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Gum cordia: physico-functional properties and effect on dough rheology and pan bread quality

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RESEARCH ARTICLE

Abstract

Freeze dried gum cordia (GC) was obtained from *Cordia myxa* (L.) fruits through hot water extraction method. Functionally GC presented high water and oil holding capacities with considerable foaming stability. The study was conducted to evaluate the effect of freeze dried GC on functional properties of dough and its possible application as an alternative hydrocolloid in controlling bread staling by replacing 0, 3, 5 and 10% wheat flour. Significantly, higher farinographic water absorption (%) and mixing tolerance index were recorded with subsequent higher gum concentrations. Conversely, dough stability and time to breakdown were negatively affected by GC addition. Similarly, with increased GC levels a declining trend in dough extensibility (mm) and energy (cm^2) were determined through Brabender Extensograph, but interestingly 3% GC presented the highest resistance to extension and maximum resistance. A significant ($P \leq 0.05$) reduction in bread loaf volume, specific volume, and darker crumb colour was measured for each increasing GC replacement level. In sensorial evaluation, control bread was liked the most, however 3% bread was also found acceptable. Bread firmness was tested under various storage conditions: time (2, 5 and 7 days) and temperature (4, 25 and -20 °C). At a given storage temperature bread crumb hardness was significantly increased with higher GC percentages and longer storage. However, the least staled bread observed was with 0% GC stored at -20°C. Overall, addition of GC demonstrated direct or indirect effect on physical and functional properties of dough and bread.

Keywords: soluble fibre, farinograph, extensograph, bread firmness

1. Introduction

The most successful transfer of baking knowledge along with the sophistication of the equipment had accustomed the pan bread in almost each and every culture of the globe. The simple basic recipe of white bread and deliciousness has resulted in its overwhelming sensory acceptance. But just after the baking, its quality begins to deteriorate rapidly due to staling. Loss of freshness and softness, and decline in aroma are the main outcomes of bread staling. Technically, bread staling is characterised by numerous physico-chemical processes, including moisture loss and its redistribution (Biliaderis, 1992), amylose and amylopectin recrystallisation (Hug-Iten *et al.*, 2003), and starch-protein interactions (Martin *et al.*, 1991). Simultaneously, to retard staling and prolong freshness of baked items many additives and technological aids have been tested. Among the various bakery additives potential of 'hydrocolloids' – high molecular weight polysaccharides – has been thoroughly exploited. Due to high water holding capacities they keep the moisture level constant and retard staling (Davidou *et al.*, 1996). Besides serving as an antistaling agent their addition into flour mixtures has the prospective to improve product textural characteristics and freeze-thaw stability (Guarda *et al.*, 2004).

Hydrocolloids addition has also been indicated to ameliorate the dough rheological and handling properties by controlling water absorption (Mandala *et al.*, 2007). Farinographic water absorption was reported to be increased by addition of various hydrocolloids (Guarda *et al.*, 2004). When carboxymethylcellulose (CMC) and hydroxypropylmethylcellulose (HPMC) were used, both the gums improved water absorption but resistance to extension was reduced during stretching of the dough, while superior antistaling properties were shown by HPMC (Tavakolipour and Kalbasi, 2006). Similarly, addition of okra gum in bread formulation increased the water absorption with increased mixing tolerance index (MTI) but lower bread volume was seen (Alamri, 2012). Normally, components with high water binding abilities improve flour water absorption, alter dough mixing and handling properties, and ultimately affect the final bread characteristics namely colour, volume and crumb texture (Mudgil *et al.*, 2014).

Cordia myxa (L.) is a deciduous tree belongs to *Boraginaceae* family. The fresh cordia fruit contains viscous transparent polysaccharide gum which turns brown on oxidation. This water soluble anionic gum has 1.8 million Da molecular weight with galactose (27%), rhamnose (21%), mannose (17%), xylose (11%), glucose (10%), arabinose (9.5%) and uronic acid (5%) as the main sugars (Benhura and Chidewe, 2002, 2011). Medicinally, gum cordia (GC) has shown analgesic, anti-inflammatory, lubricating, emollient and laxative properties, and is still being widely used in tropical Africa for treating chest-complications, gastric and urinary tracts inflammations. In fruit extract a few important phenolics with antioxidative potential have also been evaluated (Afzal *et al.*, 2007). Like many other hydrocolloids, GC is a non-starch polysaccharide but its potential has not been unveiled yet in food industry. GC solution possesses a unique pseudoplastic adhesive nature with higher viscosity that makes it a potential stabiliser, thickener and emulsifier in food and pharmaceutical applications (Rafe and Masood, 2014). Earlier, it has been successfully used in pine nuts coating to prevent oxidation (Haq *et al.*, 2013). In pharmaceutical it has been employed as an excellent emulsifying and tablet binding agent (Dinda and Mukharjee, 2009). Baked products augmented with high molecular hydrocolloids might improve their freshness and nutritional worth. So, the current research was made to explore possible use of GC in pan bread as antistaling agent along with its impact on dough rheological parameters. In addition, the bread firmness will be assessed under various storage conditions of time and temperature.

