, 7.4 % and 10.2 %, respectively, while that of >10 μm granules were 95.7 %, 92.6 % and 89.8 %, respectively for potato, mung bean and corn starches. The microscopic analysis (SEM) also revealed that potato starch granules were the largest and had oval shape and smooth surface (Fig. 2). Mung bean starch granules had smooth surface but had irregular shape which varied mainly from oval to round. On the other hand, corn starch granules were less smooth than potato and mung bean starch granules and had irregular angular shape. The morphological characteristics of starch granules were consistent with earlier reports (Singh et al. 2003; Sandhu et al. 2007). Size and shape of the starch granules is mainly a property of botanical source (Svegmark and Hermansson 1993) and is known to affect physicochemical, pasting and functional properties of starches separated from different plant sources (Singh and Singh 2001; Singh et al. 2003; Shevkani et al. 2011).



Potato **Corn**



Mung bean

Fig. 2 Scanning electron micrographs of potato, corn and mung bean starches

Table 3 Pasting properties of potato, corn and mung bean starches in the presence of guar and xanthan gums

Starch	Guar gum (%)	Xanthan gum (%)	Pasting temperature (°C)	Peak viscosity (cP)	Hot paste viscosity (cP)	Breakdown viscosity (cP)	Final viscosity (cP)	Setback viscosity (cP)
Potato	0	0	69.67±0.3	13710±118	4665±19	9045±69	6745±37	2078±56
	0.25	0	69.79±0.4	14060±56	4465±12	9595±44	6839±49	2374±61
	0.35	0	69.94±1.1	14000±99	3972±34	10028±65	6885±43	2912±7
	0	0.25	69.82±0.5	7509±60	5227±28	2282±32	6931±32	1704±4
	0	0.35	68.91±0.0	7220±11	5404±18	1816±7	7159±104	1755±122
Corn	0	0	78.76±0.4	2341±14	1495±14	846±11	3151±25	1656±11
	0.25	0	79.21±0.3	2426±35	1534±11	892±25	3205±7	1672±14
	0.35	0	79.41±0.9	2404±27	1589±40	815±13	3202±15	1613±26
	0	0.25	79.25±0.7	2656±45	1700±56	956±100	3235±11	1534±45
	0	0.35	79.14±0.7	2741±13	1733±30	1008±43	3298±9	1564±21
Mung	0	0	75.84±1.0	4541±10	2603±78	1938±88	6388±11	3786±89
	0.25	0	76.06±0.3	4657±22	2889±64	1768±42	6525±7	3640±57
	0.35	0	75.74±0.6	4675±16	2901±18	1774±23	6513±45	3612±63
	0	0.25	75.22±0.2	5175±25	2889±13	2286±38	6601±36	3712±23
	0	0.35	74.88±0.2	5053±92	2898±59	2155±23	6647±46	3751±105

Values are mean ± SD

Pasting properties

Pasting properties of starches from different sources varied significantly (Table 3). Potato starch showed the lowest pasting temperature (69.7 °C) followed by mung bean (75.8 °C) and corn starch (78.8 °C). The lowest pasting temperature for potato starch may be attributed to the lowest crystallinity as a high degree of crystallinity provides structural stability to the granules and make them more resistant towards gelatinization (Barichello et al. 1990). The highest pasting temperature for corn starch may be attributed to the presence of amylose-lipids that increase granular integrity, leading to higher pasting temperature (Shevkani et al. 2011, 2014b). Potato starch showed the highest peak viscosity followed by mung bean and corn starch (Table 3). Peak viscosity represents primarily the point of maximum starch granular swelling. Heating the pastes at 95 °C decreased the viscosity which was due to the rupturing of starch granules as a combined effect of high temperature

Table 4 Effect of guar and xanthan gums on cooking properties of potato, corn and mung bean starch noodles

Source	Xanthan gum (%)	Guar gum (%)	Cooking time (min)	Cooking loss (g/g)
Potato	0	0	3.35±0.04	0.44±0.01
	0.25	0	4.4±0.07	0.24±0.02
	0.35	0	4.3±0.02	0.23±0.01
	0	0.25	4.4±0.07	0.32±0.01
	0	0.35	ND	ND
Corn	0	0	8.35±0.03	0.46±0.01
	0.25	0	9.37±0.05	0.13±0.13
	0.35	0	10.15±0.10	0.15±0.01
	0	0.25	9.4±0.07	0.13±0.01
	0	0.35	10.3±0.07	0.15±0.01
Mungbean	0	0	10.4±0.07	0.09±0.00
	0.25	0	11.15±0.10	0.06±0.00
	0.35	0	12.65±0.24	0.06±0.00
	0	0.25	11.07±0.05	0.05±0.00
	0	0.35	11.65±0.24	0.07±0.01

