Carbohydrate Polymers 83 (2011) 291–296

Contents lists available at ScienceDirect

Carbohydrate Polymers

journal homepage: www.elsevier.com/locate/carbpol

Effect of konjac glucomannan on syneresis, textural properties and the microstructure of frozen rice starch gels

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ARTICLE INFO

Article history:
Received 23 May 2010
Received in revised form 6 July 2010
Accepted 29 July 2010
Available online 6 August 2010

Keywords:
Konjac glucomannan
Freezing
Texture
Rice starch
Retrogradation
Microstructure
Syneresis

ABSTRACT

Repeatedly frozen and thawed rice starch gel loses quality. This study investigated how incorporating konjac glucomannan (KGM) in rice starch gel affects factors used to measure quality. When rice starch gels containing 0–0.5% KGM were subjected to 5 freeze–thaw cycles KGM reduced the % syneresis and moderate increases in gel hardness. SEM of freeze–thaw gels showed starch gel with KGM had smaller pores and less well-defined surrounding matrices than those without KGM. Moreover, CLSM of unfrozen gels without KGM showed densely aggregated swollen starch granules while those in gels with KGM were more evenly distributed. Furthermore, starch pastes with KGM showed higher viscosities than paste without KGM suggesting KGM inhibited granule association. These results suggest that KGM retards rice starch gel retrogradation induced by freeze–thaw treatment and that KGM is effective in preserving quality in freeze–thaw rice starch gels.

1. Introduction

As demand for ready-to-eat food products increases, a variety of new frozen foods are continually launched into world markets. Upon freezing, however, water in the food is transformed into ice and, as the ice separates out, the concentration of the unfrozen phase in contact with the ice increases. Both the ice formation and the increasing concentration of the unfrozen component result in physical stress on the food matrix (Reid, 1999; Reid, Kerr, & Hsu, 1994). When this frozen food is thawed for consumption, the moisture readily separates from the matrix and causes a change in the texture, drip loss, and often deterioration in overall quality (Rahman, 1999).

Starch-based frozen food products undergo textural changes related to amylose and amylopectin retrogradation and show syneresis after thawing. These changes attributed to starch retrogradation (Ferrero, Martino, & Zaritzky, 1994; Jacobson & BeMiller, 1998; Varavinit, Anuntavuttikul, & Shobsngob, 2000) may make such products unacceptable to consumers (Ferrero, Martino, & Zaritzky, 1993).

Hydrocolloids are commonly used to improve the texture and rheological properties of starch-based products (Shi & BeMiller, 2002) because, through the use of small quantities of hydrocolloids (Mali et al., 2003), products can be modified to have a higher viscosity and undergo less syneresis. Furthermore, hydrocolloids reduce starch retrogradation and improve gel stability in frozen starch gel systems (Ferrero et al., 1994; Lee, Baek, Cha, Park, & Lim, 2002). Ferrero et al. (1994) report that adding xanthan gum to corn starch pastes minimizes amylose retrogradation, syneresis and rheological changes after freezing. In addition, guar gum and locust bean gum were found to reduce syneresis in freeze–thaw corn starch and waxy *Amaranthus paniculatus* starch (Sudhakar, Singhal, & Kulkarni, 1996). In both of these studies, the authors base their conclusions on pasting properties and rheological data and they attribute this reduction to a slowing of retrogradation brought about by an interaction between the hydrocolloid and amylose. In another study, Ferrero and Zaritzky (2000), using oscillatory rheological measurements and visual observation, reported that the hydrocolloid might interact with amylose released outside the starch granule, inhibiting the development of a spongy matrix.

Konjac glucomannan (KGM) is a hydrocolloid obtained from the tubers of *Amorphophallus konjac* C. Koch. KGM is comprised of blocks of β-1,4-linked mannosyl and glucosyl residues, with approximately 5–10% acetylation. It has been recognized as GRAS (generally recognized as safe) by a consensus of scientific opinion since 1994 (Khanna & Tester, 2006; Takigami, 2000). The effects of KGM on gelatinization and retrogradation of maize starch (Yoshimura, Takaya, & Nishinari, 1996), and its effects on the rheological properties of maize starch gels (Bahnassey & Breene, 1994;

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doi:10.1016/j.carbpol.2010.07.056

Fanta & Christianson, 1996; Shelso, 1990; Yoshimura, Takaya, & Nishinari, 1998) have received the most recent attention.

No reports are as yet available on the use of hydrocolloids to reduce changes in frozen rice starch gel nor on the use of confocal laser scanning microscopy (CLSM) and scanning electron microscopy (SEM) techniques to study the gel's microstructure in order to understand the effect of the hydrocolloids on rice starch gels. Therefore, the objective of this study was to determine the effect of KGM in frozen rice gels by investigating their syneresis, textural changes and the correlation between these two properties. In addition, the microstructure of unfrozen and freeze–thaw gels were studied in order to gain a greater understanding of the interaction between KGM and starch. This research will make a contribution toward the improvement in the quality of frozen rice-based products.