2. Materials and methods

Collection and preparation of raw materials

Wheat flour (Grain Silos and Flour Mills Org., Riyadh, Saudi Arabia) was purchased from a local super market, Al-Riyadh, Saudi Arabia. The flour composition as provided by supplier was: 12.5% protein, 0.80% fat, 0.25% fibre and 73.75% total carbohydrates. Instant dry yeast (DSM, Heerlen, the Netherlands), shortening (Goody, Knoxville, TN, USA), sucrose (common sugar) and table salt were purchased from a local supermarket. Unripe but mature cordia fruits were collected with intact calyces, cleaned under running water and shade dried. After removal of stones through a lemon squeezer the fruits were blended in a Waring blender (Waring, New Hartford, CT, USA) for 60s. The blended fruit material and removed seeds were suspended separately in 2 volumes of distilled water, heated in water bath at 50 °C for 2-3 h and filtered twice through muslin cloth. The gummy pulp obtained was centrifuged at 2,000×*g* for 30 min using IEC model-K centrifuge (International Equipment Co., Needham, MA, USA). The supernatant was collected, neutralised by 0.05 N NaOH and finally freeze-dried using Virtis 6000 (SP Scientific, Warminster, PA, USA) freeze drier. Dried GC was ground using a coffee grinder (Kenwood, Havant, UK) and passed through 60 mesh sieve (ASTM-E 11; Retsch, Haan, Germany) and kept air tight at 4 °C for further use. The gum yield was expressed as mass percentage of the dry gum against whole fruit.

Physico-chemical and functional characteristics of gum cordia

Proximate analysis of GC including moisture, ash, protein, fat and fibre were performed according to methods given by AACCI (2000). GC colour analysis as a function of L*, a*, and b*, was made using Satake colour grader (model NCG1a; Satake, Hiroshima, Japan) with a D65 light source. The water or oil holding capacity was estimated by taking 1.0 g GC powder in a 15 ml centrifuge tube and suspending in 10 ml of distilled water or soybean oil. After thorough mixing, the suspension was allowed to stand for 1 h at temperature about 30±2 °C and centrifuged at 300×*g* for 30 min. Water holding capacity was expressed as percentage water absorbed by 1.0 g sample. Estimation of foaming capacity (FC) and foam stability (FS) were determined following the method presented by Narayana and Narasinga Rao (1982).

Wheat flour/gum cordia blends preparation

Composite flours were prepared by replacing wheat flour with 60 mesh freeze dried GC at 3, 5 and 10% levels. Plain wheat flour with 0% GC was considered as control for all the analyses conducted in current study.

Dough farinographic studies

Dough making properties of control and composite flours were tested using Brabender® Farinograph (Brabender, Duisburg, Germany) according to the method no. 54-21 (AACCI, 2000). 50 g mixing bowl was used under standard conditions (60% absorption, 14% moisture, 500 farinographic unit (FU) consistency and 20 min test time). The dough water absorption, dough development time, stability profile, MTI, time to breakdown, and farinograph quality number were determined.

Dough stretchability studies

Stretching properties of control and composite doughs were evaluated using Brabender® Extensograph (Brabender) according the method no. 54-10 (AACCI, 2000). Each of the dough was prepared in 300 g Farinograph mixing bowl. After mixing till development (500 FU line), dough ball was cut into 3 equal weight portions (150 g each). These dough pieces were passed through rounding unit and then submitted to 45, 90 and 135 min resting periods. After 45 min of resting in the resting cabinet, the cylindrical dough piece was stretched. Following the first stretch, balling and moulding steps were repeated and the dough was tested again after 90 and 135 min. The parameters recorded were: resistance to extension (Brabender unit; BU), maximum resistance (BU), extensibility (mm), energy (cm^2) and ratio between resistance to extension and extensibility.

Bread baking

The recipe adopted for bread dough is presented in Table 1. Loaves were baked following straight dough method no. 10-09 (AACCI, 2000). Accordingly, entire wheat flour (1,100 g), sugar (66 g) and yeast (33 g) were added in the Tyrone planetary dough mixer with three speed gear box (model TS207-1/S; LJ Stuart and Co., South Windsor, CT, USA) and thoroughly mixed by keeping the mixer at 1st speed (130 rpm). The premixing was done after addition of shortening (33 g) and salt (16.5 g). Firstly, the amount of water for dough development was predicted through farinograph water absorption. But the actual water amount for 0, 3, 5 and 10% doughs were found relatively higher than farinograph results. This estimation was based on touching and feeling the dough until optimum development. So, the actual water absorption for 0, 3, 5 and 10% doughs were 61.2, 62.3, 63.1 and 65.4%, respectively. During mixing, lukewarm water (40-43 °C) was added stepwise and mixed at 1st speed for 2 min and further mixing was carried out for 7.0, 7.5, 8.0 and 10 min at 2nd speed (270 rpm) corresponding to 0, 3, 5 and 10%. After mixing, the dough was placed in proofing cabinet (National Manufacturing Co., Lincoln, NE, USA) for 30 min at 30 °C and 85% relative humidity. Then after punching the dough was divided and again proofed for 20min under the same conditions. Finally the dough balls were sheeted and moulded (Mini moulder model, CM-246; Chanmag Bakery Machine Co., New Taipei, Taiwan) into cylindrical loaves and transferred into baking pans for final proofing till 1.5cm rise above the sides of baking pan. The corresponding final proofing time was about 15, 25, 32 and 45 min for 0, 3, 5 and 10%, respectively. The loaves were baked for 20 min at 220 °C using rotary baking oven (National Manufacturing Co.). After baking, the loaves were cooled to room temperature, sliced and kept in transparent double zipper, Ziploc® bags (Classic Consumer Products Inc., Englewood, NJ, USA). So for each treatment a dough batch of about 1,900 g was prepared and only four loaves (475 g each) were baked for experimental analysis. However, with changing the water contents the batch weight was increased as higher water absorption was observed for higher GC levels.

