



Effect of frozen storage and hydrocolloids on structural and rheological properties of frozen roti dough supplemented with rice bran

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Abstract

This study investigated the effect of addition of hydrocolloids (hydroxypropyl methylcellulose: HPMC, and xanthan) and frozen storage on the structure and rheological properties of frozen roti dough supplemented with rice bran. The roti dough was frozen by air blast freezing and stored at -18 °C for 84 days. Changes in the protein structure of the frozen roti dough with HPMC produced greater changes in the gluten network and random coil conformations than that of the xanthan supplemented dough during frozen storage. The resistance to extension and the elastic modulus of the frozen roti dough with HPMC tended to decrease while the extensibility slightly increased with a longer frozen storage time. However, these parameters did not change in the frozen roti dough with xanthan. The freezable water in the frozen roti dough with HPMC and xanthan significantly increased ($p < 0.05$) with increasing frozen storage time from 0 to 84 days.

Keywords: frozen dough; rheological properties; rice bran; frozen storage.

Practical Application: Reduction the damage of gluten network of frozen roti dough with rice bran during storage using hydrocolloid.

1 Introduction

Roti is flat unleavened bread prepared from flour, water, salt, sugar and fat. About 85-90% of the consumption of wheat is in the form of roti in its various forms, such as chapatti, tandoori roti, nan, paratha and poori (Guarda et al., 2004). However, it is well known that roti has a short shelf life so has to be eaten immediately after being cooked since numerous undesirable physicochemical changes, termed *staling*, occur in a relatively short time after it is prepared. In view of this problem, freezing has been used and widely applied. However, freezing and frozen storage may have deleterious effects on the rheological properties and structural behavior of roti dough and finished products. The use of hydrocolloids to minimize the damage to the gluten network caused by freezing and frozen storage has become a common practice in bakery products. The addition of hydrocolloids to frozen dough tends to lower fusion enthalpy, causing a decrease in the freezable water content due to the binding of free water, and also helps to control moisture migration. This results in a reduction of ice crystal formation and a consequent reduction of freeze damage to the gluten network (Sharadanant & Khan, 2003).

There have been many reports published of research on the influence of hydrocolloids on frozen dough (Barcenas et al., 2004; Mandala & Sotirakoglou, 2005; Mandala et al., 2008; Matuda et al., 2008; Meziani et al., 2011). However, there have been no empirical research has been published relating to frozen roti dough supplemented with rice bran. The aim of the

research work reported herein, therefore, was to evaluate the effects of the incorporation of hydrocolloids and frozen storage on the rheological and structural properties of frozen roti dough supplemented with rice bran.

2 Materials and methods

2.1 Materials

Defatted rice bran from Thai Edible Oil Co., Ltd., Bangkok Thailand, was dried in a hot air oven at 60 °C until the moisture content was less than 5%. The other raw materials used were wheat flour, margarine, milk, egg, salt and sugar, which were obtained from a local market in Songkhla, Thailand. The hydrocolloids used in this study were HPMC (Methocel K4M, Dow Chemical, Switzerland) and xanthan (Danisco Cultor, Chile).

2.2 Dough preparation

Roti dough was prepared using two different doughs. The first dough (80 g) consisted of wheat flour, rice bran, margarine, milk, eggs, sugar, salt, water and hydrocolloids (HPMC or xanthan, separately). A control dough was prepared without the addition of hydrocolloids. The second dough (30 g) included only wheat flour and margarine. The two doughs were formed into a round shape and were proved for about 2 hours at 80% relative humidity. After proving, the second dough was covered by the first dough and formed into 2 mm-thick circular sheets

Received 08 Nov., 2020

Accepted 04 Dec., 2020

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with a 140 mm diameter. Roti doughs were analyzed before and after freezing, as described in section 2.4 to 2.7

2.3 Freezing and storage conditions

The surface of each sheet of roti dough was covered with a polyethylene sheet. Then ten pieces of roti dough were stacked vertically on an aluminium tray and frozen in an air-blast freezer at -18 °C. The temperature of the samples was measured by thermocouples connected to a data logger. Freezing was completed when the core temperature of the roti dough reached -18 °C. Each lot of ten pieces of roti dough was then packed in a polyethylene bag and stored at -20 °C for 0, 28, 56 and 84 days. The frozen roti dough sheets were thawed in a microwave oven before being analyzed.

2.4 Microstructure of the roti dough

The microstructure of the fresh and frozen roti dough with and without hydrocolloids at different storage times were analyzed using a scanning electron microscope (SEM) with 1000X magnification.

