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Influence of hydrocolloids on rheological properties of gluten free foxtail millet and quinoa biscuit doughs

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Abstract
Effect of hydrocolloid type (Guar gum, Gum acacia, tragacanth gum, xanthan gum and their combinations in 50:50 ratio) and concentration (0%, 1%, 2%, 3%, 4%/100g/ f.b) on the rheological properties of biscuit doughs made from foxtail millet and quinoa was evaluated at 35°C using a controlled stress rheometer. Biscuit dough made from wheat flour was taken as control. Addition of hydrocolloids significantly modified the rheological properties of doughs. Storage modulus (G') was significantly higher than loss modulus (G") in all types of biscuit doughs studied. Significantly higher G' was exhibited by TG GG dough followed by TG and GG and least by TG XG dough. Irrespective of grain and concentration of hydrocolloids, XG has lowest G' among the four individual hydrocolloids studied. Addition 1% and 4% of hydrocolloids increased, while 2% and 3 % decreased G' significantly, compared to those doughs without hydrocolloids. Considering, the loss tangent, it was found that application of GGXG at 1% and 4 % in foxtail biscuit dough and TGXG 1% and GAXG at 4% concentration in quinoa biscuit dough were found to be closer to the wheat biscuit dough.

Keywords: hydrocolloids, rheology, foxtail millet, quinoa, biscuit dough

1. Introduction

The demand for gluten free products is on the rise. This has generated a group of consumers going even beyond the strict requirements of Gluten sensitivity and even celiac disease. People on a strict gluten-free diet are frequently undernourished since their rapidly available-energy intake, which in the western diet is largely taken from wheat-based foodstuffs, is reduced. These circumstances have prompted the development of gluten-free foodstuffs with high nutritional quality components [1]. In this context foxtail millet is an important underutilized millet grain, grown in various parts of India. Among the millets, foxtail millet is a good source of protein, dietary fiber and minerals [2]. It is a starchy food with a 25:75 amylose to amylopectin ratio and is a fairly good source of lipids (3–6%), having about 50% of the lipids in the form of polyunsaturated fatty acids [3]. Quinoa is considered as a pseudo-cereal crop, which is a highly nutritious food; the nutritional value of this crop has been compared to that of dried whole milk by the Food and Agriculture Organization (FAO) of the United Nations. Even though the nutritional qualities of these grains have been well recorded its utilization for food is confined to the traditional consumers in tribal populations, mainly due to non-availability of consumer friendly, ready-to-use or ready-to-eat products as are found for rice and wheat. Bakery industry is the fast growing segment in India [4, 5], however gluten replacement in bakery products represents a major technological problem due to structure building properties. Gluten removal weakens dough structure to develop properly during kneading and baking.

Hydrocolloids or gums are a diverse group of long chain polymers characterized by their property of forming viscous dispersions and/or gels when dispersed in water. In addition to the obvious benefits of taste, texture, mouth feel, moisture control, and water mobility, they also improve the overall product quality and stability by withstanding the demands of processing, distribution, and final preparation [6].The foremost reason behind the ample use of hydrocolloids in foods is their ability to modify the rheology of food system. This includes two basic properties of food system namely, flow behavior (viscosity) and mechanical solid property (texture).

The modification of texture and/or viscosity of food system helps to modify its sensory properties, and hence, hydrocolloids are used as important food additives to perform specific purposes [7]. Hydrocolloids are used either alone or in combination to achieve specific synergies between their respective functional properties [8]. Effect of hydrocolloids on proso millet cookie was studied and reported that proso millet flour treated with gum acacia had the similar characteristics and were closely associated with firmness and overall quality to match the wheat product and also were best suited for dough-handling purpose [9]. Addition of hydrocolloids like Xanthan gum, HPMC, Guargum, Carboxy methyl cellulose to gluten free foods have been reported in many publications [10-14] with a positive effect on the final product. Based on these studies four different types of hydrocolloids were selected i.e Xanthan gum, Gum acacia, Guargum and Gum Tragacanth.

Number of studies were reported on wheat containing cookie dough or GF bread dough & its rheological behavior but there are very limited number of studies on rheological behavior of gluten free cookie dough. The objective of present study is to study the effect of hydrocolloids on rheological properties of gluten free biscuit doughs made from foxtail millet and quinoa in comparision with wheat flour dough.

