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Research Article

Study on Influential Factor of Texture Property of Sweet Potato Starch Gel

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Abstract: Sweet potato starch gel was prepared with thermal induction and the gel formation conditions were obtained by investigating the effects of starch concentration, pH value, heating temperature and time on gel hardness and elasticity. Furthermore, the effects of metal ions, such as K^+, Mg^{2+}, Ca^{2+} and Zn^{2+}, on gel texture properties were explored. The result revealed that the formation conditions of sweet potato starch gel were listed as following: starch concentration of 8.0 g/100 mL, pH value of 8.0 and heating for 20 min at 90°. Low concentration of K^+, Mg^{2+} and Ca^{2+} could promote the gel formation. Within the concentration range of 0.15-0.45 mol/L, the gel hardness and elasticity would enhance with the increase of Zn^{2+} concentration.

Keywords: Gel hardness, gel elasticity, metal ion, sweet potato starch gel, texture property

INTRODUCTION

As a kind of therophytes, the sweet potato is also known as ipomoea and belongs to the convolvulaceous ipomoea. Besides, its cultivated area in China accounts for approximately 65% of the area around the world (Lee and Yoo, 2011; Noda *et al*., 1992). The sweet potato possesses a high productivity but low processing and utilization rate, which is mainly applied in fresh eating and livestock feed. With abundant starch content, the sweet potato becomes one of the major sources of starch industry and food industry. Therefore, extracting sweet potato starch and developing related products are main approaches to effectively elevate the sweet potato's economic value added (Jangchud *et al*., 2003; Tia *et al*., 1991; Raouf *et al*., 1974). However, its application is restricted due to the following defects: native starch does not dissolve in cold water, it's easy to be aging after starch dextrinization and it has a poor characteristic of capsula and lacks emulsifying ability (Lee *et al*., 2002; Do *et al*., 2012). Under the condition of heating, the micromolecular amylose can be dissolved out, while in the cooling process, the amylose gradually forms a three-dimension network structure, in which the amylose and other macromolecular substances are fastened and thus thermal gels are formed (Martínez *et al*., 2015; Abegunde *et al*., 2013). Texture property, which determines consumer's sensory evaluation of food, is very important parameter of food quality assessment as well as significant factor of influencing consumer's choice of food (Krystyjan *et al*., 2015; Dhillon and Seetharaman, 2011). In this study, the effect of gel formation conditions and metal ions on Sweet Potato Starch Gel (SPSE) texture properties was investigated with hardness and elasticity as the evaluation indexes, in order to provide a theoretical and experimental basis for the application of the SPSE in food industry.

MATERIALS AND METHODS

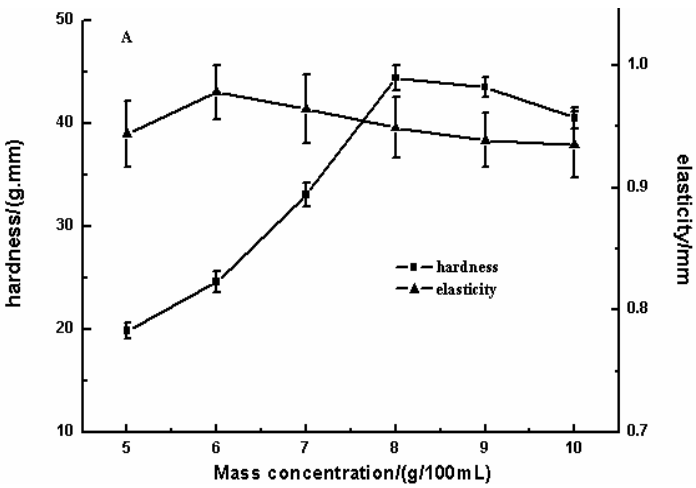
Materials and equipment: Bio-diesel, the sweet potato starch was obtained with the method of wet milling extraction (Tian *et al*., 1991; Abegunde *et al*., 2013). TA. XT. Plus. Texture Analyzer was purchased from Stable Micro Systems (Britain).