2.5 Secondary gluten structure

The secondary structure of the gluten network of the fresh and frozen roti dough with and without hydrocolloids after different storage times was investigated using Fourier transform infrared (FT-IR) spectroscopy. The protocol used in this study was that previously described by Meziani et al. (2011). The amide III band (1200-1350 cm⁻¹) deconvolution produced various peaks and frequencies corresponding to: α -helix (1330-1295 cm⁻¹), β -turn (1295-1270 cm⁻¹), random coil (1270-1250 cm⁻¹) and β -sheet (1250-1220 cm⁻¹) (Cai & Singh, 1999).

2.6 Viscoelastic properties of the roti dough

The creep and creep recovery of the fresh and frozen roti dough with and without hydrocolloids at different storage times were carried out at a constant stress ($\sigma = 100$ Pa) for 100 s, then strain (γ) recovery for 400 s after the removal of the stress. The creep data was represented by the creep compliance parameter, $J(t)$ (Pa⁻¹) = γ/σ . The compliance curve data of the roti doughs were analysed based on Burgers model (Dolz et al., 2008) calculated according to the following Equation 1.

$$J(t) = \frac{1}{G_0} + \frac{1}{G_1} \left[1 - \exp\left(-\frac{tG_1}{\eta_1}\right) \right] + \frac{t}{\eta_0} \quad (1)$$

where $J(t)$ (Pa⁻¹) describes the overall compliance at any time, G_0 (Pa) is the instantaneous elastic modulus, G_1 (Pa) is the retarded elastic modulus, η_0 (Pa.s) represents the retarded viscosity and η_1 (Pa.s) is the terminal viscosity.

2.7 Freezable water

The freezable water contents of the fresh and frozen roti dough with and without hydrocolloids at different storage times were analyzed using differential scanning calorimetry

(DSC) applying the method described by Leray et al. (2010). The ice melting enthalpy (ΔH) was obtained by integrating the ice melting peak located at 0 °C on the thermogram. The percentage of freezable water was calculated by dividing the ice melting enthalpy (J/g product) by the latent heat of ice fusion ($L = 333$ J/g) and multiplying by 100.

2.8 Statistical analysis

All the samples were compared using a complete randomize design (CRD). Analysis of variance (ANOVA) was performed and comparisons of means were carried out using Duncan's multiple range test (DMRT) with differences considered to be significant where $p < 0.05$.

3 Results and discussion

3.1 Microstructure of the roti dough

The microstructure of the roti doughs with and without hydrocolloids was investigated by SEM at a magnification of 1000X (Figure 1). The microstructure of the fresh roti dough without hydrocolloids (Figure 1a) and roti dough with HPMC (Figure 1d) and with xanthan (Figure 1g) showed the continuous matrices of the gluten networks, in which the starch granules were embedded. Both the roti dough with HPMC and that with xanthan had more filaments than the dough without hydrocolloids. This result agrees with previous studies that described fresh dough as a continuous matrix with scattered starch granules (Blaszczak et al., 2004; Chaisawang & Suphantharika, 2006; Parimala & Sudha, 2012; Rojas et al., 2000; Smitha et al., 2008).

The microstructure of the frozen roti dough without hydrocolloids was observed to be quite damaged after frozen storage (Figure 1b and Figure 1c). The damage increased after frozen storage for 84 days with the gluten strands being more porous, discontinuous and thinner than those of the frozen roti dough after 56 days storage, which could be attributed to the damage to the gluten matrix by ice crystals increasing during storage (Baier-Schenk et al., 2005; Zounis et al., 2002). This result is agreement with that of Yi & Kerr (2009) who described the dough structure after storage at -20 °C for 90 days as being less uniform and with thinner strands. In addition, Ribotta et al. (2005) reported that frozen dough was damaged after 60 days storage at -18 °C.

In contrast, in the present study, the microstructure of the frozen roti dough with HPMC (Figure 1e) and with xanthan (Figure 1h) did not change during frozen storage of up to 56 days, showing the same structure as that of the gluten matrix of fresh dough. However, increasing the storage time to 84 days resulted in the gluten network of the frozen dough with HPMC showing thinner strands. However, its gluten network was thicker than that of the frozen roti dough without hydrocolloids after storage for 84 days. These results are posited to be due to the hydroxyl groups in the hydrocolloid structure, which permit more water interactions through hydrogen bonding and thus contribute to binding the water in the frozen dough, and thus reduce water migration in the dough during frozen storage (Guarda et al., 2004; Sharadanant & Khan, 2003; Rosell et al., 2001).

