P-STARCH-7

Effect of Sucrose on Freeze-Thaw Stability and Morphology of Rice Starch Gels

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The aim of this research was to investigate effects of sucrose on freeze-thaw stability and morphology of rice starch gels. Effects of sucrose (10% and 20%) on freeze-thaw (FT) stability of rice starch gels (8% w/w) were studied. The gels containing starch and sucrose were repeatedly freeze-thawed up to five times by storing at -18 °C for 22 h and then at 30 °C for 2 h. Liquid separation (syneresis) from the freeze-thawed gels was measured after centrifugation. The results showed that sucrose was effective in reducing the syneresis and this effect increased with increasing sucrose concentrations. Moreover, morphology of starch gels has been studied by Scanning Electron Microscope (SEM). Scanning electron micrographs clearly showed pores resulted from ice crystals formation and thawing process. The matrix surrounded the pores in the starch gels containing sucrose was thicker than the one without sucrose addition. The higher sucrose concentration, the thicker matrix was found. Syneresis results were correlated to thickness of the matrix of frozen starch gels. These results indicated that re-association of starch chains (retrogradation) induced by FT treatment was also retarded by the presence of sucrose.

Keywords: Rice starch, Sucrose, Freeze-thaw stability, Syneresis, Morphology

Introduction

Starch is the major component of grains and a common ingredient used in the food industry. Starches are mainly used in foods as an agent for thickening and gelling (Singh et al., 2006). A wide range of cereal starches are currently used, and among them, rice starches are becoming quite popular because of their hypoallergenic properties to celiac patients, bland taste and characteristic whiteness and gloss (Zhou et al., 2002; Jacquies et al., 2006).

When starchy foods are frozen, the formation of ice crystals within the food matrix caused physical changes in food. The physical changes in starchy foods are due both to retrogradation of linear molecules and association of branched molecules. Upon thawing, the melting of these ice crystals lead to water expressed from the dense network, a phenomenon known as syneresis. These processes have influences on texture and often deterioration of frozen foods containing starch (Schoch, 1968; Rahman, 1999; Karim, Norziah, & Seow, 2000). Retrogradation is an important factor for starch used as a food ingredient in processing and preservation, because the quality of food's texture and physical properties deteriorate due to retrogradation as time passes (Ishiguro et al., 2000).

The ability of starch to withstand the undesirable physical changes during freezing and thawing has been commonly termed freeze-thaw stability and can be used as an indicator of the tendency of starch to retrograde (Schoch, 1968). Freeze-thaw stability of starch gels has been evaluated by measuring the quantity of liquid separated from the gel after centrifugation

(Hoover, Hannouz, & Soyulski, 1988; Wu & Seib, 1990). Repeated freeze-thaw cycles were accelerated retrogradation of starch gels (Yuan and Thompson, 1998).

In food products, starch is usually combined with various additives, and sugars are common for food application in baked goods, snacks and ready-to-eat (RTE) foods (Sopade et al., 2004). Sucrose is the most common food sweetener and it is mostly use in the food products. However, studies on the effect of sugars in the retrogradation of starch gels have been conflicting and inconclusive. Various studies reported that certain sugars could retard retrogradation (I'Anson et al., 1990; Kohyama & Nishinari, 1991; Katsuta et al., 1992) or accelerate retrogradation (Chang & Liu, 1991; Ward, Hoseney, & Seib, 1994).

The aim of this research was to investigate effect of sucrose on freeze-thaw stability using centrifugation method and morphology of rice starch gels by Scanning Electron Microscope (SEM) micrographs.

Materials and Methods

Materials

Rice Starch was a commercial product obtained from Choheng Co., Ltd. (Nakorn Prathom, Thailand). Sucrose was purchased from Mitr Phol Sugar Co., Ltd.

