International Food Research Journal 20(4): 1529-1535 (2013)

Journal homepage: http://www.ifrj.upm.edu.my

Effects of maltodextrin and trehalose on the physical properties of Chinese steamed bread made from frozen doughs

Sze-Yin, S. and *Lai-Hoong, C.

School of Industrial Technology, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia

Article history

Received: 21 June 2012
Received in revised form: 19 February 2013
Accepted:24 February 2013

Keywords

Trehalose
maltodextrin
frozen dough
Chinese steamed bread
dough elasticity

Abstract

The objective of this work was to study the effects of trehalose and maltodextrin on Chinese steamed bread (CSB) prepared from frozen dough. Trehalose (0.1 and 0.2% w/w) and maltodextrin (1 and 2% w/w) were added and CSB prepared from the fresh dough and the frozen dough was characterized in terms of spread ratio, specific volume, staling index and stress relaxation properties. Upon frozen storage, spread ratio and specific volume of CSB, and elasticity of the bread crumb were reduced. The extend of deterioration was significantly reduced with the addition of 0.1% trehalose and 2% maltodextrin. Excessive addition of trehalose and maltodextrin was found to cause detrimental effects to CSB quality.

Introduction

For the last two decades, Chinese steamed bread (CSB) has become popular and well accepted worldwide. The current market trend of CSB is inclining towards convenient preparation and nutritious products. According to Asghar et al. (2009) and Keeratipibul *et al.* (2010), shelf- life of fresh bread is relatively short due to an increase in bread crumb firmness upon staling. In addition, loss of aroma or flavour also account for a short shelf-life in CSB (Giannou *et al*., 2003). To cater for a sustainable supply of premium quality steamed bread products, frozen dough may serve as an alternative remedy that allows fresh steamed bread to be prepared on order (Asghar *et al*., 2009). The concept of frozen dough has become commonplace because it saves space, equipment and labour costs, production of dough can be centralized and frozen dough be distributed easily. This not only helps to control product quality but also enable the supply of the products to a broader retail network (Kenny *et al*., 1999; Yi *et al*., 2009).

Nevertheless, there are several shortcomings shown in frozen dough such as inconsistent dough performance, longer proofing time, lower specific volume as well as undesired bread crumb texture, when compared to products made of freshly prepared dough (Kenny *et al*., 1999; Dodic *et al*., 2007). Quality deterioration of frozen wheat dough has been ascribed to the gradual loss of dough strength due to the release of reducing substances from dead yeast cells, and to the mechanical action of ice crystals. In addition, decreased number of viable yeast cells also caused decline in gassing power (Lu and Grant 1999; Ribotta *et al*., 2004; Baier-Schenk *et al*., 2005).

Yeast is needed in dough leavening to generate adequate carbon dioxide as well as to obtain a fine aerated structure of bread. Destruction of yeast cells caused a reduction in gas production and hence affected quality of the final bakery products (Kenny *et al*., 1999; Newberry *et al*., 2002). Prolonged frozen storage and freeze-thaw cycles always results in damage to yeast cells owing to the intracellular ice crystals formation and dehydration that occurred during frozen storage. In this case, cryoprotectants are able to lessen the formation of ice crystals by causing the excretion of water out of the cell (Momose *et al.*, 2010). Study of Giannou and Tzia (2008) reported that cryoprotectant such as trehalose is able to enhance the performance of frozen dough and improve the specific volume and texture characteristics of bread prepared (Giannou and Tzia, 2008).

Trehalose, a non-reducing disaccharide, is formed from two glucose units bonded via an α,α-1,1-glycosidic bond. It is abundant and commonly found in bacteria, fungi, insects, invertebrates, plants, and yeasts (Giannou and Tzia, 2008). Trehalose is essential in enhancing stress-tolerance of yeast. As a result, yeast viability and activity is preserved during frozen storage. However, improving both yeast cells viability as well as gas retention capability of gluten network are important to ensure the gas will not lost on proofing and baking to affect a high loaf volume of bread (Huang *et al*., 2008).

*Corresponding author.
Email: *lhcheng@usm.my*
Tel: 604 6535209; Fax: 604 6573678

Maltodextrins are non-sweet polysaccharides that can be derived from various botanical sources such as corn, oat, potato, rice, tapioca or wheat starches (Oreopoulou, 2006). Maltodextrin is produced by partial hydrolysis of starch through enzymatic process or acid-conversion. The dextrose equivalent (DE) value of maltodextrin is a functionality determinant for their applications in food system. Maltodextrin with low DE is commonly used as stabilizer, thickener, texture modifier, fat or flavour binder or carrier for encapsulation (Biliaderis *et al*., 1999; Oreopoulou, 2006).