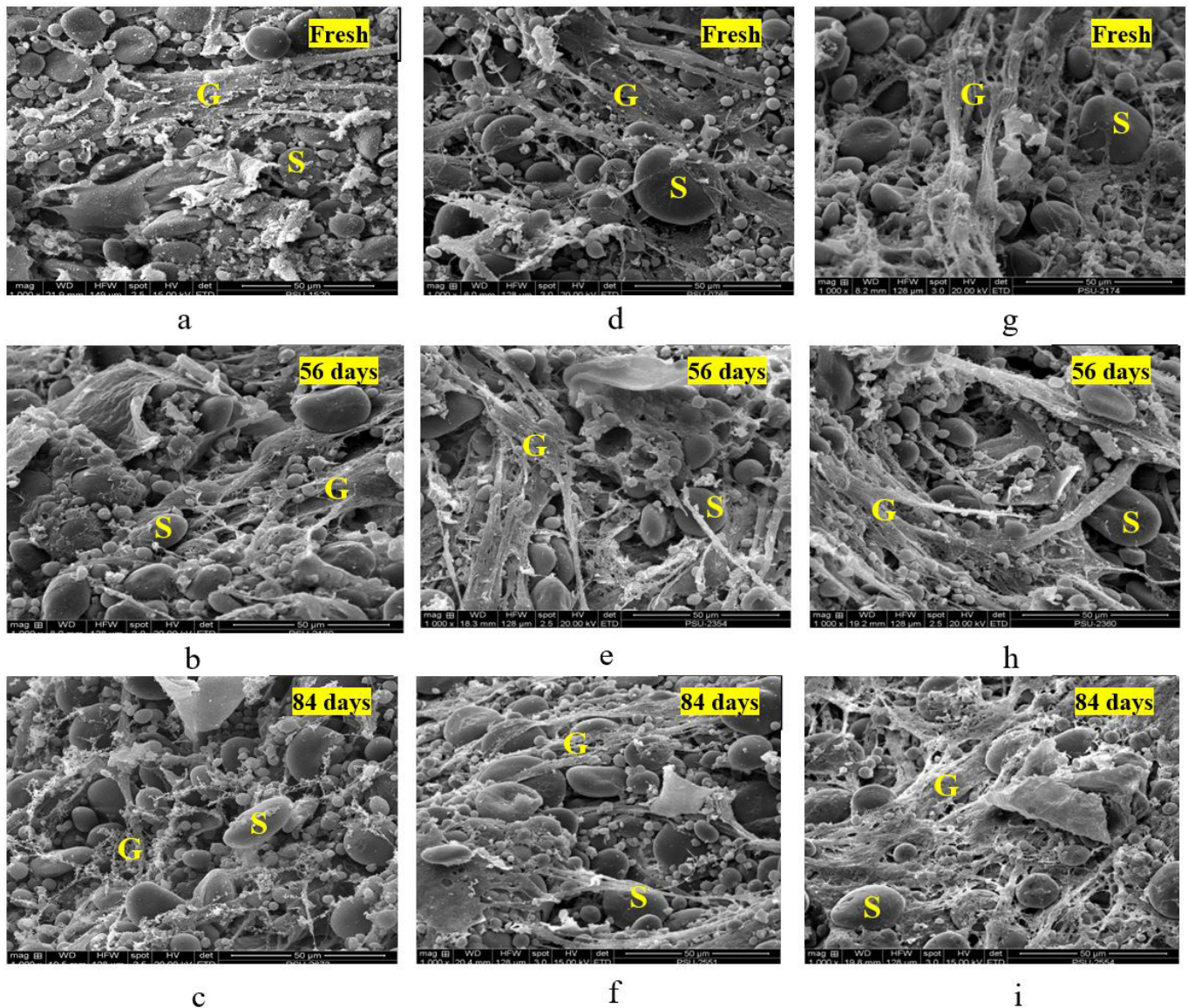


Figure 1. Scanning Electron Micrograph (SEM) at 1000X of fresh and frozen roti dough without hydrocolloids (a-c), with 0.75% HPMC (d-f) and with 0.75% xanthan (g-i). Roti doughs were frozen and frozen storage at $-18\text{ }^{\circ}\text{C}$ for 56 and 84 days. G and S stand for gluten network and starch granule, respectively.

3.2 Secondary gluten structure

Figure 2 shows the highest peak at the range of $1250\text{--}1220\text{ cm}^{-1}$ indicating that the secondary structure of the gluten was subject to β -sheet conformation (Table 1). This result agrees with that of Meziani et al. (2011) who reported that gluten proteins mainly contained around 70% β -sheet conformation. The β -sheet and β -turn conformations in the fresh roti dough with hydrocolloids significantly increased ($p < 0.05$) while there were decreases in the α -helix and random coil conformations compared with the control dough without hydrocolloids (Table 1). This was due to the hydrocolloids consisting of hydrophilic molecules with a high molecular weight, which would be expected to interfere in gluten development, leading to a change in the protein structure (Linlaud et al., 2011). This agrees with the finding of Linlaud et al. (2011) that the addition of xanthan led to a decrease in α -helix, indicating a more disordered and labile