2. Materials and Methods

2.1 Materials

Foxtail millet was procured directly from farmers, Quinoa was supplied by Inner Being & Wellness Pvt. Ltd- Hyderabad on gratis. Guar gum (Nutriroma, Hyderabad), Xanthan gum (Tapadia Marketing Services, Hyderabad), Tragacanth (Ranchhoddas Odhavji Gaglani & Sons, Mumbai) were procured from standard food ingredient suppliers. Other ingredients such as wheat flour, fat, skim milk powder, lecithin and sugar were procured from the local market, Hyderabad.

2.2 Preparation of raw material

Foxtail millet and quinoa were cleaned to remove foreign material and the grains were dehulled in an abrasive dehuller (Mathesis engineering Pvt. Ltd, Hyderabad) up to 17 percent removal of bran, then milled into flour in a pulveriser (Able manufacturers, Hyderabad) and sieved to get uniform particle size using mesh BSS No 60.

2.3 Biscuit dough preparation

All the biscuits were prepared according to a recipe described in AACC (American Association of Cereal Chemists) method 10-54 (AACC, 2000). Different concentrations of hydrocolloids added was given in Table 1.

Table 1: Concentrations of hydrocolloids used in biscuit doughs

Hydrocolloid	Concentration used
Guar Gum (GG)	0%, 1%, 2%, 3%, 4%
Gum Acacia(GA)	0%, 1%, 2%, 3%, 4%
Xanthan (XG)	0%, 1%, 2%, 3%, 4%
Tragacanth (TG)	0%, 1%, 2%, 3%, 4%
Guar Gum + Gum Acacia	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)
Guar Gum + Xanthan	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)
Guar Gum + Tragacanth	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)
Gum Acacia + Xanthan	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)
Gum Acacia + Tragacanth	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)
Xanthan + Tragacanth	0%, 1% (0.5+0.5), 2% (1+1),3% (1.5+1.5), 4% (2+2)

2.4 Dough Rheology

The fundamental rheological behavior of the doughs was studied by dynamic oscillatory measurements performed on a Physica MCR 52 Rheometer (Anton Paar GmbH, Germany), supported by the software Rheoplus version 32. These tests measure the rheological properties such as elastic and storage moduli by the application of sinusoidal oscillating stress and strain with time and measuring the resulting response (Current Protocols in Food Analytical Chemistry (2003) H3.2.1 H3.2.9). Dough sample of 3 g was carefully transferred on to the lower plate of the rheometer and the sample was allowed to rest for 10 min on rheometer to allow stresses induced during sample handling to relax and pressed down with upper plate, the gap between two plates was adjusted to 1.0 mm. an upper plate with a radius of 50mm was used. Excess dough was trimmed off carefully with a trimmer. All the tests were conducted at 35ºC, the temperature was regulated by a circulating water bath. The strain rate was kept ranging from 0.001-100s-1 at a constant oscillation frequency of 1Hz. Results were expressed in terms of G′ (storage modulus), G″ (loss modulus), yield stress and tan δ (phase angle).

2.5 Statistical analysis of the data

All the results were statistically analyzed using STAT GRAPHICS centurion version 17.1.11. Multifactor ANOVA technique was used to find out the significant effect of treatments and variations on dough rheology of the millet grains [15].

