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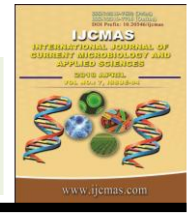

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Effect of Casein and Hydrocolloid on Maize Dough and *Chapati* Properties

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A B S T R A C T

It is difficult to handle the maize dough when *chapaties* (unleavened Indian bread) have to be prepared, due to the absence of gluten proteins in maize. For improving the dough handling and *chapati making* characteristics of maize and quality protein maize (QPM) flour, effect of addition of casein protein (5% to 15%, w/w) alone and with 3% hydoxy propyl methyl cellulose (HPMC) was studied. Rapid visco analysis of flour blends, rheological, textural, properties of dough and texture as well as sensory evaluation of *chapaties* was studied. Rapid visco analysis revealed that quality protein maize flour showed the higher values for peak, breakdown, final, and setback viscosities as compared to normal maize flour. Addition of casein alone as well as with HPMC hydrocolloid reduced the viscosity in maize and QPM flour. Rheological parameters like storage modulus (G') and loss modulus (G'') increased with an increase in protein concentration. G* was maximum for the dough sample containing 15% casein and HPMC. Addition of 3% HPMC along with 10-15% casein increased the dough strength and extensibility in both maize and QPM flour blends. *Chapaties* prepared from QPM and maize flour dough containing 10% casein and 3% HPMC were soft and rated with overall acceptability of 8.20 and 7.90 as compared to control values of 6.50 and 6.15, respectively.

Introduction

More and more people are being diagnosed with gluten intolerance/ celiac disease. Such people who have allergy to gluten cannot take foods developed from cereals *viz.* wheat, rye, barley, kamut, spelt, oats, triticale etc. The only treatment to this disease is to avoid products containing gluten proteins. To tackle with the problem of celiac disease variety of grains are utilized. The most commonly used cereal flours are of rice, sorghum, maize, millets etc.

The absence of gluten produces technological problems in the development of dough as well as product. To solve these technological problems, several additives have been tried which could mimic gluten properties (Sciarini *et al.*, 2012). Keeping in view that gluten free products are usually developed from so to improve their nutritional value proteins from different sources have been added by different workers, which not only resulted in nutritional benefits but also improved volume, appearance and sensory aspects of the products. However, although initially the aim of addition of proteins was to increase the nutritional value of gluten free products, lately, it has been reported that the formation of a continuous protein phase is vital for obtaining an improvement in the quality of gluten free products (Matos *et al.,* 2014). Therefore, the selection of the protein source with the appropriate functionality seems to play an important role in the production of gluten free products. Moreover, hyrdocolloids such as carboxymethylcellulose (CMC) and hydroxypropylmethylcellulose (HPMC) and water combinations have been reported to replace gluten in the rice based breads (Ylimaki *et al.,* 1988). Saha and Bhattacharya, 2010; Dixit and Bhattacharya, 2015 have shown that rheological properties of rice dough can be modified by addition of protein and /or hydrocolloid.

In India, maize (*Zea mays* L.) has emerged as the third important food grain crop after wheat and rice. It is mainly utilized as a source of human food (25%), animal feed (12%), poultry feed (49%), industrial products mainly as starch (12%), and 1% each in brewery and as seed out of the total maize produce in India (Dass *et al.,* 2008). Majority of the people living in the Indian subcontinent depend on unleavened bread known as *chapati*. Maize flour is used to make unleavened bread (c*hapati*), which is mainly consumed in a few Northern states of India (Sandhu *et al.,* 2007). QPM is a special variety of maize which has twice the amount of lysine and tryptophan than normal maize. Maize as well as QPM is a gluten free cereal, thus suitable to produce foods addressed to celiac patients. The utilization of maize as well as QPM for making *chapaties* shows difficulty as it does not form viscoelastic dough on kneading. Understanding of the dough rheology is an important parameter for handling with respect to sheeting or rolling particularly with *chapaties*. Keeping in view that sheeting of maize *chapati* with rolling pin is difficult so in order to improve dough handling characteristics of maize and QPM flour the present study was conducted to study the effect of casein protein at different concentrations along with hydrocolloid (3% HPMC) on a) dough rheology and texture b) on texture, sensory and nutritional characteristics of *chapaties*.

Materials and Methods

Raw materials

Quality protein maize (HQPM-5) and maize (HM-4) were procured from department of plant breeding, ICAR-Indian Institute of Maize Research, Ludhiana. The grains of QPM and maize were cleaned and pulverized into fine flour (Sieve Mesh No. 40 BSS; 0.401mm). The flour was packaged in air tight containers till further use. The proximate composition of the flour was determined by AOAC (2000). Quality protein maize flour contained 7.00 g/100 g moisture, 9.33 g/100 g protein, 4.50 g/100 g crude fat, 1.33 g/100 g minerals, 77.84g/100 g carbohydrates while maize flour had 6.91g/100 g moisture, 9.28 g/100 g protein, 4.07 g/100 g crude fat, 1.45 g/100 g minerals and 79.29g/100 g carbohydrates.

