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Creating texture in gluten-free bread
with Xanthan Gum



Abstract

The gluten-free food market is projected to reach nearly \$6.5 billion in the US and the global market is anticipated to reach more than \$40 billion by 2025. Gluten-free bread is often thought of as crumbly, dry and flavourless. Yet although hydrocolloids are known to help texturise gluten-free bread, after more than three decades of gluten-free manufacturing and R&D efforts, it has not yet been perfectly understood how they do this. Although there are studies showing effects of hydrocolloids on final gluten-free bread quality, understanding of their role in structural changes during different stages of processing is limited. This study emphasises the importance of hydrocolloids as stabilisers of the sequential foaming process during proving and baking. Four different hydrocolloids, xanthan gum, guar gum, hydroxypropyl methyl cellulose (HPMC) and psyllium husk, were tested individually at different levels of use (0.0, 0.6, 1.2, 2.4 and 3.6 wt%) in a gluten-free sandwich bread. The measurement of loaf rise showed that xanthan gum was the best stabiliser for both the cold foam during proving and the hot foam during baking, resulting in a lower-density loaf. There is a good correlation between foam stability and level of use of xanthan gum. Texture analysis results proved that xanthan gum imparted a softer, more cohesive (less crumbly), elastic texture that resembles a gluten bread. To explore potential synergies in texture, two binary blends of xanthan gum with HPMC and with psyllium husks at different ratios were tested. Contrary to our hypothesis, no advantage in texture or density was found. Finally, xanthan gum was tested in two different applications other than sandwich bread, a gluten-free baguette and an ancient-grains gluten-free bread, where the correlation between the xanthan gum content and foaming stability was corroborated.

Introduction

The challenge

The global gluten-free market originally catered to the need for gluten-free diets by people suffering from celiac disease. Over the years a gluten-free diet has become a lifestyle choice among millennials in their search for a more healthy life. This trend caused a tremendous growth in demand for gluten-free products. The trend affected all market segments. In some food categories, gluten-free alternatives could easily be brought to the market by exchanging gluten-containing ingredients. However, in other categories, the formulators have had to overcome different challenges to adapt to the trend for a gluten-free diet. The broad field of bakery products is one such challenging food category. Many of the different types of bakery products are based on complex recipes. To match the appearance, taste profile and texture of regular bakery products, not only does the gluten-containing flour have to be exchanged, but new ingredients have to be added to the recipe to compensate for the functionality of gluten. Since these new ingredients interact with other ingredients of the recipe, more adjustments and work are needed to achieve the desired outcome. The aim of the research reported here was to obtain a better understanding of the role of xanthan gum and its contribution to successful gluten-free baking.

The problem addressed

Gluten-free bakery in general lacks the binding ability and structural support that gluten imparts to the dough during the foaming process as well as the normal springiness and toughness of the breadcrumb structure. Adding biopolymers, specifically hydrocolloids, helps produce doughs with bread-like structures that more closely resemble their original counterparts. There are a wide range of hydrocolloids that can be used; however, the most commonly used are xanthan gum, guar gum, hydroxypropyl methyl cellulose (HPMC) and psyllium husk mucilage. Choosing the correct hydrocolloid to texturise bread helps stabilise the foaming processes.

Gluten-free baking is usually a two-step foaming process: first there is the cold foaming during proving and then the hot foaming during baking.^[1] The two steps are connected and sequential as under- or over-proving cannot be corrected by the hot foaming process. On the other hand, even after a good cold foaming process, a poor or unstable hot foaming process will lead to unsatisfactory results in the baked product.^[2,3] Therefore adding a hydrocolloid or a blend of hydrocolloids that can act on both processes is of utmost importance to impart the correct characteristics of breadcrumb to the baked goods.^[1] The hydrocolloids transform dough characteristics of malleability, cohesiveness, hardness and springiness through heat treatment into bread-like baked products in terms of elasticity, cohesiveness and softness.^[4]

Adding hydrocolloids can also have a significant sensory impact. This may be positive, adding cereal, earth, or wheat flavours; negative, imparting beany flavours; or neutral, with no alteration to the flavour at all. The same concept applies for appearance: hydrocolloids may darken or lighten the colour or have no visual impact.^[5]

This study focuses on four widely accepted hydrocolloids to be tested against each other under a standardised set of trials based on a gluten-free sandwich bread recipe.^[6,7,8] Their performance is tested in relation to how well they can individually stabilise a cold foam produced during proving and subsequently stabilise hot foaming during baking. The goal is to deliver a bread-like structure and breadcrumb texture that are as close as possible to the original.

By showing how hydrocolloids help deliver different characteristics to the dough and the baked goods, this study offers help to bakers and product developers choose which hydrocolloid or blend of hydrocolloids to use in their formulations.

In general, making traditional wheat bread consists of hydrating a wheat flour and kneading the dough to develop some degree of gluten network; fermentation then produces gases that are trapped in the gluten network. The gluten network relaxes over time, so a second or further kneading/fermentation sequences can be applied, until the desirable degree of trapped gas and texture is reached.^[9,10] The dough is then shaped and fermented (proved) one last time before baking. During baking, the initial warming up of the dough will accelerate the fermentation, producing more gases, and the gases already trapped will begin to expand with increasing temperature.^[9,10] This is what makes the dough rise during baking, and it is only possible due to the leading function provided by gluten. With continued heating, the gluten is denatured and the hydrated starches will take over the role as main texture agent by gelatinising, setting and then dehydrating into their final structure. On the outside the gelatinised starch will dehydrate quickly and the starches will dextrinise and burn to produce a crust, while on the inside the still aerated gel dehydrates more slowly until finally baked and dehydrated.^[11,12]