da Silva *et al.* (2008) reported that maltodextrin has freeze stabilization potential in frozen camu-camu pulp, wherein T_g' of the system was increased from -58.2°C to -39.6°C with the incorporation of 30% (w/w) maltodextrin of 20DE. The work of Carvajal *et al.* (1999) disclosed that maltodextrins may help to stabilize fish muscle proteins against denaturation during frozen storage. Their results revealed that higher molecular weight maltodextrins stabilized the protein by means of water immobilization mechanism whereas lower molecular weight maltodextrins act as cryoprotectant through solute preferential exclusion mechanism. On the other hand, Herrera *et al*. (2000) showed that addition of maltodextrins to minced blue whiting muscle was able to inhibit formaldehyde production throughout frozen storage at temperature of -10 and -20°C. The results of this study suggest that replacing sucrose with maltodextrins could give rise to a restriction on molecular diffusion and thus reducing the negative effects of temperature fluctuations in distribution chain of frozen food (Herrera *et al.*, 2000). In this work, characteristics and stability of CSB prepared from frozen dough were assessed as a function of trehalose and maltodextrin concentration.

Materials and Methods

Materials

Wheat flour with 10% protein (based on 14% moisture basis), 0.47% ash and 13.3% moisture in dry basis was obtained from United Malayan Flour Mill (Butterworth, Malaysia). Psyllium husk (Plantago ovata) (Natural psyllium husk, 99.29% purity) was procured from Country Farms Sdn. Bhd. (Selangor, Malaysia). Maltodextrin (MALTRIN® M100) was obtained from Grain Processing Corporation (Muscatine, lowa, USA). Sucrose and trehalose were supplied by Merck Sdn. Bhd. (Selangor, Malaysia). Shortening (Crisco brand) was manufactured by The J.M. Smucker Company (Orrville, OH, U.S.A.). Sodium chloride (SYSTERM® brand) and calcium propionate were purchased from Classic Chemicals Sdn. Bhd. (Selangor, Malaysia) and Sim Company Sdn. Bhd. (Penang, Malaysia), respectively. Fresh yeast was supplied by AB Mauri Malaysia Sdn. Bhd. (Selangor, Malaysia) and used within a week of receipt.

Preparation of Chinese steamed bread

As stated in Table 1, five formulations designated as Control, 0.1Tre1Mal, 0.1Tre2Mal, 0.2Tre1Mal and 0.2Tre2Mal were used to prepare Chinese steamed bread with different addition levels of trehalose and maltodextrin mixtures. Formulation Control was designated as control. Before mixing the dough, fresh yeast was dissolved in warm water (35-40°C) containing 5 g sucrose, with or without mixture of trehalose and maltodextrin, and left to rest for 10 min. Sodium chloride, calcium propionate, and the remaining sucrose were separately dissolved in different portions of warm water. The solutions were left to cool before being used. After that, the sucrose solution was added slowly to the wheat flour. Mixing was carried out in a mixing bowl attached with a dough hook. Fresh yeast solution was then added in followed by the sodium chloride solution, the calcium propionate solution, and finally the remaining cold water. After mixing for 2 min, shortening was added and mixing was continued for another 8 min.

Table 1. Formulations used to prepared Chinese steamed bread

Ingredients	Formulations (% w/w)[a]				
	Control	0.1Tre1Mal	0.1Tre2Mal	0.2Tre1Mal	0.2Tre2Mal
Wheat flour	100.00	100.00	100.00	100.00	100.00
Psyllium husk powder	0.20	0.20	0.20	0.20	0.20
Water	48.60	48.60	48.60	48.60	48.60
Compressed yeast	3.00	3.00	3.00	3.00	3.00
Sucrose	8.00	8.00	8.00	8.00	8.00
Trehalose	0.00	0.10	0.10	0.20	0.20
Maltodextrin	0.00	1.00	2.00	1.00	2.00
Sodium chloride	1.00	1.00	1.00	1.00	1.00
Shortening	2.00	2.00	2.00	2.00	2.00
Calcium propionate	0.20	0.20	0.20	0.20	0.20

[a]based on as-is moisture basis of wheat flour

The dough was divided into 100-g pieces. Each piece was molded by using balling unit of extensograph. For dough needed for frozen storage study, the dough pieces were put in plastic bag, vacuum-packed and kept in a freezer at -18°C until further analysis. Thawing was carried out by keeping samples at 4°C for about 15 hours before proofing stage. The dough pieces were then proofed at 30°C and 85% relative humidity for 60 min. After proofing, the dough was steamed for 15 min in a steamer. The samples prepared were tested after cooling for one hour.

Spread ratio, specific volume, stress relaxation properties and firmness were determined for fresh sample and samples prepared from the dough samples that have undergone 1 month, 3 months and 5 months frozen storage.

