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Staling of cake prepared from rice flour and sticky rice flour

Ying Ji, Kexue Zhu, Haifeng Qian, Huiming Zhou *

Key Laboratory of Food Science and Safety, Ministry of Education, Southern Yangtze University, 170 Huihe Road, Wuxi 214036, Jiangsu Province, PR China

School of Food Science and Technology, Southern Yangtze University, 170 Huihe Road, Wuxi 214036, Jiangsu Province, PR China

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Abstract

MiGao, prepared from rice flour and sticky rice flour, is a kind of steam cooked Chinese cake. Staling of MiGao resulted in loss in texture and eating quality. Moisture content, water activity, texture, differential scanning calorimetry thermograms and sensory quality of MiGao, were monitored and were found to be significantly affected by cake staling when stored at room temperature for up to 5 days. The moisture content decreased after 2 days of storage and during the following days the crumb moisture content remained practically unchanged. Firmness was developed mainly during the first day of storage, remained at a similar level from day 2 to 3 and increased slightly after the third day of storage. A decrease in sensory quality and acceptability of the MiGao was observed during storage. Differential scanning calorimetry was used to follow changes of starch retrogradation in MiGao crumb. Amylopectin recrystallisation in MiGao continued to increase during storage.

Keywords: Cake; Texture; Differential scanning calorimetry; Staling

1. Introduction

A small segment of the world population suffers from coeliac disease. The responsible pathogenic factor has been traced to the gliadin fraction of gluten. The only effective treatment for coeliac disease is a strict adherence to a gluten free diet throughout the patient's lifetime, which, in time, results in clinical and mucosal recovery (Gallagher, Gormley, & Arendt, 2004). Rice has properties such as the absence of gluten, low levels of sodium, protein, fat and fibre, and a high amount of easily digested carbohydrates, which are desirable for certain special diets.

Rice is one of the leading food crops in South East Asia including China, and the production of rice in this part of the world is much higher than that of wheat. It can be ground into powder and utilized to produce many kinds of foods, including several types of cake. MiGao is one of the most widespread of these types of cake. It is obtained from rice flour and sticky rice flour (in the ratio of 2:3) by steaming in a bamboo steamer. It is famous for its soft and sticky texture and it is usually served as a dessert. Traditionally, these products are packaged in polyethylene bags after steaming and cooling.

During storage at room temperature, desired characteristics, e.g., moisture loss, starch retrogradation, loss of flavour/aroma, increased firmness could change. Freshly steamed MiGao are soft, pliable and elastic, but when kept at room temperature they stale within a few hours and become tough and rigid. In less than 3 days the shelf-life of MiGao presents a major problem in China and can be costly to the producer, distributor, consumer and the country in general. The short shelf-life of MiGao, which is mainly due to staling, is a serious problem.

Firming of bread crumb during storage is a common phenomenon and leads to a crumbly texture, and lower consumer acceptance (Biliaderis, 1992; Stollman & Lundgren, 1987). Staling of products is generally defined as an

* Corresponding author. Address: School of Food Science and Technology, Southern Yangtze University, 170 Huihe Road, Wuxi 214036, Jiangsu Province, PR China. Tel./fax: +86 510 5869382.

E-mail address: hmzhou@sytu.edu.cn (H. Zhou).

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increase in crumb firmness and a parallel loss in product freshness (Short & Roberts, 1971). Staling is a complex process and the mechanism still remains unknown, despite numerous attempts to explain the mechanism responsible for bread staling (Dappolonia & Morad, 1981; Krog, Olesen, Toernaes, & Joensson, 1989; Piazza & Masi, 1995). Because starch is the major component of the system, a predominant role has been assigned to starch retrogradation, which involves the progressive association of gelatinized starch segments into a more ordered structure (Seow & Teo, 1996; Zobel & Kulp, 1996).

The increasing demand for gluten free food has created a need to meet new consumer requirements (McCarthy, Gallagher, Gormley, Schober, & Arendt, 2005; Sanchez, Osella, & Delatorre, 2002), but these foods generally have a very short shelf life. Kadan, Robinson, Thibodeaux, and Pepperman (2001) reported that rice breads had harder texture and were more prone to retrogradation during storage than whole wheat bread. Moore, Schober, Dockery, and Arendt (2004) have shown that gluten free breads were brittle after two days of storage, and the decrease in springiness, cohesiveness and resilience derived from texture profile analysis. The objective of the present study was to evaluate physicochemical characteristics of MiGao over a storage period of 5 days at 25 °C, for the evaluation of the extent of staling in MiGao.