For gluten-free breads the process is simpler, even though they do not possess gluten. Formulations are typically high in starch and so a large amount of water is needed in order to properly hydrate starches, fibres and hydrocolloids.^[13] It is not possible to over-mix a gluten-free formulation, as the viscosity is dependent on the amount of starch and hydrocolloids present; however, it is possible to under-mix by not giving enough mixing time. After properly hydrating, the dough should be shaped. For certain types of breads high viscosity is enough to maintain structure. Alternatively the dough can be placed in a baking tin. After depositing the dough, there will be only one fermentation (proving) step because the dough strength is only dependent on the viscosity imparted by the hydrocolloids, which will be weaker than a gluten network. During proving, starches and hydrocolloids should be able to hold the gases produced.^[6] The hydrocolloids mimic gluten by creating the highly viscous continuous medium in which starches can disperse but at the same time remain bound. Together the hydrocolloids and the starches form a stretchy matrix able to withstand a rupturing of the continuity of the medium while gases are produced during fermentation and baking. Specifically during baking, when fermentation is sped up and already trapped gases further expand the dough, it is of primary importance that high viscosity is maintained in hotter environments for the foam to survive until starches are gelatinised. With dehydration of the gelatinised foam, the structure sets into a breadcrumb and crust.^[3]

Experimental

Raw materials and formulation

The trials were based on the sandwich bread recipe shown in table 1. The hydrocolloids xanthan gum, guar gum, HPMC and psyllium husk were added at different concentrations to investigate the effect of viscosity and binder capability on stabilisation of the foam.^[3,14]

Table 1: Gluten-free sandwich bread formulation

Ingredients	Quantity [g]	Baker's percentage [%]	Comment on use
White rice flour	18.6	100.0	Starchy backbone, composed of different sizes and types of starch granules that can self-pack
Brown rice flour	5.8		
Potato starch	5.4		
Tapioca flour	2.3		
Oat flour	9.3		
Non-fat milk powder	4.1	9.9	Main use for browning
Glucono-Delta-Lactone F2500	0.6	1.4	Leavening system, composed of yeast and complementing chemical leavening
Sodium Bicarbonate	0.25	0.6	
Sugar granulated	0.75	1.8	
Dry yeast	2.0	4.8	
sub4salt® N1000	0.6	1.4	Salt substitute, -25% sodium
Water (6–48°C)	39.5	95.4	Main hydration
Shortening	1.8	4.3	Main fat content
Whole egg	7.4	17.9	Emulsifiers, complement fat
SSL	0.4	1.0	
Novamyl® BG	0.01	0.02	Enzyme extending shelf life
Hydrocolloid	0.0–3.6	0.0–8.7	Binders, thickeners
Total	98.8–102.4	242	

Dough preparation and baking process

The first step consisted of mixing all the powders and crystals into a homogeneous powder mix by incorporating white rice flour, brown rice flour, potato starch, tapioca starch, oat flour, non-fat milk powder, sugar, glucono-delta-lactone, sodium bicarbonate, the salt replacer, sodium stearoyl lactylate (SSL) and the hydrocolloids. The yeast was added to the powder mix and everything was blended for one extra minute. The water, whole eggs and melted shortening were added slowly while stirring. High shear mixing (180 rpm) was performed for 10 min to hydrate starches and hydrocolloids. At this point, a sample of the dough was taken to be tested in the texture analyser to understand the characteristics of the dough to be fermented.

The second step was proving. If the time and temperature are not enough to reach maximum stable foam development doughs can be under- or over-proved. Under-proving would result in denser breads with doughy sections, whereas over-proving exceeds the expansion capacity of the foam that subsequently becomes weak and starts bursting, which yields denser breads with channelling.^[12] To understand how different proving temperatures would affect the foaming process and then select the most appropriate temperature, a test matrix was designed (table 2) with three temperature and four time variables.

Table 2: Proving test conditions

Process condition	Selected temperature [°C]	Calculated optimum time [min]	Other times explored [min]
Cold temperature proving	16	84	60 30
Mild room-temperature proving	21	60	NA
Hot temperature proving	30	17	60 84

The temperature of the water and the temperature of the proving cabinet controlled the temperature of the dough. The correlation between the dough temperature reached and ingredient temperature is shown in table 3. The dough was stored in a proving cabinet with 85% relative humidity.



Table 3: Ingredient temperatures and resulting dough temperature

Process condition	Powder mix temperature [°C]	Water temperature [°C]	Obtained dough temperature [°C]
Cold temperature proving	21	6	16
Mild room-temperature proving	21	21	21
Hot temperature proving	21	48	30

The third step in making gluten-free bread was baking. After achieving a stable maximum foam during the proving step, the fermented dough was baked. Traditionally the baking temperature for sandwich breads extends from a minimum of 175°C to maximum of 190°C for 30–35 min.^[12] For this study, 175°C with steam was chosen to balance between proper starch gelatinisation and a softer crust development. Baking at a lower temperature also leads to a slower dehydration process that protects the foam. The baking time had to be extended to 90 min to properly remove additional water from the formulation.^[13]

The fourth and final step was cooling. Once the loaf had baked at 175°C for 90 min with steam, the bread was taken out of the oven and left at room temperature to cool down in the baking tin for 25 min. After unmoulding, cooling was continued at room temperature on a wire tray for 90 min. The loaves were then wrapped in a high barrier film and stored at room temperature. Analytical measurements were conducted the next day.