Values are mean ± SD

and shearing. Potato starch also showed the highest hot paste and breakdown viscosities whereas mung bean and corn starches showed lower viscosities (Table 3). Setback viscosity representing retrogradation or tendency of the gelatinized starch chains to reassociate was the highest for mung bean starch (3786 cP) followed by potato and corn starches (2078 and 1656 cP, respectively). The highest amylose content in mung bean starch may be attributable for the highest setback viscosity. Final viscosity indicate ability of starches to form a viscous paste. Potato starch showed the highest final viscosity (6745 cP) followed by mung and corn starches (6388 and 3151 cp, respectively). The highest paste viscosities of potato starch could be attributed to the presence of phosphate groups esterified to amylopectins (Swinkels 1985; Craig et al. 1989; Singh et al. 2014). Additionally, the largest granular size may also be attributable for the highest paste viscosities of potato starch. Wong and Lelievre (1982) reported that starch granular size influence its rheology. Singh et al. (2010) demonstrated that the suspensions of large granules tend to be more viscous compared to those of the counterpart smaller ones as the larger granules may possess a loose packing ability thus would occupy a relatively larger volume than the smaller granules. Similarly, Shevkani et al. (2011) also reported higher paste viscosities for wheat starches having greater proportion of large granules than those having greater proportion of small granules.

Guar and xanthan gums variably influenced paste viscosities of the starches depending upon the incorporation and