Table 1. Bread recipe with amount of respective ingredients.

Bread formulation	Amount in grams
Wheat flour (14% moisture)	100
Gum cordia (X)	100-X (X = 0, 3, 5 and 10%)
Sugar (sucrose)	6
Shortening	3
Instant dry yeast	3
Salt (NaCl)	1.5
Water	As per dough development (500 FU[1] line of farinograph)

[1] FU = farinographic unit.

Bread quality assessment

Crumb moisture was determined according to method no. 44-15A (AACCI, 2000), while water activity (a_w) was estimated using Aqua Lab Series 3, water activity meter (Decagon devices, Pullman, WA, USA). Loaf volume was assessed by rapeseed displacement method no. 10-05 (AACCI, 2000), while specific volume was calculated by volume to weight ratio. Crumbs of the control (0%) and the composite breads were dried by placing them at room temperature and ground to powder using a coffee grinder. The instrumental colour measurement of powdered crumb was made using SATAKE colour grader (NCGA) as a function of lightness (L*), redness (a*) and yellowness (b*). Bread crumb white index was calculated according to Equation 1 (Wu *et al.*, 2009) and Chroma by Equation 2 (Almeida *et al.*, 2013).

$$\text{White index} = 100 - \sqrt{(a)^2 + (b)^2 + (L)^2} \qquad (1)$$

$$\text{Chroma} = \sqrt{(a)^2 + (b)^2} \qquad (2)$$

Bread sensory evaluation

Prepared breads were subjected to sensory evaluation by a panel of 15 semi-trained judges. The subjective evaluation of samples was performed for various external and internal characteristics and scored hedonically according to Land and Shepherd (1988). In sensorial studies following hedonic scoring scales were adopted. External characteristics: (1) volume 1-10; (2) crust colour 1-8; (3) form symmetry 1-5; (4) evenness of bake 1-3; and (5) crust character 1-4. Internal characteristics: (1) grain 1-15; (2) crumb colour 1-10; (3) aroma 1-10; (4) taste 1-20; and (5) texture 1-15. Following these scoring scales the lowest and the highest scores for any parameter represents 'dislike very much' and 'like very much', respectively. However, for every parameter a mean score higher than half of the points will be considered acceptable.

Bread texture analysis

The objective texture analysis of baked loaves was made using texture analyser (TA-HDi®; Stable Micro Systems, Godalming, UK). Texture profile analysis (TPA) with 2 compression cycles was used and samples were compressed using 35 mm cylindrical probe with 50 kg load cell. Just after cooling texture measurement of control and composite breads was made using 3 central slices of thickness ca. 30mm. The parameters evaluated under textural analysis were hardness (g), springiness (mm), cohesiveness (g), chewiness (g) and resilience. The data was processed using Texture Expert Exceed® software (Stable Micro Systems).

Bread firmness study

Effect of storage time and temperature on crumb firmness was evaluated at 3 different temperatures (25, 4, and -20 °C) for 2, 5, and 7 days of storage. Before firmness study all the breads stored under different conditions were brought to room temperature. Firmness analysis was made using the same texture analyser (Stable Micro Systems) and 3 central slices (thickness ca. 30 mm) were tested using TPA with 2 compression cycles. Only hardness data was considered and processed using Texture Expert Exceed® software.

Statistical analysis

All the measurements were made triplicate except sensorial evaluation where 15 judges were considered and means were reported. Data was statistically evaluated using SPSS® version 15.0 software (SPSS Inc., Chicago, IL, USA). To elucidate the responses of various GC levels one way analysis of variance technique (ANOVA) was adopted followed by Duncan's Multiple range for means comparison at $P \leq 0.05$.

3. Results and discussion

Physico-chemical and functional properties of gum cordia

Results for moisture, crude protein, fat, ash, fibre and digestible carbohydrates are presented in Table 2. The GC powder was observed yellowish green in colour possibly due to the green pigments of fruit exocarp. According to instrumental colour grading L*, a* and b* values were 46.13, 6.41 and 25.13, respectively. Water holding capacity (WHC) is the amount of water retained by any powdered material under centrifugal gravity or compression force, and is considered as the sum of hydrodynamic and physically trapped water. WHC of GC was found 3 times of its weight. Higher water holding make suggest GC a good thickener. Soluble polysaccharide fibres exhibit higher WHC than insoluble ones, e.g. pectin can hold much more water than cellulose (Borderias *et al.*, 2005). Oil holding capacity (OHC) could be represented as the amount of oil retained by particulate blends after mixing, incubating and centrifugating in a controlled environment. The GC powder exhibited 1.58 times higher OHC compare to its weight. Proteinaceous fractions of the GC could also be a factor in improving OHC, because of their non-polar side chains that may interact hydrophobically with lipids. Ingredients with high OHC could improve product quality by improving mouthfeel, flavour retention, overall palatability; most importantly they could reduce fat in starch based food formulation.

