EFFECT OF XYLOGLUCAN AND MALTODEXTRIN ON THE RHEOLOGICAL AND THERMAL PROPERTY OF WHEAT FLOUR DOUGH

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Abtract: ***Xyloglucan (XG) and maltodextrin (MD) were added to the wheat flour to study the effect of hydrocolloid on the rheological and thermal property of dough. Rheological properties were measured with farinograph and rheometer while the thermal property was studied through differential scanning calorimeter (DSC). The XG/MD blend with the concentration of 1% w/w each exhibited maximum water absorption, arrival time, departure time, dough development time and stability. The blend having 3% XG and 1% MD showed maximum elasticity and mixing tolerance index. Dough dynamic rheological parameters storage modulus, loss modulus and damping factor were investigated as function of frequency. The addition of both the hydrocolloid increased the storage modulus. DSC results revealed two peaks in the temperature range of 30-150 ^{0}C. Gelatinization parameters were found to be lower than the control sample.***

Keywords: Xyloglucan, Maltodextrin, Farinograph, Rheology, DSC

1. Introduction

Xyloglucan (XG) is a highly substituted, food grade polysaccharide present in the primary cell walls of higher plants. It also exists in some seeds of trees growing in the tropical zone. It is a soluble hemicellulose with a back bone composed of β (1, 4)-linked glucose residues similar to cellulose. XG has found to have high viscosity, broad pH tolerance and mucoadhesivity [1], non- carcinogenicity [2], biocompatibility [3]. Japanese food industry has been using XG as thicker due to its high viscosity and stability against heat, pH, and shear [4]. The flow behaviour of the solution of xyloglucan is very close to Newtonian, and very stable against heat, pH and shear. It is expected to find new food applications, serving as thickening sauce, ice cream dressing, in processed vegetables, stabilizer, gelling agent, ice crystal stabilizer and starch modifier.

Maltodextrin is purified, concentrated aqueous solution of nutritive saccharides obtained from edible starch or the dried product derived from said solution and having a DE of less than 20. Functional properties of maltodextrin include fat replacer, bulking, crystallization prevention, promotion of dispersibility, freezing control, and binding of flavourings, pigments, and fats [5-6]. Maltodextrin has been used in variety of food products including french fries, fried snacks and other foods, frozen foods, cooked rice products, noodle-like preparations, milky paste foods, jelly compositions, food glazes and films [7-8].

Knowledge of the rheological behavior of liquid foods/semi liquid is essential for equipment projects as well as for evaluation of process conditions. The rheological data are used in engineering calculations involving a wide range of equipment such as pipelines, pumps, mixers, extruders, homogenizers, coaters, heat exchangers; in the determining ingredient functionality in the product development, shelf life testing, and in the evaluation of food texture by correlation to sensory data. Rheological data as obtained by farinograph have been used to predict processing effects, including mixing requirements for dough development, tolerance to over mixing, and dough consistency during production. Farinograph results are also useful for predicting finished product texture characteristics. Dynamic measurements have been extensively used to study viscoelasticity of polysaccharide solutions. The measurement of dynamic rheological and microstructural characteristics can provide insights into the behaviour of polysaccharide systems.

Hydrocolloids control water absorption and consequently dough rheology [9]. The effect of different hydrocolloids on baked products has been studied by several researchers [10-12]. Hydrocolloid induces structural changes in the crystalline structure of starch present in wheat flour [13]. Xyloglucan has shown synergistic interaction with gellan gum [14], topoica starch [15] and xanthan gum [16]. Similarly the effect of addition of maltodextrin alone or in conjugation with other polysaccharide has been studied. No work has been done to study the effect of blends of xyloglucan and maltodextrin on wheat flour dough. Therefore this work was carried out with the following objectives a. To investigate the effect of blends of XG and MD on the rheological including dynamic rheological properties of wheat flour dough. b. To study the effect of XG and MD on the thermal property of wheat flour dough.

2. Material and Method

2.1. Flour and Chemical

The flour used was "Hathi", commercial brand white wheat flour purchased from local market of Sonipat, Haryana, India. The moisture content of the flour was 12.82% (w.b.). The tamarind seed powder used in the experiment was procured from Akshar Exim Company Private Limited, Kolkotta, India. Maltodextrin was obtained from Sigma-Aldrich®, (India).