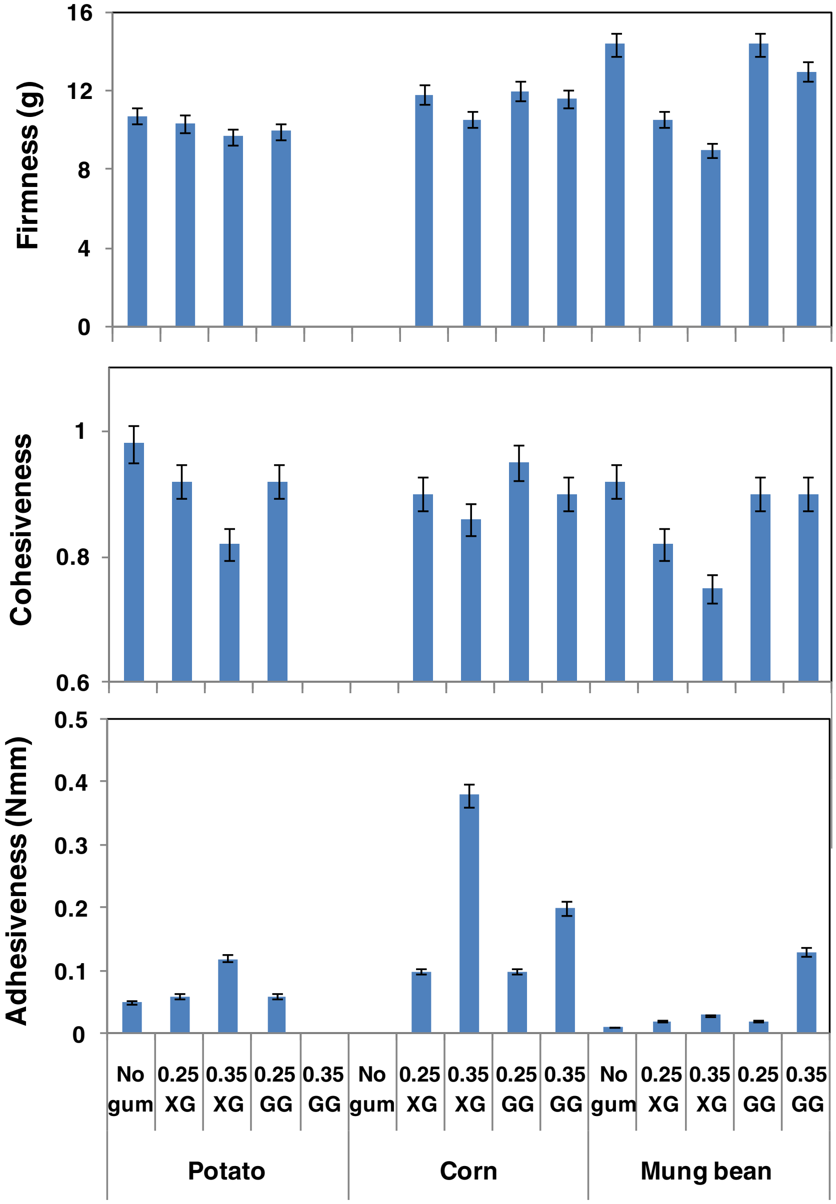


Fig. 3 Effect of guar and xanthan gums on the textural properties of potato, corn and mung bean starch noodles (*XG* xanthan gum, *GG* guar gum)

source of the starches and gums. Both gums increased peak viscosity, hot paste viscosity, breakdown viscosity and final viscosity for mung and corn starches wherein xanthan gum had greater effect (Table 3). This indicated that the gums increased the capacity of mung and corn starch granules to swell, possibly, by inhibiting leaching out of the starch components during gelatinization resulting in viscous system (Dartois et al. 2010). Potato starch showed increased peak viscosity and decreased hot paste viscosity in the presence of guar gum whereas xanthan gum caused reverse effect (Table 3). Shi and BeMiller (2002) reported that anionic hydrocolloids, like xanthan gum, inhibited swelling of potato starch granules and decreased peak viscosity. These authors attributed this inhibition to the repelling forces between the phosphate groups in potato starch granules and the negative charges on the hydrocolloid molecules. Sikora et al. (2008) found that the effect of hydrocolloids on starches was a function of both the starch used and the concentration of the hydrocolloid. Gularte and Rosell (2011) reported that guar gum increased paste viscosities of corn and potato starches while xanthan gum decreased it.

Noodles making properties

Cooking time and cooking loss of noodles made from mung bean, corn and potato starches are presented in Table 4. Cooking time and cooking loss of noodles varied significantly among different starches. Noodles prepared from mung bean starch took longest time for cooking (10.4 min) followed by that from corn (8.4 min) and potato starch (3.4 min). The variation in cooking time of the noodles prepared without hydrocolloids might be attributed to the differences in the gelatinization temperatures of the respective starches (Singh et al. 2002). The longest cooking time for mung bean noodles has been attributed to compact noodle structure (Tan et al. 2009). The shortest cooking time of potato starch noodles may be attributed to the lowest gelatinization temperature while amylose-lipids complex in corn starch might have delayed the swelling of individual starch granules within the noodle strands causing delay in cooking (Singh et al. 2002). Gums increased cooking time of noodles from all the starches (except potato starch with 0.35 % guar gum). The longer cooking time in the presence of gums may be attributed to the limited availability of water to the starch granules present in the noodle strands, causing delay in the swelling and gelatinization of granules. Source of hydrocolloid did not affect the cooking time significantly. Loss of solids during cooking of noodles is of great significance as it affects texture and appearance of the final product. Noodles made from mung bean starch showed the lowest cooking loss (0.09 g/g) while that from corn and potato showed significantly higher cooking loss (0.44 and 0.46 g/g, respectively). A significant negative correlation between cooking loss and amylose content has been observed earlier (Chen 2003); therefore, the lowest cooking loss for mung bean noodles may be attributed to the highest amylose content. The results also showed that the noodles prepared with gums showed significantly lower cooking loss than that prepared without the gums which may be due to the complex formation between amylose and hydrocolloid (Singh et al. 2002). Liu et al. (2003) also reported that hydrocolloid decreased solubility of starch polymer molecules within the swollen granules.

