Assessment of physicochemical characteristics and modifications of pasting properties of different varieties of maize flour using additives

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Revised: 28 June 2018 / Accepted: 3 July 2018 / Published online: 4 August 2018
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Abstract Maize cereal has potential to be used for food purpose but lack of viscoelastic behaviour that limits its use for this purpose. Therefore, present study on modification of pasting properties of maize flour using different additives was carried out. Flours of three maize varieties (PMH1, JL3459 and Buland) with and without additives (guar gum, xanthan gum, whey protein concentrate and potato starch) were analysed for physico-chemical and pasting properties. Maize (PMH1) had maximum thousand kernel weight (312.47 g), bulk density (0.80 g/ml), force to rupture (68.54 kg) and contained the highest starch (67.70%) and fat (5.08%) among the three varieties. Different levels of guar gum (0–1.0%), xanthan gum (0–1.0%), whey protein concentrate (0–15.0%) and potato starch (0–10.0%) were incorporated in flours from three maize varieties. Results showed that guar gum 1.0% (w/w basis) and xanthan gum 1.0% (w/w basis) incorporation led to the highest peak and final viscosity whereas whey protein concentrate and potato starch were not selected because of negative effect on these properties. These additives can be used as binding agent in chapati and other maize products.

Keywords Maize · Xanthan gum · Guar gum · Whey protein concentrate · Potato starch · Pasting properties

Introduction

Maize (*Zea mays*) is well known as queen of cereals as it has highest genetic yield potential among the cereals. In India, maize is third important crop followed by rice and wheat and 23% is used for human food purpose. Maize has very good phytonutritional profile, high production and availability at affordable price. Still, its products are less available in market in comparison to wheat. This is mainly due to lack of gluten protein in maize which is responsible for binding property. Different varieties of maize have different visco-elasticity, rheological properties and composition of flour in comparison to wheat. Due to lack of viscoelastic properties, maize use is restricted in bakery products. Therefore, need arises to use substitutes of gluten for improving the rheological, viscoelastic properties and composition of maize. Hydrocolloids and gums have been used for improving the properties of flour since decades. They are multifunctional ingredients that add flexibility, function as fat replacers, water binders, texturizers and adhesives (Kohajdová and Karovičová 2008). Addition of gums can significantly improve shape, structural and textural uniformity of the microwave-expanded samples. Gums contribute to rheology and moisture sorption capacity of the matrix. (Gimeno et al. 2004). In fact, guar gum, xanthan, arabic and locust bean gums, carrageenans, alginates, pectins and cellulose derivatives have been used to improve bread quality (Guarda et al. 2004). Hydrocolloids have a low calorific value and are generally effective in small quantities (Onweluzo et al. 1999). Addition of hydrocolloids have also account for modifying the functionality, retrogradation (Bemiller 2011) and in vitro digestibility of starch and glucose. For instances, xanthan inhibits the retrogradation of rice starch (Tang et al. 2013) and extent of inhibition of starch retrogradation depends on

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the hydrocolloid concentration (Wang et al. 2015). Guar gum reduces the starch hydrolysis in vitro digestibility due to thickening effect of guar gum, which reduced the accessibility of enzyme to substrate (Bordoloi et al. 2012). Similarly, xanthan gum reduces the starch hydrolysis and this is due to hardening effect and interaction with starch. Moreover, guar gum reduces the glucose accessibility in a simplified in vitro intestinal model (Gouseti et al. 2014). Dairy proteins and hydrocolloids can be used to mimic the viscoelastic properties of gluten and result in improved structural feel in the mouth, acceptability and shelf life (Lazaridou et al. 2007). Hydrocolloids, commonly named gums, are able to modify overall quality of the food product (Huang et al. 2001). Besides hydrocolloids, potato starch also exhibit the highest swelling power and gives the highest viscosity of pasting properties as compared to all other commercial starches (Mitch 1984). Pasting properties of potato starch as mixture of other starches and flours have been accessed for long time (Zaidul et al. 2007; Brennan et al. 2008a; Zhang et al. 2011; Waterschoot et al. 2014). Eliasson and Kim (1992) found the relationship between rheological measurements and mechanical properties of potato starch pastes. Thus a close relationship between textural and rheological properties was confirmed to make a quality product by incorporation of potato starch. More specifically the goal of study was to obtain the pasting properties of maize flour close to wheat flour for extending its use in bakery products.

For that, application of additives to improve the viscoelastic behaviour of maize is needed to be studied. Therefore, the present study was carried out to study the effect of different additives namely guar gum, xanthan gum, whey protein concentrate and potato starch incorporated in maize flour from different varieties on the pasting properties using rapid visco-analyzer.

