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Effects of Water Addition Level on Physical Properties, Rheological Profile and Sensory Evaluation of Gluten-Free Bread: A Preliminary Approach

(Kesan Tahap Penambahan Air pada Sifat Fizikal, Profil Reologi dan Penilaian Sensori Roti Tanpa Gluten: Suatu Pendekatan Awal)

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ABSTRACT

The amount of water in gluten-free recipes is very important to the quality of the end product. The research aimed to develop an alternative formula for gluten-free bread using different water levels. This research was conducted to determine the physical properties, rheological profile and sensory evaluation of natural gluten-free bread produced by adding different water levels to the recipe without adding hydrocolloid. Five types of bread with different levels of water at (A) 80%; (B) 90%; (C) 100%; (D) and control dough: 105% (control 1); (E) 60% (wheat bread-control 2) of the flour basis were investigated. Control 1 is the standard level of water for making gluten-free bread, while control 2 is the standard level of water for preparing wheat bread. Sample A has a lighter crust and crumbs, as well as a white index value and lower ΔE values comparable to wheat bread, better volume, increased pore size sharply and shows higher G' and G". G' decreased as the amount of water in the dough increased. All dough formulations had higher gelatinisation enthalpy change (ΔH) values than sample A and sample E. The bakery sector could use the findings to design and reformulate the recipes of diabetic and/or reduced calorie and gluten-free bread recipes to better fulfill consumers' expectations.

Keywords: Gluten-free bread; physical properties; rheology; sensory evaluation; water levels

ABSTRAK

Kandungan air dalam resipi bebas gluten adalah sangat penting untuk kualiti produk akhir. Penyelidikan bertujuan untuk membangunkan formula alternatif roti bebas gluten menggunakan tahap air yang berbeza. Penyelidikan ini adalah untuk menentukan kualiti terutama dari segi sifat fizikal dan profil reologi roti bebas gluten semula jadi yang dihasilkan dengan penambahan tahap air yang berbeza daripada komposisi resipi tanpa penambahan hidrokoloid. Lima jenis roti dengan tahap air yang berbeza pada (A) 80%, (B) 90%, (C) 100%, (D) 105% (kawalan 1) dan (E) 60% (tepung gandum-kawalan 2) - daripada asas tepung, telah dikaji. Kawalan 1 ialah paras air piawai untuk menghasilkan roti bebas gluten, manakala kawalan 2 ialah paras air piawai untuk menyediakan roti gandum. Sampel A mempunyai kerak dan serbuk roti yang lebih ringan, serta nilai indeks putih dan nilai ΔE yang lebih rendah setanding dengan roti gandum, isi padu yang lebih baik, saiz liang meningkat secara mendadak dan menunjukkan G' dan G" yang lebih tinggi. G' berkurangan apabila jumlah air dalam doh bertambah. Semua formulasi doh mempunyai nilai perubahan entalpi penggelatinan (ΔH) yang lebih tinggi daripada sampel A dan sampel E. Sektor bakeri boleh menggunakan penemuan ini untuk membentuk dan merumuskan semula resipi roti bebas gluten untuk diabetes dan/atau kalori berkurangan untuk memenuhi jangkaan pengguna dengan lebih baik.

Kata kunci: Paras air; penilaian sensori; reologi; roti bebas gluten; sifat fizikal

INTRODUCTION

Gluten is a complex combination of insoluble proteins that consist of gliadins and glutenins in wheat and approximately equal proteins in barley and rye. Gluten is accountable for the dough's viscoelastic behaviour and chewiness of wheat flour foods (El Khoury, Balfour-Ducharme & Joye 2018). The gluten-free products market has seen remarkable growth led by the rapid rise in the global incidence of gluten-related pathologies, namely wheat allergy, celiac disease, and non-celiac gluten sensitivity (Brouns, van Buul & Shewry 2013; Golley et al. 2014; Reilly 2016; Rosell et al. 2014), coupled with the increasing perception that gluten-free products are correlated with a healthier lifestyle (Brouns, van Buul & Shewry 2013; Fauad, Kaur & Shafie 2020; Golley et al. 2014; Reilly 2016; Rosell et al. 2014).

The gluten-free market is fascinating and recent scientific studies have devoted more and more resources to such products (Fratelli et al. 2018; Khemiri et al. 2020; Ren et al. 2020). While research and development have made tremendous progress and the growth of the gluten-free market, many gluten-free breads on the market are high in terms of prices and lack the sensory properties and nutritional quality of their wheat equivalent (do Nascimento, Fiates & Teixeiraa 2017; do Nascimento et al. 2014; Singh & Whelan 2011). Therefore, gluten-free bread is not entirely accepted by consumers (Mariotti, Pagani & Lucisano 2013).

In previous studies, many researchers have discussed the impact of different additives on the quality of gluten-free bread. The key focus of most previous studies is on enhancing the properties of gluten-free bread with many recipes and technological additives, especially the level of hydrocolloid addition. In bakery products, water content is of critical importance, as mobility and distribution influence dough rheology and baking efficiency (Leung, Magnuson & Bruinsma 1979) and quality (Sahin, Wiertz & Arendt 2020), texture, taste, odour, volume, flavours, and mouthfeel (Chieh 2006). The appropriate level of water addition was stressed to be crucial in gluten-free bread formulation (Haque & Morris 1994; Mccarthy et al. 2005). Currently, there are no studies determining the quality (especially the physical properties and rheological profile) of natural gluten-free bread developed using different water levels from the recipe composition without adding hydrocolloid. Hence, this study is the first to do so.