Pasting properties of flour with and without additives

Pasting properties were determined using a rapid visco analyzer (RVA) (Newport Scientific model 4-SA, Warriewood, Australia) by following the AACC Approved Method No. 61-02 (AACC, 1995). The QPM and maize flour blend suspension was prepared by mixing 3.5 g flour blend sample (14 g/100 g moisture basis) with 25 ml distilled water in an aluminum canister. Different parameters *viz.* peak viscosity, final viscosity, breakdown (Peak viscosity- trough viscosity) and setback (difference between final viscosity - trough viscosity) were determined. Trough viscosity is defined as minimum viscosity at 95°C. Viscosity values were taken in cP.

Dynamic oscillatory measurements

A controlled stress/strain rheometer (Paar Physica rheometer, MCR 301, Anton Paar GmbH, Germany) was used to determine dynamic rheological measurements of the dough. The equipment was fitted with parallel plate geometry (50 mm diameter, 1 mm gap). The maize and QPM dough samples were placed between the plates and after 5 min resting time was given before starting the test. The rim of the sample was coated with paraffin oil in order to prevent evaporation during the measurements. All the measurements were performed at a temperature of 25°C. In order to determine the linear viscoelastic region (LVE) the strain sweeps at 1 Hz frequency were carried out from 0.01 to 100% at temperature 25°C. Frequency sweep tests were performed from 0.01 to 10 Hz to determine the storage modulus (G'), loss modulus (G”) and loss tangent (tan) as a function of frequency. Two replicates of each measurement were made.

Dough extensibility and *Chapati* making properties of QPM and Maize flour

Dough extensibility study was done using Kieffer rig on TA/XT2 Texture analyzer (Stable Micro Systems, Surrey, England). QPM and maize flour 90g was mixed with 90ml of water for 3 min in lab mixer. The dough was rested for half an hour. For preparing *chapaties* 30g of dough sample was rounded and rolled in the form of *chapati* up to a diameter of 140 mm and thickness of 2mm. *Chapati* was baked as per method of Sandhu *et al.*, 2007. The *chapati* was allowed to cool for 10 min at 25°C and then placed in polythene pouches and placed in air tight containers at 25°C. Rectangular strips of 7x 1.5 cm were cut from the centre of the *chapati* using a metal template. This strip of *chapati* was then tested for extensibility on the TA/XT2 Texture analyzer (Stable Micro Systems, Surrey, England). One clamp was attached to the moving arm of TA/XT2 and the other was attached to the platform. A load cell of 50 N was used at a cross head speed of 1 mm/s to pull the *chapati* strip apart until it ruptured. From the force displacement curve peak force to rupture (N) and extensibility (mm) were calculated.

Sensory evaluation and proximate analysis

The sensory characteristics of *chapaties* were evaluated by the sensory panel comprised of 15 semi trained persons aged between 25 and 50. All of the samples were coded with random 3 digit numbers before presenting to the panel. The panel was provided with *chapaties* two in number for every experimental sample and asked to score them for different sensory attributes. Water was provided to the panelists for rinsing the mouth in between the evaluation of different samples. Nine point hedonic scale was used to evaluate the sensory characteristics such as appearance, texture, flavor, taste and overall acceptability for all the *chapati* samples. (BIS, 1971). The *chapati* samples prepared from QPM and maize flour were studied by the AOAC (2000) methods, for moisture, crude fat, protein and total ash content. For this the *chapati* was crumbled, mixed uniformly and known weight of the mixed material was taken to represent the whole *chapati*. Three samples were used as replicate each time.

Statistical analysis

Statistical analysis was done using SPSS software, Version 16.0 (Pascal International Software Solution, Boston, MA, USA). The effect of casein protein and HPMC on pasting profile of flour, rheological properties of the dough and textural properties of dough, and *chapati*, nutritional and sensory properties of the *chapaties* was studied using one-way ANOVA, and means were compared using least significant difference (LSD).

Results and Discussion

Pasting properties of flour blends

Pasting characteristics of maize and QPM flour and the blends with casein and HPMC are shown in Table 1. Significant differences in the pasting properties of QPM, normal maize flours and flours with added casein and HPMC were observed. The pasting profiles could be explained based on molecular characteristics of the starch components such as amylose or amylopectin contents (Nimsung *et al.,* 2007). QPM flour showed substantially higher peak, breakdown, setback, and final viscosity than that of normal maize flour. This could be due to the varietal difference. Moreover, the differences in the size and shape of starch granules could have the effect on pasting profiles.

The peak viscosity (PV) of starch paste has been reported to be an important characteristic to distinguish a given starch from the other species of starch (Huang *et al.,* 2006). Significant variation in PV between maize and QPM shows differences in their starch. Tester and Morrison (1990) reported that the pasting properties of starch are affected by amylose, lipid content and branch chain length distribution of amylopectin. The observed variation might be due to changes in the structure of the starch components *i.e.* branch chain length distribution of amylopectin.