Materials and methods

Raw materials

The varieties of maize PMH1, JL3459 and Buland were procured from the Department of Plant Breeding, PAU, Ludhiana. Hydrocolloids like xanthan and guar gum were procured from Alliance Global, New Delhi. Potato starch was purchased from S.D. Fine Chem. Ltd, Boisar-401506, India. Whey protein concentrate was collected from Mahaan Proteins Limited, New Delhi-110001, India.

Physical properties

Grains were assessed for physical properties such as 1000 kernels weight, hectolitre weight, force to rupture

(Stable Microsystem Texture Analyzer Model—TA-H di England) using AOAC procedure (1995). The colour of flour using a Hunter colorimeter, model D25 optical sensor (Hunter Associates Laboratory Inc., Reston, VA, USA) on the basis of L^* , a^* and b^* was assessed. The instrument ($45^\circ/0^\circ$ geometry, 10° observer) was calibrated against a standard light yellow-coloured reference tile ($L^* = 77.14$, $a^* = -1.52$, $b^* = 21.88$).

Preparation of flour

The varieties of maize PMH1, JL3459 and Buland were thoroughly cleaned and milled using Burr mill (*attachakki*).

Chemical analysis of flour

The chemical compositions of all three varieties of maize flour were analyzed. Standard AACC (2000) procedure was followed for determination of moisture content (44.15 A) and estimation of protein content (46-11 A), fat (Soxtech apparatus), ash (08-01), crude fibre (Fibertech) and starch on wet basis.

Incorporation of additives

Maize flour of three different varieties were blend with additives such as xanthan gum (0–1.0%), guar gum (0–1.0%), whey protein concentrate (0–15.0%) and potato starch (0–10.0%) after passing through 60 μm sieve.

Pasting properties

Flour pasting properties were determined using a rapid visco-analyzer (RVA) starch master R & D pack V 3.0 (Newport Scientific Narrabeen, Australia) (Batey et al. 1997). RVA analysis of maize flour (var. PMH1, JL3459 and Buland) with and without additives was performed. The blends were made using maize flour with guar gum (0–1.0% w/w basis), xanthan gum (0–1.0% w/w basis), whey protein concentrate (0–15.0% w/w basis) and potato starch (0–10.0% w/w basis). The sample 3 ± 0.01 g was weighed on basis of 14% moisture content for maize flour and their blends. Weighed flour was put in an aluminium cup (canister) and then 25 ml of water was added in it. After that, the solution was quickly mixed with paddle. The canister was inserted in equipment as recommended. Peak viscosity (first peak viscosity after gelatinization), hold viscosity, breakdown, final viscosity (paste viscosity at the end of the test) and setback were read from the pasting profile with the aid of thermocline windows software connected to a computer. The viscosity parameters have been recorded in centipoise (cP).

Statistical analysis

The data was statistically accessed using CPCS version 1NCPCS1 [Om (0.1)]. One way analysis of variance (ANOVA) was used for finding significant difference ($p < 0.05$) using complete randomized design (Gomez and Gomez 2010).

Results and discussion

Assessment of physicochemical properties of maize varieties

The physicochemical properties of different maize varieties were assessed to determine the quality and nutritional value. Physicochemical characteristics of maize varieties such as PMH1, Buland and JL3459 were elucidated in Table 1. Thousand kernel weight of maize varieties ranged between 197 and 312.67 g. Bulk density of PMH1 and JL3459 was found to be same (0.80 g/ml) whereas Buland had minimum bulk density (0.76 g/ml). The L^* (indicator of lightness), b^* (indicator of blueness and yellowness) value of colour was observed to be maximum for JL3459 being 84.84 and 24.21, respectively. The highest a^* (indicator of redness and greenness) 1.35 was observed in Buland. Similar to the findings of corn grits colour were reported by Jamin and Flores (1998). Among the three varieties, force to rupture was the highest in PMH1 (68.54 kg) followed by Buland (68.42 kg) and JL3459 (67.20 kg). Maize grains had moisture content ranging between 9.53 and 16.03%. The values observed for protein, starch and fat content ranged between 10.36–11.30, 64.66–67.70 and 4.97–5.13%, in the order. The fibre and

ash contents of maize varieties were obtained from 2.05 to 2.38 and 1.34 to 1.52% in the order. The chemical composition of maize varieties was in good agreement with the previous study (Thakur et al. 2015).