GEI preparation: Weigh a certain amount of sweet potato starch and place in a 50 mL beaker. Add deionized water, stir evenly and heat on a thermostat water bath for a specified time with continuous stirring. And then, cool for 24 h at 0-4°C. Finally, adopt Texture Analyzer to determine texture properties (Do *et al*., 2012; Dhillon and Seetharaman, 2011).

Determination of texture property: TPA operation mode was adopted with a P/0.5 Diameter Cylinder Probe. Speed before the test was 5.00 mm/s with a triggering force of 5.00 g and a test speed of 1.00 mm/s. The speed after the test was 5.00 mm/s and the number of cycles was 2 (Mandala *et al*., 2002; Maria and Maria, 1998).

RESULTS AND DISCUSSION

Mass concentration: Under the pH of 6.0, heating temperature of 95°C and heating time of 10 min, the SPSE was respectively prepared with the mass concentrations of 5.0, 6.0, 7.0, 8.0, 9.0 and 10.0 g/100 mL. The effect of mass concentration on gel hardness and elasticity was presented in Fig. 1a.



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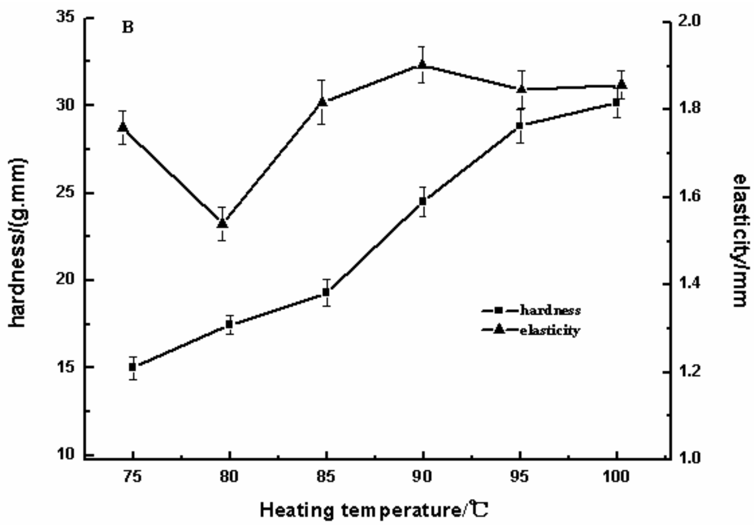

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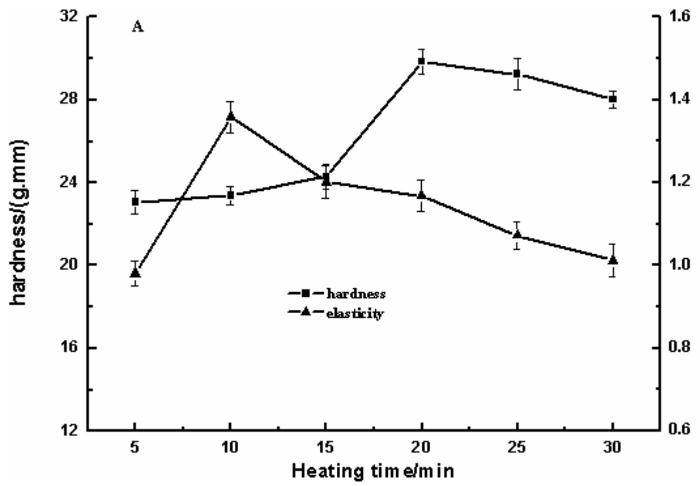
Fig. 1: Effect of starch concentration and temperature on texture property of sweet potato starch gel

From the analysis of Fig. 1a, it can be known that within the range of 5.0-8.0 g/100 mL, gel hardness increases with the rise of mass concentration. After that, gel hardness decreases slightly as mass concentration continuously rise. The elasticity curve becomes flat, which shows that the effect of mass concentration on the gel elasticity is not obvious. This is mainly because as the sweet potato starch concentration increases, the probability of intermolecular contact increases and total intermolecular force for gel formation becomes larger. Consequently, gel network structure is more compact and gel hardness is greater. This feature is consistent with the following phenomenon, namely, gelatin and sodium alginate gels hardness increases with the rise of mass concentration (Dhillon and Seetharaman, 2011; Morita *et al*., 2005). When the mass concentration is 8.0 g/100 mL, the hardness of SPSE is the highest with a good elasticity and uniform texture. Therefore, the mass concentration of 8.0 g/100 mL is appropriate.