3 Results

3.1 Effect of Hydrocolloids

The storage modulus (G’) was significantly ($p<0.05$) higher than loss modulus (G”) in all types of biscuit doughs studied which indicates that the doughs were more elastic than viscous in nature. In the linear viscoelastic region, at which rheological properties are independent of strain, was determined through strain sweep tests. Storage modulus (G′) usually remains independent up to a critical value and then decreases when samples start to move [16]. Significant effects of hydrocolloids, concentrations and the grain on storage modulus was observed when compared with the dough without any hydrocolloids. Irrespective of grain and concentration, the overall mean of storage modulus of the dough was found to be 1.73E+05. Among the hydrocolloids TG dough (1.83E+05) found to have highest G’ followed by GG (1.77E+05), GA (1.76E+05) and lowest was found in XG (1.53E+05). TG is an exudate composed basically of high molecular weight polysaccharides (galactoarabans and acid polysaccharides), which contains galacturonic acid. Tragacanth gum, when using oscillatory shear at 25°C, behaves as a flexible coil in solution[17].G’ of XG biscuit dough was found to be lower but closer to the wheat dough compared to all others irrespective of grain and concentration which is due to the ability of xanthan gum to increase the viscosity[18]. Significantly higher ($p<0.05$) G' was exhibited by TG GG dough (2.29E+05) followed by TG (1.83E+05) and GG dough (1.77E+05) and lower G' by TG XG dough (1.44E+05). The effect of hydrocolloids was more pronounced on G' when they are combined rather than individual, which can be attributed to the synergetic effect which might be due to the molecular interaction between the gums. Blending of different polysaccharides lead to the development of synergistic mixtures with improved or induced gelation[18]. Addition of TG to GG increased G', while that to GA and XG decreased. Similarly, XG when combined with GA, GG and GA significantly lowered the G' (Table 2). The rheological behavior of hydrocolloid solutions is affected by the molecular weight and the conformation of the hydrocolloid molecule as well as the solvent conditions. Dextran solutions, for example, can be designed to show Newtonian flow behavior (constant shear viscosity), whereas guar gum and xanthan gum are classical examples of hydrocolloids forming shear-thinning solutions (shear viscosity decreases with the increasing shear rate or shear stress). The features determining the rheological behavior of hydrocolloid gums are, in principle, the same as for synthetic polymers[19]. In biscuits, only small amount of gluten development is needed so that dough can be sheeted and cut [20]. Hydrocolloids are used either alone or in combination to achieve specific synergies between their respective functional properties. Many rheological studies of dough reported relevant interactions between different hydrocolloids [21]. XG has lowest G' among the studied hydrocolloids in the biscuit dough model, thus when combined with other hydrocolloids resulted in lowered storage modulus significantly.

The mean of loss modulus (G") was 3.46E+04 which was lower than G'. Even though there was significant difference among overall hydrocolloids certain hydrocolloids and their combinations were not different with each other (Table 2) Among the individual hydrocolloids maximum G" was observed in TG followed by GA, XG and GG. This shows that both G' and G" acted differently under similar amplitude sweep with different hydrocolloids. Among the hydrocolloids combination the G" was found to be in the order of TGGG>GGGA>TGXG>GGXG>GAXG. Irrespective of grain and the concentration, combination of GA when combined with GG resulted in higher G" while that of with TG and XG resulted in lower G". Similarly, GG when combined with either TG or XG the loss modulus was increased significantly. Similar observations were reported by[22], in which he reported that the mixtures of xanthan and guargum resulted in higher combined viscosity than that occurring in each separate gum. There was no significant difference between, TGGA and GAXG, XG and GGXG, TGXG and GGGA, TG and TGGG.

Table 2: Effect of Hydrocolloids, Concentration and grain type on foxtail and quinoa biscuit dough rheology in comparison with wheat dough rheology

Main effects	Storage modulus (G')	Loss modulus(G")	Yield Stress	Loss tangent (δ)
GRAND MEAN	1.73E+05	3.46E+04	7.26E+03	0.21
Hydrocolloid				
GA	1.76E+05	3.74E+04^{ab}	7.45E+03^{abcd}	0.21
GA XG	1.73E+05	2.82E+04^{c}	5.69E+03^{e}	0.17
GG	1.77E+05	2.54E+04	6.89E+03^{f}	0.16
GG GA	1.66E+05	3.73E+04^{ad}	5.17E+03^{ag}	0.16
GG XG	1.64E+05	3.37E+04^{e}	6.95E+03^{h}	0.21
TG	1.83E+05	4.26E+04	5.19E+03^{bi}	0.27
TG GA	1.69E+05	2.79E+04^{c}	1.67E+^{04cefghijkl}	0.19
TG GG	2.29E+05	4.28E+04	5.40E+03^{dj}	0.25
TG XG	1.44E+05	3.69E+04^{bd}	6.38E+03^{k}	0.23
XG	1.53E+05	3.36E+04^{e}	6.79E+03^{l}	0.21
Grain				
FM	2.28E+05	2.88E+04	1.83E+04^{ab}	0.14
QA	1.35E+05	3.72E+04^{a}	2.66E+03^{ac}	0.24^{a}
WH	1.58E+05	3.77E+04^{a}	8.58E+02^{bc}	0.24^{a}
Concentration				
0	1.65E+05	2.18E+04	2.22E+04^{abcd}	0.14
1	2.00E+05	3.81E+04^{a}	4.25E+03^{ae}	0.21^{a}
2	1.57E+05	3.82E+04^{a}	3.69E+03^{b}	0.20
3	1.63E+05	3.51E+04	2.79E+03^{ce}	0.21^{a}
4	1.82E+05	3.96E+04	3.34E+03^{d}	0.26
P- Value	Values with similar superscripts are significantly not similar in same the column 0.05	Values with similar superscripts are significantly similar in the same column at P, 0.05	Values with similar superscripts are significantly different with each other in the same column at P, 0.05	Values with similar superscripts are significantly not different in the same coloumn at P, 0.05