Spread ratio of CSB

Spread ratio was determined using a modification of the method stated by Lijuan *et al.* (2007). The height and bottom width of CSB were measured at three different locations with a ruler and the average was recorded. Spread ratio (width/height) was calculated.

Specific volume of CSB

The weight of CSB was measured to the nearest of 0.01 g. The volume of Chinese steamed bread was determined using rapeseed displacement method according to Plessas *et al.* (2005) and AACC method 10-05 (AACC 2000). Specific volume (ml/g) which is the ratio of volume to weight of CSB was calculated.

Firmness of CSB

Firmness of CSB was determined using a TA-XT Plus Texture Analyzer (Stable Micro Systems, Surrey, England) equipped with a 30-kg load cell and a 1-inch diameter Delrin ball probe. Parameter was set at pre-test speed of 1.0 mm s^{-1}, a test speed of 1.7 mm s^{-1}, a post-test speed of 10.0 mm s^{-1}, and 5.0 g trigger force. The deformation level was 75% of the sample height and the samples were penetrated once. Increase of firmness is calculated as follows (Equation 1):

$$\text{Increase of firmness} = \frac{\text{Firmness after storage - Initial firmness x 100\%}}{\text{Initial firmness}}$$

Stress relaxation properties of CSB

Bread crumb of the central part of CSB was cut into cube shapes with a dimension of 2×2×2 cm. The test samples were subjected to uniaxial compression using a TA-XT Plus Texture Analyzer (Stable Micro Systems, Surrey, England) attached with a 5-kg load cell and 36 mm diameter cylinder probe. The test was carried out with a pre-test speed of 1 mm s^{-1}, test speed of 0.5 mm s^{-1}, and post-test speed of 10 mm s^{-1}. The relaxation test was fixed at 20% strain and the test was lasted for 10 min. The force-relaxation curve obtained was normalized using the following equations (Equation 2):

$$[F_o t/(F_o\text{-}Ft)] = k_1 + k_2 t$$

where F_o is the initial force , F_t is the decaying force after t time, k_1 and k_2 are constants. Percentage of stress relaxation (%SR) was calculated from the equation of $(F_t/F_o) \times 100$. This test was done according to Mandala *et al*. (2007) and Peleg (1979, 1980).

Statistical analysis

For storage study of CSB, measurements were performed on three sub-samples from each preparation with a completely randomized design. CSB preparation was done in duplicate. Where necessary, general linear model was applied in the analysis of variance and means were compared by the Duncan's test at 95% significance level using SPSS software for Windows Release 15.0 (SPSS Inc., Chicago, Illinois, USA).

Results and Discussion

Spread ratio of CSB

Spread ratio values of Chinese steamed bread (CSB) prepared is depicted as a function of dough frozen storage time in Figure 1A. It is noticed that spread ratio of CSB progressively decreased with dough frozen storage period for all sample types ($P < 0.01$) and generally most obvious drop was shown after 3 months storage. This may indicate that frozen dough is stable in term of spread ratio for only 3-4 months of frozen storage. From the statistical analysis, trehalose and maltodextrin were found to show significant interactive effects on spread ratio of CSB ($P < 0.05$). To have a better comparison, relative changes in spread ratio was calculated in percentage and normalized by the initial spread ratio of the respective sample. Results are shown in Figure 1B, wherein all samples show a progressive decrease in spread ratio with dough frozen storage period. From the statistical analysis, it is revealed that only sample added with 0.2% trehalose and 1% maltodextrin (0.2Tre1Mal) showed significantly higher reduction trend in spread ratio when compared to the control sample ($P < 0.05$).

A high spread ratio is normally related to more spreadable wheat dough that could be ascribed to the viscous flow of the dough (Dogan *et al*., 2010). According to Hoseney *et al*. (1979), reduction in spread ratio is a consequence of decrease in dough elasticity properties. This may be caused by an increase in dough rigidity owing to re-arrangement and re-association of gluten molecules during frozen storage. Besides, physical degradation on gluten molecules could be another plausible explanation for the trend observed. Apart from these, frozen dough may experience loss of water molecules through desiccation upon frozen storage. Water molecules are generally recognized as a universal plasticizer that could facilitate polymer chains mobility. Therefore, "desiccated" gluten molecules may not be strained easily during proofing and baking processes to affect an even rise in the dough.