Heating temperature: Under the mass concentration of 8.0 g/100 mL, pH value of 6.0 and heating time of 10 min, the SPSE was respectively prepared at 75, 80, 85, 90, 95, 100°C, respectively. The influence of heating temperature on gel hardness and elasticity was shown in Fig. 1b.

From the analysis of Fig. 1b, it can be known that gel hardness increases continuously with the rise of temperature. However, gel elasticity decreases firstly and then increases. After that, gel elasticity tends to be gentle and reaches maximum when heating temperature is 90°C. Heating temperature is one of the main factors effecting texture properties of starch gels. Starch molecules can fully extend under appropriate



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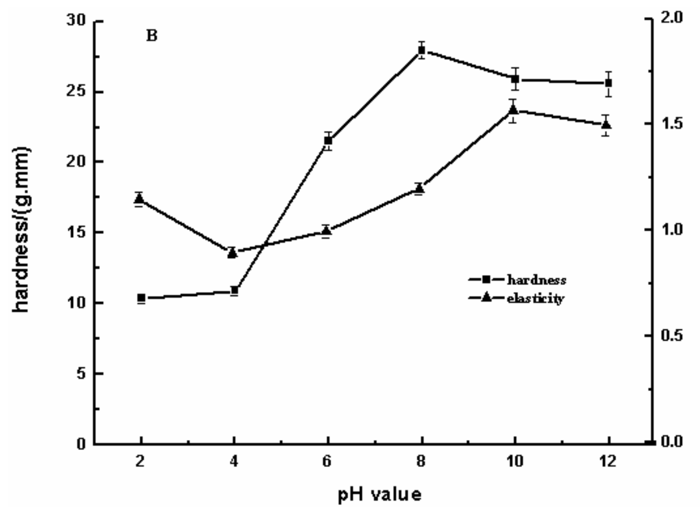


(b)

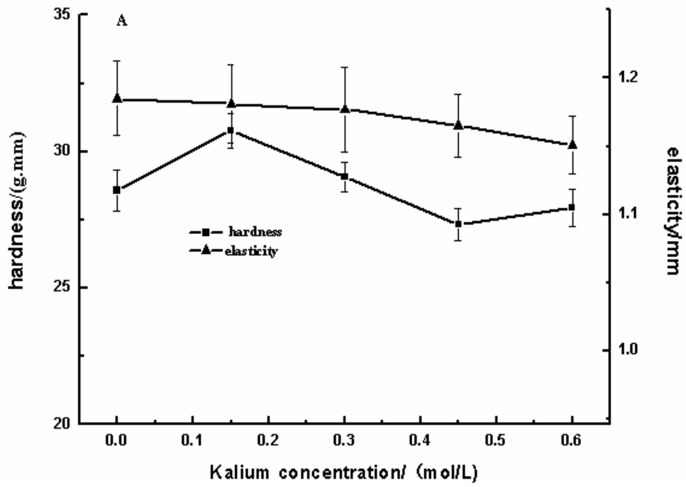
Fig. 2: Effect of heating time and pH value on texture property of sweet potato starch gel

temperature, part group is exposed and intermolecular cross-linking is produced. Therefore the bond necessary for building the gel macroscopic molecular network structure could be increased and the intermolecular force can be enhanced, which make the gel hardness increase and the elasticity improve (Yang *et al*., 2014; Albano *et al*., 2014). Taking the gel hardness and elasticity into account, heating temperature of 90°C is appropriate.

Heating time: Under the mass concentration of 8.0 g/100 mL, pH value of 6.0 and heating temperature of 90°C, the SPSE was respectively prepared with the heating time of 5, 10, 15, 20, 25, 30 min. The influence of heating time on the gel hardness and elasticity was shown in Fig. 2a.