Table 2. Physico-chemical and functional properties of gum cordia.

Properties	Values
Yield (%)	4.20
Crude composition (% DB[1])	
Moisture	14.21
Protein	3.19
Fat	1.08
Ash	7.33
Fibre	15.72
Carbohydrates	58.43
Colour parameters	
L*	46.13
a*	6.41
b*	25.13
Water holding capacity (%)	305.1
Oil holding capacity (%)	158.4
Foam capacity (%)	9.51
Foam stability (%)	61.52

[1] DB = dry weight basis of the gum.

FC is the volume of foam formed by shaking GC solution in an enclosed container whereas FS is a measure of decrease in foam volume with time. The results of FC and FS for GC are presented in Table 2. The foaming property of ingredients is generally related to the presence of protein fractions. Ingredients having better foaming capacities and stabilities could be the part of those products where aerated texture is desired, e.g. frozen desserts and bakery foods.

Farinographic studies

Farinographic water absorption is the amount of water added in wheat flour for dough making that will centre the farinogram (curve of farinograph) on 500 FU. Dough containing higher GC levels resulted significant increase in water absorption (Table 3). In general, at higher gum concentrations more water will be needed for wheat gluten hydration (Sim *et al.*, 2009). Higher water absorption could be attributed to hygroscopic nature of GC, due to the presence of high number of hydroxyl groups that may interact with water molecules. These results are in line with Alamri (2012) who used alkaline okra extract in bread fortification. Dough development is the time duration (min) measured from point of water addition to flour until the farinogram indicated the first drop in maximum consistency. Gluten hydration process is considered the key determinant of this process of development. Dough development was not effected much by changing the GC levels except for 3%, which was developed 0.5 min earlier than control dough. Less gluten development could be result of GC replacements.

With increasing GC replacement dough stabilities were decreased where control dough (0% GC) stood the most stable one. The duration in minutes between the points where the farinogram line approaches 500 FU and where it leaves 500 FU is regarded as dough stability. It also characterises the resistance of dough exhibited during mechanical stress and enzymatic influence to a lesser extent. It was observed that higher GC percentages retarded gluten development by competing for water and resulted in poor dough stability. Gluten dilution phenomenon could also be a plausible explanation to be correlated to dough stability of composite doughs. Conversely, control dough demonstrated a maximum stability that might concern high protein fractions of wheat flour (12.5%) presenting its resistance to stress. Addition of water soluble konjac-glucomannan has shown dough weakening effect (Correa *et al.*, 2012). In dough making, MTI is an indication of the resistance presented by dough for mixing. It represents how quickly dough structure breaks down after reaching to its optimum development. MTI values obtained were found significantly different ($P\leq0.05$) where the difference was more at higher GC levels. Higher MTI values reflected dough stiffness. This is probably due to competition for water between gluten and GC, which has ultimately driven the system in low water state. It is believed that the MTI has relation to final baking, so the bread with highest GC will have the lowest quality. Current study is in line with Alamri (2012) who evaluated dough mixing properties by adding okra extract.

Another important parameter for dough quality is the time to breakdown and is expressed as a decrease of dough consistency for 30FU than the value at peak time. Also, it is an indicator of dough stability and strength. Alternatively, the highest time to breakdown was seen in control dough. The GC addition at 3% level resulted in significant reduction in breakdown time as compared to control wheat flour (14.3 – 3.1=11.2 min), but further increase respond insignificantly. Again the GC negatively affected the dough by interrupting the gluten functionalities. Relatively lower breakdown time was depicted when konjac-glucomannan was added in dough (Sim *et al.*, 2009). Farinograph quality number (FQN) is expressed as the number indicating the length of timeline between the point of water addition and the point when dough consistency lowers 30 FU from the maximum consistency. Wheat flour with 0% GC presented the highest quality number with a value of 131. Following the pattern of breakdown time higher GC levels did not influenced FQN.

Dough stretchability studies

Stretching parameters of composite doughs were assessed in terms of resistance to extension, extensibility, their ratio and energy applied for stretching. Energy is the measurement of area (cm^2) under the extensogram (force-time curve) and is presented as the work required for dough stretching until its point of rupture. The energy values among all the treatments were found to be statistically significant ($P\leq0.05$) at a given resting time. Higher energy value is the

Table 3. Farinographic parameters of wheat flour at different gum cordia levels.

Farinographic parameters	Gum cordia			
	0%	3%	5%	10%
Water absorption (%)[1]	60.8±0.6c	61.6±0.9b	62.3±1.1b	64.2±0.5a
Dough development time (min)	2.4±0.1a	1.9±0.1b	1.8±0.2b	1.6±0.2b
Dough stability (min)	13.8±0.8a	2.3±0.2b	2.0±0.1b	1.7±0.2b
Mixing tolerance index	18.3±1.5d	72.3±8.6c	93.3±0.5b	112.3±8.7a
Time to breakdown (min)	14.3±1.1a	3.1±0.2b	2.8±0.1b	2.5±0.2b
Farinograph quality number (FU)[2]	131.0±6.0a	31.0±2.6b	28.0±1.0b	25.3±2.1b

[1] Mean values following the same letter within a row are not statistically significant ($P\leq0.05$).