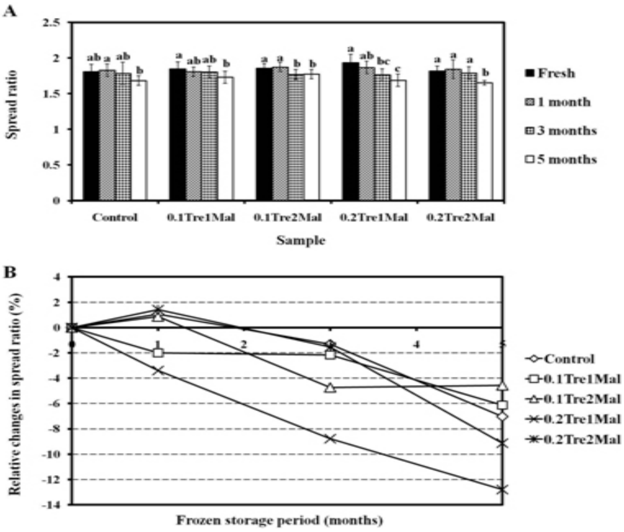

Figure 1. Effects of trehalose and maltodextrin on spread ratio of Chinese steamed bread as a function of frozen storage time. (A) Absolute spread ratio values of samples prepared. The error bar represents ± standard deviation (n = 6). Bars of a specific storage period followed by the same letter are not significantly different at 95 % probability. (B) Relative changes in spread ratio as a function of frozen storage periods. [Typical coefficient of variance is not more than 10%]

Specific volume of CSB

Figure 2A shows changes in specific volume of CSB samples prepared from doughs that have been freezer stored for a period of 5 months. From the statistical analysis, it is significantly shown that specific volume decreased consistently with frozen storage ($P < 0.01$). This observation is in line with those reported in Ribotta *et al*. (2004) and Phimolsiripol *et al*. (2008). From Figure 2B, it can be evident that control sample showed a sharp decrease in specific volume during the first 3 months of storage, after which the relative loss in specific volume was leveled off. From the statistical analysis, it is reported that there is no significant difference between samples of Control, 0.2Tre1Mal and 0.2Tre2Mal. On the other hand, samples coded as 0.1Tre1Mal and 0.1Tre2Mal show better performance in term of retaining a relatively higher specific volume, when compared to the other samples.

According to Giannou and Tzia (2007), specific volume is an indicator of inflating capability as well as oven spring of wheat dough. It is correlated with the qualities of flour protein, gluten development, recipe and processing conditions (Sahi and Little, 2006). Too small a loaf volume can give rise to a closed and compact crumb structure, whereas excessively large loaf volume may contribute to an open crumb structure (Sharadanant and Khan, 2003). Based on the statistical analysis, there is significant interactions between trehalose and dough storage time on specific volume ($P < 0.05$). Results from both Figure 2A and 2B indicate that binary mixture of trehalose (0.1%) and maltodextrin (1 or 2%) is capable of enhancing specific volume of steamed bread prepared from frozen dough. Nevertheless, when trehalose content was increased to 0.2%, specific volume of CSB was decreased to a greater extent as compared to the counterparts with 0.1% trehalose. In addition, the combination of trehalose, maltodextrin and storage period give significant interactive effects on specific volume ($P < 0.05$) according to the statistical analysis.

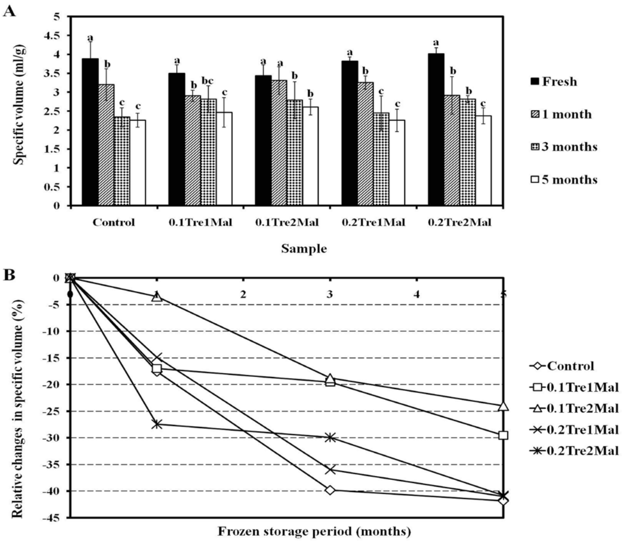

Figure 2. Effects of trehalose and maltodextrin on specific volume of Chinese steamed bread as a function of frozen storage time. (A) Absolute specific volume values of samples prepared. The error bar represents ± standard deviation (n = 6). Bars of a specific storage period followed by the same letter are not significantly different at 95 % probability. (B) Relative changes in specific volume as a function of frozen storage periods. [Typical coefficient of variance is not more than 10%]