The objective of this study was to investigate the effects of water addition without adding hydrocolloid on physical properties (colour, morphology and specific volume) and the rheological profile (fundamental rheological measurements and differential scanning calorimetry measurements and sensory evaluation (hedonic test) of gluten-free bread based on brown rice flour, corn starch and tapioca starch. Brown rice flour was used to enhance both the dietary fibre content and the nutritional value of the final product. To achieve this goal, the different levels of water were used at 80%, 90%, 100%, 105% (control 1), and 60% (wheat flour-control 2) of the flour basis.

MATERIALS AND METHODS

MATERIALS

The commercial gluten-free bread was purchased from a local shop (Knney Hills Bakers). The whole grain brown rice flour was purchased from Bob's Red Mill Natural Food, Inc. USA. Other materials were purchased from the local market such as wheat flour, corn starch, tapioca starch, glucose, salt, instant dry yeast, butter, milk powder, lecithin, baking powder, apple cider vinegar and egg (BWY Holding Sdn Bhd. Bangi, Malaysia).

METHODS

BREAD-MAKING

A modified version of a previous gluten-free bread method by Aboukzail, Abdullah and Ghani (2017) was used. Gluten-free bread formulas are prepared as follows: whole grain brown rice flour, corn starch and tapioca starch (150 g) (33.33%: 33.33%: 33.33%), 3 g glucose, 2g salt, 4.5 g instant dry yeast, 7.5 g butter, 15 g powdered milk, 0.8 g lecithin, 3 g of baking powder, 3 g of apple cider vinegar and 5 g of eggs. Water was used at three different levels, from 80-100% of the flour basis. Water was used at three different levels, from 80-100% of the flour basis. Warm water (40 °C) was mixed with glucose and instant dry yeast. The percentage of water of 105% (flour basis) was used as control 1, which is the standard water level for making gluten-free bread (Schober et al. 2005). The percentage of water at 60% (flour basis) was used for preparing wheat bread (control 2) (Mondal & Datta 2008). All wet ingredients were mixed manually (30 s) and mixed with all dry ingredients using a mixer (Milux 2 in 1 stand mixer, model MSM-9901, Malaysia) for 30 s. The warm water (40 °C) with glucose and instant dry yeast was mixed using a mixer for 10 min until all the ingredients were thoroughly combined. The dough was put into conical tin bread forms of 14.5 cm × 8.0 cm × 5.0 cm (length × width × height) and set for proofing for 20 min at 27 °C and baked for 50 min at 200 °C in a bakery oven (Morgan, model MEO-602RC, Malaysia). The loaves were then removed from the conical tin bread container, cooled at room temperature (27 °C) for one hour and wrapped in sealed polyethylene bags in order to avoid dehydration. Two hours after baking, all the bread analyses were conducted. For each sample, three batches were made.

COLOUR OF CRUST AND BREAD CRUMBS

The colour analyses of the crust and bread crumbs were conducted using a chromameter (Konica Minolta, model CR-400, Japan) with a CIELab colour system and were determined according to the previous method (Huerta et al. 2018).

BROWN INDEX (BI)

The brown index (BI) was calculated to determine the colour change in bread crust according to Das, Raychaudhuri and Chakraborty (2012) as follows:

$$BI = 100 \times (\frac{x - 0.31}{0.17}) \quad (1)$$

$$x = \frac{a^* + 1.75L^*}{5.645L^* + a^* - 3.012b^*} \quad (2)$$

WHITE INDEX (WI)

The white index (WI) was calculated to determine the colour change in bread crumb according to Wu, Sung and Yang (2009) as follows:

$$WI = 100 - \sqrt{(100 - L^* + a^* + b^*} \quad (3)$$

THE CHANGES IN COLOUR (ΔE)

Equation (4) measured the changes in colour (ΔE) of the total colour differences (Liu et al. 2010).

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (4)$$

SPECIFIC VOLUME (SV)

The specific volume of the loaves was described by a millet seeds (occupied mass) displacement method, and its volume was measured in a graduated cylindrical. The specific volume ($mL.g^{-1}$) was calculated using Equation (5) (El-Dash, Camargo & Diaz 2006; Pizzinatto, Magno & Campagnolli 1993).

SV(mL/g) =(volume (mL))/(weight (g)) (5)

MORPHOLOGY OF BREAD

Bread samples for scanning electron microscope (SEM) examination were prepared, then frozen (-45 °C) and freeze-dried. The freeze-dried pieces of the bread samples were fractured into sizes of about 1 cm × 1 cm × 0.5 cm (length × width × height). Then, placing the bread samples on aluminium stubs and covering them with gold in a fine coat ion sputter (Polaron, model SC7680, United Kingdom). A SEM (VPSEM, model 1450, United Kingdom) was used to display the SEM image of the samples with a voltage of 15 kV (Bárcenas, Altamirano-Fortoul & Rosell 2010).

FUNDAMENTAL RHEOLOGICAL MEASUREMENTS

The dough was produced under the same conditions as when baking bread but without adding yeast to the mix. It was loaded into a Rheometer (Anton Paar Physica, model MCR301, Malaysia) with a parallel plate of 50 mm and a gap size of 1 mm. The sample was placed in the rheometer at a temperature of 25 °C. After that, the dough was allowed to rest for 5 min to allow residual stresses to be relaxed. The frequency sweep was 0.1-10 HZ, and the strain was 0.1 % (Renzetti & Arendt 2009). The linear viscoelastic region was previously observed with strains ranging from 0.01 to 100 % with a constant frequency of 1 Hz (Leray et al. 2010). The flow behaviour was observed at shear rates ranging from 1-500 1/s. There were fundamental rheological measurements made (steady-shear flow and oscillatory shear [elastic (G') and viscous (G") moduli]). The Cross model was used to determine the relationship between steady-state flow data (apparent viscosity η (Pa s) against shear rate γ (1/s).