GA (Gum Acacia), GA XG (Gum Acacia+ Xanthangum), GG (Guar Gum), GG GA (Guar gum+ Gum Acacia), GG XG (Guargum+Xanthan gum), TG(Tragacanth gum), TG GA(Tragacanth gum), XG(Xanthan gum), FM(Foxtail Millet), QA(Quinoa), WH(Wheat)

3.2 Effect of hydrocolloid concentration

Addition of 1% and 4% hydrocolloids increased, while 2% and 3 % decreased G', compared to that of the dough without hydrocolloids. Among the different concentrations studied 2% hydrocolloid doughs were found to be closer to the G' of wheat dough irrespective of type and grain used. Much higher G' was achieved with 1% followed by 4% addition of hydrocolloids irrespective of type of grain and hydrocolloid. The amplitude of the deforming strain also affects the relative magnitudes of the storage and loss moduli. At higher strains, the relative magnitude is reversed. Thus, increasing strain causes the behavior of a dough to change from that of a viscoelastic solid to that of an elastoviscous liquid. Addition of hydrocolloids at all concentrations decreased the yield stress significantly. The ratio of the viscous to elastic modulus (G"/G') is equal to the tangent of the phase angle (tan δ). A material having higher degree cross-linking is expected to have a low tan δ. The Loss tangent (δ) varies between 0 and 1, it is zero in case of a purely elastic material and 1 for a purely viscous fluid. Addition of hydrocolloids had significant effect ($p<0.05$) on tan δ of both the biscuit doughs. The treatment mean of loss tangent was 0.21 with a significant difference ($p<0.05$). However, no significant difference was observed between GA and XG, GG and GG GA among hydrocolloids (Table 2). Constant increase in tan δ was observed from 0% (0.14) to 4% (0.26) irrespective of the type of hydrocolloid added and the grain type. There was no significant difference between 1% (0.21) and 3% (0.21).

3.3 Effect of grain

Maximum G' was found in FMBD(Foxtail millet biscuit dough) (2.28E+05) followed by wheat dough (1.58E+05) and least in QABD(Quinoa biscuit dough) (1.35E+05). It was also observed that, G' of QABD was relatively closer to wheat, than that of FMBD, however there was a significant difference among the three grains ($p<0.05$), irrespective of the hydrocolloid and concentration added. Maximum yield stress was observed in FM flowed by QA and WH. There was no significant difference in loss tangent between wheat (0.24) and quinoa (0.24), while there was difference between wheat and foxtail (0.14), foxtail and quinoa ($P<0.05$). Irrespective of hydrocolloid and their concentrations, there was no significant difference in the loss tangent (δ) between QA and WH but not from FM.

Table 3: Interaction of Hydrocolloids, Concentration and grain type on foxtail and quinoa biscuit dough rheology in comparison with wheat dough rheology