2. Materials and methods

2.1. Materials

Rice flour and sticky rice flour were obtained from the local market and stored at 25 °C during the study. MiGao was made from 180 g sticky rice flour; 120 g rice flour and 60 g sucrose. Ingredients were mixed with water thoroughly, sieved through a 50 mesh sifter, shaped by a mold, and then steamed in a bamboo steamer for 15–20 min. After cooling for 10 min, the MiGao samples were packaged in polyethylene bags. Six loaves were made in each trial and these trials were repeated three times during the duration of the study.

2.2. Storage studies

MiGao samples packaged in polyethylene bags and sealed were marked for 0, 1, 2, 3, 4 and 5 days of storage at room temperature. The temperature in the laboratory during the entire 5 days storage period was 25 ± 1 °C. These MiGao samples were analyzed daily for various physicochemical and sensory features.

2.3. Chemical analysis

On each day of storage, the center of the MiGao samples were analyzed for moisture content, water activity, texture properties and sensory quality. To determine moisture content, 2 g of MiGao were weighed in aluminum dishes and dried to a constant weight in a vacuum oven at 70 °C. The difference in the weight of the sample before and after drying was used to calculate the moisture content (AOAC, 1990). To measure water activity, 50 g of MiGao was quickly chopped into small pieces and taken into a conical flask and the water activity was measured with a hand-held digital water activity probe (Rotronic hygrolabaw3, Switzerland). All analyses were conducted in triplicate and the average values were reported.

2.4. Objective texture measurements

An Instron universal testing machine (TA-XT2, Texture Analyser, USA) was used to measure the objective texture of the MiGao during storage. MiGao samples, having a thickness of approximately 1.5 cm and 60 cm^2 slice area, were taken for instrumental texture measurement. A double cycle was programmed and the texture profile was determined using Xrad software (Stable Micro systems). A plunger (Part No: P/0.25S) compressed samples to 30% of their original height with pre-test speed of 2.0 mm/s, test speed of 5.0 mm/s, and post-test speed of 5.0 mm/s. On each MiGao, the measurements were carried out on the centre of the sample and all analyses were conducted six times.

2.5. Differential scanning calorimetry

Analyses were performed in a DSC-7 (Perkin–Elmer, USA), using stainless steel pans (PE 0319-0218). The equipment was calibrated with Indium and an empty pan was used as a reference.

The samples were removed from the central portion of the MiGao and samples (8 mg) were immediately weighed into the pan, and placed in hermetically sealed aluminium pans in order to avoid moisture loss. Duplicate sample pans were prepared and each sample was heated from 20 to 140 °C using a scanning rate of 10 °C/min. The temperature values obtained were the onset temperatures of transition (T_o) and the temperatures at the completion of the transition (T_c). The peak transition temperature (T_p) was defined as the temperature at the peak maximum. The enthalpy of transition was estimated from the integrated heat flow over the temperature range of the transition, and is expressed as joule per gram sample (J/g).

2.6. Sensory analysis

On each day of storage, sensory evaluation was carried out on the representative samples of MiGao on the day of production and at daily intervals during the storage period. Ten panelists gave a score between 1 and 9 for tenderness, colour, texture, flavour and overall acceptability and a mean score was estimated for each product.

2.7. Statistical analyses

The experimental data obtained were analyzed statistically for variance (Sokal & Rohlf, 1981) and inference reported at the appropriate places. For the results, the mean values and standard deviations were calculated.

3. Results and discussion

3.1. General

The rice flour and sticky rice flour used for the production of MiGao were analyzed for moisture, protein, ash and fat contents by standard AACC, 1990 methods. The sticky rice flour had protein, ash and fat contents of 7.06%, 0.55% and 1.01%, respectively. The rice flour had higher protein (7.27%), ash (0.63%) and fat (1.26%) contents than sticky rice flour.

3.2. Storage studies

During the storage studies, MiGao were analyzed for moisture content, water activity and sensory quality. The moisture content and water activity of the crumb samples were measured at the center of the MiGao as for the thermal profiles (see Fig. 1).

As expected, all MiGao samples showed a definite decrease in crumb moisture content during 5 days of storage (Fig. 2). The moisture content of the MiGao stored at room temperature decreased from 39.5% to 28.3% after 2 days of storage and during the following days, the crumb moisture content remained practically unchanged. In the course of storage, the moisture migrates from the crumb toward the crust and evaporates from the surface of the product (Piazza & Masi, 1995).