network, while there was an increased proportion of β -turn and β -sheet conformations. In addition, Correa et al. (2014) found a higher contribution of less ordered structures, which was able to accelerate protein interaction. In addition, the results suggested that the roti dough with xanthan had higher β -sheet conformation than that of the dough with HPMC, because of the stronger interaction between the anionic functional group (COO^-) of xanthan and the cation functional group of the flour proteins. This affects the dough development and results in a higher level of β -sheet conformation. Moreover, Belton et al. (1995) suggested that β -sheet conformation is associated with the higher chain mobility created by the increased hydration of glutenin. As protein is hydrated, protein-protein bonds are replaced by protein-water interactions and this permits greater movement of sections in the polypeptide chain, thus forming β -sheet structures.

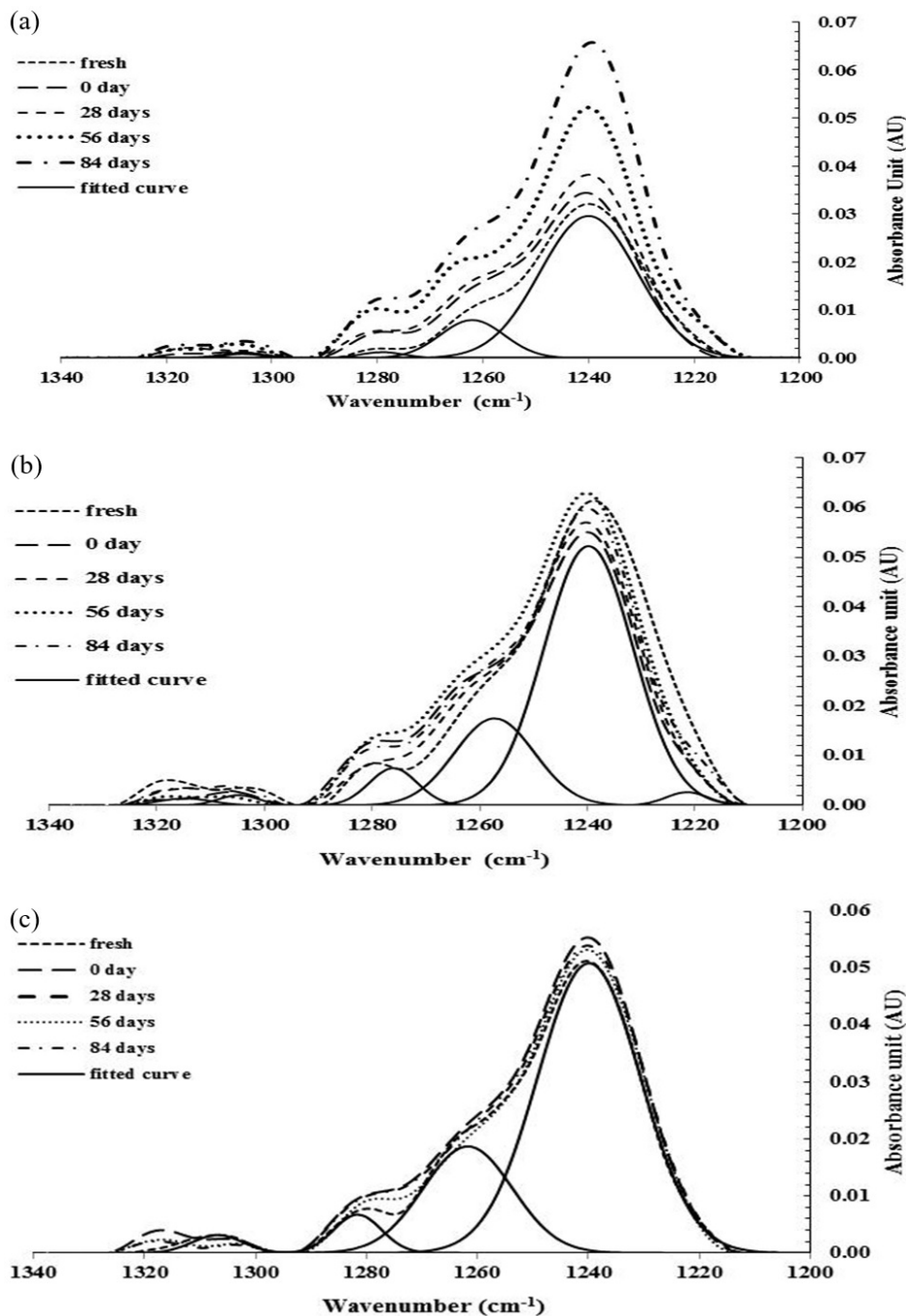


Figure 2. Absorbance Fourier transform infrared spectroscopy (FTIR) spectrum of the 1200-1350 cm⁻¹ region (amide III band) of fresh and frozen roti dough without hydrocolloids (a) with 0.75% HPMC (b) and with 0.75% xanthan (c) during frozen storage time at -18 °C for 28, 56 and 84 days.

