EFFECT OF SUCROSE AND SODIUM POLYPHOSPHATE ON RETROGRADATION OF RICE STARCHES

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ABSTRACT

Starch retrogradation is a process occurred in many food products made from starch-containing raw materials. It affects qualities of food during storage. In this research, the effects of sucrose and phosphate on rice starch retrogradation were studied. Experiments were conducted with sucrose content ranged from 1\(\text{–}5\)% (w/w) and sodium polyphosphate – from 0.1\(\text{–}1\)% (w/w). Results showed that sucrose and polyphosphate reduced the syneresis of starch gel 1.19 - 1.44 and 4.6 - 4.87 times respectively. Both substances reduced the hardness of starch gel, but sucrose reduced the stickiness while polyphosphate increased stickiness of rice starch gel.

Keywords: hardness, stickiness, sodium polyphosphate, sucrose, starch retrogradation.

1. INTRODUCTION

Rice is common food that is widely consumed in the world, especially in Asia as a cooked whole grain in hot meals or prepared dishes, which then are stored cooled or frozen. Because of high amount in grain constituents, starch properties strongly determine the texture of rice starch-containing products.

Starch retrogradation is the phenomenon that gelatinized starch changes from an initially amorphous state to a more ordered or crystallized state. These changes are manifested by different processes, which include helix formation and helix-helix aggregation. Displacement and variable process of the free or linking state of water in the starch constituents are two of the most important factors in controlling structural change [1]. This is a phenomenon, which is undesirable to the starch-containing products, resulting in many unwanted effects on some starch-containing products as they need to be preserved, stored for a long time.

Factors other than the starch components themselves are also very important, such as the water content of the gel and the storage temperature which affect the rate and extent of
retrogradation [2]. Solute such as sugars, salts, surfactants, antioxidant, etc... affect the retrogradation of starch gel by their anti-plasticizing effect, compared to water alone. They reduce the mobility of the chains in the amorphous matrix [2, 3]. There were many studies about the effects of sugar and salt on starches during thermal processing around the world. Sugar slowed the retrogradation of potato starch [4], prevents the retrogradation of rice starch [5]. Besides, salt increased the retrogradation of corn starch and rice starch [6, 7]. In Vietnam, there were very few studies on starch retrogradation. In 2013, Luong Hong Nga reported that temperature, time, pH and amylose content affected the ability of the retrogradation as well as the texture of the rice starch gel [3]. In this study, we focused on the effect of sugar and sodium phosphate on the retrogradation based on starch syneresis and gel texture change of rice starch.

2. MATERIALS AND METHODS

2.1. Materials

Four rice varieties Nep Cai Hoa Vang, Bac Huong, Tap Giao and Q5 of 2012 summer-winter season were purchased at Vietnam Agricultural Science Institute. Sucrose was supported by Lam Son Sugar Company. Sodium polyphosphate (food grade) was supported by Ba Dinh Company.

2.2. Rice starch isolation

Starches were isolated from rice kernels according to Yang C-C et al. [8]. Rice was soaked in NaOH 0.01 N in 24 h to soften the kernels. After soaking, rice kernels were washed by clean water before milling to break the cell and to release starches. The starch slurry was passed though N°200 sieve to remove the pulp. The starch milk was centrifuged 2 times in alkaline solution, then it was neutralized by HCl 0.1 % and refined by distilled water for several times. Pure starches were dried at 40 °C in 24 h.

2.3. Starch syneresis was determined according to Amani N’G.G [11] with small modification. Pastes of starches were prepared by cooking starch slurries (6 % db, w/w) in water. Starch pastes were frozen at -18 °C when another were held at 4 °C, 12 °C in 24 h. The starch syneresis was evaluated by measuring the percentage of syneresis by centrifugation at 6000 rpm for 15 min. after thawing at room temperature for refrigerated sample and at 50 °C in water bath for 90 min. for frozen sample.

2.4. Starch gel texture

Texture of the starch gel was determined by method of Yibin Z. et al. [Error! Reference source not found.] using a texture analyser TA.XT Plus (Stable microsystem, UK). The starch gel was prepared by totally gelatinizing 8 % (db w/w) starch dispersion in distilled water. The gelatinized starch was poured into a PVC cup of 3.5 cm in diameter and 4 cm in height, which was then sealed and stored at defined different temperatures in defined different period of time. After storage, the gel was compressed by P/25 probe, trigger force 5 g, pre-test speed of 10 mm/s, test speed of 1 mm/s, post test speed of 5 mm/s. The gel texture parameters recorded were the peak force at maximum compression expressed in g and the peak area under the axis expressed in g.mm. The results were calculated from 5 replications per sample.