Analytical measurements

Doughs and breads were assessed using a texture analyser with a 38.1 mm diameter acrylic probe. A Texture Profile Analysis method with a 5 g trigger was used, at 10 mm-deformation and a speed of 0.5 mm/s, to measure hardness, cohesiveness and springiness. Two hundred gram samples from each dough and 1.5 cm thick slices from each loaf were analysed. The height of the loaf was measured by cutting the loaf into three equal sections. The middle section was measured using callipers to the highest peak.

The performance during dough preparation, proving, baking and in the final bread was evaluated based on the characteristics below. Attributes differ depending on whether they were analysed in the dough or a finished baked loaf.

■ **Hardness**

Hardness was determined by measuring the peak load when pressing the probe onto a defined amount of dough. The harder the dough, the more rising during proving is restricted. On the other hand, too soft a dough leads to collapsing. For the baked bread, hardness provides a first indication of mouthfeel when chewing.

■ **Cohesiveness**

Cohesiveness represents the tendency of the dough to stick together. A lower cohesiveness is favourable to support the rising of the dough. In the baked bread, greater cohesiveness is desired to provide a firm, bread-like crumb.

■ **Springiness**

Springiness refers to the elastic recovery of the dough or of the baked goods when releasing an external force. Depending on the type of baked goods, more or less springiness can be desirable. For example wheat breads should show greater springiness, whereas cookies should be less springy.

■ **Adhesion**

Adhesion indicates the bonding strength to a surface. A dough with high adhesion in combination with very low cohesion appears sticky. Adherence to baking tin walls can help the dough to rise.

Results and Interpretations

Dough and proving

The texture of gluten-free bread is developed through two sequential foaming processes – the first cold and the second hot. As they are connected and the final baked texture is dependent on both foaming processes, understanding how hydrocolloids affect each foaming process can help to understand how the hydrocolloid works and how to use it in different formulations and types of gluten-free bakery.^[3] Prior to foaming, the textural characteristics hydrocolloids imparted to the dough were measured.

The hardness of the doughs prepared with the four different hydrocolloids is shown in figure 1. Only minor differences between xanthan gum, psyllium husk and HPMC are noticeable. The hardness of guar gum increases substantially with increasing concentration, which has a negative effect on rising performance during fermentation.

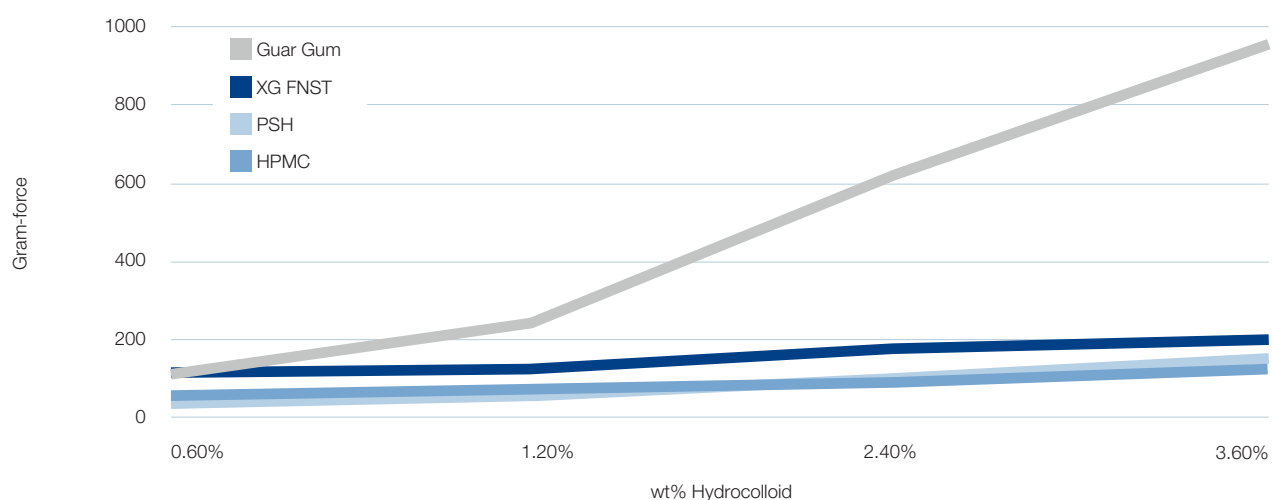


Figure 1: Dough hardness

The behaviour of cohesiveness in relation to hydrocolloid concentration is shown in figure 2.