DIFFERENTIAL SCANNING CALORIMETRY MEASUREMENTS

In accordance with the method of Sciarini et al. (2012), differential scanning calorimetry (DSC) measurements were carried out using a differential scanning calorimeter (model DSC8223, Switzerland). The dough was produced in order to make bread without the use of yeast. First, 5 mg of dough was weighed, and the dough was then placed in the DSC pan to rise. Then, it was heated from 0-120 °C at a rate of 10 °C min^{-1}. Temperatures of starch gelatinisation [onset temperature (T_o), peak temperature (T_p), endset temperature (T_{end})] and enthalpy changes (ΔH) were all measured in this study.

HEDONIC TEST

The hedonic test was conducted to evaluate the degree that the gluten-free breads were liked overall. The sensory evaluation tests were conducted according to Aminah (2004), where 50 untrained panellists from the

Department of Food Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia were asked to rate two samples based on the degree of liking on a seven-point hedonic scale (1 = dislike extremely, 2 = very dislike, 3 = dislike, 4 = moderately, 5 = like, 6 = very like, 7 = extremely like). The panellists were asked to indicate their level of acceptance in the seven-point hedonic scale questionnaire, comprising appearance, aroma, taste, texture and overall acceptance. The samples were placed on plates and identified with random three-digit numbers. The panellists evaluated the two samples in a testing area and were asked to rinse their mouths with water between samples to avoid any residual effects.

STATISTICAL ANALYSIS

All data were analysed using one-way ANOVA and Duncan's multiple range test (DMRT) in the Statistical Package for the Social Sciences (SPSS) software version 23. The mean ± standard deviation was expressed to describe the significant difference between the samples using the confidence interval of 95%.

RESULTS AND DISCUSSION

Table 1 depicts the colour characteristics for the samples A, B, C, D, and E used in this study. No significant differences ($p > 0.05$) were noted between sample E and sample A in a* crust and BI, so sample A improved the a* value and browning index (BI) of the crust. Crust colour darkening is beneficial as gluten-free bread is typically lighter than wheat bread (Gallagher et al. 2003). The increase in water (80-105%) (Samples A, B, C, and D) significantly affects the colour of the crust and crumbs of gluten-free bread. Samples A, B, C, and D changed from darker to lighter in crust colour but from light to darker in crumb colour. The darkening of the crumb in gluten-free bread is due to increased water content, which is in line with earlier research (Skendi et al. 2018). The water content plays a crucial role in the Maillard reaction and caramelisation that lead to colour development (Sahin, Wiertz & Arendt 2020). The water addition may be due to water distribution (migration of water from crumb to crust) (Kerch, Zicans & Meri 2010) that can affect darkening, the Maillard reaction and caramelisation. It should be noted that the browning reaction decreases at higher water contents and during dilution of raw material contact (Fatemi 2010). The white index of sample A was higher than samples B, C, and D but lower than sample E. All samples had negative a* crumb values, which indicate green colour, and positive b* values, which indicate yellowness (Phimolsiripol, Mukprasirt & Schoenlechner 2012). Hence, sample A made a better bread colour. As a result, sample A has a lighter crust and crumbs, as well as a white index value comparable to wheat bread. The ΔE values of crust samples ranged from 0.45 to 2.13 at various water addition levels. It should be noted that 105% water addition has low ΔE values compared to 60% (control 2) water addition. The L* values increased as water addition increased, indicating increased crust brightness. This suggests that the colour difference was less noticeable at higher water amounts (Karp, Wyrwisz & Kurek 2020). Meanwhile, the ΔE values of crumb samples ranged from 0.55 to 1.84 at various water addition levels, contras from crust samples. Moreover, the 80% water addition gave a good indicator for making gluten-free bread based on brown rice flour, corn starch, and tapioca starch.