Starch gel preparation

The preparation method of starch gel followed in Tatirat and Charoenrein (2007). Rice starch suspensions (8% w/w) containing 0%, 10% and 20% w/w sucrose were heated range to 80-83 °C in water bath and continuous stirring at 200 rpm for 25 min. The starch suspensions of 10 mL were placed into syringes (20 mm diameter) and steamed for 9 min. Subsequently, samples were placed in incubator at 25 °C for 2 h.

Freezing and thawing

Starch gel samples were frozen in a chest freezer (Sanyo refrigerator, model SF-C1497) at -18 °C for 22 h and then thawed at 30 °C for 2 h. This freeze-thaw cycle was repeated for up to five cycles.

Syneresis measurement

The thawed gels (three samples from each condition) were centrifuged as described by Tatirat & Charoenrein (2007). The amount of liquid separated from the gel was measured in a burette. The percentage of syneresis was then calculated as the ratio of the amount of liquid separated to the total weight of the gel before centrifugation and multiplied by 100.

Frozen structure by Scanning Electron Microscope (SEM)

The freeze-thaw samples were cut and gradually dehydrated in 50, 70, 90% and absolute ethanol at room temperature for 24 h at each concentration and finally dehydrated using a critical point dryer. The cut surface samples were mounted on the stub, coated with gold and observed with a JSM-5600LV microscope (JEOL, England). The accelerating voltage and the magnification are shown on the micrographs.

Statistical analysis

We used a completely randomized design. The difference between means was determined using the Duncan News Multiple Range Test. The data in the figure were reported as the averages of triplicate observation. All data were analyzed using SPSS 12.0 for Windows.

Results and Discussion

Freeze-thaw stability

Freeze-thaw stabilities of starch gels were assessed by measuring liquid separated after freezing/thawing 1-5 cycles. The effect of sucrose on the amount of syneresis in starch gel is presented in Table 1.

Table 1 Percentage of liquid separated (syneresis) of rice starch gels (8% w/w) containing sucrose 0%, 10% and 20% at each FT cycle

Treatments	Syneresis (%)				
	Number of freeze-thaw cycles				
	1	2	3	4	5
Rice starch	44.85 aA ± 0.73	46.17 aA ± 1.58	42.16 aB ± 0.57	42.13 aB ± 0.70	40.64 aB ± 0.11
Rice starch + 10% sucrose	5.42 bE ± 0.54	12.64 bD ± 0.84	19.73 bC ± 1.49	23.32 cB ± 2.44	29.40 bA ± 2.62
Rice starch + 20% sucrose	0.49 cC ± 0.02	1.32 cC ± 0.69	16.76 cB ± 0.55	28.33 bA ± 1.43	28.40 bA ± 3.80

a-c Mean values in each column with different superscripts are significantly different ($p \leq 0.05$).
A-E Mean values in each row with different superscripts are significantly different ($p \leq 0.05$).

In the first to fifth cycles, the analysis of variance shows that rice starch gels containing 10% and 20% sucrose most significantly ($p \leq 0.05$) affects the percentage of syneresis of rice starch gels. Rice starch gels without sucrose showed a considerable amount of syneresis, discharging more than 40% after 1-5 FT cycles. Rice starch gels with sucrose addition showed obviously lower in %syneresis. The higher concentration of sucrose added, the less %syneresis.

It is well known that when a starch gel is frozen, starch-rich regions are created in the matrix, where water remains partially unfrozen. High solid concentration in the regions facilitates the starch chains to associate forming thick filaments, whereas water molecules coagulate into ice crystals forming a separated phase. These effects contribute to spongy structure and released liquid or syneresis (Ferrero et al., 1993; Lee et al., 2002), which can be reduced by adding sucrose. We assumed that sucrose probably affected the syneresis by sucrose hydrated water in system leading to lower frozen water content and consequently reduced %syneresis.