2.2. Isolation of Tamarind Seed xyloglucan (TSX)

The isolation of Tamarind Seed xyloglucan was performed by method suggested by Rao and Srivastava [17]. 20 g of tamarind kernel powder was added to 200 ml of cold distilled water to prepare slurry. The slurry was poured into 800 ml of boiling distilled water. The solution was boiled for 20 min with continuous stirring. The resulting solution was kept overnight and the supernatant centrifuged at 5000 rpm for 20 min. The supernatant liquid was separated and poured into twice the volume of absolute alcohol with continuous stirring. The precipitate obtained was washed with absolute ethanol and dried at 50°C for 8h. The dried polymer was milled, passed through sieve no.60 and stored in a desiccator until further use.

2.3. Preparation of sample

Dough was prepared using wheat flour, distilled water with the addition of xyloglucan (XG) and maltodextrin (MD) in five different mixing ratios. The range of percentage addition of XG and MD were chosen based on application of these hydrocolloid in literature. The percentage of XG and MD used in wheat flour samples numbered as 1-5 were in the ratio of 3:1, 3:2, 2:1.5, 1:1 and 1:2 respectively. The same five ratios were used for all the study presented here. The control sample had no XG or MD added into it.

2.4. Rheological characteristics

Rheological characteristics of flour samples were determined with Brabender farinograph. The 300 grams flour samples having five different combinations of XG and MD on a 14% moisture basis is weighed and placed into the corresponding farinograph mixing bowl. Water from a burette was added to the flour and mixed to form dough. As the dough was mixed, the farinograph recorded a curve on graph paper.(AOCC method No.54-21). Dough characteristics such as water absorption, dough stability, dough development time, Mixing tolerance index (MTI) and softening of dough were interpreted from farinogram.

2.5. Dynamic Rheological Measurements

Dynamic rheological measurements were performed on controlled shear/stress rheometer (Anton Paar MCR 301, Germany). Parallel plate geometry (25 mm diameter, 2 mm gap) was used for dynamic test. Dough was placed between plates of rheometer and excess batter was trimmed off carefully. The edge was coated with mineral oil to prevent drying. Dough samples were allowed to rest for 5 min after loading on plate to allow dough relaxation. The linear viscoelastic range was first determined using strain sweep test keeping the frequency constant (5 rad s^{-1}). Dough showed linear viscoelastic region below 0.1% stain. All the further test were carried out in linear viscoelastic region. The frequency sweep test were carried out at 0.1-200 rad s^{-1} at 30 ^{0}C.The experimental set up allowed the measurement of storage modulus (G'), loss modulus (G''), complex modulus and damping factor as a function of frequency.

2.6. Differential scanning calorimetry (DSC)

A differential scanning calorimeter (DSC, Pyris-1, Perkin Elmer, Norwalk, CT, USA) was used to determine thermal properties of wheat flour, XG and MD mixture. The heating rate was 10 ^{0}C min^{-1} from 30 to 150 ^{0}C with an empty pan as the reference. The DSC analyzer was calibrated using indium (T_m=156.6 ^{0}C, ΔH=28.5 J g^{-1}), mercury (T_m= -38.9 ^{0}C, ΔH=11.4 J g^{-1}), tin (T_m=231.9 ^{0}C, ΔH=60.6 J g^{-1}), and zinc (T_m=419.5 ^{0}C, ΔH=108.0 J g^{-1}). Samples were weighed (~12 mg) into aluminium pans and hermetically sealed prior to analysis. Thermal transitions of dough samples were defined as T_o (onset temperature), T_p (peak temperature) and T_c (end point temperature).