Effect of incorporation of guar gum on pasting properties of maize flour from three varieties

The effect of guar gum (0.25, 0.50, 0.75 and 1.0%) on pasting properties of maize flour from various varieties is presented in Table 2. The parameters namely: peak viscosity (PV), the maximum viscosity that the slurry attains; hold viscosity (HV), the trough at minimum hot paste viscosity; break down viscosity (BV); set back (SB) and final viscosity (FV), the viscosity of slurry after cooling to 50 °C and holding the temperature) were measured. Statistically significant effect of guar gum on PV, HV, FV, BV and SB was measured. In variety PMH1, with increase in addition of guar gum from 0.25 to 1.0% in maize flour a significant increase in PV, HV and FV was observed and higher the level of guar gum, higher was the viscosity (Table 2). Moreover, in maize flour JL3459 and Buland, similar trends were observed i.e. PV, HV and FV increased with increase in level of guar gum from 0.25 to 1.0% (Table 2). Data presented was in agreement with the previous findings where the addition of guar gum resulted in increase in peak and final viscosities of extruded products (Brennan et al. 2008b; Dikeman and Fahey 2006). Same findings were observed by Yoon et al. (2016) using the xanthan and guar gums on barley flour. HV and FV were maximum at 1.0% level of guar gum. Increase in viscosity has been attributed to higher hydration capacity and water binding capacity than raw flour (Tudorica et al. 2004; Tester and Somerville 2003). Increase in concentration of

Table 1 Physico-chemical properties of maize flour of different varieties

Characteristics	PMH1	JL3459	Buland	CD ($p < 0.05$)
Thousand kernel weight (g)	312.47	197.26	216.47	3.20
Bulk density (g/ml)	0.80	0.80	0.76	0.18
Colour				
L^*	83.55	84.84	19.77	0.26
a^*	− 0.25	0.28	1.35	0.11
b^*	23.01	24.21	24.04	0.26
Force to rupture (kg)	68.54	67.20	68.42	0.35
Moisture (%)	9.52	16.04	11.34	0.32
Protein (%)	10.66	11.34	10.32	0.42
Starch (%)	67.70	66.46	64.59	0.62
Fat (%)	5.08	4.98	5.22	NS
Fibre (%)	2.05	2.27	2.35	NS
Ash (%)	1.42	1.34	1.54	0.63

Each value is mean of three observations $\pm$ SD

Table 2 Effect of incorporation of guar gum on pasting properties of maize flour from three varieties

Maize variety	Guar gum (%)	Peak viscosity (cP)	Hold viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
PMH1	0	221.00	126.00	352.67	94.67	227.00
	0.25	403.00	364.00	1183.67	39.33	1020.67
	0.50	471.00	405.00	1109.00	12.00	652.33
	0.75	420.00	410.33	1432.00	8.67	820.00
	1.00	555.00	489.00	1549.00	107.00	1101.33
CD (0.05)		3.39	3.95	3.25	1.99	3.45
JL3459	0	501.33	435.00	1039.00	66.00	604.33
	0.25	313.67	298.00	846.33	16.00	547.33
	0.5	373.67	336.33	927.67	38.67	592.33
	0.75	465.67	389.67	1048.00	75.67	659.00
	1.00	531.33	434.00	1136.00	97.33	702.33
CD (0.05)		7.52	8.78	3.68	2.30	6.31
Buland	0	413.00	406.33	813.67	6.67	407.67
	0.25	303.33	300.33	664.00	2.67	374.67
	0.50	366.33	363.33	771.67	2.67	408.33
	0.75	454.00	452.67	933.33	1.33	480.33
	1.00	493.00	491.67	963.00	1.33	471.67
CD (0.05)		4.05	3.21	4.85	1.05	12.90

CD critical difference at 5% level

guar gum resulted in increase of viscosity and may be attributed to thickening effect of gum (Weber et al. 2009; Yoon et al. 2016). This could also be possible due to interaction between starch and gum resulting in reduced mobility of starch molecule (Shi and BeMiller 2002). Satrapai and Supphantharika (2007) suggested that the hydrocolloid reduced the availability of water for granule swelling. The increased viscosity thereby increased the shear forces exerted on the swollen granules, thus increasing the breakdown viscosity. Associations between starch polymer molecules and hydrocolloids molecules could be responsible for increased SB and FV. BV and SB were found to vary significantly on increasing the level of guar gum in maize flour. The higher the BV of the flour paste, the lower was its capacity to withstand heating and shear stress during cooking. The low BV of flour can be used in the production of dishes that do not need to stick together and retains its firmness (Park et al. 2007). FV (indicates the ability of the starch to form a viscous paste) was found maximum at 1.0% level of guar gum (1549 cP) in comparison to control (352.67 cP). Chaisawang and Supphantharika (2006) explained that guar gum did not wrap the native and anionic tapioca starch granules but formed a sheet structure in the continuous phase. Therefore, the starch granules can swell freely before their physical breakdown which resulted in a significantly

($p < 0.05$) higher peak viscosity during pasting as compared with the controls.