2.6. Data analysis
All the experiments were at least triple and calculated the mean value. Statistical analysis was carried out by ANOVA with 95 % (p < 0.05) by Microsoft Excel 2010 and SPSS 17 software.

3. RESULTS AND DISCUSSION

3.1. Effect of sucrose on rice starch retrogradation

The effects of sucrose on rice starch retrogradation were evaluated by two parameters: starch syneresis and gel texture.

3.1.1. Effect of sucrose on rice starch syneresis

The changes of rice starch syneresis in the presence of sucrose are presented in Figure 3.1 a, b. From Fig. 3.1, it is shown that the rice starch syneresis decreased when increasing sucrose concentration at 4, 12 and -18°C. Gels of sticky rice starch (Nep cai hoa vang) stored at 4 °C and 12 °C synered no water when adding low sugar concentration (1 % w/w). At -18 °C, starch syneresis of Bac Huong rice variety reduced from 1.60 to 1.17 %, of Q5 variety reduced from 53.70 to 37.46 %, of Tap giao variety reduced from 46.18 to 36.86 %. In general, when adding sucrose, starch syneresis decreased 1.19–1.44 times as compared to non adding samples.

Sucrose is able to stabilize the starch-water system because of its structure, particularly its –OH group in the center of sucrose molecules, which can take an important part in keeping the water structure around the others water and starches molecules. The average number of –OH group in the center plays an important role in balancing, transferring and the biochemical characteristics of sucrose solution [5]. Sucrose penetrates in the crystalline regions, which was melted in the gelling process and the links with sucrose are formed in both crystalline region and amorphous region in gelatinizing process. When starches gel is cooled, the starches molecule become less flexible, the hydrogen bonds among starches molecules become more stable. This process relates to the recrystallization of starches molecules, which is called retrogradation process. When adding sucrose to the starches-water-sucrose system, sucrose molecules prevent hydrogen bonds among starch molecules, therefore, it makes starches gel more stable, retards the retrogradation of starches. In general, factors influencing starch retrogradation in sugar solution included: 1. Sugar-water interactions, resulting in a decrease in water activity and the amount of water available for retrogradation. 2. The plasticizing effect of sugar-water sosolutes, which may
increase the free volume of water available to starch molecules, consequently leaded to the dilution of starch components available for retrogradation. Sugar-starch interactions, which gave an antiplasticising effect by reducing the mobility of starch molecules. It has been recognized that amylose and amylopectin were respectively responsible for short-term and long-term re-crystallisation, and cooperatively form the continuous and dispersed phased in the starch gel composite. The actions of sugars and maltodextrins on retrogradation were complicated and may proceed through modification of the interactions between starch molecules within these two phases.

3.1.2. Effects of sucrose on gel texture of rice starch

Effects of sucrose on rice starch gel structure are presented in Fig. 3.2a, b. Results in Fig. 3.2a, b showed that when adding sucrose, rice starch gel texture changed during storage in comparison with the non-adding sucrose sample. At 4 °C, gel hardness of Nep Cai Hoa Vang starch reduced from 0.23 g to 0.01 g when sucrose concentration was up to 5%, reduced 20 times as compared with non-adding sample. The hardness of Bac Huong and Q5 starch gels decreased 9 - 10 times while those of rice Tap Giao starch gels decreased 1.6 times when sucrose was added to 1% and it was an unprecedented change when sucrose was added from 1% to 5%. The stickiness of starch gel slightly increased when a low concentration of sucrose was added (1%) and decreased when the sucrose increased more than 3%. Gel stickiness decrease to zero when the addition sucrose in Tap Giao starches is 5% and Q5 starches is 3%. The stickiness of Nep Cai Hoa Vang and Bac Huong starches decrease 1.5 - 1.7 times when sucrose was added to 5%. That may be caused by the difference in structures and ingredients of starches of the different rice varieties. There was similar phenomenon occurred at freezing temperature -18°C. Therefore, adding of sucrose made the hardness of gel decreased. The higher storage temperature was, the weaker gel texture was.

It caused by the rearrangement of starches molecules in the gel during storage. In the armophous state, gel texture became soft. After starch molecules rearranged, they tend to crystallize, causing water separation and harder gel. The added sucrose molecules stabilized starches gel system, prevented the recrystallization of starch molecules, so that water separation decreased, starches gel became softer. At 12 °C, rice starch gels had worse texture than those at 4 °C and -18 °C, so that their texture couldn’t be determined by texture analyser as gel which stored at lower temperatures conditions.
3.2. Effects of sodium polyphosphate on rice starch gel

3.2.1. Effects of sodium polyphosphate on rice starch syneresis

The effects of sodium polyphosphate on rice starch syneresis are presented in Figure 3.3a, b. It is clearly seen from Figure 3.3 that water amount released from retrogradated rice starch gel network decreased when increased sodium polyphosphate amount. Nep Cai Hoa Vang starch gel released no water when adding 0.1 % at 4 °C and 0.3 % at -18 °C of sodium polyphosphate respectively. Rice starch gel syneresis reduced 4.6 to 8.7 times when adding sodium polyphosphate, faster then when adding sucrose which reduced 1.19–1.44 times.