The water activity of these MiGao samples did not vary significantly during storage periods. The value of water activity was around 0.92. The free water present in the freshly steamed MiGao, which gave higher water activity values, was probably bound to the hydrophilic constituents (e.g., starch) of the MiGao during storage.

The result of sensory analyses demonstrated that storage for two days did not modify the sensory characteristics of the standard. After two days MiGao became more harder in texture and taste scores were lower (results not shown). Shelf stability of MiGao has been reported to be about 3 days (Wang, Zhou, & Qian, 2006).

3.3. Texture

MiGao samples stored for 5 days were evaluated at intervals for objective texture using the Instron universal testing machine. Results of three major textural parameters (firmness, gumminess, chewiness) are shown in Fig. 2. As was expected, the crumb firmness increased as a consequence of storage. Fresh MiGao had the lowest firmness values and these values increased significantly after 1 day of storage, remained at a similar level from 2 to 3 days and slightly increased after 3 days of storage. Most of the loss of texture occurred during the first day of storage under ambient conditions.

The increase of chewiness and gumminess values with ageing was observed in all samples. Both, gumminess and chewiness, are parameters dependant on firmness, therefore, their values, both in fresh and stored cakes, followed a similar trend to that of firmness.

Textural changes in MiGao occur faster than bread but the mechanism of bread firming is complex and not well understood (He & Hoseney, 1990; Zeleznak & Hoseney, 1986). It has been stated that gluten present in wheat bread slows down the movement of water by forming an extensible protein network, thus keeping the crumb structure

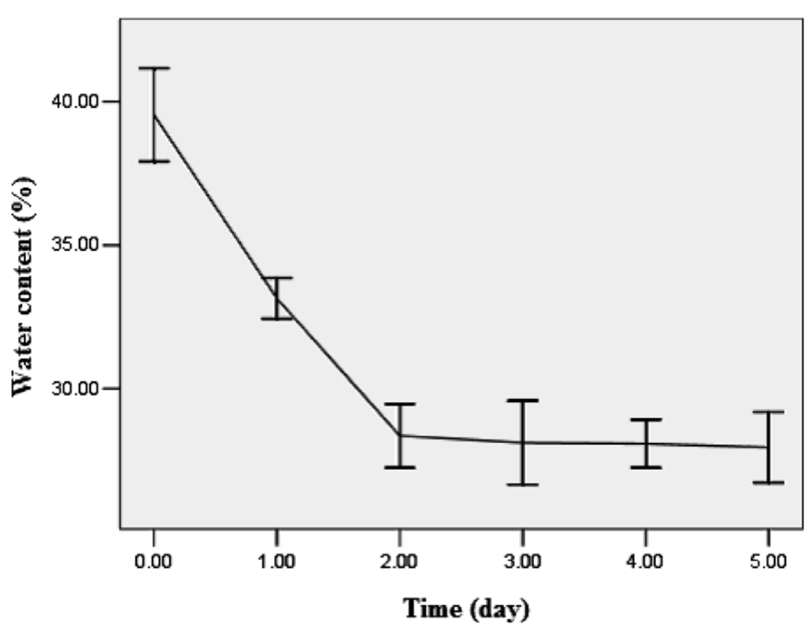

Fig. 1. Changes of water content in MiGao during storage at 25 °C for 5 Days.