2. Materials and methods

2.1. Materials

Rice starch was supplied by Choheng Rice Vermicelli Co., Ltd., Nakornpathom, Thailand. The amylose content and moisture content of rice starch was 31.58% and 11.41% respectively (AACC, 2000). Purified KGM (KGM ≥ 90%) was purchased from Diethelm Co., Ltd., Bangkok, Thailand.

2.2. Sample preparation

A rice starch suspension (8.0% (w/w) total solids) was prepared by stirring rice starch and water continuously at 250 rpm for 60 min. The suspension was gelatinized by placing it in a water bath at 80 °C for 25 min with continuous stirring at 200 rpm. Ten ml samples were then loaded into syringes (25 ml with a 20 mm diameter) and steamed for 9 min. Finally, the samples were placed in an incubator at 25 °C for 120 min.

Suspensions containing 0.3% and 0.5% KGM (8.0% (w/w) total solids) were prepared in two steps. KGM was sprinkled into 75% of the total suspension volume of water at room temperature and the mixture was stirred at 250 rpm for 120 min. The rice starch was suspended in the remaining 25% of the total suspension volume of water and was then added to the KGM solution. Both rice starch suspensions containing KGM (0.3 and 0.5%) were gelatinized using the same process as was used for the control rice starch suspension. Each experiment was repeated twice.

2.3. Freezing and thawing

Starch gel samples were frozen in a chest freezer at −18 °C for 22 h and then thawed at room temperature (25 ± 2 °C) for 120 min. This freeze–thaw cycle was repeated for up to 5 cycles. After thawing, gels were removed from the syringes prior to performing the following tests.

2.4. Syneresis measurement

Syneresis measurements followed the method of Charoenrein, Tatirat, and Muadklay (2008). The thawed starch gel samples were removed from their syringes and put in a cylindrical plastic tube with a perforated bottom which was covered with filter paper (Whatman No. 41). These tubes were then placed in centrifuge tubes and centrifuged at 100 × *g* (centrifuge CN-1050, MRC Ltd., Holon, Israel) for 15 min. The cylindrical plastic tube with cover was removed from the centrifuge tube, and the liquid which had separated from the starch gel was weighed. The percentage of syneresis was then calculated as the ratio of the weight of liquid separated from the gel to the total weight of the gel before centrifugation and multiplied by 100. The data were reported as the average of five measurements.

2.5. Determination of the microstructure of frozen starch gel with SEM

The freeze–thaw rice starch gels with and without KGM 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 a stub, coated with gold and observed using a JSM-5600LV microscope (JEOL, England). The accelerating voltage and the magnification are shown on the micrographs.

2.6. Determination of the microstructure of unfrozen starch gel with CLSM

The unfrozen rice starch gels with and without KGM were cut into sections of 1–3 mm thickness using a razor blade. The sections were stained by immersion into FITC-dextran (fluorescein isothiocyanate dextran 0.01% (w/v) in distilled water) for 2 min followed by rinsing in distilled water for 3 times. The sample was mounted in a slide well and covered with a cover glass. Images were recorded using a confocal laser scanning microscope (Axio Imager MI, Carl Zeiss PTe Ltd., Germany). A HeNe laser with an excitation wavelength of 488 nm was used. CLSM digital images were acquired using the LSM 5 PASCAL program.

2.7. Pasting profile

The pasting properties of rice starch suspension (8%, w/w) with 0, 0.3 and 0.5% KGM were determined using a Rapid Visco-Analyzer (model RVA-4C, Newport Scientific Pty. Ltd., Warriewood, Australia). The slurry was held at 50 °C for 1 min, heated to 95 °C at a constant rate of 12 °C/min and then held at 95 °C for 2.5 min. It was subsequently cooled to 50 °C at the same rate and then held at 50 °C for 2 min. The data were reported as the average of triplicate measurements.

2.8. Texture measurement

The thawed rice starch gel was transferred from the syringe into a rectangular mold approximately 150 mm × 40 mm and 30 mm deep which had a gap for sample cutting and the middle of the gel was cut into a sample 20 mm in length. The texture was determined using the Texture Profile Analysis method (five replicates per treatment) with a Stable Micro System (TA-XT plus) Texture Analyzer. Samples were compressed with a 100 mm diameter probe at a test speed of 0.5 mm/s. The deformation level was 60% of the original sample height and the gels were compressed twice. Hardness was expressed as the maximum force exerted during the first compression cycle.

2.9. Statistical analysis

We used a completely randomized design. The difference between means was determined using the Duncan's new multiple range test. All statistical analyses were performed using SPSS 12.0 for Windows.

3. Results and discussion

3.1. Percent syneresis

The determination of % syneresis from freeze–thaw starch gels is used to evaluate the ability of starch to withstand the undesirable