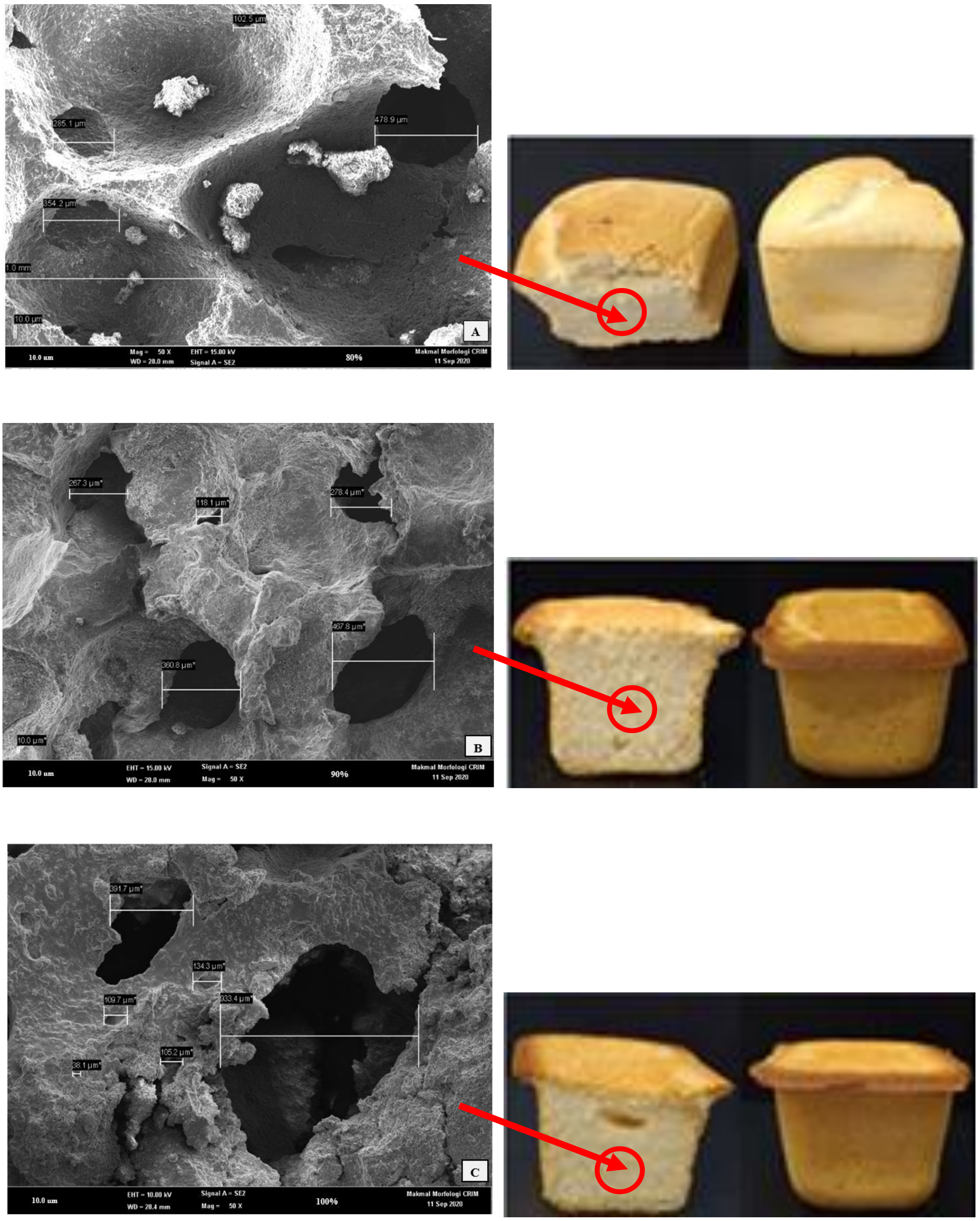
One of the important parameters for bread quality is specific volumes (Ren et al. 2020). As shown in Table 1, gluten-free bread using 80% water level was significantly differences ($P<0.05$) on specific volume which was 4.25 ± 0.15 mL/g compared to gluten-free bread using 90% and 100%, 105% (control 1) water level and wheat flour (control 2) (3.97 ± 0.03 mL/g, 3.26 ± 0.11 mL/g, 1.32 ± 0.02 mL/g and 5.20 ± 0.23 mL/g). In making gluten-free bread, the plasticising effect of the water is important as it helps to expand the dough's properties during mixing (Marco & Rosell 2008). Increase the percentage of water led to an increase in specific volume. Xanthan gum and water have shown significant interactions at specific volumes, and 0.3% xanthan gum and 114.9% water was optimised level that made the excellent quality of gluten-free bread (Schober et al. 2005). Instead, a higher level of water addition contributes to a lower specific volume, as described in this report. The hydrocolloid and water impact on the volume of the loaf can thus be complicated. In comparison, the water absorbability of inputs without adding hydrocolloid to the formulation and water may overdilute in some areas of the dough, leading to reduced stability, less gas trapping and lower loaf volume may be due to different observations in this analysis. A report by Różyło et al. (2015) is also the first time bread from rice flour was found to have had better volume and quality when using lower water levels (80%). In the literature, there is no number of studies determining the quality (especially in the physical properties) of natural gluten-free bread developed using the addition of different water levels from the recipe composition without adding hydrocolloids.

The findings examined suggest a significant dependence on the overall appearance of the gluten-free bread (Figure 1) on the quantity of water applied (as well as on dough efficiency) to the composition of the recipe. Figure 1 shows the morphological properties of gluten-free bread at different water addition levels: (A) 80%; (B) 90%; (C) 100%; (D) 105% (control 1); (E) 60% (wheat bread-control 2) (Magnification-10.0 µm, 50X). The influence of water content on the physical appearance of gluten-free bread is presented in this figure. In general, when too much water was applied (90-105%, flour basis), the bread collapsed due to denser crumbs and more compact cells. The addition of water may reduce pore size, making the crumb structure denser and more difficult to work with due to its harder texture (Amir, Hanida & Syafiq 2013). The results of this study are similar to findings from a previous study (Schoenlechner et al. 2010). The result for sample A increased the pore size sharply. In terms of pore size and bread structure, samples A and E are nearly identical. High water content was anticipated to create large bubbles and reduce firmness, which is well found in typical breads. In dough handling, the water content was also important. The ingredients such as flour quality, water content, additional lipids, enzymes, and emulsifiers are used for the development of an open pore network. The variations in pore size in the structure of starch and protein were linked. An increase in the size of the pores and a decreasing pore number were associated with the degree of leakage of starch-polymers (gelatinisation) (Naito et al. 2005; Salmenkallio-Marttila et al. 2004). Differences in the amount of water in the dough are primarily the cause of the degree of gelatinisation. Increased water and protein (gluten) resulted in softer, less gummy breads with smaller pore sizes (Salmenkallio-Marttila et al. 2004; Schoenlechner et al. 2010). Small pores were related to low dough expansion as well as larger and coarser gluten networks (Schoenlechner et al. 2010). The 80% water addition was the most suitable level of water to formulate gluten-free bread.