Effect of guar and xanthan gum on textural properties of cooked noodles

Textural properties of cooked starch noodles are shown in Fig. 3. Mung bean starch noodles showed the highest firmness with the lowest adhesiveness. High firmness of mung bean noodles may be attributed to the highest amylose content which has been considered as an important factor affecting the firmness of cooked noodles (Toyokawa et al. 1989). A positive correlation between firmness and amylose content of noodles from pea and lentil starches has been reported earlier (Wang et al. 2013). Texture of corn starch noodles prepared without the addition of hydrocolloids could not be evaluated as the noodle strands were too soft and got disintegrated easily. Therefore, it was not possible to get noodle strands of appropriate length required for textural analysis. Potato starch noodles prepared using 0.35 % guar gum got completely disintegrated during cooking hence they were not evaluated. Gums decreased firmness and cohesiveness of the noodles but increased adhesiveness (Fig. 3). This might be attributed to the delayed swelling of granules as well as lesser interaction and association within the granules in the presence of gums. Less amylose leaching due to complex formation may also have decreased the cohesiveness and increased the adhesiveness for most of the noodles (Kaur et al. 2005).

Conclusion

Starches from mung bean, corn and potato differed significantly for physicochemical, morphological, pasting and noodle-making properties. Guar gum and xanthan gum influenced the pasting properties of the starches variably depending upon their sources. Gums improved the cooking properties of the noodles as they increased cooking time and decreased cooking losses.

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References

Barichello V, Yada RY, Coffin RH, Stanley DW (1990) Low temperature sweetening in susceptible and resistant potatoes: starch structure and composition. J Food Sci 55:1054–1059

Chen Z (2003) Physicochemical properties of sweet potato starches and their application in noodle products. PhD dissertation No 90-5808-887-1

Chen Z, Schols HA, Voragen AGJ (2003) Physicochemical properties of starches obtained from three varieties of Chinese sweet potatoes. J Food Sci 68:431–437

Collado LS, Mabesa LB, Oates CG, Corke H (2001) Bihon-type noodles from heat-moisture-treated sweet potato starch. J Food Sci 66:604–609

Craig SAS, Maningat CC, Seib PA, Hoseney RC (1989) Starch paste clarity. Cereal Chem 66:173–182

Dartois A, Singh J, Kaur L, Singh H (2010) Influence of guar gum on the in vitro starch digestibility – rheological and microstructural characteristics. Food Biophys 5:149–160

Edwards NM, Scandal MG, Kruger JE (1996) Oriental noodle dough rheology relationship to water absorption formulation and work input dough sheeting. Cereal Chem 73:708–711

Gularte MA, Rosell CM (2011) Physicochemical properties and enzymatic hydrolysis of different starches in the presence of hydrocolloids. Carbohydr Polym 85:237–244

Hoover R, Li YX, Hynes G, Senanayake N (1997) Physicochemical characterization of mung bean starch. Food Hydrocoll 11:401–408

Kaur L, Singh J, Singh N (2005) Effect of glycerol monostearate on the physicochemical, thermal, rheological and noodle making properties of corn and potato starches. Food Hydrocoll 19:839–849

Kaur S, Singh N, Kaur A, Sodhi NS (2013) Effect of shearing on functional properties of starches isolated from Indian kidney beans. Starch/Starke 65:808–813

Kim YS, Wiesenborn DP, Lorenzen JH, Berglund P (1996) Suitability of edible bean and potato starches for starch noodles. Cereal Chem 73: 302–308

Leach HW, McCowen LD, Schoch TJ (1959) Structure of the starch granule. I. Swelling and solubility patterns of various starches. Cereal Chem 36:534–537

Lii CY, Chang SM (1981) Characterization of red bean starch and its noodle quality. J Food Sci 46:78–81

Liu H, Eskin NAM, Cui SW (2003) Interaction of wheat and rice starches with yellow mustard mucilage. Food Hydrocoll 17:863–869

Norton IT, Foster TJ (2002) Hydrocolloids in real food systems. In: Williams PA, Phillips GO (eds) Gums and stabilizers for the food industry, vol 11. The Royal Society of Chemistry, Cambridge, pp 187–200

Ring SG, Collona P, Panson KJ, Kalicheversky MT, Miles MJ, Morris VJ et al (1987) The gelation and crystallization of amylopectin. Carbohydr Res 162:277–293

Sandhu KS, Singh N (2007) Some properties of cornstarches II: physicochemical, gelatinization, retrogradation, pasting and gel textural properties. Food Chem 101:1499–1507

Sandhu KS, Singh N, Lim ST (2007) Functional properties of normal, waxy and sugary corn starches. J Food Sci Technol 44:565–571