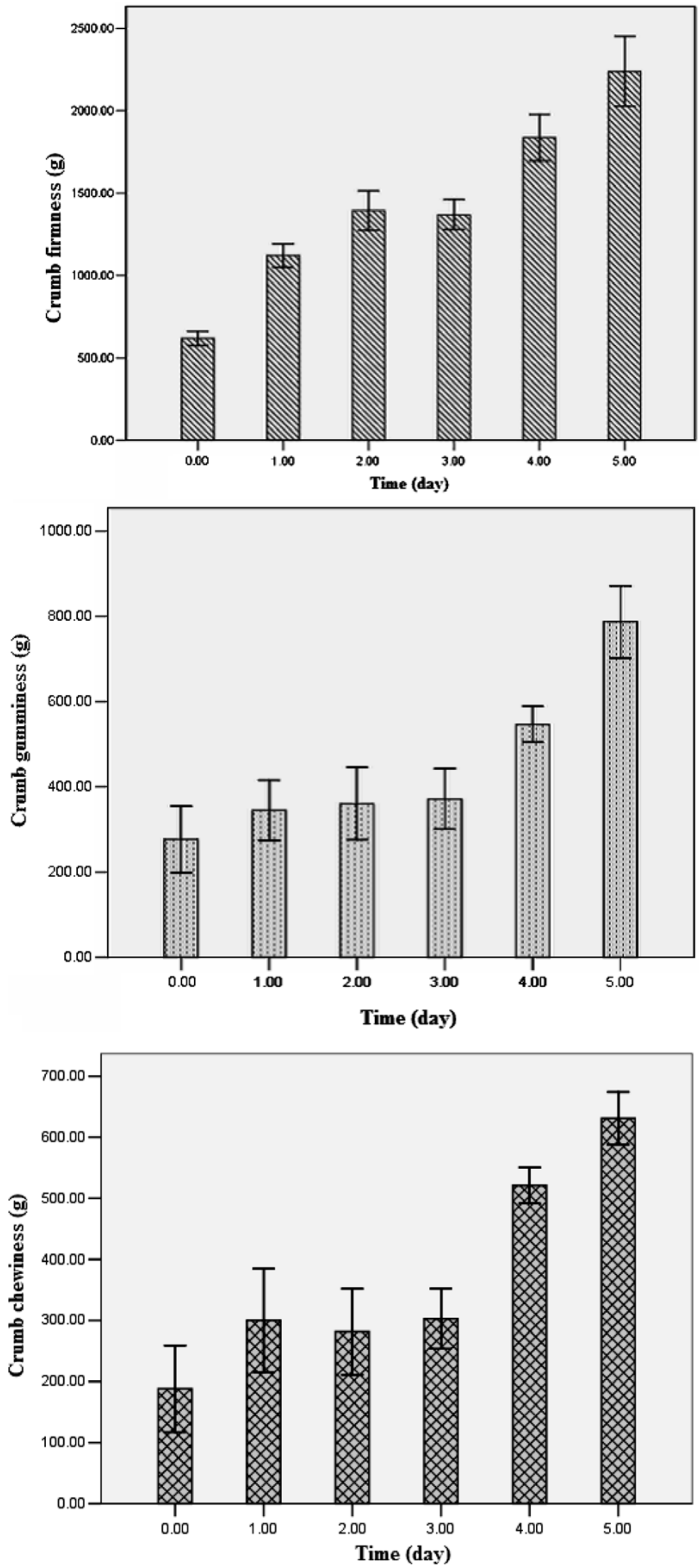

Fig. 2. Changes in crumb texture values during storage at 25 °C for 5 Days.

together (Roach & Hoseney, 1995). Therefore, the absence of gluten should increase the movement of water from the bread crumb to crust, resulting in a firmer crumb.

In our experiments, firmness values increased steadily in all MiGao whereas the water content was found to be stable after 2 days of storage. We assume that the moisture losses from MiGao crumb that caused a rigidification of its crumb structure as a primary firming process and the secondary firming process included starch retrogradation or moisture redistribution.

3.4. Differential scanning calorimetry

Starch retrogradation, namely amylopectin retrogradation, is one of the most important factors responsible for bread staling (Armero & Collar, 1998; Martin, Zeleznak, & Hoseney, 1991), and it is thought to contribute to crumb firmness (Kim & D'Appolonia, 1977; Schiraldi, Piazza, & Riva, 1996). Because of that, the thermal properties of the samples obtained from the center were measured by using DSC.

Two endotherms were observed by DSC studies of MiGao crumb (Fig. 3). The first transition with a peak temperature (T_p) at approximately 58.1 °C is characteristic of the melting of retrogradated amylopectin. As was expected, retrogradation enthalpy increased during the storage time. The ΔH value continued to increase when the MiGao were stored at room temperature whereas the firmness remained stable from 2 to 3 days. This shows, in accordance with other studies that bread firming is not a simple function of starch retrogradation (Ghiasi, Hoseney, Zeleznak, & Rogers, 1984; Morgan, Gerrard, Every, Ross, & Gilpin, 1997). The second endotherm observed by DSC above 100 °C is characteristic of melting of the amylose–lipid complex of starch. During storage there was a significant shift in the endotherm towards higher temperatures where the peak transition temperature increased from 107.5 to 112.1 °C. Contrary to ΔH, no significant change was observed in the enthalpy value for the amylose–lipid complex during storage (Table 1). This is in accordance with the studies of Czuchajowska and Pomeranz (1989) who reported no changes in the enthalpy of the amylose–lipid complex during storage of bread over a period of 7 days. They suggested that the amylose–lipid complex was formed during or immediately after baking.