Firmness of CSB

Figure 3 illustrates changes in firmness of CSB prepared from frozen dough. Statistical analysis showed that dough frozen storage period has significant ($P < 0.01$) effects on firmness for all CSB samples. As shown in Figure 3A, CSB firmness increased progressively as dough frozen storage was prolonged. This result was in agreement with those reported by Yi *et al.* (2009), and Sharadanant and Khan (2003). Based on the means pair-wise comparison statistical analysis results for each group of sample, it is noticed that firmness of control sample significantly ($P < 0.05$) increased with storage time, whereas others showed insignificant differences and lower values within the first 3 months of storage. This shows that trehalose and maltodextrin are capable of preserving the frozen dough and maintaining the soft texture of CSB. From the statistical analysis, trehalose and storage time provide interactive effects on firmness of CSB prepared from frozen dough ($P < 0.05$). This indicates that trehalose confers softening effect to CSB. As reported by Giannou and Tzia (2008), bread with softer texture and smoother crumb can be produced from frozen dough added with trehalose. Among all the trehalose and maltodextrin added samples, sample coded as 0.1Tre2Mal showed relatively lower firmness throughout the dough frozen storage. This appeared to be the best combination among all the others. Nevertheless, as for fresh sample per se, trehalose and maltodextrin at 0.2% and 2% addition level, respectively seems to produce the softest texture CSB.

Figure 3B shows the trend of relative changes in firmness for CSB samples as compared to the fresh counterpart for all sample types studied. The slope of the line shown in Figure 3B indicates the rate of changes in firmness, and it is interesting to note that control sample shows a linear line. There means to say, the degree of increment in firmness as shown by CSB control sample was consistent throughout the storage. This result was consistent with those reported in Yi *et al*. (2009), Bhattacharya *et al.* (2003), and Ribotta *et al*. (2004). Statistical analysis showed that only sample coded as 0.1Tre2Mal was significantly different from the others. The slope value of this particular sample was the lowest and the highest increment in firmness achieved after 5 months storage was only 50%. These show that addition of 0.1% trehalose and 2% maltodextrin is able to stabilize dough during frozen storage. On the other hand, insufficient or excessive amount of trehalose and maltodextrin caused destabilization effects. This suggests that adequate and optimum amount of low molecular weight compounds such as trehalose and maltodextrin is essential to control ice melting and recrystallization in the dough matrix during frozen storage (Phimolsiripol *et al*., 2008; Yi *et al*., 2009). Excessive amount of trehalose and maltodextrin could cause detrimental effects to CSB firmness.

Stress relaxation properties of CSB

According to Peleg and Normand (1983), stress relaxation data has been used to quantify the viscoelastic behaviour of foods. In this study, stress relaxation data of CSB samples were studied as a function of dough frozen storage period, and data was obtained by means of compressive method to simulate how freshness of CSB used to be tested, i.e. soft press with finger. Force relaxation curve obtained was normalized as described in the Materials and Methods section, to resolve the problems where food materials exhibit non-linear viscoelastic properties under large deformation and its biologically active

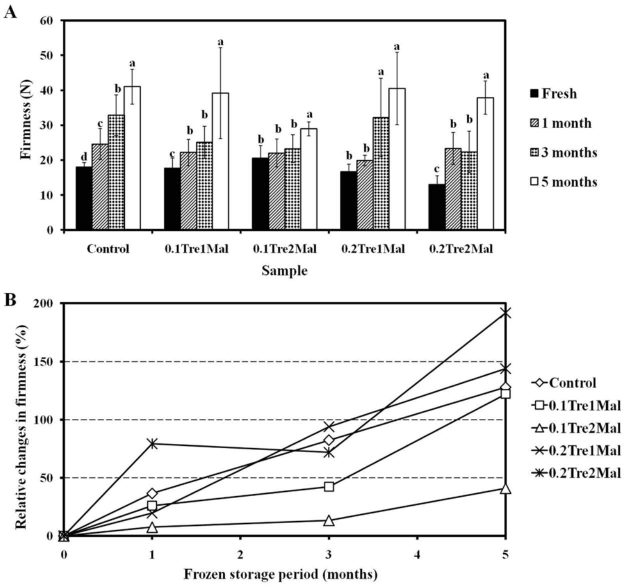

Figure 3. Effects of trehalose and maltodextrin on firmness of Chinese steamed bread as a function of frozen storage time. (A) Absolute firmness values of samples prepared. The error bar represents ± standard deviation (n=6). Bars of a specific storage period followed by the same letter are not significantly different at 95 % probability. (B) Relative changes in firmness as a function of frozen storage periods. [Typical coefficient of variance is not more than 10%]

nature (Peleg and Normand, 1983). The viscoelastic properties of CSB samples were characterized by maximum force which served as initial force for the force decay curve, percent of stress relaxation, k_1 and k_2 parameters as obtained from Equation 2.