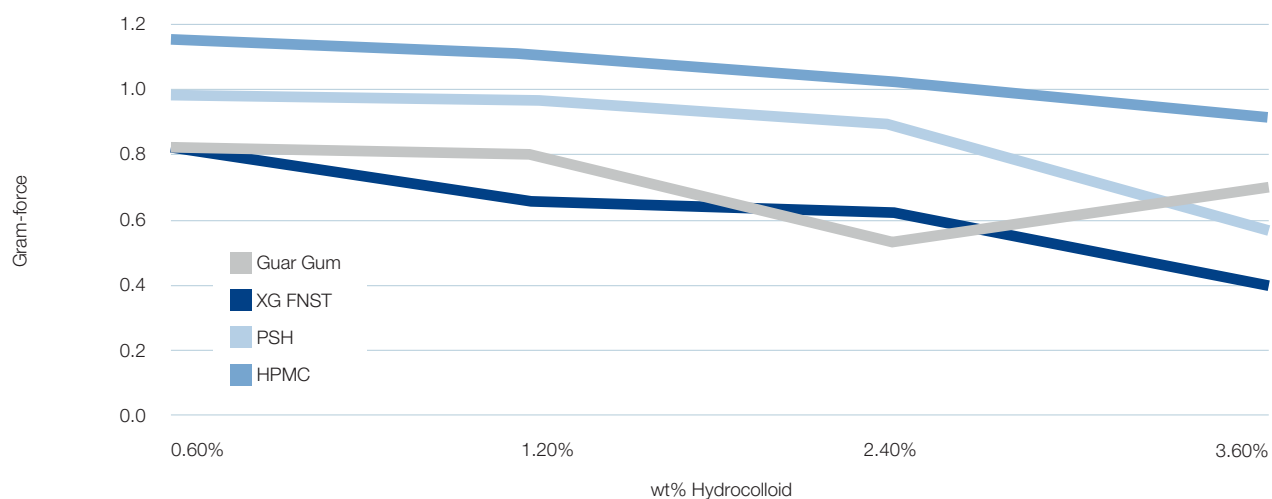


Figure 2: Dough cohesiveness

With increasing hydrocolloid concentration the cohesiveness in the dough decreases for all four hydrocolloids. All four hydrocolloids show similar cohesiveness behaviour in the dough. Xanthan gum has the overall lowest values, making it more favourable because high cohesiveness between the starch granules will restrict the spread through the continuous viscous phase as the foaming process takes place.^[6]

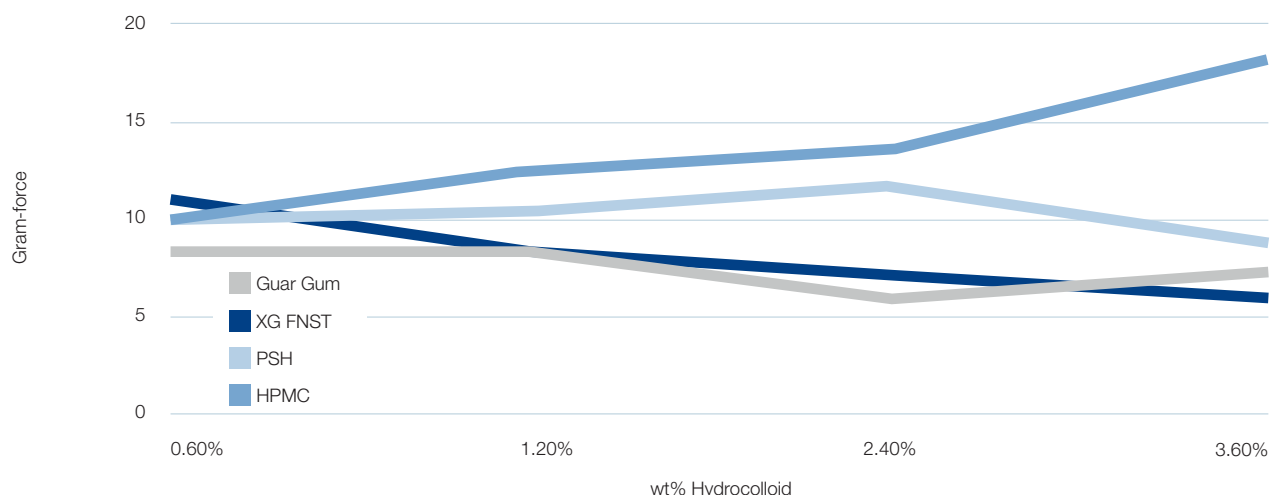


Figure 3: Dough springiness

Springiness is differently affected by the hydrocolloids. HPMC increases the springiness of the dough with increasing concentration, whereas for psyllium husk and guar gum the springiness mostly remains the same at different concentrations. Xanthan gum is the only hydrocolloid that reduces the springiness of the dough with increasing concentration. The reduced springiness is beneficial for the dough as it will have a lower elastic contraction while foaming, producing a more stable foam.

From the dough measurements it can be concluded that doughs or batters should not be too hard or too cohesive so the starches in the continuous medium can easily trap gases and expand by dispersing throughout the expanded medium. Doughs and batters should also not be too springy so the foam remains more stable with less elastic contraction while fermenting.^[7]

Proving (cold foaming) tests

Table 4: Tested proving conditions

Temperature [°C]	Proving time [min]	Result
16	30	under-proved
	60	under-proved
	84	proved
21	60	proved
30	17	proved
	60	over-proved
	90	over-proved

Proving at a cold temperature of 16°C requires longer proving times – about 40% longer than at room temperature – to achieve maximum foaming. It also requires a refrigerated chamber. The slower cold fermentation did produce a stable foam, whereas hot proving at 30°C with accelerated fermentation resulted in a more aggressive foaming process that required shorter times but increased monitoring of foaming as it was easy to over-prove. The higher the temperature the more aggressive the foaming because of increased activity by the yeast, but this more aggressive foaming is also less stable.^[12]

The most reproducible results with an open crumb structure, evenly distributed gas cells and low deformation after baking were achieved at 21°C with 60 min proving time. Based on these findings the proving conditions chosen were room temperature of 21°C for 60 min for all hydrocolloid testing, as this required neither a refrigeration chamber nor very long times for the cold foaming.

Baking (hot foaming) and final texture

During baking, the proved foamed dough continues to rise as fermentation continues and is accelerated by increasing temperature and expanding gases in the foam. As the yeast is killed by temperature, the starch gelatinisation helps stabilise the colloidal foam into a foamed gel. Baking dehydration also increases viscosity of the hydrocolloids in the continuous phase, helping to further stabilise the foam. As the bread is taken out of the oven, the foamed gel cools down. If the structure is strong enough it will resist contraction as the hot expanded gas cells cool down and contract. If the structure is weak the bread can collapse in on itself, yielding a denser product.^[15]

After cooling down to room temperature the loaf height was measured to represent the stability and strength of the foamed gel. The effect of the hydrocolloid concentration on the loaf rise is shown in figure 4.