The band intensity of the frozen roti dough without hydrocolloids is shown in Figure 2a. The results showed that the β -sheet conformation significantly increased ($p < 0.05$) while the random coil and α -helix conformations significantly decreased ($p < 0.05$) during frozen storage (Table 1). This was probably because during freezing, water diffuses and migrates to form ice crystals which disturb the organized hydrogen bonding system that stabilizes the protein structure. Therefore, hydrophobic and hydrophilic regions of the proteins are exposed to a new environment and new intermolecular cross-links can arise within the protein molecules or between neighboring

molecules (Sharadanant & Khan, 2003). This result agrees with that of Meziani et al. (2011), who described the β -sheet fraction as being sensitive to freezing and frozen storage with the β -sheet conformations being increased during the first four weeks of storage. However, the conformational structure of the frozen roti dough with both of the hydrocolloids did not alter during frozen storage (Figure 2b and Figure 2c). This result is most likely due to the hydrophilic character of the hydrocolloids which alters the degree of water absorption when added to dough (Linlaud et al., 2011), leading to a reduction in the level of freezable water in the dough, and also less changes in the

Table 1. Conformational changes in the secondary structures of amide III band of fresh and frozen roti dough (FD) with and without hydrocolloids during frozen storage at -18 °C or 28, 56 and 84 days.

Treatment/Storage time (day)	Secondary structure (%)			
	α -helix	β -turn	random coil	β -sheet
1. No hydrocolloids				
fresh dough	4.61 \pm 0.40 c	3.54 \pm 0.17abc	25.60 \pm 0.26 h	65.89 \pm 0.50a
FD 0 day	4.01 \pm 0.38bc	3.33 \pm 0.38ab	22.21 \pm 0.27fg	67.31 \pm 0.25b
FD 28 days	3.58 \pm 0.55ab	3.28 \pm 0.56 a	21.81 \pm 0.56efg	68.21 \pm 0.89b
FD 56 days	3.20 \pm 0.15 a	3.27 \pm 0.17 a	19.78 \pm 0.78bc	71.18 \pm 0.81cd
FD 84 days	3.12 \pm 0.48 a	3.26 \pm 0.14 a	18.41 \pm 0.98a	72.56 \pm 0.35ef
2. HPMC				
fresh dough	4.53 \pm 0.35 c	3.92 \pm 0.08cde	20.56 \pm 0.70cd	72.06 \pm 0.65cde
FD 0 day	4.47 \pm 0.31 c	3.87 \pm 0.25bcde	20.54 \pm 0.39cd	71.78 \pm 0.54cde
FD 28 days	4.45 \pm 0.04 c	3.79 \pm 0.69abcd	21.83 \pm 0.38efg	72.50 \pm 0.70ef
FD 56 days	4.28 \pm 0.30 c	3.80 \pm 0.45abcd	21.07 \pm 0.56de	72.15 \pm 0.54de
FD 84 days	4.38 \pm 0.07 c	4.12 \pm 0.10cde	21.49 \pm 0.63def	70.99 \pm 0.73c
3. Xanthan				
fresh dough	3.28 \pm 0.61 a	4.42 \pm 0.13 e	20.64 \pm 0.54 cd	74.06 \pm 0.46gh
FD 0 day	3.14 \pm 0.12 a	4.22 \pm 0.25 de	19.82 \pm 0.65bc	73.43 \pm 0.78fg
FD 28 days	3.12 \pm 0.12 a	4.33 \pm 0.40 de	19.41 \pm 0.28 b	73.91 \pm 0.30gh
FD 56 days	3.26 \pm 0.06 a	4.39 \pm 0.14 de	19.95 \pm 0.45 g	74.83 \pm 0.15h
FD 84 days	3.24 \pm 0.24 a	4.27 \pm 0.32 de	19.57 \pm 0.57defg	73.95 \pm 0.66gh

Each value is mean of triplicate \pm SD. The different superscript letter under the same column are significantly different ($p < 0.05$).

gluten matrix due to formation of ice crystals during freezing and frozen storage. In addition, The frozen roti dough with xanthan was found to experience less changes in the random coil conformation during frozen storage than that in the frozen roti dough with HPMC, probably because of the stronger interaction between this hydrocolloid and the flour proteins (Rosell et al., 2001; Mandala et al., 2008).