[2] FU = farinograph unit.

characteristic indicator for the stronger dough with good gas holding capacity in the final product. Maximum energy (146 cm^2) for the control dough was observed after 90 min of resting that was reduced to 124 cm^2 after 135 min. At each resting time a trend of decreasing energy was observed with increasing GC levels from 0 to 10% (Table 4). The highest energy value of the control suggested maximum strength of gluten network that was weakened by GC addition. Apparently but not statistically, by increasing the resting time from 45 to 90 min a rise in energy values was seen for all GC concentrations. However, this regularity was interrupted by further increase in resting time (135 min). Multiple stretching might have made the dough fragile and weaker. Interestingly, 3% dough presented more strength compared to control after resting 90 min. Moazzezi *et al.* (2012) reported increasing energy for all three resting times when CMC was added in dough.

Resistance to extension is another important parameter for dough quality and is a measure of dough strength and gas holding capacity during proofing. It is measured 5cm after the test starts. All tested dough samples were found statistically different ($P \leq 0.05$) at each replacement level. The highest resistance was shown by 3% composite dough for all the three resting periods, while the least was observed for dough with 10% GC after third resting time (135 min). Similar to energy values, the maximum increase in resistance was observed for dough with 3% GC rested for 90 min. Sudha *et al.* (2007) found that addition of apple fibre increased dough resistance to stretching. In extensogram, 'maximum (BU)' represents the peak maximum height it can attain and it shows the resistance implied at a given extension. The highest curves were obtained for dough with 3% GC. However control wheat flour (0% GC) presented the lowest peak height. The order of decreasing maximum was 3% > 5% > 10% > 0%.

During dough testing the extent of dough stretching before breakage is represented as extensibility (mm). Higher GC levels showed lower extensibilities although the effect was non-significant ($P \leq 0.05$). Of all the tested periods, the dough samples rested for 45 min indicated the highest extensibility values (Table 4). It could be hypothesised that longer resting time result in a cohesive gluten network through intra and inter-molecular interactions that ultimately rendered the dough tougher and less stretchable. Impaired dough elasticity was observed when apple fibre was added (Sudha *et al.*, 2007).

Bread baking and quality assessment

The amount of water used in dough preparation was higher than farinographic water absorption. This water addition was adjusted by mixing and feeling the dough, and estimating its ability to make film with optimum stretchability. Higher water addition during dough preparation could be due to addition of other hygroscopic ingredients along with wheat flour. The dough mixing times were 9.0, 9.5, 10 and 12 min for 0, 3, 5 and 10%, respectively. Higher mixing times could be attributed to GC interference in gluten development through water competition. More final proofing time was observed for higher GC levels because its addition inhibited yeast activity.

Higher crumb moisture was observed by increasing the GC from 0 to 10% (Table 5).The plausible explanation could be the higher water addition and better water holding capacity of GC. Similarly, addition of fenugreek gum in bread

Table 4. Extensographic evaluation of wheat dough with various levels of gum cordia.[1]

Time (min)	Gum (%)	Energy (cm^2)	Resistance to extension (BU)[2]	Extensibility (mm)	Maximum (BU)	Ratio no.
45	0	116.6±10.6^{a}	648.0±41.3^{b}	174.3±9.1^{a}	490.6±21.9^{c}	1.9±0.1^{b}
	3	84.3±7.7^{b}	799.0±53.6^{a}	82.6±6.0^{b}	799.6±53.1^{a}	9.6±1.0^{a}
	5	65.6±6.3^{c}	648.0±41.3^{b}	76.3±8.0^{b}	700.3±32.7^{b}	8.5±1.2^{a}
	10	57.0±2.6^{c}	531.0±7.2^{c}	63.3±2.1^{c}	723.3±43.7^{b}	8.4±0.4^{a}
90	0	146.0±10.8^{a}	431.3±8.7^{c}	167.3±12.7^{a}	659.3±3.2^{d}	2.6±0.2^{d}
	3	122.6±9.4^{b}	1,218.3±11.3^{a}	78.3±7.5^{b}	1,258.6±10.1^{a}	15.3±1.3^{a}
	5	77.3±1.5^{c}	813.0±17.6^{b}	69.6±2.1^{bc}	909.3±10.2^{b}	11.6±0.5^{b}
	10	54.3±2.5^{d}	405.3±1.5^{d}	57.0±6.2^{c}	785.0±21.9^{c}	7.4±0.4^{c}
135	0	124.3±8.3^{a}	437.6±10.6^{c}	150.0±4.5^{a}	633.3±17.6^{c}	3.1±0.2^{d}
	3	106.6±7.1^{b}	1,079.6±15.1^{a}	76.3±7.5^{b}	1,203.6±15.5^{a}	14.3±1.3^{a}
	5	84.0±3.0^{c}	871.6±16.5^{b}	67.3±6.8^{bc}	1,096.0±72.6^{b}	12.2±1.2^{b}
	10	53.6±3.5^{d}	389.6±11.6^{d}	60.3±2.1^{c}	717.6±50.01^{c}	6.6±0.7^{c}

[1] Means ± standard deviations are of three replicates (n=3); means in the same column per dough rest time followed by the same superscript letter are not significantly different ($P \leq 0.05$).