Hydrocolloid x Grain	**Storage modulus (G')**	**Loss modulus(G")**	**Yield Stress**	**Loss tangent (δ)**
GA x FM	2.61E+05	2.78E+04	2.10E+04	0.10
QA	1.10E+05	4.67E+04	5.28E+02	0.28
WH	1.58E+05	3.77E+04	8.58E+02	0.24
GA XG x FM	2.60E+05	1.14E+04	1.44E+04	0.05
QA	1.02E+05	3.53E+04	1.83E+03	0.21
WH	1.58E+05	3.77E+04	8.58E+02	0.24
GG x FM	2.38E+05	1.37E+04	1.43E+04	0.05
QA	1.35E+05	2.47E+04	5.46E+03	0.19
WH	1.58E+05	3.77E+04	8.58E+02	0.24
GG GA x FM	2.44E+05	3.35E+04	1.36E+04	0.14
QA	9.51E+04	4.06E+04	1.08E+03	0.11
WH	1.58E+05	3.77E+04	8.58E+02	0.24
GG XG x FM	1.78E+05	3.35E+04	1.41E+04	0.22
QA	1.56E+05	2.99E+04	5.88E+03	0.19
WH	1.58E+05	3.77E+04	8.58E+02	0.24
TG x FM	2.81E+05	5.34E+04	1.29E+04	0.18
QA	1.11E+05	3.67E+04	1.80E+03	0.40
WH	1.58E+05	3.77E+04	8.58E+02	0.24
TG GA x FM	2.08E+05	3.04E+03	4.87E+04	0.01
QA	1.41E+05	4.31E+04	6.82E+02	0.30
WH	1.58E+05	3.77E+04	8.58E+02	0.24
TG GA x FM	2.35E+05	4.68E+04	1.43E+04	0.22
QA	2.94E+05	4.38E+04	1.06E+03	0.29
WH	1.58E+05	3.77E+04	8.58E+02	0.24
TG XG x FM	1.64E+05	2.97E+04	1.46E+04	0.21
QA	1.10E+05	4.32E+04	3.74E+03	0.23
WH	1.58E+05	3.77E+04	8.58E+02	0.24
XG x FM	2.07E+05	3.51E+04	1.49E+04	0.17
QA	9.35E+04	2.80E+04	4.57E+03	0.21
WH	1.58E+05	3.77E+04	8.58E+02	0.24
Hydrocolloid Concentration	Storage modulus (G')	Loss modulus(G")	Yield Stress	Loss tangent (δ)
GA x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	2.07E+05	3.16E+04	1.17E+04	0.18
2	1.52E+05	4.73E+04	1.10E+03	0.13
3	1.94E+05	4.07E+04	9.01E+02	0.22
4	1.63E+05	4.56E+04	1.36E+03	0.35
GA XG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	1.88E+05	1.86E+04	1.24E+03	0.12
2	1.82E+05	3.00E+04	1.02E+03	0.08
3	1.59E+05	1.98E+04	2.83E+03	0.13
4	1.72E+05	5.06E+04	1.11E+03	0.36
GG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	2.16E+05	3.29E+04	3.57E+03	0.15
2	1.83E+05	1.94E+04	2.91E+03	0.13
3	1.63E+05	2.16E+04	3.25E+03	0.17
4	1.57E+05	3.11E+04	2.46E+03	0.22
GG GA x 0	1.65E+05	2.18E+04	2.22E+04	0.14

1	2.20E+05	3.77E+04	1.24E+03	0.20
2	1.11E+05	4.69E+04	6.80E+02	0.17
3	1.90E+05	2.83E+04	1.39E+03	0.15
4	1.41E+05	5.16E+04	2.98E+02	0.14
GG XG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	1.67E+05	4.39E+04	3.37E+03	0.26
2	1.57E+05	3.33E+04	3.78E+03	0.21
3	2.01E+05	3.76E+04	2.37E+03	0.20
4	1.30E+05	3.19E+04	2.97E+03	0.26
TG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	2.21E+05	5.31E+04	3.93E+02	0.25
2	1.87E+05	3.97E+04	2.37E+03	0.22
3	1.50E+05	4.93E+04	6.40E+02	0.41
4	1.91E+05	4.91E+04	3.06E+02	0.35
TG GA x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	2.12E+05	3.43E+04	1.47E+04	0.21
2	1.69E+05	2.80E+04	1.98E+04	0.18
3	1.51E+05	2.60E+04	9.63E+03	0.19
4	1.46E+05	2.95E+04	1.73E+04	0.21
TG GG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	2.05E+05	4.14E+04	2.17E+03	0.22
2	1.57E+05	5.30E+04	6.72E+02	0.34
3	1.52E+05	5.86E+04	2.95E+02	0.40
4	4.65E+05	3.90E+04	1.62E+03	0.14
TG XG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	1.83E+05	3.95E+04	3.46E+03	0.22
2	1.36E+05	4.42E+04	1.20E+03	0.34
3	1.09E+05	3.65E+04	3.28E+03	0.08
4	1.25E+05	4.23E+04	1.74E+03	0.35
XG x 0	1.65E+05	2.18E+04	2.22E+04	0.14
1	1.75E+05	4.83E+04	7.00E+02	0.34
2	1.32E+05	4.06E+04	3.40E+03	0.17
3	1.62E+05	3.21E+04	3.34E+03	0.20
4	1.30E+05	2.53E+04	4.25E+03	0.19
Grain x Concentration	Storage modulus (G’)	Loss modulus(G”)	Yield Stress	Loss tangent (δ)
FM x 0	1.95E+05	2.83E+01	6.46E+04	0.00
1	2.85E+05	3.68E+04	8.95E+03	0.14
2	2.34E+05	3.82E+04	7.24E+03	0.19
3	2.18E+05	3.09E+04	3.88E+03	0.14
4	2.06E+05	3.81E+04	6.73E+03	0.21
QA x 0	1.43E+05	2.77E+04	1.32E+03	0.19
1	1.56E+05	3.99E+04	2.95E+03	0.26
2	7.82E+04	3.89E+04	2.97E+03	0.16
3	1.14E+05	3.66E+04	3.64E+03	0.27
4	1.83E+05	4.30E+04	2.43E+03	0.32
WH x 0	1.58E+05	3.77E+04	8.58E+02	0.24
1	1.58E+05	3.77E+04	8.58E+02	0.24
2	1.58E+05	3.77E+04	8.58E+02	0.24
3	1.58E+05	3.77E+04	8.58E+02	0.24
4	1.58E+05	3.77E+04	8.58E+02	0.24