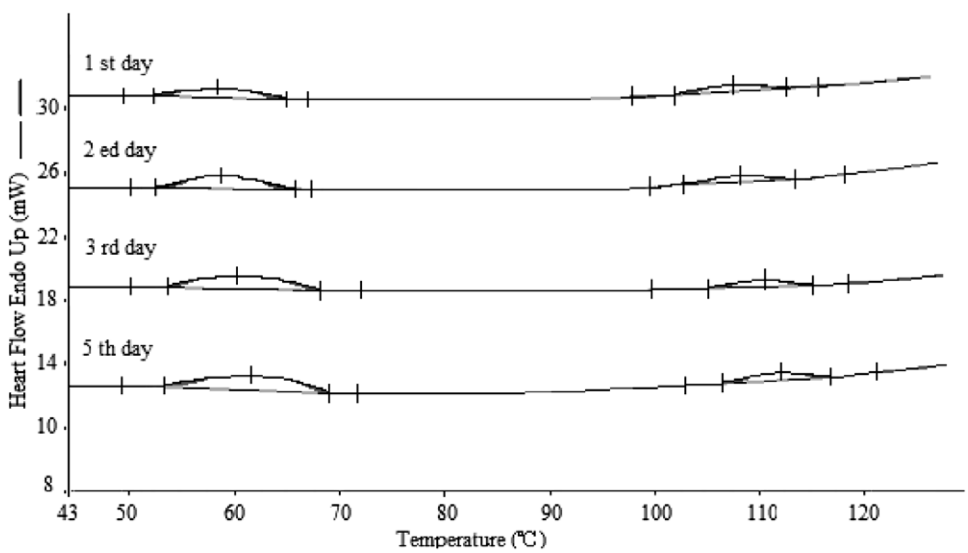

Fig. 3. Differential scanning calorimetry of MiGao during storage at 25 °C for 1, 3, and 5 days.

Table 1
Differential scanning calorimetric data in the crumb of MiGao during storage at 25 °C for 1, 2, 3, and 5 days

Storage time (day)	Amylopectin				Amylose–lipid complexes			
	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (J/g)	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (J/g)
1	52.4 ± 0.5	58.1 ± 0.4	65.1 ± 0.9	0.68 ± 0.13	102.2 ± 0.5	107.5 ± 0.4	112.7 ± 0.8	0.37 ± 0.06
2	52.6 ± 0.3	58.9 ± 0.8	66.3 ± 0.6	1.45 ± 0.08	102.6 ± 0.8	107.7 ± 0.6	113.2 ± 0.5	0.33 ± 0.05
3	53.7 ± 0.8	60.2 ± 0.3	68.2 ± 1.0	1.65 ± 0.06	105.2 ± 0.7	110.3 ± 0.9	115.3 ± 0.6	0.36 ± 0.08
5	53.1 ± 0.7	61.6 ± 0.5	68.8 ± 0.7	1.86 ± 0.12	106.4 ± 0.3	112.1 ± 0.5	117.1 ± 0.8	0.38 ± 0.10

Data are the mean ± standard deviation.
1. T_o = onset temperature; 2. T_p = peak temperature; 3. T_c = conclusion temperature; 4. ΔH = enthalpy of gelatinization.

Starch retrogradation, or partial recovery of the ordered structures, takes place on cooling and during aging. It is known that retrogradation consists of two different processes: gelation of amylose solubilized during gelatinization and amylopectin recrystallization within the gelatinized granules. Amylose gelation via chain entanglement involved a rapid network development typically within less than 1 day, while amylopectin is responsible for slow development of the crystallinity in the polymer-rich regions, which may continue for weeks (Biliaderis, 1990). Starch retrogradation in MiGao occurs faster than in bread due to the higher starch concentration and lower fat content of MiGao. Roulet, Mac Innes, Wursch, Sanchez, and Raemy (1988) investigating starch retrogradation in gels by scanning calorimetry, reported that higher starch concentrations resulted in faster retrogradation.

4. Conclusion

The present study on staling of MiGao has established some new findings. The process and mechanism of staling differ between MiGao and bread. The MiGao loses its softness very fast, becomes stale and hard. The loss of MiGao texture in this study occurred faster after 1 day of storage at room temperatures, which was likely due to starch retrogradation. Initial rate of staling is higher and possibly amylose is responsible for this process, as is evident from the DSC thermograms, where the melting of the crystallites occurs in the range 100–120 °C. Fundamental data obtained will be useful in further kinetic studies as well as understanding product quality during bread making, particularly MiGao.

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