[2] BU = Brabender unit.

Table 5. Instrumental measurement of composite breads quality.[1]

Gum cordia (%)	Volume (cm^3)	Weight (g)	Specific volume (cm^3/g)	Moisture (%)	Water activity
0	1,517.5±75.1^a	428.5±4.9^d	3.54±0.17^a	31.92±0.40^d	0.915±0.001^a
3	1,206.3±11.1^b	434.2±1.4^c	2.77±0.03^b	34.26±0.52^c	0.919±0.002^a
5	1,053.7±17.9^c	437.3±2.8^b	2.41±0.04^c	36.04±1.01^b	0.923±0.005^a
10	805.0±12.9^d	441.8±1.7^a	1.82±0.03^d	38.57±0.91^a	0.925±0.004^a

[1] Means in the same column followed by the same superscript letter are not significantly different ($P \leq 0.05$).

resulted in higher moisture contents (Roberts *et al.*, 2012). a_w of composite bread crumbs was remained unchanged. In case of loaf volume a significant decrease in loaf volume was observed directly with increased GC percentage. In plain wheat bread a volume decrease of 20% was observed after 3% GC addition. Similarly, the loaf volume was reduced to half by 10% addition of GC confirming extensibility data. The reduction in volume could be due to gluten dilution, disruption of gluten-starch matrix and inhibition of yeast activity which was clearly observed during dough proofing. Accordingly, with increasing GC replacement levels lower specific volume (cm^3/g) was observed.

Colour components (L*, a*, b*) of the bread were significantly ($P \leq 0.05$) affected GC (Table 6). The darkness of bread crumb was due to Maillard reaction that occurs between free amino group of proteins and the carbonyl group of reducing sugars. Another possible reason might be the green pigments of powdered GC. The highest L* was observed for 0% GC bread, while the lowest value (maximum darkness) was exhibited by bread with 10% GC. Wheat bran addition in bread also increased darkness (lower L*) as reported by Basman and Köksel (1999). The lowest a* value (-1.37) representing 'greenness' demonstrated by control bread while all other treatments presented increasingly positive a* with the maximum seen for 10% GC. A direct relation was observed between GC and b* values. Alamri (2012) observed lower L* values compared to control bread when okra extract was added in formulation.

Chroma – colourfulness of bread in terms of intensity perceived – of bread crumb was also determined. Maximum colour intensity was observed for 10% GC bread; a clear indicator of darker crumb. Higher chroma values are also an indicator of colour saturation of crumbs. Similarly, increased chroma values were observed for bread containing added wheat bran (Almeida *et al.*, 2013). Whiteness index is a characteristic attribute by which an object is perceived to approach the preferred white coloration. Maximum whiteness was demonstrated by 0% GC bread because the crumb lightness (L*) was maximum (84). For all the GC percentages a significant ($P \leq 0.05$) variation in whiteness index was observed with a decreasing order 0% > 3% > 5% > 10%.

Sensory evaluation of composite breads

The results for sensory scoring are presented in Table 7. Overall bread appearance was judged in terms of volume, colour, symmetry and uniformity of baking. Volume is an indicator of dough gluten development and its gas retaining capacity. In line with instrumental bread volume measurements, significantly ($P \leq 0.05$) lower sensory scores were obtained by loaves with subsequently higher GC levels. This lower volume could be due to the lack of enough

Table 6. Instrumental colour analysis of composite bread crumbs.[1]

Gum cordia (%)	Colour components			Chroma (C*)	White index
	Lightness (L*)	Redness (a*)	Yellowness (b*)		
0	83.32±0.02^a	-1.37±0.11^d	18.11±0.44^d	18.16±0.09^d	75.34±1.22^a
3	68.23±0.04^b	2.07±0.03^c	20.43±0.63^c	20.53±0.35^c	62.17±0.87^b
5	64.27±0.14^c	2.72±0.24^b	21.47±0.12^b	21.64±0.16^b	58.22±1.07^c
10	52.19±0.13^d	4.45±0.52^a	23.94±0.41^a	24.35±0.27^a	46.34±0.41^d

[1] Means in the same column followed by the same superscript letter are not significantly different ($P \leq 0.05$).

Table 7. Sensory assessment of external and internal characteristics of composite breads.[1]