Schoch TJ, Maywald EC (1968) Preparation and properties of various legume starches. Cereal Chem 45:564–571

Shevkani K, Singh N, Singh S, Ahlawat AK, Singh AM (2011) Relationship between physicochemical and rheological properties of starches from Indian wheat lines. Int J Food Sci Technol 46: 2584–2590

Shevkani K, Kaur A, Singh G, Singh B, Singh N (2014a) Composition, rheological and extrusion behaviour of fractions produced by three successive reduction dry milling of corn. Food Bioprocess Technol 7:1414–1423

Shevkani K, Singh N, Kaur A, Rana JC (2014b) Physicochemical, pasting, and functional properties of amaranth seed flours: effects of lipids removal. J Food Sci 79:C1271–C1277

Shi X, BeMiller JN (2002) Effects of food gums on viscosities of starch suspensions during pasting. Carbohydr Polym 50:7–18

Sikora M, Kowalski S, Tomasik P (2008) Binary hydrocolloids from starches and xanthan gum. Food Hydrocoll 22:943–952

Silva E, Sagis LMC, van der Linden E, Scholten E (2013) Effect of matrix and particle type on rheological, textural and structural properties of broccoli pasta and noodles. J Food Eng 119:94–103

Singh J, Singh N (2001) Studies on the morphological, thermal and rheological properties of starch separated from some Indian potato cultivars. Food Chem 75:67–77

Singh N, Singh J, Sodhi NS (2002) Morphological, thermal, rheological and noodle-making properties of potato and corn starch. J Sci Food Agric 82:1376–1383

Singh N, Singh J, Kaur L, Sodhi NS, Gill BS (2003) Morphological, thermal and rheological properties of starches from different botanical sources–A review. Food Chem 81:219–231

Singh N, Isono N, Srichuwong S, Noda T, Nishinari K (2008) Structural, thermal and viscoelastic properties of potato starches. Food Hydrocoll 22:979–988

Singh S, Singh N, Isono N, Noda T (2010) Relationship of granule size distribution and amylopectin structure with pasting, thermal and retrogradation properties in wheat starches. J Agric Food Chem 58:1180–1188

Singh N, Kaur A, Shevkani K, Ezekiel R (2014) Potato: production, composition and starch processing. Chapter 2. In: Visakh PM, Iturriaga LB, Ribotta PD (eds) Advances in food science and nutrition, volume 2. Scrivener Publishing, Wiley, Beverly, pp 23–48

Singh JP, Kaur A, Shevkani K, Singh N (2015) Influence of jambolan (*Syzygium cumini*) and xanthan gum incorporation on the physicochemical, antioxidant and sensory properties of gluten-free eggless rice muffins. Int J Food Sci Technol 50:1190–1197

Srichuwong S, Jane J (2007) Physicochemical properties of starch affected by molecular composition and structures: a review. Food Sci Biotechnol 16:663–674

Svegmark K, Hermansson AM (1993) Microstructure and rheological properties of composites of potato starch granules and amylose: a comparison of observed and predicted structure. Food Struct 12: 181–193

Swinkels JJM (1985) Composition and properties of commercial native starches. Starch/Starke 37:1–5

Tan HZ, Li ZG, Tan B (2009) Starch noodles: history, classification, materials, processing, structure, nutrition, quality evaluating and improving- a review. Food Res Int 42:551–576

Toyokawa H, Rubenthaler GL, Powers JR, Schanus EG (1989) Japanese noodle qualities. II. Starch components. Cereal Chem 66:387–391

van Soest JJG, Tournois H, de Wit D, Vliegenthart JFG (1995) Short-range structure in (partially) crystallinepotato starch determined with attenuated total reflectance Fourier-transform IR spectroscopy. Carbohydr Res 279:201–214

Wang N, Warkentin TD, Vandenberg B, Bing DJ (2013) Physicochemical properties of starches from various pea and lentil varieties, and characteristics of their noodles prepared by high temperature extrusion. Food Research Int 55:119–127

Williams PC, Kuzina FD, Hlynka (1970) A rapid colorimetric procedure for estimating the amylose content of starches and flours. Cereal Chem 47:411–420

Wong RBK, Lelievre J (1982) Rheological characteristics of wheat starch measured under steady shear conditions. J Appl Polym Sci 27: 1433–1440