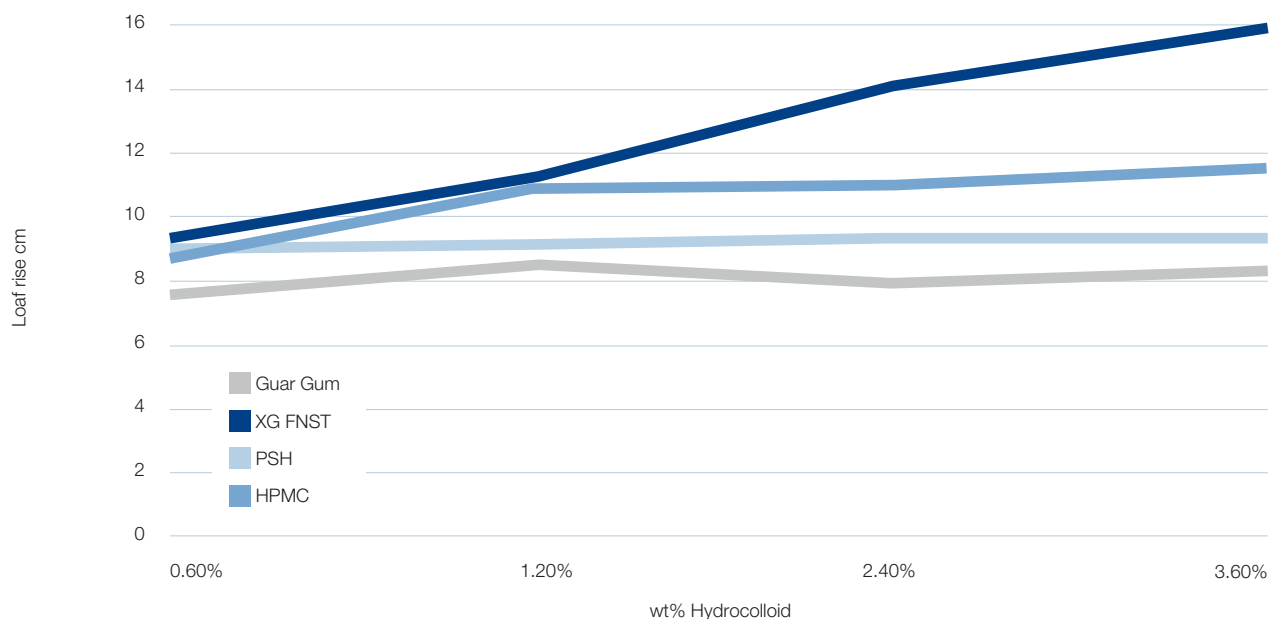


Figure 4: Loaf rise after baking for different hydrocolloid concentrations

The loaf rise of the sandwich bread with xanthan gum correlates well with the concentration used. A high rise can be achieved by choosing the corresponding xanthan gum concentration. The difference in loaf rise is also clearly visible when comparing the sandwich loaves themselves, as shown in figure 5.



Figure 5: Baked sandwich breads with 0–3.6 wt% xanthan gum

The other three hydrocolloids – psyllium husks, HPMC and guar gum – have a weaker effect on loaf rise than xanthan gum. This can be explained by analysing where in the two sequential foaming processes they fail. Psyllium husk upon hydration produces a weak gel that can help stabilise a foam during proving, but upon heating during baking this psyllium gel melts, leaving a rather low viscosity when compared to the other hydrocolloids studied.^[16] The gel melts at quite low temperatures, before all the starches can gelatinise and set, and so the foam loses support during baking, yielding lower expansion of gas cells and a denser product.^[5,16] With guar gum a different phenomenon occurs: foaming through fermentation is a low-shear process, and guar gum exhibits low viscosity at low shear.^[17] Thus during proving the viscosity of the dough is quite low, which leads to reduced foam stability. HPMC is quite similar in its behaviour to psyllium: HPMC exhibits low viscosities in cold low-shear processes and as such it stabilises much less during proving.^[4,7] Even though HPMC does impart high viscosity in hot environments, this does not overcome the weak foam stabilisation during cold foaming. Xanthan gum is a shear-thinning hydrocolloid, which means that at low shear it exhibits high viscosity.^[17,18] In hot environments, xanthan gum does lose some viscosity but the viscosity it maintains is still substantial. Xanthan gum helps to stabilise foaming during proving in the cold step and during baking in the hot step. Xanthan gum continues to stabilise the foam through its relatively high viscosity as the medium rapidly dehydrates, until starches gelatinise and set. This results in a not too hard, not too cohesive, not too springy dough with enough viscosity to facilitate the foaming process.

Texture of baked bread

As seen in figure 4 and figure 5, xanthan gum delivered a less dense, more aerated breadcrumb with a high rise.