3.3 Viscoelastic properties

The creep compliance curve of the roti dough with and without hydrocolloids exhibited a typical combination of elastic and viscous components (Figure 3), which was able to be fitted to a 4-element Burgers model. This curve was similar to that derived in previous studies of wheat dough (Lazaridou et al., 2007; Rouille et al., 2005; Wang & Sun, 2002). The fresh roti dough with hydrocolloids had lower instantaneous elastic modulus (G_0), retarded elastic modulus (G_1), retarded viscosity (η_1) and terminal viscosity (η_N) than those of the fresh dough without hydrocolloids as showed in Table 2. This result agrees with that of Rosell & Foegeding (2007) who found decreased storage modulus (G') with the addition of hydrocolloids to bread. The decrease in G_0 and G_1 indicates a decrease in elastic properties and the lower η_1 and η_N indicate a lower resistance to flow (Mandala, 2005). The fresh roti dough with xanthan had higher G_0 and G_1 than the roti dough with HPMC and this agrees with the results of previous studies, that G' , which indicates the strength of the dough, decreased with the addition of HPMC (Cai & Singh, 1999; Lorenzo et al., 2009; Mandala, 2005; Rosell et al., 2001). Further, Lorenzo et al. (2009) found that dough formulated with xanthan and guar gum had the highest G' values, while the lowest values were found in HPMC dough. This effect has been attributed to the hydroxyl groups in the HPMC structure

which allow more water interactions through hydrogen bonding (Rosell et al., 2001).

The G_0 and G_1 of the frozen roti dough without hydrocolloids (Table 2) significantly decreased ($p < 0.05$) during frozen storage, which indicates a decrease in the elastic properties and lower recoverability of the dough due to ice crystal formation during frozen storage. This agrees with previous studies, which found that the G' of dough decreased during frozen storage (Angioloni et al., 2008; Ribotta et al., 2004) and in this study, the G' of the roti dough with both HPMC and xanthan did not change during 84 days frozen storage due to the strong interaction between the hydrocolloids and protein previously mentioned.

3.4 Freezable water

The amount of freezable water in the fresh and frozen roti dough was investigated by DSC as shown in Table 3. The ΔH value, calculated as the area under the peak of the freezing endotherm and representing the energy change that occurred during the melting of ice in the frozen dough, was taken as an indicator of the amount of freezable water present in the dough. The ΔH , and thus, the freezable water in the fresh dough without hydrocolloids was higher than that of the roti dough with hydrocolloids. This result agrees with that of Sharadanant & Khan (2003), who found that the addition of different hydrocolloids to dough caused significantly decreased ($p < 0.05$) freezable water, probably due to the hydroxyl groups in the hydrocolloid structure allowing more water interaction (Guarda et al., 2004; Rosell et al., 2001), leading to more water absorption. In this study, the roti dough with HPMC had a lower ΔH and thus, freezable water than that of the roti dough with xanthan. This is probably due to the substitution of the hydroxyl groups of the cellulose by the hydroxyl, methoxyl and hydroxypropyl group of