3. Result and Discussion

3.1. Effect of XG and MD on dough rheological property

The effect of XG and MD addition on wheat flour farinogram is summarized in Table 1. The Farinograph test results are used as parameters in formulation to estimate the amount of water required to make dough as well as to evaluate the effects of ingredients on mixing properties. The flour blending requirements and its uniformity can also be evaluated by farinograph. Arrival Time is the time when the top of the curve touches the 500-BU line. This indicates the rate of flour hydration. Result indicates arrival time increased with the addition of XG and MD. However for the sample having XG and MD in the ratio 1:2 the arrival time decreased as compared to control sample. Maximum arrival time of 4.5 min was observed for sample having 1% XG and MD each. Collar et al. [18] reported increase in arrival time with the addition of genu freeze, genu-freeze pectin type big, xanthan and hydroxylmethylpropylcellulose in wheat dough. Departure Time is the time when the top of the curve leaves the 500-BU line. This indicates the time when the dough is beginning to break down and is an indication of dough consistency during processing. All the sample showed less departure time as compared to control sample. Minimum departure time was observed for sample having 3% XG and 1% MD. Stability time indicates the time the dough maintains maximum consistency and is a good indication of dough strength. It is the difference in time between arrival time and departure time. All the sample tested had less stability as compared to control sample. Ghanbari and Farmani [19] reported decrease in stability with the addition of k-Carrageenan and HPMC. Tavakolipour and Kalbasi [20] found a decrease in stability time by addition of CMC or HPMC to the dough formulation. Water absorption is the amount of water required to center the Farinograph curve on the 500-Brabender Unit (BU) line. This relates to the amount of water needed for a flour to be optimally processed into end products. The addition of XG and MD had increased water absorption of wheat flour dough except for the sample 5. Maximum water absorption was observed for the sample having 1% XG and MD each. Increase in water absorption with the addition of hydrocolloid is due the presence of hydroxyl group in the hydrocolloid which allows more water interaction due to hydrogen bonding [21]. Hydrocolloid absorbs water in their interrelated network and interacts with starch granules. Higher water absorption capacity of dough represents consistency which is desirable in bread making. The results agree with the earlier work reported by Ghanbari and Farmai [19], Rodge et al. [22], Smitha et al. [23] and Guarda et al. [21]. Development time is the time required for the dough development or time required to reach the maximum consistency. Development time was found to be lesser as compared to control for all the sample except sample having 1% XG and MD each which had development time of 7.1 min. Mixing Tolerance Index (MTI) is the difference in BU value at the top of the curve at peak time and the value at the top of the curve 5 minutes after the peak. Mixing tolerance index (MTI) indicates resistivity of wheat flour to the mixing as well as the degree of softening during mixing. Stronger flour has higher the mixing tolerance. All the sample showed higher MTI as compared to control. Sample having concentration of XG and MD in the ratio 3:1 had highest MTI of 114.4 FU. This sample also showed highest elasticity or softening of 114.4 FU. Peak energy value also increased by the addition of XG and MD.

Table 1. Rheological characteristics of dough prepared with different incorporation level of XG and MD.

Sample	Arrival Time (min)	Departure Time (min)	Stability time (min)	Water Absorption (%)	Development time (min)	Softening (FU)	MTI (FU)	Peak Energy (Wh/kg)
Control	2.4±0.02^a	12±0.12^a	9.6±0.22^a	60.2±0.37^a	6.9±0.56^a	24.6±0.58^a	33.7±0.47^a	10.2±0.54^a
1 (3:1)	3.2±0.07^b	6.9±0.54^b	3.6±0.13^b	61.4±0.87^b	4.8±0.75^b	114.4±0.51^b	133.1±1.04^b	11.4±0.29^b
2 (3:2)	3.2±0.05^b	7.7±0.19^c	4.5±0.09^c	61.3±0.88^b	5.0±0.48^c	84.1±0.49^c	103.5±1.07^c	11.6±0.75^b
3 (2:1.5)	3.5±0.04^c	8.6±0.43^d	5.1±0.06^d	64.4±0.44^c	6.1±0.56^d	71.8±0.95^d	86.9±0.92^d	11.6±0.61^b

4 (1:1)	4.5 ± 0.03^{d}	10.2 ± 0.14^{e}	5.8 ± 0.28^{e}	66.4 ± 0.67^{d}	7.1 ± 0.30^{e}	50.6 ± 0.31^{e}	$61.9\pm0.66_{e}$	11.1 ± 0.22^{b}
5 (1:2)	2.0 ± 0.01^{e}	7.0 ± 0.32^{b}	5.1 ± 0.09^{d}	61.4 ± 0.39^{b}	4.8 ± 0.24^{b}	67.2 ± 0.89^{f}	85.8 ± 0.46^{f}	9.2 ± 0.38^{c}

Values in bracket in sample column indicates the percentage of XG and MD added in the flour for dough preparation
Values are means ± SD of triplicate. Means with different subscript within the same column are significantly different ($p < 0.05$)