Scanning electron microscopy

This experiment was aimed to investigate the effect of sucrose on morphology of rice starch gels. Along with syneresis, a thick fibrillar network of starch gel was formed in the spongy structure during the repeated FT cycles (Ferrero et al., 1993). In Fig. 1, scanning electron micrographs of rice starch gel revealed the gel matrix was changed by the sucrose addition. The matrix surrounded the pores in the starch gels containing sucrose was thicker than the starch gels without sucrose (Fig. 1a, 1c and 1e). At 20% sucrose systems, the matrix surrounded the pores was thickest. However, when the number of freeze-thaw cycles increased, the matrix surrounded the pores in the starch gels was thinner and more compact. Furthermore, the starch gels had a spongy structure, and that this phonemenon was related to amylose retrogradation.

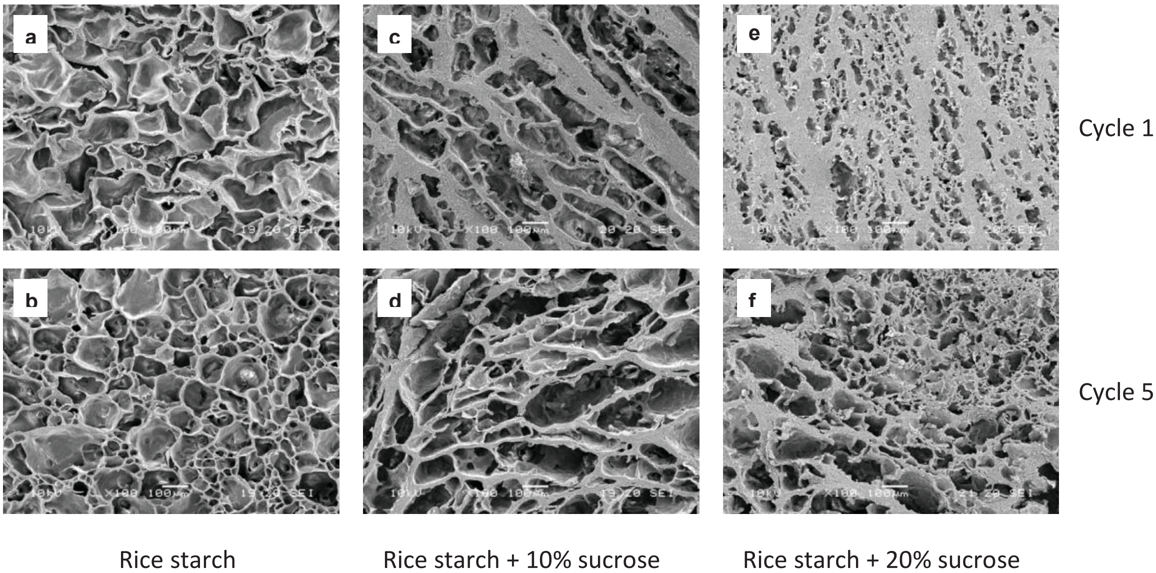

Fig. 1. SEM micrographs of rice starch gels (8% w/w) containing sucrose 0%, 10% and 20% after freeze-thaw for 1 and 5 cycles (100x, Bar = 100 µm).

The microscopic observations showed that sucrose affected the morphology of rice starch gels because sucrose could maintained the matrix surrounded the pores in the starch gels. The pores created by ice crystals in the frozen state can be seen after the ice had melted. We were hypothesized that sucrose hydrated water in system leading to lower frozen water content. Thus, the pores size resulted from ice crystals formation were smaller. These results were correlated to syneresis data.

Conclusion

The addition of sucrose was effective in reducing the syneresis and this effect increased with increasing sucrose concentration. In this work, sucrose was most effective in enhancing freeze-thaw stability of starch gels at 20%. Therefore, sucrose could retard changing of texture in rice starch gel to spongy structure during repeated freeze-thawing.

Acknowledgements

We gratefully acknowledge the Thailand Research Fund - Master Research Grants (TRF-MAG) under the Project No. MRG495S024 and Kasetsart University Research and Development Institute (KURDI), under the SRU-FPF project. The authors also thanks Choheng Co., Ltd. for donating rice starch.

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