Pasting temperature (PT) provides an indication of the minimum temperature required to cook the flour. Results revealed that there is no significant difference between the PT of maize and QPM. Pasting temperature for the flour blends ranged from 78.10 to 79.83 °C. PT increased with addition of HPMC. It could be due to the reason that hydrocolloid may compete with prime starch chains and may be responsible for raising gelatinization temperature.

Addition of casein significantly reduced the viscosities in both flours. Viscosities further dropped down when the flour blends with casein were supplemented with HPMC. This negative influence of protein and hydrocolloids could be due to dilution of starch component. Increasing concentration of protein may compete with starch granules for water absorption and thus cause hindrance in the swelling of starch granules (Nimsung *et al.,* 2007). Similar decrease in viscosity with addition of different concentration of whey protein concentrate in water chestnut flour has been reported by Sarabhai and Prabhasankar (2015).

Breakdown viscosity (BV) for different flour blends varied from 93.67 to 607.67cP. BV expresses the ability of starches to withstand heating at high temperature and shear stress.BV of QPM was more than maize flour. Higher BV may be due to the presence of increased number of shorter amylopectin branch chains (Patindol *et al.,* 2005).

A negative correlation between long chains of amylopectin and breakdown viscosity has been reported by Han and Hamaker (2001). A greater proportion of short branched chain amylopectin may result in swollen, more breakable starch granules. Maize flour with 15% protein and 3% HPMC showed the least breakdown among all the studied samples. The lowest BV of maize flour blend indicated its high paste stability under heat and shear.

During the final cycle of cooling viscosity increased further in all samples. This increase in viscosity could be due to the alignment of amylose chains (Flores-Farias *et al.,* 2000). During the cooling cycle, the viscosity of all starch pastes increased rapidly because of the large number of intermolecular hydrogen bonds that were formed, resulting in gel formation at lower temperatures (Leelavathi *et al.,* 1987).

Setback viscosity (SV) of QPM and maize flour decreased from 1681.7 to 769 cP and 931.3 to 455.3cP, respectively, the lowest was observed for maize flour blend with 15% casein and 3% HPMC and the highest for QPM flour. The lowest SV of flour indicated its lower tendency to retrograde. QPM displayed a higher SV indicating a higher retrogradation tendency than the maize which might be due to the effect of amylose and amylopectin composition. Starch with high amylose could undergo the retrogradation process faster than the starch with low amylose content. Yam starches gave a higher setback indicating a higher retrogradation tendency. This was most likely due to the greater amount of amylase present, which resulted in the shorter amylose chains causing intermolecular association, thus producing retrogradation (Hoover and Sosulski, 1991). Starch retrogradation is the process, which occurs when the molecular chains in gelatinized starches begin to re-associate in an ordered structure (Sandhu and Singh, 2007). During retrogradation; amylose forms double-helical associations of 40-70 glucose units while amylopectin crystallization occurs by re-association of the outermost short branches.

The RVA data provided useful information for food processing and product development. QPM displayed very high viscosities which is desirable for the products such as breads for increased texture quality. However, addition of casein and HPMC had significantly reduced the viscosities to the tune that is well below the levels of normal maize flour.

Dynamic oscillatory measurements

Amplitude sweep

The viscoelastic properties of the maize and QPM dough containing casein at different levels (5, 10, 15%) as well as with addition of HPMC (3%) and control samples were studied by dynamic oscillatory test. Small amplitude measurements not only provides information about microstructure of samples under study, but also distinguishes weak gels from strong gels and gives information about their linear viscoelastic (LVE) region. The amplitude sweep test of maize and QPM flour blends, at various concentration of casein, with and without hydrocolloids was carried out at fixed temperature of 25°C and frequency of 1 Hz. LVE region was found to be limited up to a strain of 0.1%.

The results revealed that the tau values for maize and QPM ranged from 109-111 and 158-163, respectively. Both maize as well as QPM dough showed LVE upto 0.1% strain only showing them to be weak gels as it has been reported that strong gels remain in the linear viscoelastic region over greater strains than weak gels (Steffe, 1996).

Frequency sweep

In order to evaluate material specification and comparison of viscoelastic behavior of different dough formulations, the frequency sweep test was carried out at 25°C, at a strain of 0.1% and frequency range of 0.1 to 10 Hz. Frequency sweep gives information about how the viscous and elastic behavior of the sample changes with rate of applied strain at a constant amplitude (Steffe, 1996). Elastic or storage modulus (G') and viscous or loss modulus (G") represents the non-dissipative (elastic) and dissipative part (viscous flow) of the mechanical properties of the material under study.