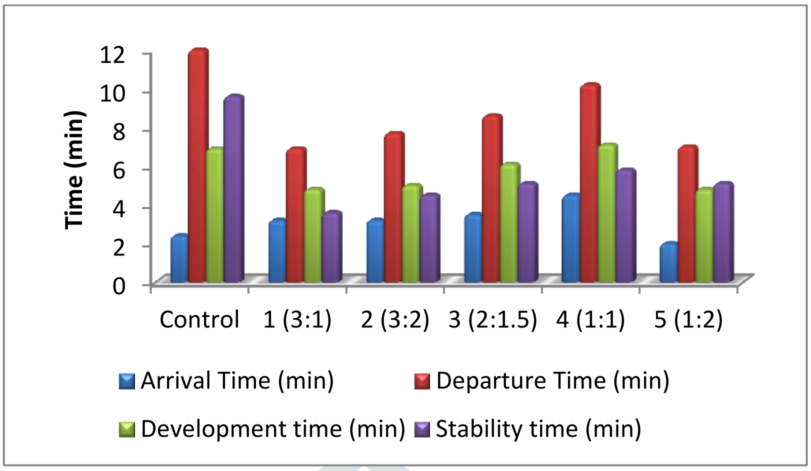


Fig. 1 Effect of XG and MD on the rheological characteristics of wheat flour dough

3.2. Effect of XG and MD on dough dynamic rheological property

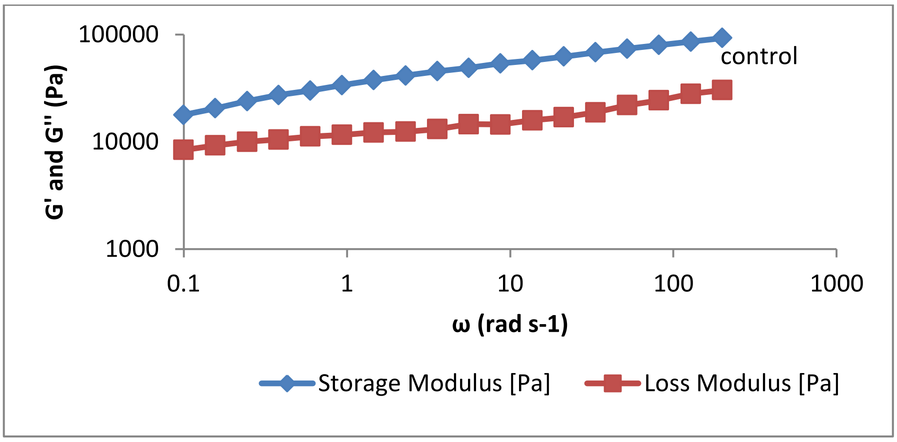
Frequency sweep test results are depicted in fig. 2. Storage modulus (G') and loss modulus (G'') were found to be function of frequency for all the samples. G' was larger than G'' indicating that all samples had a firm, elastic-like behaviour. Both dynamic modulus G' and G'' showed almost linear and slightly parallel nature in the experimental frequency range. As per Winter's gel theory this linearity suggest that in the considered time scale the sample behaved like a critical gel. Flour-water dough is considered as gel-like network capable of flowing whose flow property follows power law as function of frequency. The power law constant were calculated using following equation

$$G' = G'_0 \omega^n$$

where, G' represent the storage modulus and n is the power law exponent (dimensionless), ω is frequency and G'_0 is the intercept of the power law model for frequency sweeps. The constants were obtained from the linear regression analysis after a logarithmic transformation of the raw data. The value of n varied from 0.19 to 0.27 for G' and 0.14 to 0.20 for G'' (Table 2). The R^2 value for all the regression equation was more than 0.95. The slope of log G' vs log ω provides useful insight into the structure of biopolymer [24]. Material behaves like rubbery material when the magnitude of slope (n) of log G' vs log ω has value closer to 0 while liquid flow behaviour is exhibited when the slope approaches 2 [25]. Gabriele et al. [26] suggested that when a 3D network is present the slope to be near zero can be expected. In the present work linear regression of log G' vs log ω data showed that the resulting values of n were low (<0.3) for all the sample, indicating the existence of a 3D network. The values of tanδ (damping factor), defined as the ratio of the loss (viscous) to storage (elastic) modulus (G''/G'), have been presented in Table 2. Material showing damping factor less than 1 (G' > G'') are considered to be dominantly gel or solid-like else if damping factor is greater than 1 (G' < G'') then the material may be taken to be more liquid like. Similar results have been reported by Georgopoulos et al. [27], Tanner et al. [28], Uthayakumaran et al. [29], Phan-Thienet al. [30], Berland and Launay [31] and Upadhyay et al. [32].