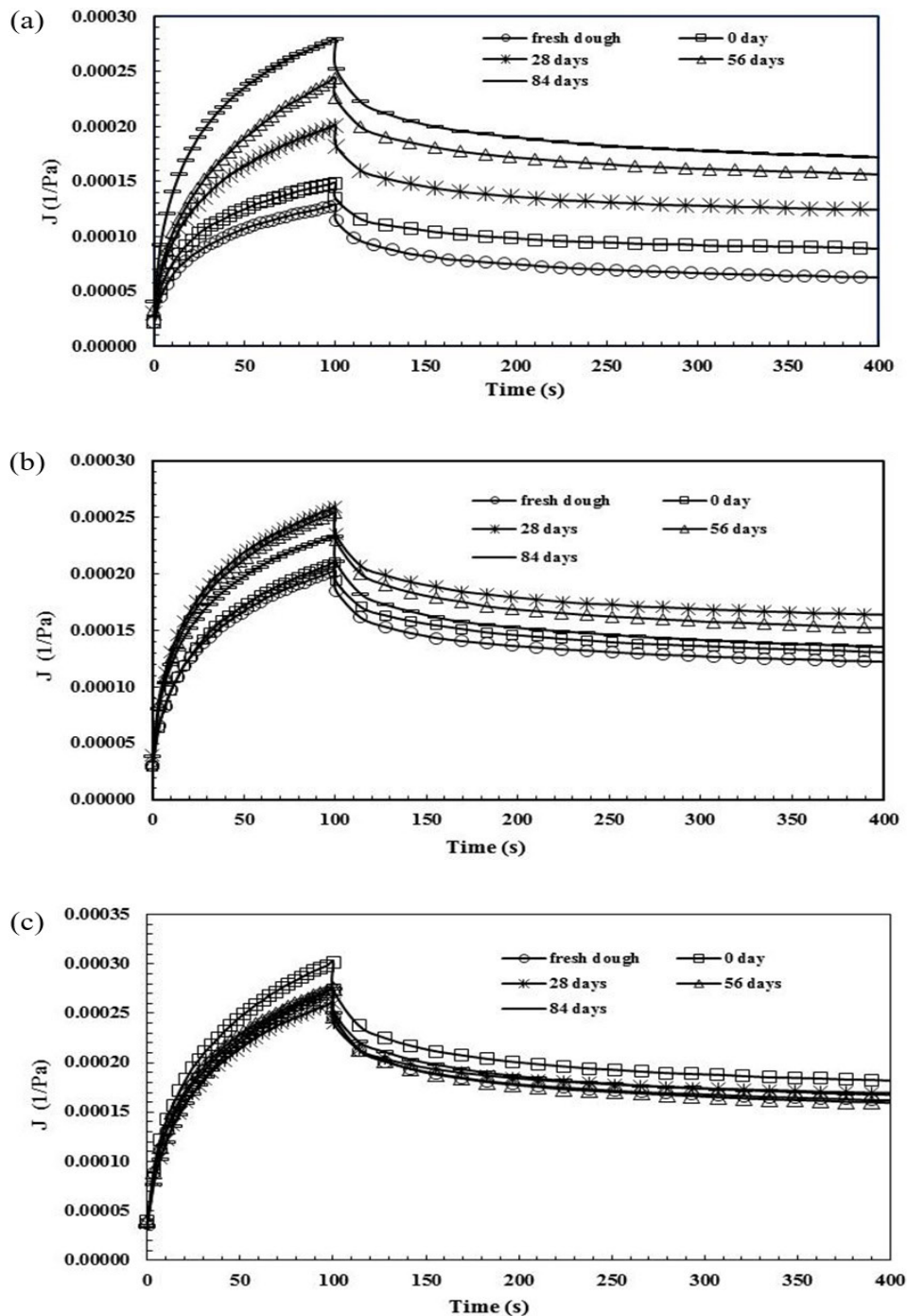


Figure 3. Creep compliance and creep recovery of fresh and frozen roti dough without hydrocolloids (a), 0.75% HPMC (b) and 0.75% xanthan (c) during frozen storage at $-18\text{ }^{\circ}\text{C}$ for 28, 56 and 84 days. All samples were measured at $25\text{ }^{\circ}\text{C}$ and strain at 100 Pa.

the HPMC which increased the water absorption in the HPMC-supplemented dough (Barcenas et al., 2004). Sharadanant & Khan (2003) reported that decreasing freezable water led to reduced ice crystals in the dough, consequently improving the frozen dough quality.

The frozen roti dough without hydrocolloids showed a significantly increased ΔH ($p < 0.05$) with longer frozen storage time. The freezable water in the frozen roti dough without hydrocolloids increased from 42.79 to 74.11% with

increased frozen storage time from 0 to 84 days, the difference being significant at $p < 0.05$, and this result agrees with those of previous studies (Sharadanant, & Khan, 2003; Matuda et al., 2008). Increasing freezable water causes deterioration in the gluten network as a result of ice crystals forming during freezing, with recrystallization of the ice crystals during frozen storage inducing the separation of water from the other components of the dough (Sharadanant & Khan, 2003). The ΔH and freezable water of the frozen roti dough with HPMC and xanthan both

Table 2. Creep parameter of fresh and frozen roti dough (FD) with and without hydrocolloids during frozen storage at -18 °C for 28, 56 and 84 days.