Table.1 Pasting characteristics of maize and quality protein maize blends

	PV (cP)	BV(cP)	FV(cP)	SV(cP)	P_T (Min)	T_P (°C)
M control	1005.00^{f}	307.00^{d}	1629.33^{e}	931.33^{e}	4.65^{bcd}	78.15^{b}
M+5% C	770.67^{h}	211.67^{e}	1260.33^{h}	706.67^{h}	4.55^{cdfg}	78.77^{ab}
M+10% C	610.67^{j}	196.33^{ef}	954.00^{k}	533.67^{j}	4.45^{g}	78.68^{ab}
M+ 15% C	534.33^{k}	162.00^{g}	833.67^{l}	454.33^{k}	4.45^{g}	79.08^{ab}
M+5% C+3% H	680.00^{i}	114.33^{h}	1171.00^{i}	636.67^{i}	4.60^{bcdf}	78.45^{b}
M+10% C+3% H	560.67^{k}	106.00^{hi}	1032.00^{j}	559.00^{j}	4.51^{fg}	78.78^{ab}
M+ 15% C+3% H	438.00^{l}	93.67^{i}	839.00^{l}	455.33^{k}	4.51^{fg}	79.03^{ab}
Q control	1650.33^{a}	607.67^{a}	2769.33^{a}	1681.67^{a}	4.78^{a}	78.43^{b}
Q+5% C	1351.33^{b}	449.00^{b}	2207.67^{b}	1282.67^{b}	4.62^{bcd}	78.10^{b}
Q+10% C	1184.00^{c}	447.00^{b}	1694.67^{d}	1052.33^{d}	4.49^{fg}	78.50^{b}
Q+ 15% C	1063.00^{e}	395.33^{c}	1565.33^{f}	884.00^{f}	4.53^{dfg}	78.48^{b}
Q+5% C+3% H	1112.67^{d}	188.67^{f}	2031.00^{c}	1127.00^{c}	4.71^{ab}	78.97^{ab}
Q+10% C+3% H	958.00^{g}	203.00^{ef}	1655.00^{de}	907.33^{ef}	4.69^{ab}	79.25^{ab}
Q+ 15% C+3% H	777.00^{h}	104.33^{hi}	1421.67^{g}	769.00^{g}	4.67^{abc}	79.83^{a}

M: Maize; Q: QPM; C: Casein; H: Hydroxy propyl methyl cellulose; T_p: pasting temperature; P_T: pasting time; PV, FV, BV and SV: peak, final, breakdown and setback viscosity, respectively. Values are mean of three replications. Values bearing same superscript do not differ significantly (p<0.05).

Table.2 QPM, maize based dough and *chapati* Texture studies and their sensory evaluation

	Dough characteristics		Chapati characteristics		
	Extensibility (mm)	**Rupture force (g)**	**Extensibility (mm)**	**Hardness (g)**	**Sensory score**
M control	4.59^{c}±0.64	5.6^{def}±0.33	4.21 ^{a} ±0.45	5.4^{a}±0.20	6.15^{c}±0.38
M+5% C	4.16^{c}±0.35	7.65^{ab}±0.13	3.91 ^{a} ±0.40	3.6^{b}±0.35	6.55^{c}±0.44
M+10% C	3.51^{c}±0.32	7.75^{a} ±0.17	3.81 ^{a} ±0.20	3.4^{b} ±0.12	6.30^{c} ±0.26
M+ 15% C	3.61^{c}±0.67	7.8^{a}±0.15	3.21 ^{a} ±0.15	2.6^{cd}±0.17	6.85^{b}±0.70
M+5% C+3% H	10.19^{a} ±0.30	6.9^{c}±0.17	3.51 ^{a} ±0.37	2.6 ^{cd} ±0.20	6.60^{bc} ±0.25
M+10% C+3% H	10.11^{a}±0. 73	7.8^{a}±0.13	3.61 ^{a} ±0.31	2.8 ^{cd} ±0.40	7.90^{a}±0.40
M+ 15% C+3% H	9.20^{ab}±0.67	7.5^{ab}±0.33	3.44 ^{a} ±0.06	2.7 ^{cd} ±0.12	7.35^{a,b}±0.60
Q control	4.45^{c}±0.45	5.1^{f}±0.25	4.73 ^{a} ±0.21	5.4 ^{a} ±0.20	6. 50^{bc}±0.68
Q+5% C	3.74^{c}±0.68	5.9^{c}±0.26	4.15 ^{a} ±0.33	3.1^{bc}±0.36	6.40^{c}±0.94
Q+10% C	3.27^{c}±0.44	7.4^{ab} ±0.15	3.83 ^{a} ±0.60	2.7^{cd} ±0.12	6.48^{bc}±0.60
Q+ 15% C	3.21^{c}±0.67	7.1^{bc}±0.18	4.68 ^{a} ±0.38	2.3^{d}± 0.15	7.10^{b,c}±0.52
Q+5% C+3% H	9.06^{ab}±0.30	5.8^{de}±0.50	4.47 ^{a} ±0.66	2.2^{d} ±0.10	6.20 ^{c}±0.75
Q+10% C+3% H	8.93^{ab}±0.73	7.1^{bc}±0.14	4.53 ^{a} ±0.23	2.3^{d}±0.15	8.20 ^{a}±0.63
Q+ 15% C+3% H	8.58^{b}±0.67	7.0^{bc}±0.17	4.00 ^{a} ±0.10	2.2^{d}±0.06	7.25^{b}±0.68

M: Maize; Q: QPM; C: Casein; H: Hydroxy propyl methyl cellulose. Values are mean of three replications. Values bearing same superscript do not differ significantly (p<0.05).