Table 2. Effect of XG and MD addition on dynamic rheological property of dough at constant frequency 0.935 rad s^{-1}

Sample	G' (kPa)	G'' (kPa)	tanδ	η* (kPa.s)	n for G'	n for G''
Control	33.7	11.6	0.343	38.1	0.21	0.16
1 (3:1)	39.9	15.4	0.387	45.7	0.23	0.16
2 (3:2)	36.7	11.8	0.321	41.2	0.19	0.14
3 (2:1.5)	16.7	6.9	0.415	19.3	0.21	0.16
4 (1:1)	31.1	11.6	0.373	35.4	0.24	0.17
5 (1:2)	22.1	9.1	0.414	25.6	0.27	0.20



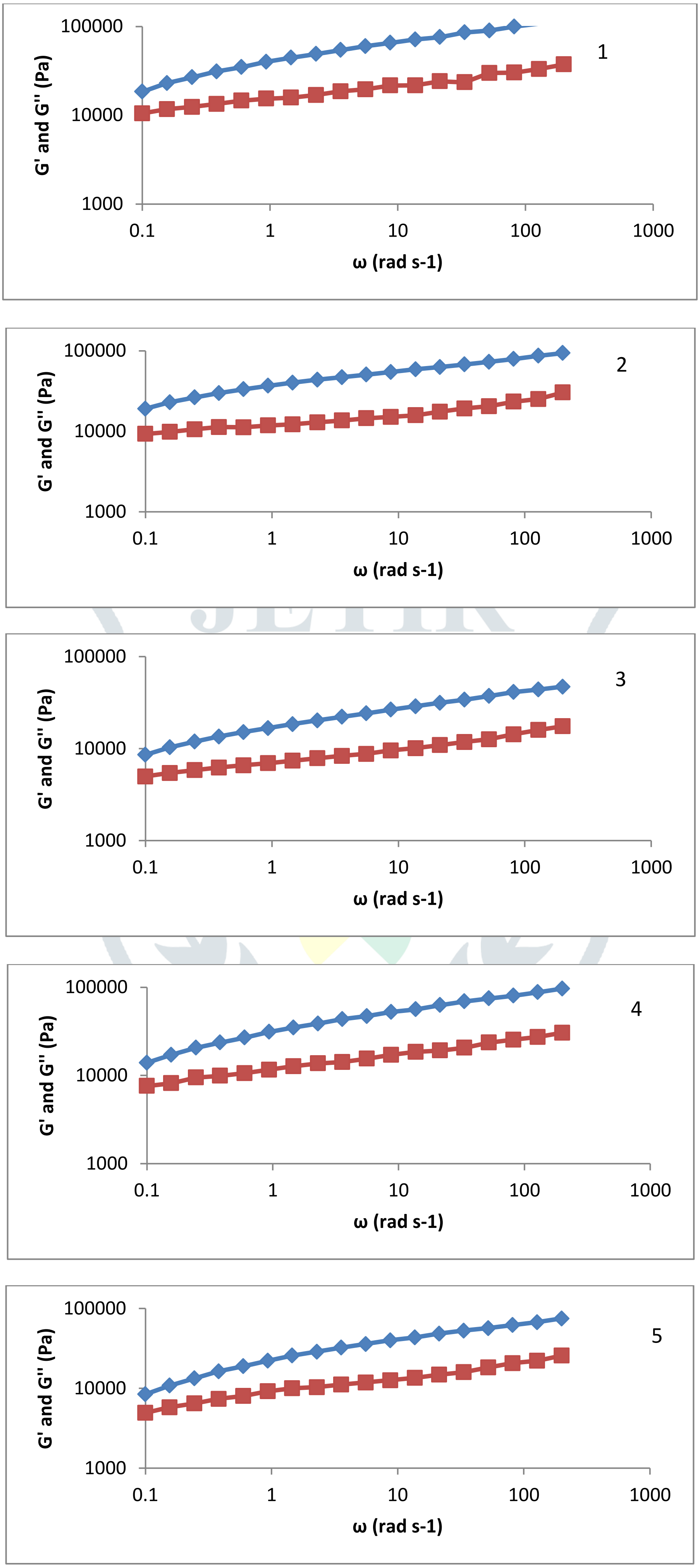


Fig. 2. Dynamic frequency sweep test of dough showing G’ and G’’ containing 0 (control), 3:1 (1), 3:2 (2), 2:1.5 (3), 1:1 (4) and 1:2 (5) concentration ratio of XG and MD.