As shown in Table 2, initial force (F_o) of all sample types was decreased progressively with increase in dough frozen storage time ($P < 0.01$). Overall, sample added with 0.1% trehalose and 2% maltodextrin showed significantly ($P < 0.05$) lower Fo even after the dough has been freezer stored for 5 months, when compared to other samples. This result trend is in good agreement with our firmness result and increase in F_o observed could be attributed to bread staling.

Pertaining to percent stress relaxation (%SR) results, it is evident that the values of %SR decreased with dough frozen storage period ($P < 0.01$). This indicates that F_t decreased progressively with dough frozen storage period. This shows that CSB sample may lose its elasticity if the dough was subjected to prolonged frozen storage. Interestingly, CSB samples showed a big drop in %SR only after the dough had been stored for 1 month and no significant difference in %SR was observed for samples subjected to 3 and 5 months storage. This may suggest that dough gluten molecules start experiencing large physical changes between second and third month of frozen storage. Comparing all sample types, once again sample added

Table 2. Stress relaxation parameters of different formulations of Chinese steamed bread prepared from frozen dough as a function of frozen storage periods

Sample	Parameters	Fresh	1 month	3 months	5 months
Control	F_{max} (N)	0.520 ± 0.272 d	0.832 ± 0.201 c	1.853 ± 0.309 b	2.125 ± 0.377a
	%SR	49.896 ± 2.956 a	49.107 ± 3.809 a	38.821 ± 6.720 c	41.930 ± 2.332 b
	k_1	16.236 ± 2.671 a	15.573 ± 2.294 a	10.742 ± 2.924 b	11.444 ± 0.894 b
	k_2	2.373 ± 0.176 a	2.301 ± 0.189 a	1.885 ± 0.238 b	1.953 ± 0.088 b
0.1Tre1Mal	F_{max} (N)	0.610 ± 0.183 d	0.820 ± 0.161 c	1.321 ± 0.329 b	2.120 ± 0.319 a
	%SR	52.546 ± 2.053 a	48.051 ± 2.836 b	38.825 ± 5.430 d	41.546 ± 2.240 c
	k_1	17.398 ± 2.003 a	15.068 ± 1.659 b	10.537 ± 2.215 c	11.135 ± 1.167 c
	k_2	2.486 ± 0.118 a	2.239 ± 0.134 b	1.878 ± 0.210 c	1.942 ± 0.081 c
0.1Tre2Mal	F_{max} (N)	0.718 ± 0.252 c	0.803 ± 0.136 c	1.155 ± 0.357 b	1.783 ± 0.211 a
	%SR	48.089 ± 2.461 b	50.972 ± 2.208 a	35.582 ± 2.645 c	36.613 ± 2.636 c
	k_1	14.236 ± 1.689 b	16.418 ± 1.679 a	9.367 ± 1.267 c	9.291 ± 0.896 c
	k_2	2.251 ± 0.126 b	2.367 ± 0.115 a	1.770 ± 0.091 c	1.780 ± 0.083 c
0.2Tre1Mal	F_{max} (N)	0.668 ± 0.215 c	0.758 ± 0.217 c	1.238 ± 0.356 b	2.123 ± 0.269 a
	%SR	48.473 ± 1.490 a	48.944 ± 4.553 a	40.398 ± 4.585 b	39.357 ± 3.890 b
	k_1	14.790 ± 0.964 a	15.789 ± 2.685 a	11.267 ± 1.846 b	10.480 ± 1.682 b
	k_2	2.266 ± 0.076 a	2.297 ± 0.220 a	1.939 ± 0.161 b	1.871 ± 0.131 b
0.2Tre2Mal	F_{max} (N)	0.449 ± 0.158 d	0.783 ± 0.364 c	1.214 ± 0.290 b	2.004 ± 0.355 a
	%SR	50.163 ± 3.136 a	49.676 ± 5.143 a	40.200 ± 2.595 b	37.157 ± 2.980 c
	k_1	16.527 ± 2.676 a	16.304 ± 3.542 a	10.505 ± 0.752 b	9.568 ± 0.901 b
	k_2	2.370 ± 0.179 a	2.326 ± 0.244 a	1.912 ± 0.087 b	1.794 ± 0.090 c

F_{max}, Initial force; %SR, Percentage of stress relaxation; Tre, Trehalose; Mal, Maltodextrin.
Means ± standard deviation (n=20). Values followed by the same letter in the same column are not significant different at 95% confidence interval in the comparison between frozen storage periods.

with 0.1% trehalose and 2% maltodextrin shows the lowest %SR after a 5 month frozen storage.