3.4 Interaction effects of grain, hydrocolloid and their concentration

The interaction effect of grain and hydrocolloids revealed that, compared to FMBD, QABD exhibited significantly ($P<0.05$) lower G’ with all hydrocolloids except with TGGG, which was highest among all the QA doughs (Table 3). Among the FMBD formulations highest G’ was observed with TG followed by GA and least with TGXG, which was close to the G’ of wheat dough. Amongst, QABD formulations highest and lowest was observed with TG GG and XG respectively. Further, GG XG formulation of QABD was found to be very close to the G’ of wheat dough. This indicates that in the development of gluten free biscuits, hydrocolloids influence differently in different grains. This suggests that application of hydrocolloids is grain specific. This information is useful to choose the right hydrocolloid when particular G’ is required. The loss tangent (δ) of GG XG (0.22), TG GG (0.22) of FM doughs and TG XG (0.23), GA XG (0.21) of QA doughs were close to that of wheat (0.24). Significant interaction effect of concentration and grain was observed on all rheological parameters. Compared to FMBD, QABD achieved very high G’ with 2% hydrocolloids however there after there was a higher reduction in G’ unlike FMBD. Compared to all individual and combination hydrocolloids, TG behavior was out standing in enhancing the G’ at 1% concentration. When the effect of individual hydrocolloids concentration was studied, it was observed that synergetic effect of GA and GG was significantly higher than their individual effect on the storage modulus. There was a significant effect of hydrocolloids on the modulus, except 3% concentration of GG and XG ($P>0.05$).

It can be observed from the individual rheograms, in the foxtail millet grain even after application of hydrocolloids, the G’ was higher at all percentages relative to wheat, except 3 %

and with the increasing strain more viscous dough was resulted, reflecting that at higher frequencies the dough behaves more like a liquid. With respect to quinoa doughs, application of GG, GA increased G’ up to 3% concentration, while XG & GG XG increased G’ at all concentrations, GAXG decreased G’ significantly ($p<0.05$) from the wheat and quinoa control. There were no two hydrocolloids behaved similarly, some hydrocolloids increased G’ and G” with the increasing concentrations up to 3% and later decreased at higher concentrations. The flow curves of the rheograms (Fig 1 - 3) indicated that the LVE region was up to 1% strain. From the rheological studies, it was found that among the hydrocolloids studied, the application of GGXG at 1and 4 % in foxtail millet (fig.1) and TGXG 1% (fig.2) and GAXG at 1% (fig.3) concentration in quinoa were found to be closer to the wheat biscuit dough.