Bread sensory components	Gum cordia			
	0%	3%	5%	10%
External characteristics				
Volume	8.8±0.83^{a}	7.2±0.57^{b}	5.6±1.1^{c}	3.5±0.5^{d}
Colour of crust	7.6±0.54^{a}	7.5±0.74^{a}	4.1±0.96^{b}	2.1±0.41^{c}
Form symmetry	4.2±0.44^{a}	3.3±0.45^{b}	2.5±0.5^{c}	1.2±0.75^{d}
Evenness of bake	2.5±0.51^{a}	1.9±0.22^{b}	1.6±0.41^{bc}	1.2±0.27^{c}
Crust character	3.2±0.44^{a}	2.7±0.83^{a}	1.9±0.27^{b}	1.0±0.54^{c}
Internal characteristics				
Grain	13.0±1.22^{a}	10.5±1.2^{b}	7.9±1.14^{c}	3.1±1.08^{d}
Crumb colour	8.9±1.24^{a}	6.8±1.02^{b}	6.1±0.74^{b}	2.4±0.82^{c}
Aroma	8.3±1.48^{a}	7.8±0.89^{a}	5.0±0.57^{b}	2.9±0.41^{c}
Taste	15.0±1.87^{a}	12.8±0.53^{b}	7.3±0.83^{c}	4.4±0.65^{d}
Texture	13.3±1.09^{a}	9.8±0.57^{b}	7.5±0.79^{c}	3.4±1.19^{d}

[1] Mean values of n=15; means in the same row followed by the same superscript letter are not significantly different ($P \leq 0.05$). Maximum points for volume (10), colour of crust (8), form symmetry (5), evenness of bake (3), crust character (4), grain (15), crumb colour (10), aroma (10), taste (20), and texture (15).

gluten that hold gas bubbles. No vital gluten was added in GC containing breads that might improve final bread volume. Similar results of reduced bread volume have been reported by various researchers (Filipovic *et al.*, 2007; Wang *et al.*, 2002).

Crust colour is attributed to the spectral distribution of light emerging from its surface and is a function of Maillard reaction. The sensory acceptance score was lowered at higher GC concentrations, while 3% GC bread observed statistically similar to control (0%). In bread baking form symmetry and evenness of baked loaf are the shape uniformity and harmoniousness. It is notable that the addition of GC reduced the gluten strength, and enhanced uneven and non-uniform vapour production. This distortion in symmetry and lack of evenness was maximised by higher GC replacements and resulted in lower sensorial ratings for the loaves. Again, in case of crust character, 3% GC bread represented statistically similar acceptance scoring as for control (0% GC) bread. However, increased GC concentrations rendered breads least preferred.

Bread internal characteristics are basically the crumb characteristics together with taste and aroma. Crumb grain is assessed visually, in terms of cell size, shape and wall thickness. Cells with uniformly thin walls and of smaller size are considered superior in quality. For all the GC levels significant change in crumb grain structure was detected by panellists, where the control bread stood the best by obtaining 13 points. However, compact and dense crumb with fewer grains rendered 10% GC bread the least preferred one. Loaves with higher GC replacement percentages were found darker in colour; possibly contributed by GC powder. Koca and Anil (2007) reported darker crumb with higher sesame meal addition in bread. Taste and aroma are combined to develop flavour and both are associated with smaller molecular mass components that are perceived by chemical pathways. Scoring order for bread taste and aroma was as 0% > 3% > 5% > 10%. The higher GC levels might have trapped aroma causing volatiles and restricted their interactions with taste buds declining aroma and ultimately the taste. In addition the bland taste of GC could also be a significant contributor in reducing the deliciousness of loaves. Statistically, similar aroma was perceived for control and 3% GC bread at 5% level of significance.

Texture is a major contributor in bread palatability and sometimes its share is considered above 30%. Preferences for texture were found to be significantly ($P \leq 0.05$) affected among all the composite breads, with the highest and the lowest for control and 10% GC breads, respectively. Wang *et al.* (2002) concluded increased dietary fibre enhanced the crumb firmness. In short, the addition of higher GC percentages negatively affected bread external and internal quality characteristics. In an overall scoring, control bread was found most preferred while 3% GC bread was also found statistically similar in crust colour, crust character and aroma. Moreover, as the average score obtained in each parameter were found higher than half of the hedonic scale so 3% bread was also rated as 'acceptable'.

Bread texture analysis

Instrumental bread texture parameters measured were; hardness, springiness, cohesiveness, chewiness and resilience. Hardness is the force (g) needed to pierce bread slice using incisors or technically it is the maximum peak force applied during the first compression cycle of texture analyser. At higher gum level bread hardness was enhanced but non-linearly. Significant change in hardness was observed by 3% GC, but no mentionable difference was observed between 3 and 5% composite breads. The maximum hardness for 10% GC bread was also supported the lowest specific volume and denser crumb. As mentioned earlier higher GC addition might have resulted in limited yeast activity or dough stiffening and thus prevented dough volume to rise during fermentation. Addition of elevated levels of date pit powder also enhanced the bread hardness (Alamri *et al.*, 2014).

Springiness (mm) is the rate at which a compressed bread sample regains its original undeformed shape after the removal of deforming force. Control wheat bread presented the highest springiness (0.942 mm). The lowest springiness values were observed for bread with the highest GC, i.e. 10%. The lower springiness reflects the crumb brittleness and tendency to crumble upon slicing. Cohesiveness is the strength or force (g) of internal bond holding of bread crumb. The highest cohesiveness (0.659) was demonstrated by control bread indicting maximum tensile strength but decreasing cohesiveness was observed for increasing GC concentrations. Higher cohesiveness of bread is desirable, so that it can form a bolus in mouth during mastication. Chewiness is the energy required to masticate bread sample until to a swallowable state, and technically it is the product of hardness, cohesiveness and springiness. Mastication energy values obtained for all the GC levels were found significantly different ($P \leq 0.05$). Increasing chewiness values were observed by increasing GC concentration in composite breads (Table 8). Resilience is defined as the instant ability of bread crumb to retain its original geometry. The highest and the lowest resilience values were observed for control and 10% GC breads, respectively. Reduced resilience is the characteristic indicative of loss of elasticity. Correa *et al.* (2012) evidenced improved resilience on pectin addition.