Flow behaviour of samples of dough at different water addition levels: (A) 80%; (B) 90%; (C) 100%; (D) and control dough: 105% (control 1); (E) 60% (wheat bread-control 2) were determined by measuring the viscosity shear stress with shear rate. It can be shown in Figure 2 that dough viscosity decreases with increasing shear rate. Due to increasing shear rate, deformed and rearranged starch particles may lead to lower flow resistance, followed by lower viscosity, indicating the shear-thinning behaviour and having a non-Newtonian dough (Moreira et al. 2010). Figure 3 depicts the thixotropic behaviour of all doughs due to the decreasing viscosity of doughs with increasing time. Figures 2 and 3 also show that dough samples with lower water content and control 2 have higher viscosity. This might be related to the release of soluble components and amylose from the dough system, which decreased the amount of free water in the dough system. It is claimed that lower water content is responsible for the increased viscosity (Rohaya, Maskat & Ma'aruf 2013). According to Figure 4, the storage modulus (G') and loss modulus (G") increased with increasing frequency for samples of dough at different water addition levels: (A) 80%; (B) 90%; (C) 100%; (D) and control dough: 105% (control 1); (E) 60% (wheat bread- control 2). In all the cases, the values of the storage modulus were consistently greater than the values of the loss modulus G' > G", demonstrating the predominance of elastic properties over viscous properties and confirming previous findings of the viscoelastic character of starch-based gluten-free dough (Korus et al. 2017; Witczak et al. 2017). All five doughs are solid-like because G' is greater than G", even though their frequency dependence of moduli differs. Sample A shows higher G' and G" than other samples but lower than sample E. G' decreased as the amount of water in the dough increased. This phenomenon is related to the simple dilution of ingredients, and it has been well established for wheat flour doughs (Autio et al. 2001) as well as for gluten-free doughs (Ronda et al. 2013; Witczak et al. 2021). At the deformation rates, gluten-free doughs are more fluid-like than wheat doughs during the proving process (Ren et al. 2020).

Generally, the gelatinization of starch in wheat dough and gluten-free batter relies on the quantity of water provided (Föste et al. 2020). Salmenkallio-Marttila et al. (2004) have described the correlation between the degree of starch gelatinization and the amount of water present. The thermal properties of dough, such as gelatinization behaviour temperature and enthalpy changes, are essential to comprehending baking phenomena. These qualities are dependent on the starch source, moisture content, and amylose/amylopectin ratio (Li, Yeh & Fan 2007). When a higher level of water is added to the dough (Table 3), the onset, peak, end temperature of gelatinization occurs at a higher temperature. This could be explained by the fact that salt and sugar both contribute to an increase in the temperatures at which gelatinization occurs (Hoseney 1998). All dough formulations had higher gelatinisation enthalpy change (ΔH) values than gluten-free dough (80% water addition) and wheat dough. This was because the gluten-free dough had more water (Dalgetty & Baik 2006) (Figure 5). Reduced endotherm peak surfaces can be seen in Figure 6 for all dough types except gluten-free dough made with 105% water. It was hypothesised by Miah et al. (2002) that fast expansion of the starch granules and water uptake by the amorphous background region constitute the earliest stages of gelatinization. After this, the granules' structures become disordered (Aini & Purwiyatno 2010).

Table 2 showed that a statistical difference ($p<0.05$) was observed between the two samples for the acceptability of the attributes of appearance, aroma, taste, texture and overall acceptance. The consumer lowlily accepted commercial gluten-free bread. Gluten-free breads with the addition of 80% water level are preferred by the consumers indicating that water level is important for the quality of gluten-free bakery products. The bakery industry could apply the findings to develop and reformulate the recipes of diabetic and/or reduced calorie and gluten-free breads to better meet consumer requirements.