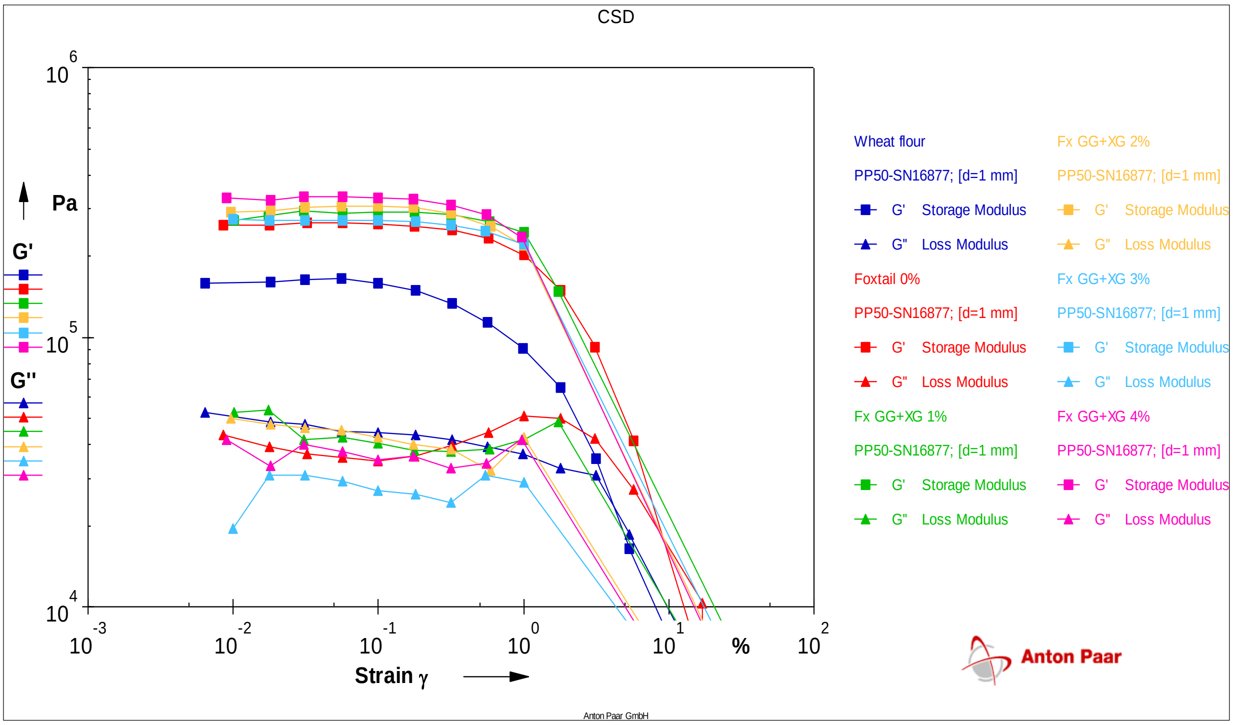

Fig 1: Effect of Guar gum and Xanthan gum on rheology of foxtail millet biscuit dough in comparison with wheat dough