Bread firmness study

Bread firmness – technically staling – is a typical index of quality during storage, where loss of aroma is also an output along with bread hardening. During bread storage multitude of changes takes place that characterise staling. Some of the proposed mechanisms involved are amylopectin retrogradation, amylose recrystallisation, loss of moisture and its redistribution, and interaction between gluten and starch (Bárcenas and Rosell, 2007). The control bread presented the least firmness at all storage temperatures (25, 4, -20 °C) and times (days). For all composite breads under the same storage time and temperature conditions the order of staling was 10% > 5% > 3% > 0%. Mudgil *et al.* (2014) suggested that the addition of non-starch polysaccharides impart greater hardness to bread crumb.

In general, the composite breads with lower storage temperatures (4 and -20 °C) exhibited less firmness. Interestingly, the control bread stored at 25 °C demonstrated the lowest firmness after 2 days of storage, while the maximum firmness (94.7 g) was observed for bread with 10% GC stored for 7 days at the same storage temperature. This highest firmness could be due to the most compact and dense crumb structure as seen by least specific volume. It is suggested that elevated concentrations of gum directly affect water migration from gelatinised starch and protein which ultimately results in higher bread firmness (Alamri *et al.*, 2014). Comparative effect of the storage conditions on bread firmness is presented in Figure 1. Overall, in case of storage time, at a given GC level higher firmness was observed by increasing the storage time. Alamri *et al.* (2014) also reported the maximum bread firmness for the highest concentration of date pit powder. Of all the storage periods the lowest firmness was observed for control bread after 2 days stored at -20 °C.

Table 8. Instrumental texture analysis for composite breads.[1]

Bread texture components	Gum cordia			
	0%	3%	5%	10%
Hardness (g)	3.641±0.106^{c}	17.827±1.685^{b}	19.259±0.145^{b}	28.942±0.175^{a}
Springiness (mm)	0.942±0.026^{a}	0.893±0.008^{ab}	0.872±0.008^{b}	0.847±0.019^{b}
Cohesiveness (g)	0.659±0.013^{a}	0.604±0.006^{b}	0.581±0.011^{bc}	0.566±0.003^{d}
Chewiness (g)	2.413±0.102^{d}	9.476±0.831^{c}	11.289±0.012^{b}	15.598±0.457^{a}
Resilience	0.449±0.024^{a}	0.403±0.013^{ab}	0.378±0.021^{bc}	0.331±0.001^{c}

[1] Means in the same row followed by the same superscript letter are not significantly different ($P \leq 0.05$).

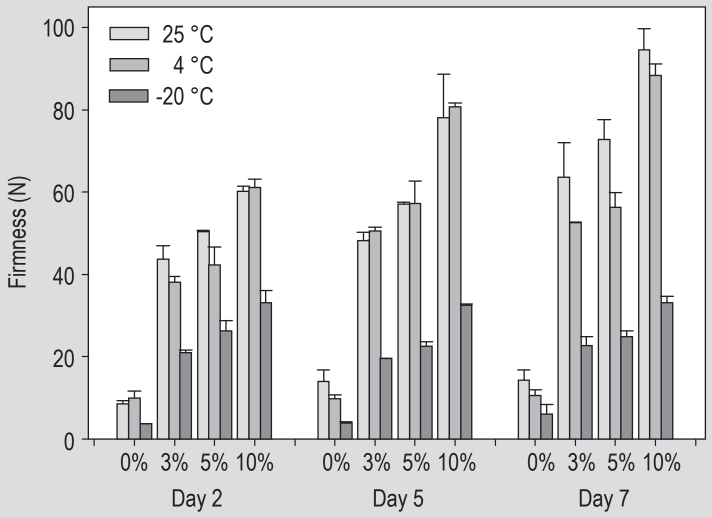

Figure 1. Comparative effect of storage conditions on bread firmness prepared with various gum cordia percentages (0, 3, 5 and 10%).

4. Conclusions

Higher water and oil holding capacities with considerable FC and FS suggested GC a good thickener and stabiliser. But, poor manipulation of dough rheological properties especially the decreased dough stability, extensibility and higher stretching resistance indicted its negative effects on wheat flour dough. In instrumental and sensory studies the decrease in the volume and darker crumb also resulted in lack of preference of higher GC levels in white bread. Anyhow, 3% bread was found acceptable and even in some sensorial parameters it obtained scores similar to control bread. Results for textural analysis depicted higher hardness of bread with subsequent higher GC levels. Bread firmness study reinforced inability of GC in controlling staling, as higher firmness was seen with elevated concentrations. Interestingly, the least firmness was observed for breads stored at lower temperatures (4 and -20 °C). However, decolouring GC and reducing the replacement levels might be helpful in depicting desirable attributes in bread formulations. Further experimentation is required to understand its exact chemical nature to extrapolate its use as an alternative hydrocolloid in bakery items.

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