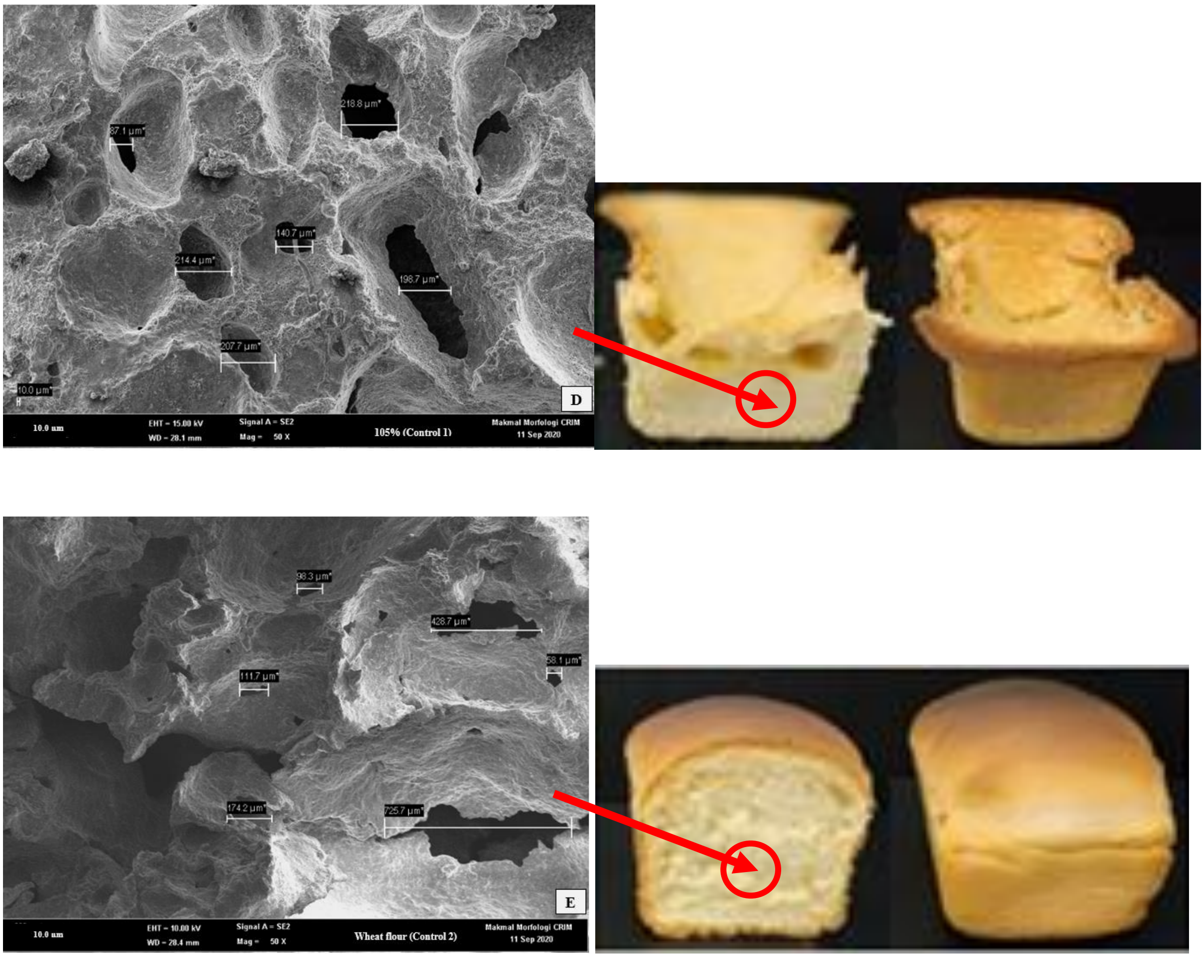


FIGURE 1. Morphological properties of gluten-free bread at different water addition level: (A) 80%, (B) 90%, (C) 100% (D) 105% (control 1) (E) 60% (Wheat bread – control 2) (Magnification -10.0 µm, 50 X)

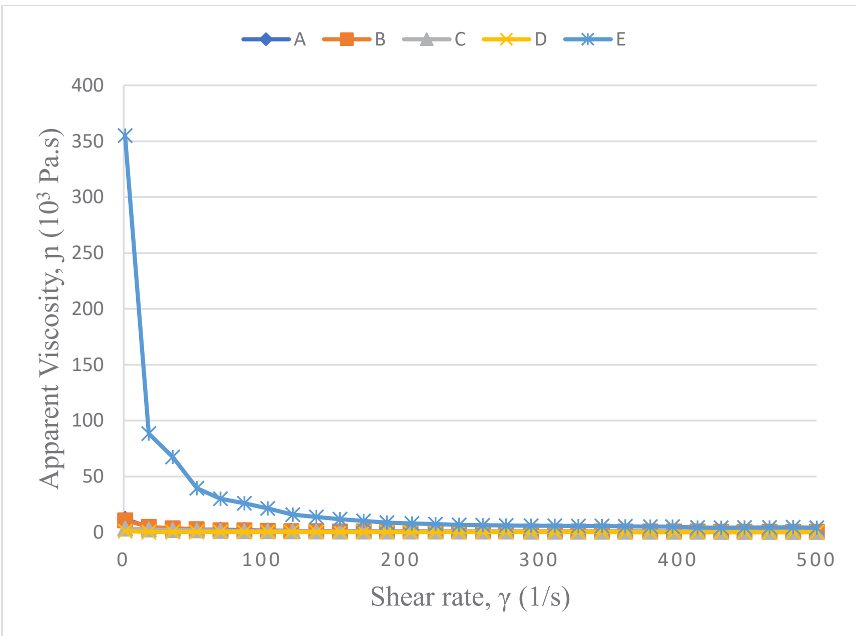


FIGURE 2. Flow behaviour of samples of dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1), (E) 60% (Wheat bread - control 2) by measuring viscosity with shear rate

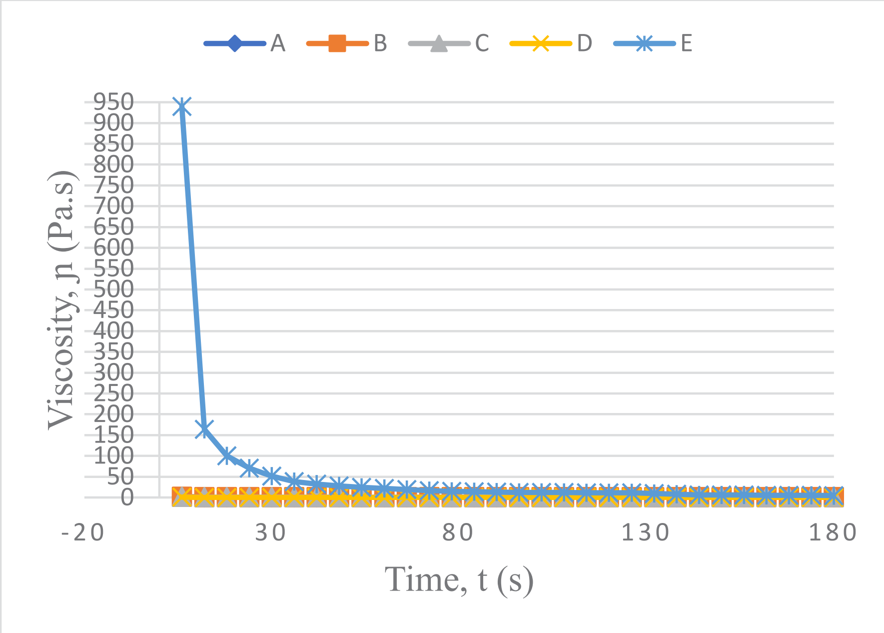


FIGURE 3. Flow behaviour of samples of dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1), (E) 60% (Wheat bread - control 2) by measuring viscosity with time