Table.3 Proximate composition of *chapaties* prepared from maize and quality protein maize flour blends

Sample	Moisture	Protein	Fat	Ash	Total Carbohydrates
M control	31.54(0.19)^{h}	3.10(0.10)^{e}	4.13(0.15)^{ab}	0.92(0.01)^{ef}	60.30(0.09)^{a}
M+5% C	37.43 (0.93)^{bc}	4.91(0.31)^{d}	3.65(0.17)^{c}	0.92(0.01)^{fg}	53.09(1.35)^{cde}
M+10% C	35.17(0.10) ^{fg}	8.01(0.14)^{bc}	3.28(0.08)^{c}	0.90(0.01)^{g}	52.65(0.19)^{def}
M+ 15% C	34.45(0.48) ^{g}	9.68(0.16^{a}	3.19(0.27)^{c}	1.02(0.01)^{bc}	51.66(0.51)^{fg}
M+5% C+3% H	35.67(0.21)^{ef}	4.47(0.24)^{d}	3.62(0.19) ^{bc}	0.91(0.01) ^{fg}	54.94(0.49)^{b}
M+10% C+3% H	36.63(0.18)^{de}	7.57(0.26) ^{bc}	3.25(0.05)^{c}	0.94(0.02)^{de}	51.91(0.30)^{efg}
M+ 15% C+3% H	35.47(0.15)^{ef}	9.62(0.16) ^{a}	3.20(0.13)^{c}	0.99(0.01) ^{c}	50.72(0.12)^{g}
Q control	32.07(0.43)^{h}	3.37(0.32)^{e}	4.25(0.05)^{a}	1.01(0.01)^{bc}	59.31(0.31)^{a}
Q+5% C	36.77 (0.25)^{cd}	4.62(0.24)^{d}	3.30(0.23)^{c}	1.02(0.01)^{bc}	54.29(0.71)^{bc}
Q+10% C	37.97(0.45) ^{b}	8.28(0.19)^{b}	3.37(0.13)^{c}	1.05(0.01)^{a}	49.34(0.56)^{h}
Q+ 15% C	38.17(0.29) ^{b}	9.73(0.21)^{a}	3.25(0.23)^{c}	1.03(0.02)^{ab}	47.82(0.34)^{i}
Q+5% C+3% H	37.53(0.30)^{bc}	4.37(0.15)^{d}	3.31(0.18)^{c}	0.91(0.01)^{fg}	53.85(0.36)^{bcd}
Q+10% C+3% H	39.31(0.55)^{a}	8.03(0.06)^{bc}	3.23(0.24)^{c}	0.96(0.01)^{d}	48.46(0.43)^{hi}
Q+ 15% C+3% H	38.22(0.21)^{b}	9.50(0.30)^{a}	3.37(0.31)^{c}	0.95(0.01)^{de}	47.96(0.40)^{i}

M: Maize; Q: QPM; C: Casein; H: Hydroxy propyl methyl cellulose. Values are mean of three replications. Values bearing same superscript do not differ significantly ($p<0.05$).

Fig.1 Frequency sweep analysis of QPM flour dough information about G' and G''