From the analysis of Fig. 2a, it can be known that short heating time has no significant effect on the gel hardness. The hardness rises rapidly after 15 min and decreases slightly after 25 min. However, short heating time is beneficial to gel elasticity and the elasticity is gradually decreased after heating for 15 min. The possible cause is that within a certain range, the sol state of starch molecules turns into pre gel state as time increases and the gel hardness increases due to unfolded molecules, exposed functional groups, reasonable and compact arrangement between molecular chains and continuously increased intermolecular binding force (Dhillon and Seetharaman, 2011; Leelayuthsoontorn and Thipayarat, 2006). Taking the gel hardness and elasticity into consideration, heating time of 20 min is appropriate.

pH value: Under the mass concentration of 8.0 g/100 mL, heating temperature of 90°C and heating time of 20 min, the SPSE was respectively prepared at pH



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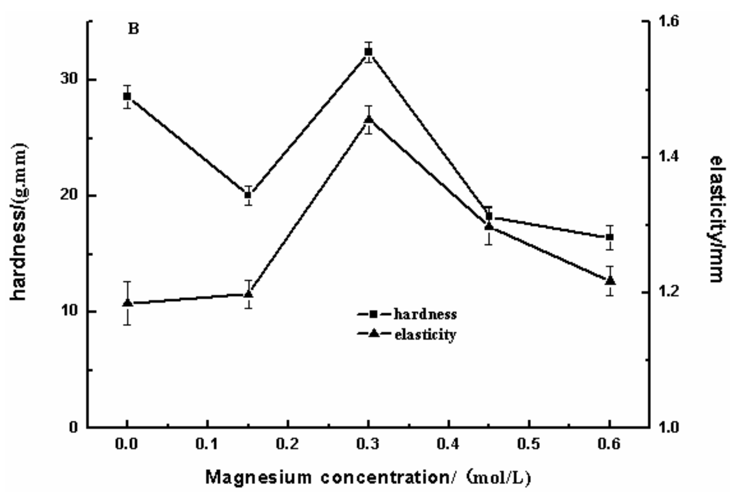


(b)

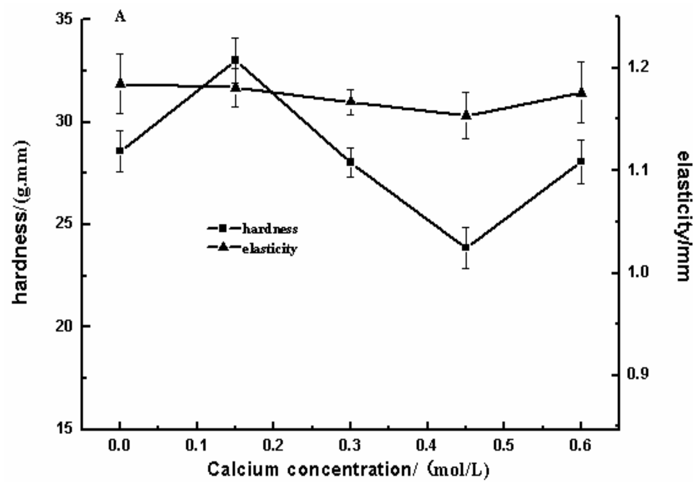
Fig. 3: Effect of kalium and magnesium ion concentration on texture property of sweet potato starch gel

values of 2.0, 4.0, 6.0, 8.0, 10.0 and 12.0. The influence of pH value on the gel hardness and elasticity was shown in Fig. 2b.

pH value significantly influence the properties of thermally induced gel by adjusting the balance of nonpolar and polar residues. It can be known from the analysis of Fig. 2b that the hardness and elasticity of SPSE are dissatisfactory ivory-white and opaque under the condition of strong acid (pH 2.0-4.0), on a declining curve under strong alkali (pH 10.0-12.0), but rising fast under pH 6.0-8.0. The possible cause of this result may be that under the condition of strong acid or alkali, the content of polysaccharide molecules falls, meanwhile intermolecular hydrogen bonds are damaged because of sweet potato starch hydrolyzing. However, the gel hardness and elasticity corresponding increase due to tightly molecules cling when pH value close to neutral (Qin *et al*., 2015; Liu *et al*., 2010). Considering the gel hardness and elasticity, the pH value of 8.0 is appropriate.