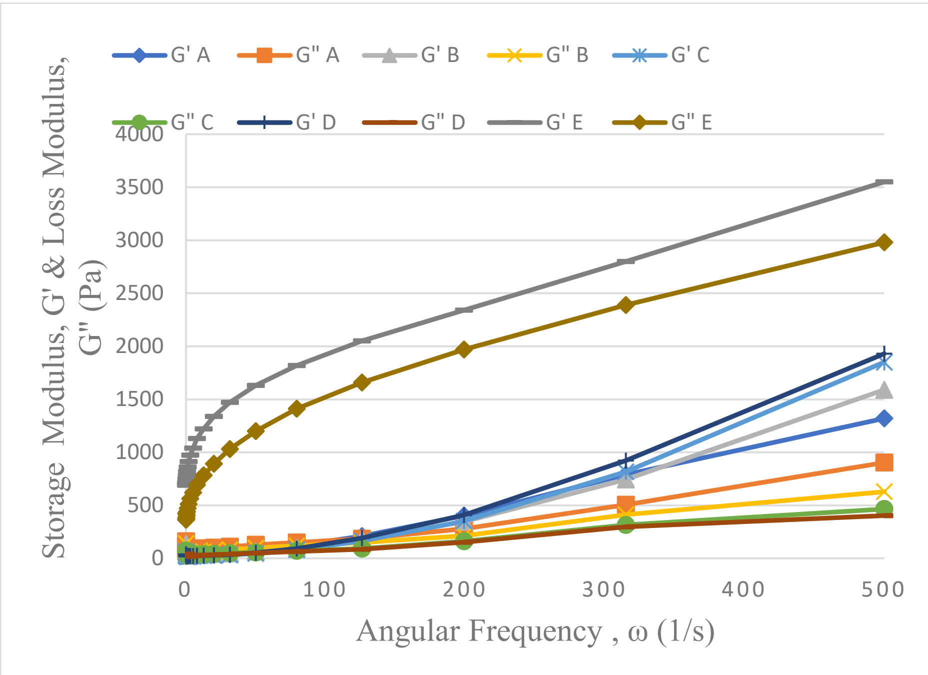


FIGURE 4. Oscillatory shear measurements (G', G") for samples of dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1), (E) 60% (Wheat bread - control 2)

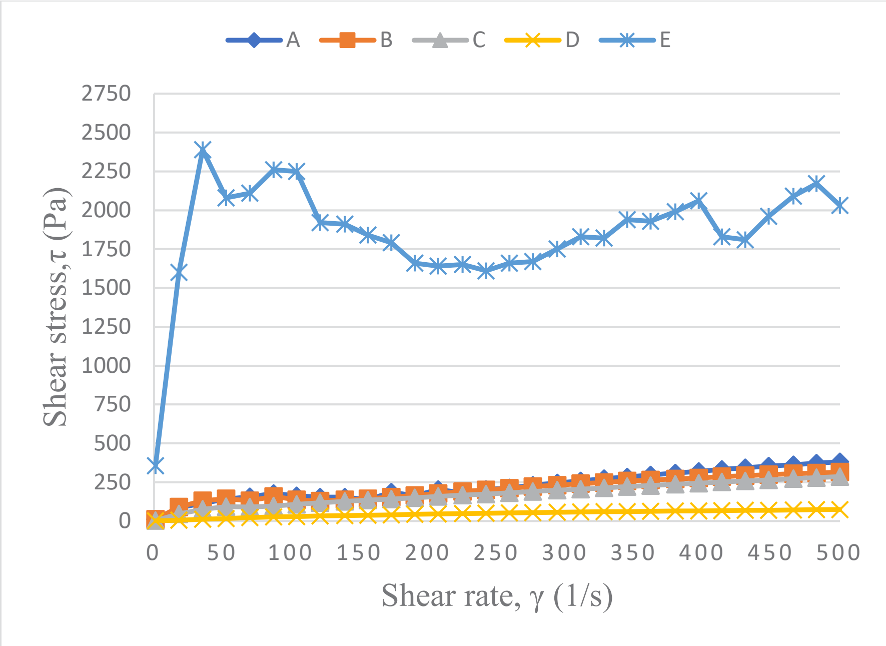


FIGURE 5. Flow curves of samples of dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1), (E) 60% (Wheat bread - control 2)