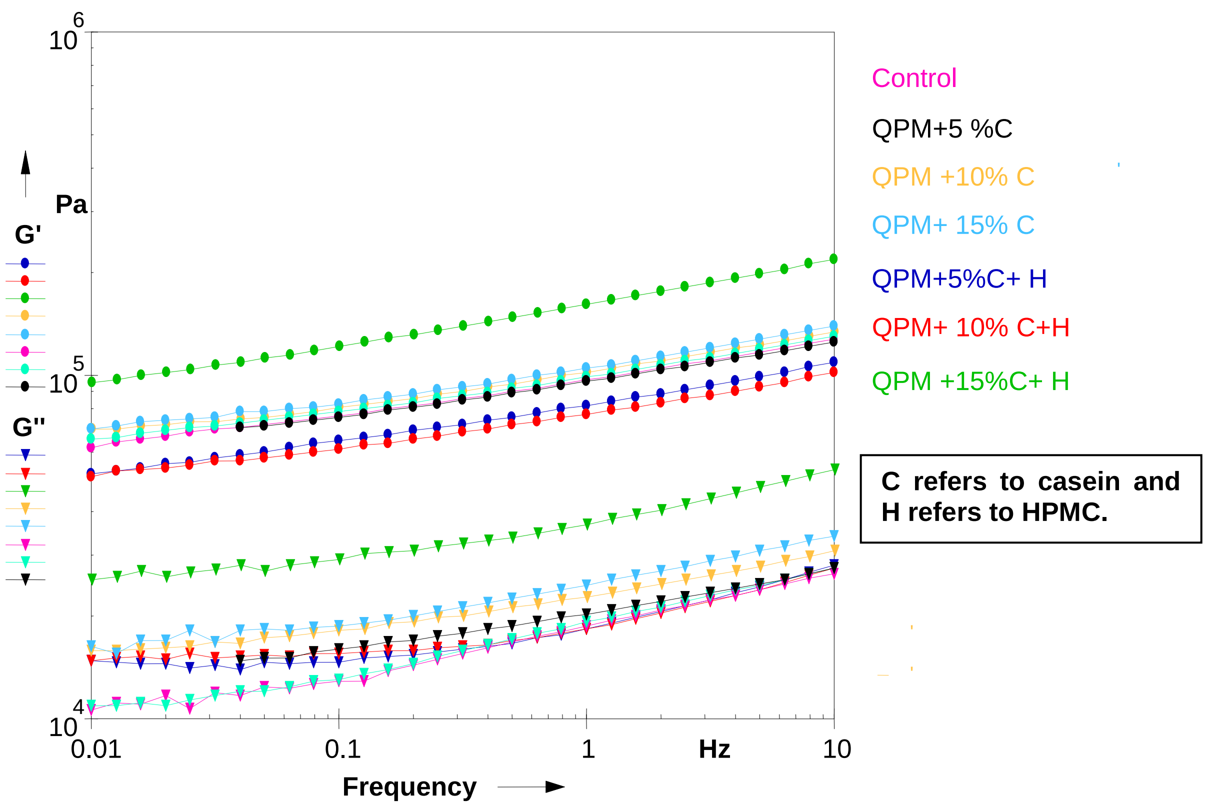


Fig.2 Frequency sweep analysis of maize flour dough giving information about G' and G''