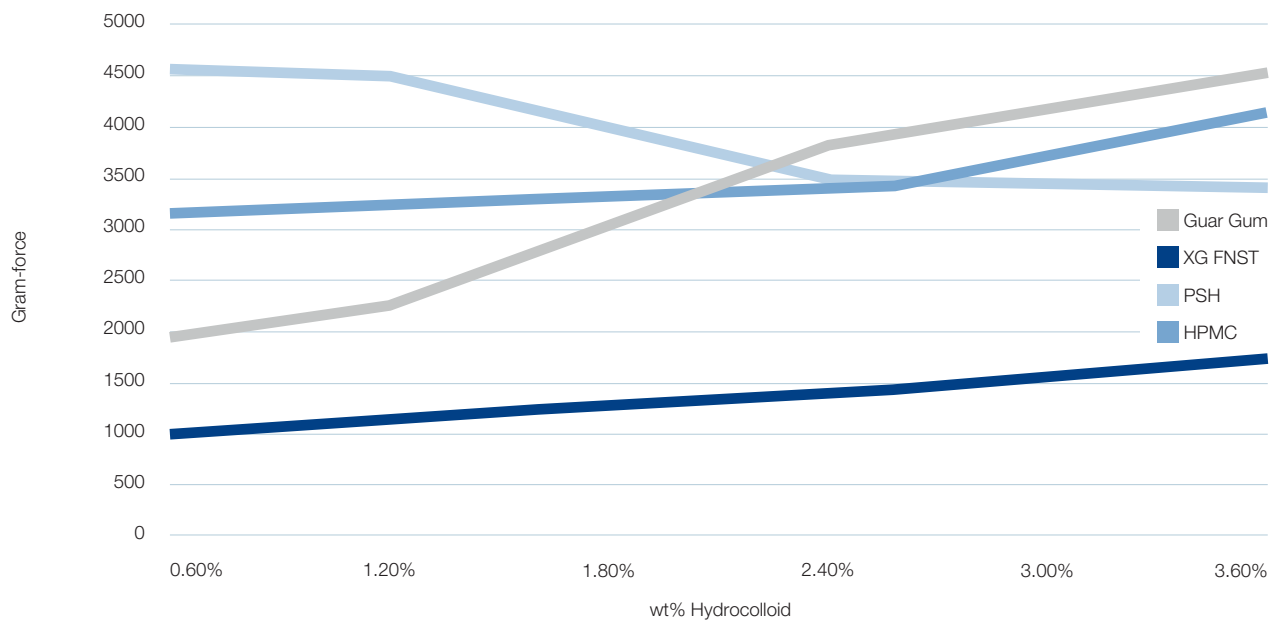


Figure 6: Hardness of breadcrumbs



Psyllium husk was the only hydrocolloid used that yielded a weaker structure in baked bread with increasing use of it. This may be due to the bread's very crumbly structure. Guar gum, HPMC and xanthan gum all increased hardness as the concentration was increased. The baked bread made with xanthan gum is substantially softer due to the fact the breadcrumb structure is more open and aerated. This is also related to the following attributes of cohesiveness and elasticity as shown in figure 7 and figure 8, respectively.

As can be seen in figure 7, xanthan gum imparts a more cohesive texture in the more aerated soft structure, which results in a less crumbly product. HPMC has the lowest value for cohesiveness, which makes the bread more crumbly.

For springiness, which is desired in some baked products, it can be seen that psyllium husk has the highest measurement, followed closely by xanthan gum and guar gum, and significantly lower springiness for HPMC.

Overall, it can be seen that xanthan gum imparts a softer, more aerated baked texture with higher cohesiveness, meaning less crumbliness and high springiness. This is because xanthan gum is able to properly stabilise the foam in both cold and hot environments as well as to keep viscosity high enough to bind the breadcrumb.