The value of k_1 was reported to be corresponded to the rate of stress relaxation and k_2 represents the extent of relaxation (Singh *et al*., 2006). According to Peleg and Normand (1983), solid materials had higher values of k_2 while the soft or semi-solidlike foods showed a value close to unity. However, in the same study, the k_2 value for clay and sand mix was shown to be lower than that of corn grains (Singh *et al.*, 2006). Hence, Singh *et al.* (2006) stated that k_2 is better to be used to characterize the elastic nature rather than solid nature of food materials. The results clearly demonstrate that for all sample types k_1 and k_2 values decreased with increase in dough frozen storage time ($P < 0.01$) based on the statistical analysis. One of the reasons for this is that CSB samples prepared from frozen dough showed less elasticity. According to Varriano-Marston *et al*. (1980) and Berglund *et al*. (1991), the abovementioned could be ascribed to the degradation and/or dehydration of gluten molecules during frozen storage.

In addition, statistical analysis showed that addition of maltodextrin and interaction effects between trehalose and storage time, maltodextrin and storage time, trehalose and maltodextrin as well as the combination of these three factors give significant impact on %SR, k_1 and k_2 parameters ($P < 0.05$). An exception was found in the interaction effects between trehalose and storage time, which showed insignificant effect on k_1 parameter ($P > 0.05$). This indicates that frozen storage causes deterioration in dough matrix and become worse with extended freezer storage period. Generally, addition of trehalose and maltodextrin affect the viscoelastic properties of bread crumb. The sample coded with 0.1Tre2Mal show better performance among the samples studied in which a relatively low %SR was revealed with prolonged frozen storage time.

Conclusions

Dough network and yeast viability were found to be deteriorated when steamed bread dough was subjected to freezing and frozen storage. This resulting in poorer spread ratio, specific volume, firmness as well as viscoelastic characteristics of bread crumb. However, the extent of deterioration could be reduced significantly with the addition of trehalose and maltodextrin at a level of 0.1% and 2%, respectively.

Acknowledgements

This study was financially supported by Kuok Foundation and Malayan Sugar Manufacturing Co. Bhd through a research grant (304/PTEKIND/650441/K132). S.Y. Sim wishes to thank Institute of Postgraduate Studies, Universiti Sains Malaysia for fellowship support.

References

AACC. 2000. Approved methods of the American Association of Cereal Chemists. St. Paul, Minnesota, USA:AACC International.

Asghar, A., Anjum, F.M., Allen, J.C., Daubert, C.R. and Rasool, G. 2009. Effect of modified whey protein concentrates on empirical and fundamental dynamic mechanical properties of frozen dough. Food Hydrocolloids 23:1687-1692.

Baier-Schienk, A., Handschin, S. and Conde-Petit, B. 2005. Ice in Prefermented Frozen Bread Dough-An Investigation Based on Calorimetry and Microscopy. Cereal Chemistry 82:251-255.

Berglund, P.T., Shelton, D.R. and Freeman, T.P. 1991. Frozen bread dough ultrastructure as affected by duration of frozen storage and freeze-thaw cycles. Cereal Chemistry 68: 105-107.

Bhattacharya, M., Langstaff, T.M. and Berzonsky, W.A. 2003. Effect of frozen storage and freeze-thaw cycles on the rheological and baking properties of frozen doughs. Food Research International 36:365-372.

Billiaderis, C.G., Swan, R.S. and Arvanitoyannis, I. 1999. Physicochemical properties of commercial starch hydrolyzates in the frozen state. Food Chemistry 64:537-546.

Carvajal, P.A., Macdonald, G.A. and Lanier, T.C. 1999. Cryostabilization Mechanism of Fish Muscle Proteins by Maltodextrins. Cryobiology 38:16-26.

Da Silva, M., Do Amaral, S.P. and Kieckbusch, T.

2008. Phase Transitions of Frozen Camu-camu (*Myrciaria dubia* (H.B.K.) McVaugh) Pulp: Effect of Cryostabilizer Addition. Food Biophysics 3:312-317.

Dodic, J., Pejin, D., Dodic, S., Popov, S., Mastilovic, J., Popov-Raljic, J. and Zivanovic, S. 2007. Effects of hydrophilic hydrocolloids on dough and bread performance of samples made from frozen doughs. Journal of Food Science 72(4):235-241.

Dogan, I.S., Yildiz, O. and Tasan, B. 2010. Spread and microwave-oven baking test for bread making quality. International Journal Agriculture and Biololgy 12:697-700.

Giannou, V., Kessoglou, V. and Tzia, C. 2003. Quality and safety characteristics of bread made from frozen dough. Trends in Food Science and Technology 14: 99-108.

Giannou, V. and Tzia, C. 2007. Frozen dough bread: Quality and textural behavior during prolonged storage - Prediction of final product characteristics. Journal of Food Engineering 79:929-934.

Giannou, V. and Tzia, C. 2008. Cryoprotective role of exogenous trehalose in frozen dough products. Food Bioprocess Technology 1:276-284.