Effect of incorporation of xanthan gum on pasting properties of maize flour from three varieties

Increasing incorporation level of xanthan gum from 0.25 to 1.0% showed increase in PV (372–469.33 cP), HV (367.67–457 cP) and FV (1028–1108.67 cP) of maize flour from PMH1 (Table 3). Likely, the addition of xanthan gum caused significant increase in the viscosities (PV, HV and FV) of flour as compared to control. With increase in addition level from 0.25 to 1.0% there was increase in PV and FV of maize flour from JL3459 and Buland. PV is the maximum viscosity attained by gelatinized starch during heating in water. It indicates the water binding capacity of the starch granule. BV and SB changed significantly ($p < 0.05$) on increasing the level of xanthan gum from 0.25 to 1.0%. On comparing the both gums, it was found that the effect of guar gum in increasing viscosity was more pronounced than xanthan gum. In other studies, incorporation of guar gum and xanthan gum (Achayuthakan and Supphantharika 2008; Weber et al. 2009) had also shown the same effect on viscosities. It might have been due to fact that guar gum molecule has smoothness, linearity and exterior long chain which could have been responsible for

Table 3 Effect of incorporation of xanthan gum on pasting properties of maize flour from three varieties

Maize variety	Xanthan gum (%)	Peak viscosity (cP)	Hold viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
Control	0	221.00	126.00	352.67	94.67	227.00
PMH1	0.25	372.00	367.67	1028.00	4.00	660.00
	0.50	429.00	426.00	1080.67	2.67	655.00
	0.75	462.33	451.00	1288.00	11.33	837.00
	1.00	469.33	457.00	1108.67	11.67	652.00
	CD (0.05)	3.15	3.12	3.04	1.69	3.04
JL3459	0	501.33	435.00	1039.00	66.00	604.33
	0.25	423.00	421.00	887.67	2.33	466.33
	0.50	496.00	493.67	901.00	2.67	407.33
	0.75	503.33	500.00	871.33	3.33	370.67
	1.00	585.67	581.00	1017.00	4.67	436.00
	CD (0.05)	3.74	4.01	3.20	1.88	4.18
Buland	0	413.00	406.33	813.67	6.67	407.67
	0.25	423.00	419.00	751.67	3.67	359.00
	0.50	444.00	432.67	793.67	10.00	331.00
	0.75	473.33	470.00	827.67	2.00	357.00
	1.00	574.00	569.33	956.00	4.67	387.33
	CD (0.05)	3.39	5.21	7.99	0.94	3.51

CD critical difference at 5% level

high viscosity. Moreover, guar gum in flour/water mixture remains in continuous phase of medium and volume of phase resulted using high concentration of guar gum which improved the viscosity to higher extent (Numfon 2017). Earlier, greater improvement by guar gum has been reported due to strong interaction between galactomannan and starch molecule (Rosell et al. 2011). Therefore, among both the gums, guar gum would be more useful to improve the viscosity of maize flour and have maize product quality comparable to wheat during making of bakery and confectionary.

In previous study, Arif et al. (2014) studied the effect of pentosan on the pasting properties of eight wheat cultivars. All the cultivars showed varied magnitude of pasting properties with same level of pentosan substitution. Thus, we could suggest that varietal difference of maize flour might have been the cause of different magnitude of viscosity. But on comparing the varieties the addition of xanthan gum caused more improvement in viscosities in PMH1 than JL3459 and Buland, in the order. The physico-chemical data showed that starch content was the highest in PMH1 followed by JL3459 and Buland. Waterschoot et al. (2014) observed that the blends of potato starch with maize starch at total high starch concentration had higher viscosity in line than at the lower concentration.

Effect of incorporation of whey protein concentrate on pasting properties of maize flour from three varieties

The addition of WPC decreased the PV, HV and FV for all varieties (Table 4). The increase in level of WPC from 5.0 to 15.0% caused an increase in FV. Similar findings were observed by Onwulata and Konstance (2006). This study showed a marked decrease in the PV and FV with addition of WPC. WPC showed negative correlation with pasting properties of rice flour (Lim et al. 1999; Tan and Corke 2002), may be due to dilution of starch. Marco and Rosell (2008) made it evident that dilution factor could not solely be responsible for decrease in the viscosity. It was reported that the extent of pasting viscosity was higher for whey protein than the other protein isolates. Thus, the negative correlation might have been due to difference in whey protein properties from other protein isolates.