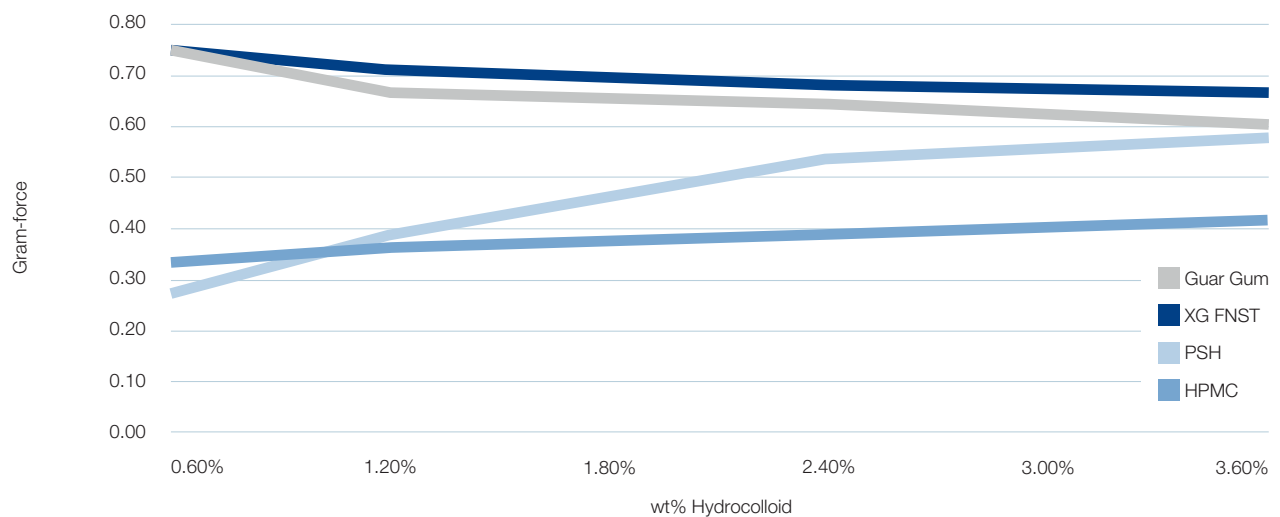


Figure 7: Cohesiveness of breadcrumbs

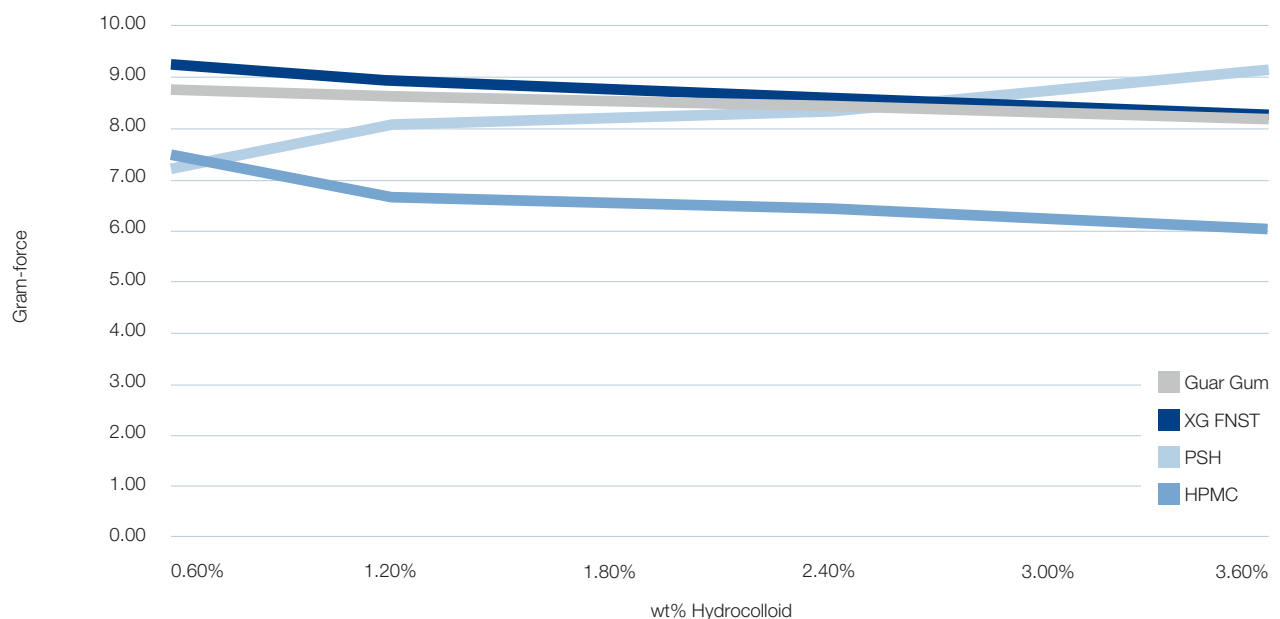


Figure 8: Springiness of breadcrumbs

Testing of HPMC and xanthan gum blend in bread

Up to this point, the hydrocolloids were only tested individually to understand how they affect dough foam stability and how they impart texture characteristics to baked bread. It is common to combine hydrocolloids to impart different textures, flavours and appearance to gluten-free breads.^[2,4,6,7,8,15,16] For xanthan gum and HPMC it is known that their viscosity is temperature dependent. Xanthan gum shows a reversible process of decreasing viscosity with rising temperature, whereas HPMC gels with increasing temperature.^[17]

Due to these contrasting properties, it was assumed that a combination of these two hydrocolloids would have a beneficial effect on loaf rise and the texture of the breadcrumb. Six different ratios of xanthan gum and HPMC blends were tested and the loaf rise and bread texture were analysed.

Table 5: Tested xanthan gum/HPMC ratios and loaf rise

Test	Ratio XG/HPMC	XG [wt%]	HPMC [wt%]	Loaf rise [cm]
Run 1	0:1	0	2.4	9.9
Run 2	1:7	0.3	2.1	10.4
Run 3	1:3	0.6	1.8	10.6
Run 4	3:5	0.9	1.5	10.7
Run 5	1:1	1.2	1.2	10.9
Run 6	1:0	2.4	0	13.5



The loaf rise correlates with the xanthan gum concentration in the dough, whereas for HPMC there does not seem to be a positive correlation with the rise of the loaf. As such, it can be concluded that there is no benefit to using both hydrocolloids together. In terms of hardness the breadcrumb behaved similarly to the individual results shown previously: the more xanthan gum that was used in the blend the more expanded the loaf of bread and so the softer the texture became. In contrast, the more HPMC was used in the blend, the less expanded the bread was, resulting in a denser, harder texture.

Although no synergy was found, these results do confirm that loaf rise and crumb texture are mainly supported by the addition of xanthan gum.

Testing of psyllium husk and xanthan gum blend in bread

As with HPMC, different ratios of xanthan gum and psyllium husk blends were tested, in this case five.

Table 6: Tested xanthan gum/psyllium ratios and loaf rise

Test	Ratio XG/HPMC	XG [wt%]	Psyllium husk [wt%]	Loaf rise [cm]
Run 1	0:1	0.0	2.4	9.5
Run 2	1:3	0.6	1.8	10.2
Run 3	1:1	1.2	1.2	11.2
Run 4	3:1	1.8	0.6	12.7
Run 5	1:1	2.4	0.0	13.7



This series of tests also showed no synergetic effect from combining the hydrocolloids. Increasing the amount of xanthan gum increased the height of the loaf, which is a sign of a more stable foam able to retain more and bigger gas cells. In a direct comparison, the texture of the bread made with only psyllium husk was dense and crumbly.^[15]

Unlike the HPMC, the psyllium husk does improve the taste, by adding bread-like and cereal flavours.^[5,15]

Testing xanthan gum in other gluten-free bases

Ancient-grain gluten-free bread

In this section, the study explored a different gluten-free base that contained a larger amount of fibres and protein but had a lower starch content (table 7 in appendix) to see whether xanthan gum was able to stabilise the foam in this formulation as it had in the sandwich bread. A hydrocolloid-free formulation was tested and compared with the same formulation to which 1.0 wt% of xanthan gum had been added.