Herrera, J.J.R., Pastoriza, L. and Sampedro, G. 2000. Inhibition of formaldehyde production in frozen-stored minced blue whiting (*Micromesistius poutassou*) muscle by cryostabilizers: An approach from the glassy state theory. Journal of Agricultural and Food Chemistry 48:5256-5262.

Hoseney, R.C., Hsu, K.S. and Junge, R.C. 1979. A simple spread test to measure the rheological properties of fermenting dough. Cereal Chemistry 56:141-143.

Huang. W., Kim, Y., Li, X. and Rayas-Duarte, P. 2008. Rheofermentometer parameters and bread specific volume of frozen sweet dough influenced by ingredients and dough mixing temperature. Journal of Cereal Science 48:v639-646.

Keeratipibul, S., Luangsakul, N., Otsuka, S., Sakai, S., Hatano, Y. and Tanasupawat, S. 2010. Application of the Chinese steamed bun starter dough (CSB-SD) in breadmaking. Journal of Food Science 75(9):596-604.

Kenny, S., Wehrle, K., Dennehy, T. and Arendt, E.K. 1999. Correlations between empirical and fundamental rheology measurements and baking performance of frozen bread dough. Cereal Chemistry 76:421-425.

Lijuan, S., Guiying, Z., Guoan, Z. and Zaigui, L. 2007. Effects of different milling methods on flour quality and performance in steamed breadmaking. Journal of Cereal Science 45: 18-23.

Lu, W. and Grant, L.A. 1999. Effects of Prolonged Storage at Freezing Temperatures on Starch and Baking Quality of Frozen Doughs. Cereal Chemistry 76:656-662.

Mandala, I., Karabela, D. and Kostaropoulos A. 2007. Physical properties of breads containing hydrocolloids stored at low temperature. I. Effect of chilling. Food Hydrocolloids 21:1397-1406.

Momose, Y., Matsumoto, R., Maruyama, A. and Yamaoka, M. 2010. Comparative analysis of transcriptional responses to the cryoprotectants, dimethyl sulfoxide and trehalose, which confer tolerance to freeze-thaw stress in Saccharomyces cerevisiae. Cryobiology 60: 245-261.

Newberry, M.P., Phan-Thien, N., Larroque, O.R., Tanner, R.I. and Larsen, N.G. 2002. Dynamic and Elongation Rheology of Yeasted Bread Doughs. Cereal Chemistry 79: 874-879.

Oreopoulou, V. 2006. Fat replacers. In: Hui YH, Corke H, De Leyn I, Nip WK, Cross N, editors. Bakery products: science and technology Iowa, USA: Blackwell Publishing. p 193-210.

Peleg, M. 1979. Characterization of the stress relaxation curves of solid foods. Journal of Food Science 44:277-281.

Peleg, M. 1980. Linearization of relaxation and creep curves of solid biological materials. Journal of Rheology, 24:451-463.

Peleg, M. and Normand, M.D. 1983. Comparison of two methods for stress relaxation data presentation of solid foods. Rheologica Acta, 22:108-113.

Phimolsiripol, Y., Siripatrawan, U., Tulyathan, V. and Cleland, D.J. 2008. Effects of freezing and temperature fluctuations during frozen storage on frozen dough and bread quality. Journal of Food Engineering 84: 48-56.

Plessas, S., Pherson, L., Bekatorou, A., Nigam, P. and Koutinas, A.A. 2005. Bread making using kefir grains as baker's yeast. Food Chemistry 93:585-589.

Ribotta, P.D., Pérez, G.T., León, A.E. and Aňón, M.C. 2004. Effect of emulsifier and guar gum on micro structural, rheological and baking performance of frozen bread dough. Food Hydrocolloids 18:305-313.

Sahi, S.S. and Little, K. 2006. In Quality control. In: Hui YH, Corke H, De Leyn I, Nip WK, Cross N, editors. Bakery products: science and technology Iowa, USA: Blackwell Publishing. p 319-36.

Sharadanant, R. and Khan, K. 2003. Effect of Hydrophilic Gums on the Quality of Frozen Dough: II. Bread Characteristics. Cereal Chemistry 80:773-780.

Singh, H., Rockall, A., Martin, C.R., Chung, O.K. and Lookhart, G.L. 2006. The analysis of stress relaxation data of some viscoelastic foods using a texture analyzer Journal of Texture Studies 37:383-392.

Varriano-Marston, E., Hsu, K.H. and Mahdi, J. 1980. Rheological and structural changes in frozen dough. Bakers Digest 54:32- 41.

Yi, J., Johnson, J.W. and Kerr, W.L. 2009. Properties of bread made from frozen dough containing waxy wheat flour. Journal of Cereal Science 50:364-369.