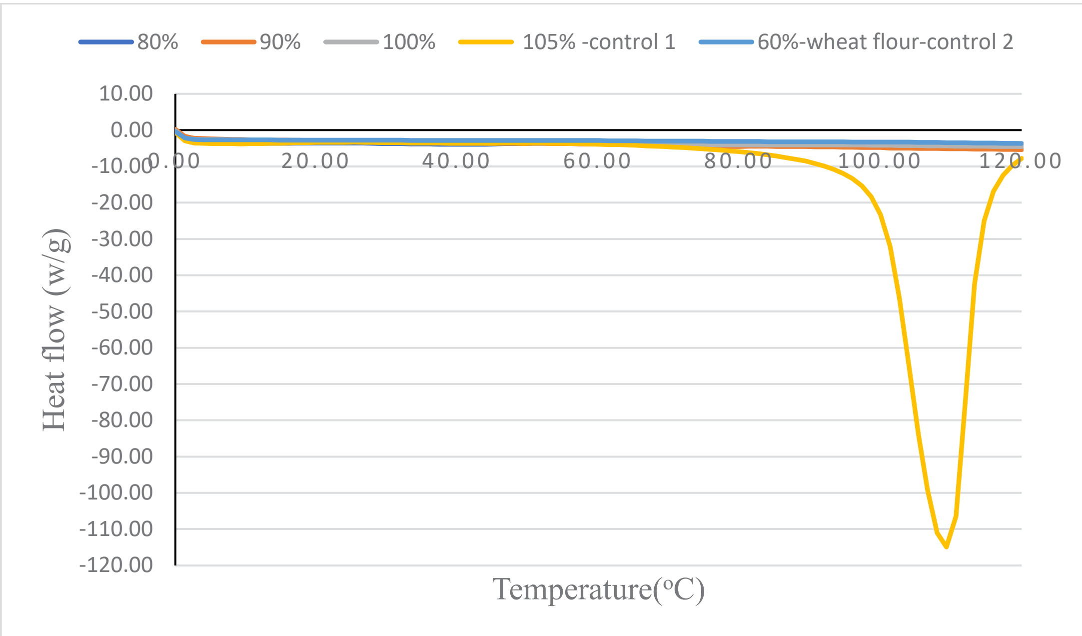


FIGURE 6. Differential calorimetric thermal curves of gluten-free dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1) and wheat dough (E) 60% (Wheat bread - control 2)

TABLE 1. Bread and colour characteristics for water addition level in gluten-free bread compared with the standard level of water for making gluten-free bread (control 1) and wheat bread (control 2)

Sample	Specific volume (mL/g)	L* crust	a* crust	b*crust	BI	ΔE*	L* crumb	a* crumb	b*crumb	WI	ΔE*
A	4.25 ± 0.15^{b}	57.70 ± 2.15^{c}	12.66 ± 0.53^{a}	38.10 ± 0.75^{b}	113.73 ± 6.80^{a}	1.31	73.87 ± 0.75^{b}	-1.80 ± 0.04^{c}	18.57 ± 1.02^{b}	93.45 ± 0.13^{b}	0.57
B	3.97 ± 0.03^{c}	62.42 ± 0.37^{b}	10.36 ± 0.52^{b}	39.68 ± 0.19^{a}	105.88 ± 0.00^{b}	1.20	70.58 ± 0.16^{c}	-2.52 ± 0.05^{b}	18.16 ± 0.23^{b}	93.29 ± 0.03^{c}	0.55
C	3.26 ± 0.11^{d}	62.64 ± 0.09^{b}	7.07 ± 0.19^{c}	37.76 ± 0.22^{b}	94.12 ± 0.00^{c}	0.60	70.18 ± 0.26^{c}	-2.93 ± 0.03^{a}	16.57 ± 0.18^{c}	93.41 ± 0.03^{bc}	1.84
D	1.32 ± 0.02^{e}	66.47 ± 0.62^{a}	3.63 ± 0.25^{d}	27.53 ± 0.70^{d}	54.90 ± 3.39^{d}	0.45	70.30 ± 0.69^{c}	-1.19 ± 0.11^{d}	18.72 ± 0.15^{b}	93.13 ± 0.06^{d}	1.33
E	5.20 ± 0.23^{a}	55.33 ± 1.02^{d}	12.30 ± 0.16^{a}	36.32 ± 0.56^{c}	117.65 ± 0.00^{a}	2.34	78.12 ± 1.00^{a}	-2.62 ± 0.13^{b}	21.00 ± 1.38^{a}	93.66 ± 0.07^{a}	1.03

a-e Means with different letters in the same columns are significantly different ($p<0.05$), (A) 80%, (B) 90%, (C) 100% (D) 105% (control 1) (E) 60% (Wheat bread - control 2)

TABLE 2. Hedonic test score for each sample of gluten-free bread

Sample	F1	F2
Appearance	4.84 ± 0.91^{a}	3.52 ± 1.28^{b}
Aroma	5.06 ± 0.91^{a}	3.60 ± 1.20^{b}
Taste	4.68 ± 1.10^{a}	3.24 ± 1.00^{b}
Texture	4.56 ± 0.97^{a}	2.86 ± 1.11^{b}
Overall Acceptance	4.94 ± 0.84^{a}	3.04 ± 0.99^{b}

a-b Means with different letters in the same rows are significantly different (*p*<0.05), F1: 80 % level of water and F2: commercial products

TABLE 3. Gelatinization parameters of gluten-free dough at different water addition levels: (A) 80%, (B) 90%, (C) 100% (D) and control dough: 105% (control 1) and wheat dough (E) 60% (Wheat bread - control 2)

Sample	T_o (°C)	T_p (°C)	T_e (°C)	ΔH (J/g)
80%	71.46	76.53	81.19	-0.23
90%	71.49	76.17	81.91	-1.30
100%	72.69	76.55	81.52	-1.13
105% -control 1	99.13	104.50	113.13	-1018.39
60%-wheat flour-control 2	63.32	69.89	77.37	-0.24

To- onset temperature; Tp- peak temperature; Te- end temperature; ΔH- gelatinization enthalpy change

Conclusion

The water content in gluten-free bread was found to be a significant factor in its final structure. The best quality score for a gluten-free bread formulation is achieved with the lowest water addition of 80% (sample A). No significant differences ($p > 0.05$) between sample E and sample A were observed for a* values and the BI for crust. Therefore, sample A improved a* values and the BI of crust. The white index of sample A was higher than samples B, C, and D and lower than sample E. Hence, sample A produced a better colour for bread. The result for sample A increased the pore size sharply. In terms of pore size and bread structure, samples A and E are nearly identical, giving quality bread. Dough samples with lower water content and control 2 have higher viscosity. Sample A shows higher G' and G" than other samples but lower than sample E. In conclusion, the lowest amount of 80% water addition was the most suitable level to formulate gluten-free bread. These attributes of the hedonic test can be considered as the preference for gluten-free breads in this context, and bakery manufacturers should consider them when developing new gluten-free products.

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