Figure 9: Ancient grain cross section comparing no hydrocolloid (left) to a formulation containing 1 wt% xanthan gum (right)

As can be seen in figure 9 (left), an ancient-grains loaf containing no hydrocolloid caves inward due to lack of structure. The image on the right shows how xanthan gum was able to stabilise the foam until the starches gelatinise and set, resulting in an aerated breadcrumb. This higher fibre content formulation was less prone to foam because of the lower starch content, giving a somewhat denser baked product.^[5,12,19] However, this type of bread also contains inclusions (suspended particles) of legumes and grains such as quinoa, sprouted lentils and millet. This demonstrates that the viscosity produced by xanthan gum, again during both cold and hot foaming, guaranteed homogeneous suspension. The hydrocolloid-free ancient-grain bread had a rise height of 8.0 cm, while the bread containing xanthan gum reached a height of 9.5 cm, showing the benefit of adding xanthan gum.

Gluten-free baguette

It has been shown that xanthan gum is able to stabilise gluten-free foams to have an open breadcrumb. About 1 wt% of xanthan gum is able to deliver an aerated texture similar to traditional gluten-containing sandwich bread. Increasing the amount of xanthan gum increases the number of gas cells as well as the size of gas cells. For this reason a xanthan gum concentration of 2.5 wt% was used to develop a formulation (table 8 in appendix) to mimic the open crumb of an artisan bread such as a baguette.



Figure 10: Pictures of open crumb of gluten-free baguettes. Bigger air cells stabilised by xanthan gum.

The crumb structure with large air cells is shown in figure 10. By increasing the amount of xanthan gum from 1 wt% in sandwich bread to 2.5 wt% in the baguette it was possible to achieve a structure similar to the open crumb of a traditional artisan bread. Xanthan gum also increased hardness and cohesion of the baked goods, which are typical for these types of breads.

These experiments demonstrate the stabilising potential of xanthan gum for cold and hot bakery foams across different types of baked goods.

Conclusions and future work

This study compared the effects of individual hydrocolloid stabilisers on gluten-free sandwich bread foams and baked bread textures. Xanthan gum, HPMC, guar gum and psyllium husk were tested individually at varying use levels. Because xanthan gum is a shear-thinning hydrocolloid, it showed greater stability effects in both low-shear sequential cold and hot processes,^[9] yielding a higher loaf rise and a softer, more cohesive yet elastic baked gluten-free sandwich bread texture. The optimum amount of xanthan gum use for gluten-free sandwich bread is between 1.0 and 1.2 wt%.

It was also shown that blending xanthan gum with either HPMC or psyllium at levels of use between 0.6–2.4 wt% does not give rise to synergy effects, and it was the xanthan gum that produced the primary foam stabilising effect of the blend. Finally, increasing the xanthan gum level of use to 2.5 wt% stabilised bigger air cells in the foam, simulating a gluten-free artisan baguette, and 1 wt% stabilised a more complex gluten-free formulation made up of ancient grains. The study demonstrated that xanthan gum is the best-performing hydrocolloid of those tested, as it better stabilises the foam through different thermal processes and formulations, imparting high viscosity in low shear (foaming). It is hoped that these insights will help product designers towards a more focused approach when developing gluten-free bakery products.

This case study is not intended to be an exhaustive review of all potential hydrocolloids or blends of hydrocolloids to be used in gluten-free bakery, nor a full exploration of all gluten-free formulations. Further studies on different gluten-free applications such as cookies, pastry, pasta and other savoury food groups are needed to expand the understanding of hydrocolloids as stabilisers in more delicate foams and texture-specific bakery products.

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Appendix

Table 7: Gluten-free ancient-grain formulation

Ingredients	Quantity [g]	[wt%]	Baker's percentage [%]
Dough			
Teff flour	212.0	18.3	53.3
Brown rice flour	71.0	6.2	17.8
Golden flaxseed flour	71.0	6.2	17.8
Sweet white rice flour	44.0	3.8	11.1
Xanthan Gum FNST	13.8	1.2	3.5
sub4salt® N1000	8.7	0.8	2.2
Glucono-Delta-Lactone	6.6	0.6	1.7
Sodium Bicarbonate	3.0	0.3	0.8
Yeast	13.0	1.1	3.3
Raw honey	43.0	372.0	10.8
Cider vinegar	18.0	1.6	4.5
Water	368.4	31.9	92.6
Sprouted inclusions			
Millet	150	13.0	37.7
Quinoa	42.5	3.7	10.7
Lentils	42.5	3.7	10.7
Topping			
Pumpkin seeds	42.5	3.7	10.7
Sesame seeds	5	0.4	1.3
Total	1155	100	290

Table 8: Gluten-free baguette formulation

Ingredients	Quantity [g]	[wt%]	Baker's percentage [%]
Starter			
Oat flour	57.0	8.4	20.4
Water	113.0	16.6	40.4
Sugar, granulated	10.0	1.5	3.6
Yeast	3.0	0.4	1.1
Dough			
White rice flour	129.0	19.0	46.2
Brown rice flour	40.0	5.9	14.3
Potato starch	37.5	5.5	13.4
Tapioca flour	16.0	2.4	5.7
Non-fat milk powder	4.0	0.6	1.4
Water	105.0	15.4	37.6
Sugar, granulated	6.0	0.9	2.1
Cider vinegar	15.0	2.2	5.4
Psyllium husk (NOW!®)	17.0	2.5	6.1
Yeast	5.0	0.7	1.8
Xanthan Gum FNST	17.0	2.5	6.1
sub4salt® N1000	5.5	0.8	2.0
Whole eggs	100.0	14.7	35.8
Total	680	100	243

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