3.3. Effect of XG and MD on thermal property of wheat flour dough

Thermal parameters onset temperature (T_o), peak temperature (T_p) and endpoint temperature (T_c) as measured by DSC are shown in Table 3. Two peaks were observed when the dough samples containing different concentrations of XG and MD were heated from 30 ^{0}C to 150 ^{0}C to imitate the conditions prevailing in oven. First peak was observed in the temperature range of 40-70 ^{0}C while second peak was observed in the temperature range of 113-123 ^{0}C for different samples. The first peak may be attributed to the gelatinization of starch while the second peak may be due to the dextrinization. It was observed that addition of XG and MD lowered the gelatinization parameters. Gelatinization is second order phase transition which involves loss in the crystalline structure of amylopectin, uptake of water molecules by starch granules, swelling, amylose leaching and loss of birefringence [33]. Amylopectin, the major component of starch forms crystalline structure of starch through hydrogen bonding. Diffusion of water molecules aided with heat leads to the breakdown in crystalline structure. The degree of breakdown in structure depends upon the distribution of water molecules among colloidal components in the system [34]. Interaction of hydrocolloid among themselves and with the starch effect the starch gelatinization by changing the chain mobility of the starch component. Hydrocolloid showing stronger interaction with starch than that present between water and starch increases the gelatinization parameters while those showing weaker interaction with starch decrease the parameters. Addition of XG and MD in different ratios delayed the starch dextrinization. The onset temperature for dextrinization varied from 113.7-121.6 ^{0}C with the addition of XG and MD which was higher than the control sample onset temperature, 115 ^{0}C. Peak and end point dextrinization temperature was also delayed with the addition of XG and MD.

Table. 3. Thermal properties of wheat flour dough with the addition of XG and MD

Sample	Gelatinization			Dextrinization		
	T_0 (^{0}C)	T_P (^{0}C)	T_c (^{0}C)	T_0 (^{0}C)	T_P (^{0}C)	T_c (^{0}C)
Control	58.2±0.67^a	59.2±0.33=	59.8±0.65^a	115±1.28^a	116.9±1.23^a	119.2±1.06^a
1 (3:1)	46±0.47^b	54.8±0.76^b	63.5±0.71^b	113.7±1.09^b	116.1±1.49^a	116.3±1.41^b
2 (3:2)	47.1±0.61^b	57.7±0.98^c	68.3±0.34^c	114.6±1.12^b	117±1.35^a	121±1.26^c
3 (2:1.5)	44.7±0.49^b	47±0.49^d	56.6±0.88^d	118.7±1.20^c	119.2±1.28^b	119.7±1.29^a
4 (1:1)	42.3±0.87^c	48.3±0.37^d	54.4±0.50$_d$	120.6±0.79^d	120.9±1.87^b	121.2±1.03^c
5 (1:2)	40.1±0.36^d	43.1±0.77^e	46.2±0.18e	121.6±0.96^d	122.4±1.65^c	122.5±1.74^c

Values in bracket in sample column indicates the percentage of XG and MD added in the flour for dough preparation

Values are means ± SD of triplicate.Means with different subscript within the same column are significantly different ($p < 0.05$)

4. Conclusion

This study revealed that addition of XG and MD simultaneously in wheat flour had positive effect on the dough rheological properties. The combined effect of both the hydrocolloid increased the arrival time, water absorption, elasticity, mixing tolerance index and peak energy. Dynamic rheological test performed showed that power law exponent 'n' values were close to 0 indicating 3D network in the mixture. Gelatinization parameters were lowered while dextrinization parameters were delayed due to the presence of XG and MD. Knowledge of thermal and rheological parameters of wheat flour with the addition of XG and MD will help the food industry for the development of various bakery products.

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