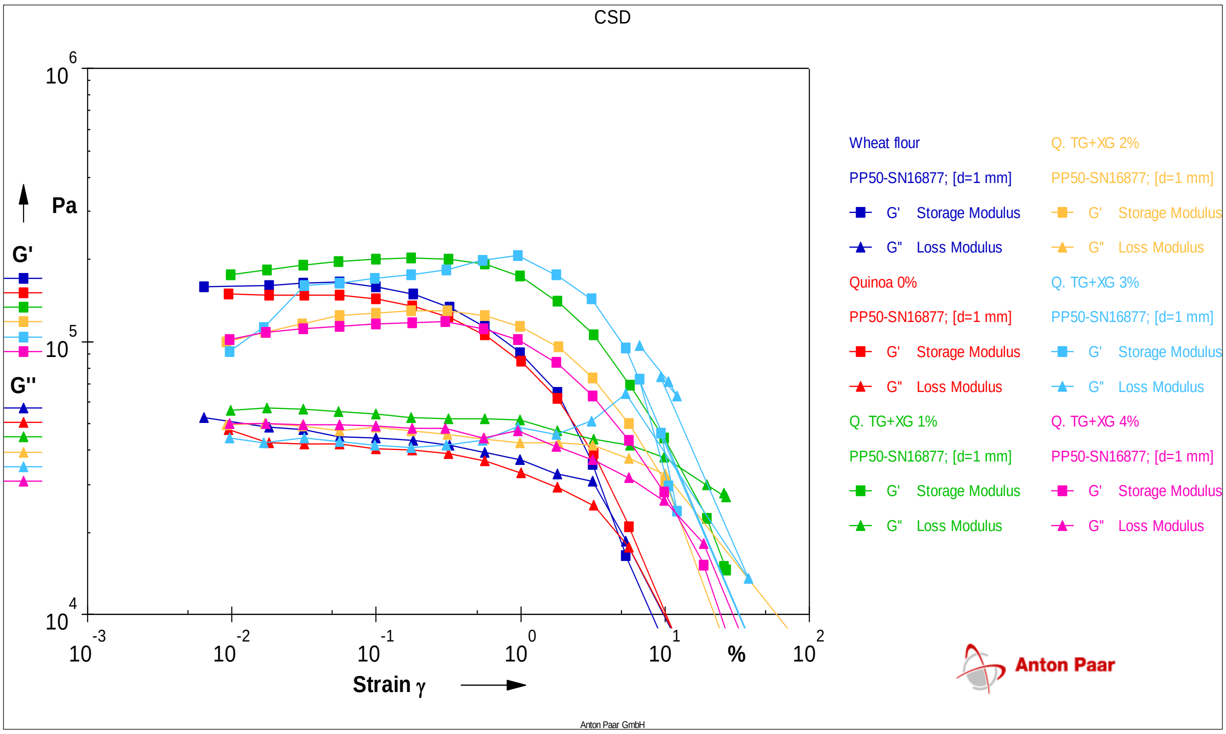

Fig 2: Effect of Gum tragacanth and Xanthan gum on rheology of quinoa biscuit dough in comparison with wheat dough

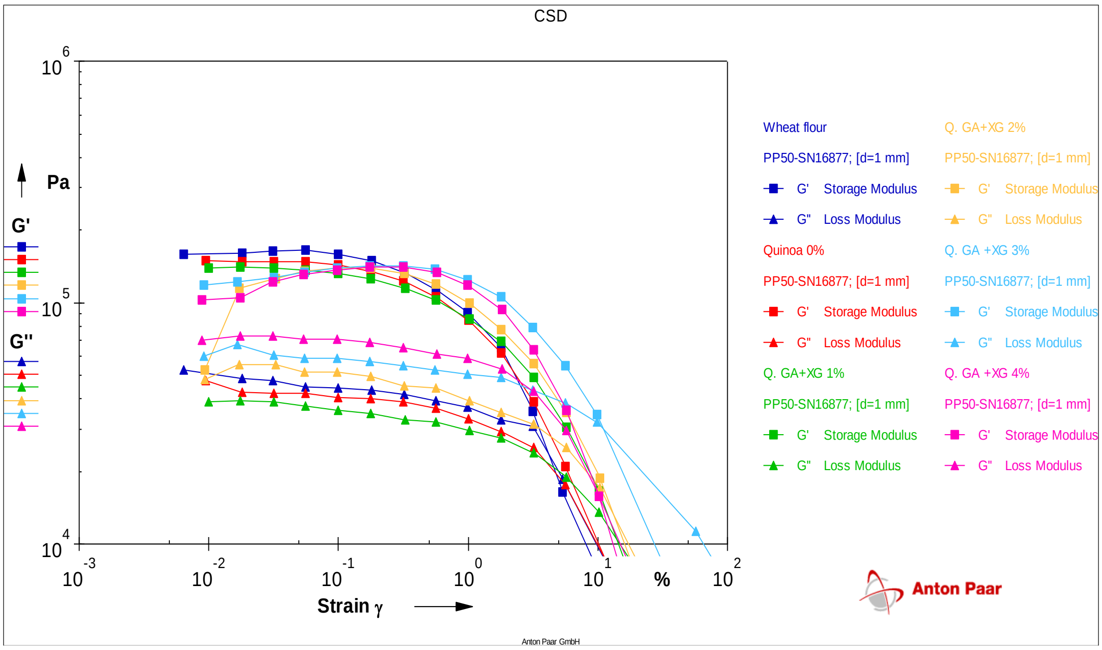

Fig 3: Effect of Gum acacia and xanthan gum on rheology of quinoa biscuit dough in comparison with wheat dough

4. Conclusion

The work primarily has explored that the addition of hydrocolloids has significant effect on dough rheology. Addition of hydrocolliods in combinations yielded better results than that of single hydrocolloid. It also could be concluded that the action of hydrocolloids has a grain specific effect as each hydrocolloid exhibited different properties when added to FMBD and QABD however addition of xanthan gum had a significant effect in all types of doughs added due to its synergestic nature. Addition of hydrocolloids even at low concentrations significantly improved the rheological properties of dough. From the present study it could be concluded that application of GGXG at 1% and 4 % in foxtail millet and TGXG 1% and GAXG at 4% concentration in quinoa were found to be suitable to make gluten free biscuits. This shows that gluten free biscuits which are highly nutritious can be made out of these flours without affecting the texture and taste of biscuits.

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