![Figure 3.3. Effects of sodium polyphosphate on rice starch syneresis. a) -18 °C, b) 4 °C.](image)

Thus, it were indicated that similarly to sucrose, sodium polyphosphate reduced the rice starch syneresis. Phosphate salts were the anion salt, which played a role as gelatinizing inhibitor because they prevent the swelling to starch by breaking the hydrogen bonds between fractions inside rice starch molecules [14, 15].

3.2.2. Effects of sodium polyphosphate on rice starch gel texture

![Figure 3.4. Effects of sodium polyphosphate on rice starch gel texture. a) Hardness, b) Stickiness](image)
Beside syneresis, the effects of sodium polyphosphate on rice starch gel texture were presented in Fig. 3.3a, b. Fig. 3.3a indicates that adding sodium polyphosphate reduced the hardness of rice starch gels. Gel hardness declined from 1 to 2.49 times as compared to the on adding sample. The lowest effects were seen on gel of Nep Cai Hoa Vang variety, when the gel hardness reduced from 0.29 to 0.2 g (1.07 times) at -18 °C and from 0.23 to 0.17 g (1.20 times) at 4 °C. The highest effects were on Q5 variety (at 4 °C, gel hardness decreased 2.49 times) and on Bac Huong variety (at -18 °C, gel hardness reduced 2.45 times). It was due to the higher amylose content of Q5 and Bac Huong varieties and the very low content of amylose in Nep Cai Hoa Vang variety, which was the main component that determine the retrogradation properties of starch by their association and crystallization during storage.

Moreover, adding sodium polyphosphate increased the rice starch gel stickiness except that of Nep Cai Hoa Vang starch of which the gel stickiness decreased from -0.045 to -0.015 g.mm\(^2\). This was different effect as compared with that of sucrose.

4. CONCLUSION

In conclusion, sugar and sucrose reduced the rice starch retrogradation. Sucrose decreased the rice starch syneresis from 1.19 to 1.44 times as compared with non adding sucrose sample. Adding sodium polyphosphate to < 1% lead to the reduction of rice starch syneresis from 4.6 to 8.7 times. Both sucrose and sodium polyphosphate decreased rice starch gel hardness. The hardness of gel adding with sucrose reduced from 9 to 10 times, while that with sodium polyphosphate reduced from 1 to 2.49 times. Gel stickiness decreased when adding sucrose while increased when adding sodium polyphosphate. In general, sodium polyphosphate was more effective in preventing rice starch retrogradation.

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TÓM TÁT

ÂNH HƯỞNG CỦA DƯỠNG SUCROSE VÀ NATRI POLYPHOSPHATE ĐẾN SỰ THOÁI HÓA TINH BỘT GẠO

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Hiện tượng thोái hóa là hiện tượng xảy ra trong các sản phẩm có nguồn gốc tinh bột. Trong nghiên cứu này, chúng tôi đã tiến hành nghiên cứu sự chống thôái hóa của chất điện ly d denial các loại thôai hóa gạo trong các nước. Nghiên cứu đã tiến hành thí nghiệm với hai chất là dung dịch saccarose (1,5 %, w/w) và muối natri polyphosphate (0,1–1 %, w/w). Kết quả thu được cho thấy đường và muối này có tác dụng làm giảm sự thôai hóa của gel tinh bột. Dung dịch saccarose cho lượng nước tách ra giảm từ 1,19–1,44 lần khi bô sung 5 %. Với hàm lượng bổ sung thấp hơn, 1 %, muối natri polyphosphate cho lượng nước tách ra giảm 4,6–8,7 lần, cao hơn khi sử dụng đường. Cả hai chất bô sung đều làm giảm độ cứng của gel tinh bột. Gel có bổ sung đường có độ cứng giảm từ 9–10 lần khi gel bô sung muối cho độ cứng giảm từ 1–2,49 lần. Độ dính của gel sủ dụng đường giảm so với mẫu dính của gel tuyến bột. Độ dính của gel sủ dụng đường giảm so với mẫu dính của gel tuyến bột. Độ dính của gel sủ dụng đường giảm so với mẫu dính của gel tuyến bột.

Từ khóa: độ cứng, độ dính, natri polyphosphate, saccarose, thôái hóa tinh bột.