Kalium: To investigate the effect of different metal ions on texture properties of SPSE, KCl, $MgCl_2$, $CaCl_2$ and ZnCl2 of 0.15, 0.30, 0.45, 0.60 mol/L were, respectively added under the mass concentration of 8.0 g/100 mL, pH value of 8.0, heating temperature of 90°C and heating time of 20 min, then the effect of various metal ions on the gel hardness and elasticity was investigated.

It can be known from the analysis of Fig. 3a that adding K^+ has no significant effect on the elasticity of SPSE and the elasticity decreases slightly with the increase of concentration. Low concentration (0.15 mol/L) of K^+ is favorable for the gel formation and the hardness is enhanced and then the hardness decreases. This may be due to the low concentration of K^+ involving in gel formation but superfluous K^+ neutralizing the charge carried by polysaccharide molecule, which weaken the intermolecular repulsion, accelerate gel aging and produce shrinking fluid leading



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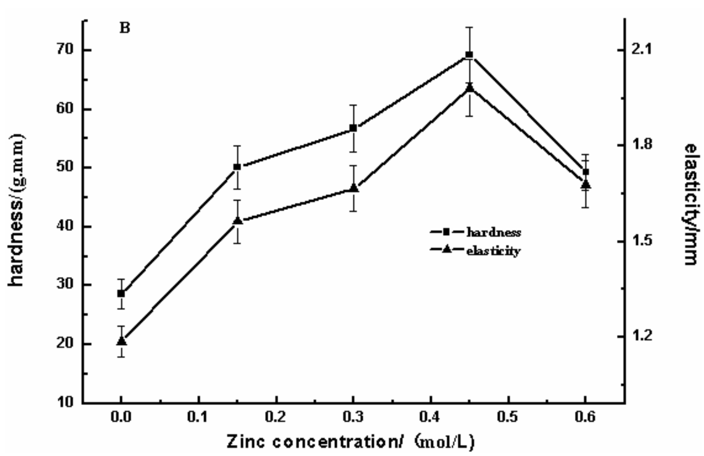

(b)

Fig. 4: Effect of calcium and zinc ion concentration on texture property of sweet potato starch gel

to the descent of hardness and elasticity (Lee *et al*., 2002; Dhillon and Seetharaman, 2011).

Magnesium: According to the analysis of Fig. 3b, it can be known that the hardness and elasticity of the SPSE decrease firstly and then increase with the increase of Mg^{2+} concentration. When Mg^{2+} concentration is 0.30 mol/L, hardness and elasticity reach the maximum and then drop rapidly, indicating that the formation of the SPSE can be promoted by low Mg^{2+} concentration (0.30 mol/L). This may be due to low Mg^{2+} concentration of 0.30 mol/L could promote the generation of hydrogen bond and ionic bond necessary for the formation of network structure, which impels the sol state to turn into a gel like state and thus improves the gel hardness and elasticity (Morita *et al*., 2005; Ramlan *et al*., 2004).

Calcium: Based on the analysis of Fig. 4a, it can be infered that adding Ca^{2+} has no significant effect on the elasticity of SPSE, while the hardness is enhanced at the low concentration of 0.15 mol/L. After that, the hardness decreases within the concentration range of 0.35-0.45 mol/L. When the concentration is up to 0.60 mol/L, the hardness and elasticity increase again, which roughly balance with 0.15 mol/L. This may be due to the fiber-bridge formation via the reaction between Ca^{2+} and starch molecule and the formation of space network structure (Yang *et al*., 2014; Tabilo-Munizaga and Barbosa-Cánovas, 2005).

Zinc: According to the analysis of Fig. 4b, it can be known that within the concentration range of 0.15-0.45 mol/L, the hardness and elasticity of the SPSE rise with the increase of Zn^{2+} concentration. However, the hardness falls rapidly when the concentration reaches 0.60 mol/L, which implies that the formation of starch gel could be promoted by Zn^{2+} within a certain concentration range. This may be owing to the increased hydrophilicity because Zn^{2+} is absorbed on the surface of starch molecules and increased interaction force between solvent molecule and starch molecule. The network is enhanced and thus the hardness and elasticity are improved. However, the hardness and elasticity of gel reduce, as high concentration of Zn^{2+} competes for water with polysaccharide molecule and the surface water film is destroyed (Choi and Kerr, 2003).

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