Effect of incorporation of potato starch on pasting properties of maize flour

Pasting viscosity decreased with the addition of potato starch in maize flour from PMH1 (Table 5). The viscosity of maize flour was significantly ($p < 0.05$) affected with addition of potato starch. On increasing the addition level

Table 4 Effect of incorporation of whey protein concentrate on pasting properties of maize flour from three varieties

Maize variety	Whey protein concentrate (%)	Peak viscosity (cP)	Hold viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
PMH1	0	221.00	126.00	352.67	94.67	227.00
	5.0	73.33	79.67	81.67	2.33	18.00
	10.0	41.33	39.00	192.67	2.33	154.00
	15.0	32.67	30.33	169.67	2.67	139.67
CD (0.05)		3.44	2.98	6.34	1.09	3.03
JL3459	0	501.33	435.00	1039.00	66.00	604.33
	5.0	343.33	341.67	782.67	2.00	442.00
	10.0	278.33	272.67	602.67	4.67	330.67
	15.0	241.33	240.67	560.00	1.00	320.67
CD (0.05)		2.87	6.66	4.26	1.96	5.41
Buland	0	413.00	406.33	813.67	6.67	407.67
	5.0	293.33	291.33	608.33	2.67	318.67
	10.0	224.00	223.00	486.33	1.00	262.67
	15.0	176.00	173.33	398.67	2.67	226.00
CD (0.05)		8.28	5.81	5.67	0.94	8.26

CD critical difference at 5% level

of potato starch (5.0 and 10.0%), significant decrease in PV from 188.67 to 119 cP, HV from 103.33 to 60 cP and FV from 307.67 to 220.33 cP were observed. On increasing the level of potato starch from 0 to 10.0%, significant decrease in PV from 501.33–133 cP, HV from 435 to 131.33 cP and FV from 1039 to 489 cP was observed for maize flour from JL3459 and flour from Buland showed similar trends. Pasting properties of potato starch alone and as mixture with different starches and flours have been already tested (Zhang et al. 2011). Generally, difference in amylose and

lipid content of starches was contributed to different functional properties (Singh et al. 2003). Earlier authors also reported that potato starch had highest pasting viscosity among all other starches. (Zaidul et al. 2007) and addition of potato starch as mixture in other starches and flours caused the increase in viscosity of mixture (Zaidul et al. 2007). Additionally, Kaur et al. (2015) reported that potato starch had higher PV, hot paste and FV than maize starch. It has been claimed that potato starch has high amount of phosphate monoester which esterified with

Table 5 Effect of incorporation of potato starch on pasting properties of maize flour from three varieties

Maize variety	Potato starch (%)	Peak viscosity (cP)	Hold viscosity (cP)	Final viscosity (cP)	Breakdown viscosity (cP)	Setback viscosity (cP)
PMH1	0	221.00	126.00	352.67	94.67	227.00
	5.0	188.67	103.33	307.67	86.33	202.67
	10.0	119.00	60.00	220.33	59.00	160.00
CD (0.05)		5.25	6.28	8.24	2.21	3.88
JL3459	0	501.33	435.00	1039.00	66.00	604.33
	5.0	216.67	212.33	683.00	5.00	471.33
	10.0	133.00	131.33	489.00	2.33	358.67
CD (0.05)		2.75	4.85	4.76	2.40	6.92
Buland	0	413.00	406.33	813.67	6.67	407.67
	5.0	204.00	202.00	532.67	1.67	331.33
	10.0	113.67	112.33	344.00	2.33	232.00
CD (0.05)		5.81	4.10	4.70	1.15	4.10

CD critical difference at 5% level

amylopectin resulting in higher viscosities than maize starch (Craig et al. 1989). However, in this study, the mixture of maize flour with potato starch at different concentrations has resulted in decrease in viscosities. This could be attributed to nature of flour, particle size difference of flour, varietal difference and amylose-lipid complex formation.

Conclusion

Effect of xanthan gum (0–1.0%), guar gum (0–1.0%), whey protein concentrate (0–15.0%) and potato starch (0–10.0%) on pasting properties of maize flour were evaluated. The results showed that maize flour viscosity improved with the incorporation of xanthan and guar gums. However, guar gum showed the greatest effect on viscosity amongst the additives studied and further the effect was concentration dependent. On the other hand, WPC and potato starch showed negative effect with the viscosity of flour. Thus, among the additives, xanthan gum 1.0% (w/w) and guar gum 1.0% (w/w) were selected. Study suggested that xanthan and guar gum may be used for the preparation of products from maize flour to improve the texture, binding ability and paste viscosity.

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