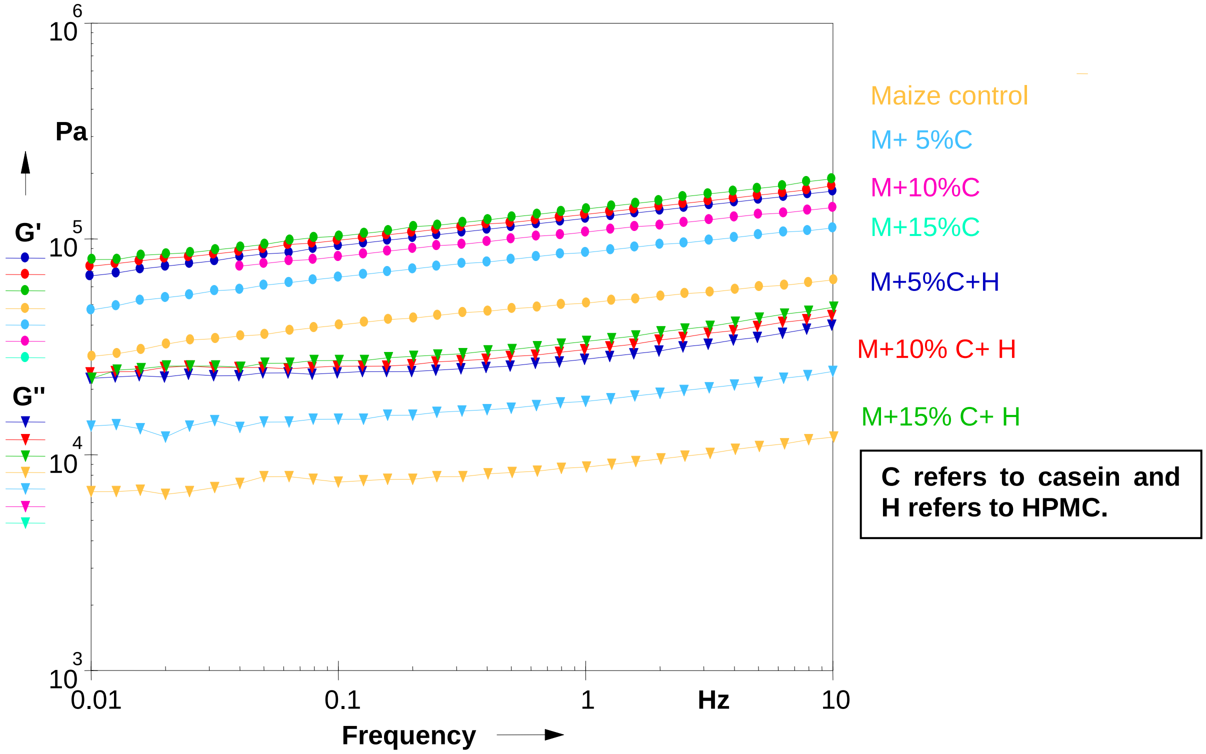


Fig.3 Frequency sweep analysis of QPM flour dough information about G*

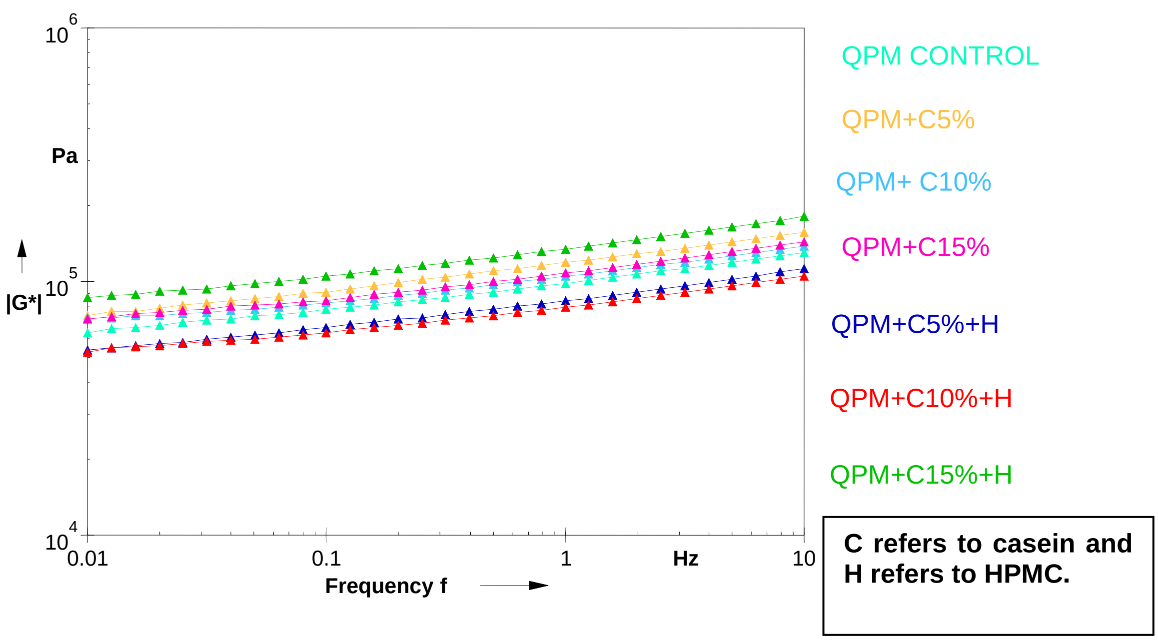
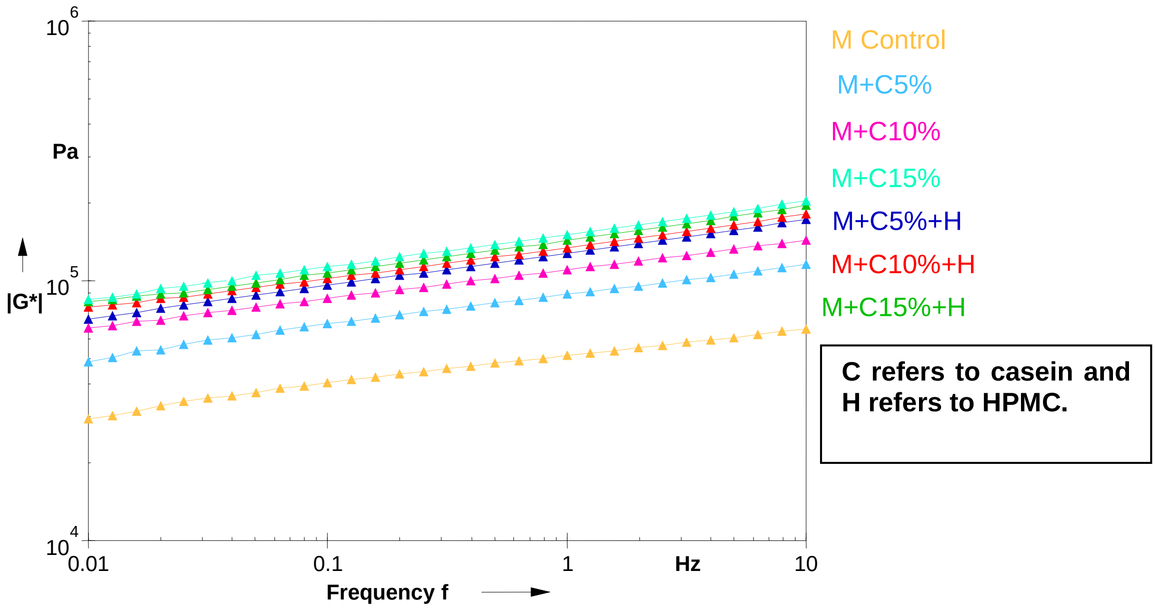


Fig.4 Frequency sweep analysis of maize flour dough giving information about G*



Mechanical spectra of all the tested samples showed that values for storage or elastic modulus (G') were higher than the values for loss or viscous modulus (G'') at all the tested frequency range (Fig. 1 and 2), which suggested a solid elastic behavior of the dough samples. It has been reported that low moisture containing corn flour doughs without any added gum showed more viscoelastic solid behavior than samples with higher moisture content and or gum.

As per Lai and Liao (2002) material showing higher values of (G') could be classified as elastic gels. Addition of protein and hydrocolloid increased the values of dynamic moduli (G') and (G'') of dough as compared to control dough which showed that the new hydrophilic and hydrophobic interactions may be developing in the system.

The highest values of storage (G') and loss (G'') moduli and large difference in their values were observed for maize flour sample containing 15% casein and QPM flour with 15% casein and 3% HPMC and as compared to control, which showed that these flour formulations contributed to a less viscous but more elastic property (Lee and Inglett, 2006). The increase in elastic character is reported to be responsible for shape retention properties during dough handling (Inglett *et al.*, 2013).