Storage time (days)	Ideal elastic		Viscoelastic		Viscosity
	G_0 (Pa) x 10 ⁴	G_1 (Pa)x10 ⁴	η_1 (Pa.s)x10 ⁵	τ_1 (Sec)	η_N (Pa.s) x 10 ⁶
1. No hydrocolloids					
Fresh dough	4.68 ± 0.09 c	1.50 ± 0.04 e	3.65 ± 0.30 e	23.82 ± 0.57 e	3.16 ± 0.18 d
FD 0 day	4.27 ± 0.77 c	1.39 ± 0.15 e	3.26 ± 0.42 e	23.33 ± 0.26 de	3.26 ± 0.20 d
FD 28 days	3.13 ± 0.02 b	0.82 ± 0.07bcd	1.91 ± 0.14cde	23.17 ± 0.28 de	2.62 ± 0.25bc
FD 56 days	2.85 ± 0.22 b	0.74 ± 0.16bd	1.60 ± 0.26bcd	21.76 ± 1.10abc	2.26 ± 0.30 b
FD 84 days	2.30 ± 0.15 a	0.50 ± 0.09 a	1.10 ± 0.15 a	20.94 ± 0.74 a	1.75 ± 0.27 a
2. HPMC					
Fresh dough	2.92 ± 0.28 b	0.88 ± 0.14 cd	1.97 ± 0.30 de	22.39 ± 0.45bcd	2.46 ± 0.13bc
FD 0 day	2.80 ± 0.18ab	0.81 ± 0.10bc	1.80 ± 0.30bcd	22.19 ± 0.83bcd	2.39 ± 0.18bc
FD 28 days	2.74 ± 0.20ab	0.72 ± 0.04bc	1.60 ± 0.13bcd	22.16 ± 0.72abcd	2.32 ± 0.24bc
FD 56 days	2.77 ± 0.12ab	0.64 ± 0.08 b	1.44 ± 0.16 b	21.71 ± 0.14abc	2.22 ± 0.14 b
FD 84 days	2.82 ± 0.22 b	0.69 ± 0.04 b	1.49 ± 0.08bc	21.62 ± 0.87abc	2.28 ± 0.03bc
3. Xanthan					
Fresh dough	3.13 ± 0.23 b	0.99 ± 0.13 d	2.25 ± 0.26 e	22.73 ± 0.34cde	2.80 ± 0.55 cd
FD 0 day	3.12 ± 0.29 b	0.77 ± 0.13bc	1.71 ± 0.31bcd	22.34 ± 0.43bcd	2.54 ± 0.31bc
FD 28 days	2.92 ± 0.30 b	0.70 ± 0.03bc	1.85 ± 0.29bcde	21.41 ± 0.87ab	2.55 ± 0.31bc
FD 56 days	2.79 ± 0.04ab	0.67 ± 0.06 b	1.48 ± 0.10bc	22.23 ± 0.43bcd	2.37 ± 0.36bc
FD 84 days	3.01 ± 0.08 b	0.70 ± 0.66 b	1.58 ± 0.16bcd	22.67 ± 0.70bcde	2.52 ± 0.21bc

Each value is mean of triplicate ± SD. The different superscript letters under the same column are significantly different ($p < 0.05$).

Table 3. Enthalpy of ice melting (ΔH) and freezable water of fresh and frozen roti dough with air blast freezing during frozen storage at -18 °C.

Storage time (days)	Enthalpy (ΔH , J/g)	Freezable water (% of total water)
1. No hydrocolloids		
fresh dough	43.22 ± 0.61 ^d	37.67 ± 0.53 ^c
FD 0 days	48.29 ± 0.63 ^f	42.79 ± 0.56 ^f
FD 28 days	51.69 ± 0.42 ^{gh}	45.80 ± 0.37 ^h
FD 84 days	83.64 ± 0.87 ⁱ	74.11 ± 0.77 ⁱ
2. HPMC		
fresh dough	36.67 ± 0.59 ^a	33.13 ± 0.53 ^a
FD 0 days	38.21 ± 0.77 ^b	34.52 ± 0.70 ^b
FD 28 days	43.81 ± 0.35 ^d	39.58 ± 0.32 ^d
FD 84 days	52.44 ± 0.42 ^h	47.37 ± 0.38 ⁱ
3. Xanthan		
fresh dough	41.73 ± 0.87 ^c	36.98 ± 0.77 ^c
FD 0 days	44.07 ± 0.68 ^d	39.05 ± 0.61 ^d
FD 28 days	47.10 ± 0.30 ^e	41.73 ± 0.26 ^e
FD 84 days	51.28 ± 0.83 ^g	44.70 ± 0.72 ^g

Each value is mean of triplicate ± SD. The different superscript letters under the same column are significantly different ($p < 0.05$).

significantly increased ($p < 0.05$) with increasing frozen storage from 0 to 84 days. However, the freezable water in the frozen roti dough with hydrocolloids showed less change than that experienced by the roti dough without hydrocolloids. This result could be due to the strong interaction between the hydrocolloids and protein previously mentioned. Moreover, the freezable water in the frozen roti dough with HPMC showed a greater increase than that in the xanthan-supplemented dough during frozen storage. This probably due to the greater ability of xanthan to bind freezable water and thus, reduce ice crystal formation, which was also evident from the decrease resistance-to-extension values.

4 Conclusion

Increasing the storage time of frozen roti dough supplemented with rice bran leads to a decrease in its quality by changing the protein structure (β -sheet and random coil) and increasing the freezable water content. Furthermore, a decreased resistance to extension and instantaneous elastic modulus but increased extensibility indicates a decrease in the elastic properties of the frozen roti dough as well as lower recoverability after storage. However, the quality of the frozen roti dough was improved by adding 0.75% of the hydrocolloids HPMC or xanthan, with the best improvement in overall quality being produced by the addition of xanthan. The frozen roti dough made with these hydrocolloids had a stable structure and rheological properties after frozen storage.

Acknowledgements

The authors would like to express their sincere thanks to Prince of Songkla University for supporting the Government Budget fund (AGR540066M).

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