The values of loss tangent (tan δ) are obtained from the ratio of energy lost to the energy stored (G''/G'). As compared to maize, tan values were less for QPM dough. In present study QPM flour formulation with 5% and 10% casein alone and 10% casein and 15% casein with 3% HPMC and maize flour formulations with 15% casein alone and with HPMC showed consistency in the value of tan δ over a certain frequency range and for all studied samples (G') was more than (G''). It has been suggested that material shows elastic or rubber like behavior if the value of (G') is independent of frequency and greater than (G'') over a certain frequency range (Inglett *et* *al.,* 2013). Therefore, results revealed that addition of casein (10-15%) in presence of hydrocolloid showed increase in elasticity of dough (Fig. 1 and 2).

The complex modulus (G*) gives information (Fig. 3 and 4) about the elasticity and the viscosity of the material; which in turn gives information on the strength of the samples (Fevzioglu *et al.,* 2012). Highest G* values were obtained for dough with 15% casein followed by 15% casein and HPMC in case of maize, while for QPM dough prepared from 15% casein and HPMC showed highest G* value. Highest G* values indicated a strong structure compared to the other doughs.

Textural properties of dough and *chapati*

It has been reported that textural qualities of dough and *chapati* directly affect its overall acceptability (Yadav *et al.,* 2008). Addition of casein alone at all studied levels of concentration (5-15%) did not significantly affect the dough extensibility in QPM and maize flour. However, addition of 3% HPMC increased the dough extensibility in both QPM and Maize flour blends having casein at different levels (Table 2). The dough extensibility ranged from 3.21-9.06 mm and 3.51-10.19 mm for QPM and maize flour blends, respectively. The addition of gum/ hydrocolloid in dough can induce several changes. It can affect the protein network formation, allow dough plasticity and cohesiveness. The maximum force required to rupture the dough was found to increase with addition of casein at all concentrations, with and without HPMC.

In case of *chapati* samples the force needed to extend the *chapati* strip increased during extension and reached a maximum before the strip ruptured, followed by a decrease. Control *chapaties* from QPM and maize showed peak force required to rupture *chapaties* as 4.35N and 4.21N, respectively and these values decreased significantly with addition of casein (Table 2). The data revealed that *chapaties* prepared from QPM and Maize flour with addition of casein alone as well as with hydrocolloid were soft in texture as compared to their control samples due to less peak load values.

Extensibility of *chapati* did not improve on addition of casein and hydrocolloid. *Chapati* extensibility in QPM and maize ranged from 3.83–4.73 and 3.21–4.21, respectively (Table 2). Although dough extensibility increased significantly with hydrocolloid but increase in *chapati* extensibility was not observed with addition of hydrocolloid in the presence of protein. This behavior could be correlated with results of Stathopoulos and O'Kennedy (2008) who have reported that aggregated casein samples were more elastic than gluten at room temperature but upon heating produced materials that were weaker and had a predominately viscous character. However, increase in extensibility of wheat flour dough *chapati* with addition of carboxymethylcellulose (CMC) has been reported (Gujral and Pathak, 2002).

Sensory analysis and nutritional composition

The sensory analysis of the fresh *chapati* was performed. This was carried out by 15 semi-trained panelists using a 10 point hedonic scale. The *chapati* prepared from flour with 10% protein and 3% HPMC scored highest for QPM as well as maize and showed significant difference from control samples (Table 2). Proximate analysis (Table 3) of *chapaties* showed that addition of casein alone and casein with HPMC significantly increased the moisture content of *chapati*. It showed that addition of protein as well as hydrocolloid helped to retain more water and as a result *chapaties* were more pliable and showed lower peak load during texture studies. An inverse relation between rate of firming of *chapati* and water has also been reported by Roger *et al.*, (1988). As reported by Sahraiyan *et al.,* (2013), the extent of water absorption increases markedly when hydrocolloids are used alone or in combination. Protein content of *chapaties* increased with increase in concentration of casein. Fat content was slightly less than control *chapaties*. This slight decrease could be due to increased concentration of protein. *Chapati* samples with more moisture and protein showed less value for carbohydrate content.

The results revealed that the progressive addition of casein in QPM and maize flour decreased the viscosity parameters significantly and this decrease was dependent on percentage of casein addition. Rheological data revealed that dough containing 15% casein and HPMC showed highest strength. Dough extensibility studies revealed that addition of HPMC (3%) along with protein at all concentrations significantly increased extensibility of dough as compared to control. Incorporation of protein and hydrocolloid improved the flours of QPM and maize. Panelists rated the *chapaties* containing 10% casein and 3% HPMC with overall acceptability of (8.20 and 7.90) as compared to control (6.50 and 6.15) for QPM and maize flour, respectively. From the results it can be inferred that a judicious selection of protein and/or hydrocolloid in appropriate levels can develop QPM as well as maize dough that possess the desirable handling properties for preparation of different products.

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