Food Chemistry 151 (2014) 162–167

Contents lists available at ScienceDirect

Food Chemistry

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

Effects of amino acids on the physiochemical properties of potato starch

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ARTICLE INFO

Article history:
Received 8 August 2013
Received in revised form 31 October 2013
Accepted 6 November 2013
Available online 21 November 2013

Keywords:
Amino acid
Swelling power
Solubility
Colour
Gel strength
Potato starch
Rheology

ABSTRACT

The objective of this study was to evaluate effects of different amino acid additives (phenylalanine (Phe), methionine (Met), lysine (Lys), arginine (Arg), aspartic acid (Asp) and glutamic acid (Glu)) on the physicochemical properties of potato starch gels. Charge-carrying amino acids (Lys, Arg, Asp and Glu) significantly decreased the swelling power, solubility, light transmittance, L^* value and gel strength of potato starch, but increased syneresis during freeze–thaw treatment, while neutral amino acids (Phe and Met) did not cause modifications in starch gels. During heating, potato starch with fortified charge-carrying amino acids showed a lower peak G′ (storage modulus), when compared with Phe and Met. Results showed that charge-carrying amino acids could modify physicochemical properties and improve the nutritional values of starch-based products.

1. Introduction

Starches prepared from different sources are known to have different functional properties. Potato starch has highly desirable properties for use of food processing. It contains a large amount of amylopectin, is high soluble, and has a high swelling ability, because of the weak internal organization due to the presence of negatively charged phosphate ester groups within the granule (Kim, Wiesenborn, Lorenzen, & Berglund, 1996). During heating, the starch granules absorb larger amount of water at a certain temperature ($\geqslant$50 °C) and rapidly swell, leading to collapse of the intra- and intermolecular hydrogen bonds stabilizing the crystalline structure. This process is called as gelatinization (Tester & Morrison, 1990). It is accompanied by a dramatic increase in the viscosity of starch solutions (Yang & Rao, 1998). The gelatinization and retrogradation characteristics of starch during heating and cooling are very important, since they play important roles in the texture of starch-based products. Many coexisting substances, such as amino acids and peptides (An & King, 2009; Ito, Hattori, Yoshida, & Takahashi, 2004, Ito, Hattori, Yoshida, and Takahashi, 2006; Ito et al., 2006; Li, Vasanthan, Bressler, & Tyler, 2010; Liang & King, 2003; Lockwood & King, 2008; Lockwood, King, & Labonte, 2008), can significantly influenced on the gelatinization and retrogradation behaviour of starch.

The additions of positively and negatively charge-carrying amino acids had stronger effect on pasting properties of rice starch than neutral ones (Liang & King, 2003). The charge-carrying ones decreased the cooking stability and increased the crystallinity of the rice starch, due to their charges (Liang & King, 2003). The addition of charge-carrying amino acids might probably regulate the gelatinization temperatures of potato starch (Ito, Hattori, Yoshida, & Takahashi, 2004). The gelatinization temperature of sweet potato starch increased by adding lysine (Lys) and aspartic acid (Asp) (Lockwood & King, 2008). The swelling and peak viscosity decreased when poly(ε-lysine) (PL), Lys, and monosodium glutamate (GluNa) were added (Ito et al., 2004). Glycine and alanine with zero net charge had little effect on these properties of starch. Moreover, Asp made sweet potato starch less stable during cooking and lowered its potential for retrogradation (Lockwood et al., 2008).

Amino acids can be added into food products to improve their nutritional values. Starch is one of major ingredients in food products. There were few studies about effects of amino acids on the characteristics of starch gels. Therefore, the objective of this study was to determine effects of amino acids, including phenylalanine (Phe), methionine (Met), lysine (Lys), arginine (Arg), aspartic acid

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http://dx.doi.org/10.1016/j.foodchem.2013.11.033

(Asp), and glutamic acids (Glu), on the physicochemical properties of potato starch.

2. Materials and methods

2.1. Materials

Potato starch (Xue Guan Starch Company, Ning Xia, China) was provided after drying in the oven at 50 °C for three days. Six amino acids were used, including Lys and Arg (positively charged), Asp and Glu (negatively charged), and Phe and Met (neutral) (Biosharp, Korea).

2.2. Swelling power and solubility measurement

The swelling power and solubility of starch was measured using the procedure described by (Collado, 1997). Potato starch (0.5 g) with amino acids (1%, 5% and 10% on a starch weight basis, % w/w) was suspended in a beaker with 25 mL of distilled water, and then heated in a water bath at 70 °C for 30 min with manual stirring. The control was starch sample without amino acids. After cooling to room temperature and transferring to a 50 ml centrifuge tube, the starch suspension was centrifuged at 1950*g* for 30 min at 20 °C. The resulting supernatant was placed in a petri dish and dried at 105 °C to constant weight (W_s). The precipitate was weighed (W_p) and also dried at 105 °C for 24 h to obtain a constant weight (W_d). The swelling power and solubility was calculated by the following equation:

$$\text{Swelling Power} = W_p/W_d$$

$$\text{Solubility} = W_s/0.5 \times 100$$

2.3. Transparency

Aqueous suspensions of potato starch (1%, w/w) with different levels of amino acids were placed in the beaker and heated in boiling water bath (95 °C) heating for 30 min with manual stirring. Then, fully gelatinized starch suspension was cooled to room temperature. The transmittance (%T) of samples was determined against water blank with UV/VIS spectroscopy (Lambda 35, Perkin Elmer Corp., USA) at 650 nm (Craig, Maningat, Seib, & Hoseney, 1989).

2.4. Syneresis after freeze–thaw

Potato starch pastes (3%, w/w) with different levels of amino acids were prepared by heating at 95 °C for 20 min in a water bath with manual stirring. Then the pastes were weighed (30 g) accurately into centrifuge tubes and stored in a freezer (−25 °C) for 24 h. The frozen pastes were thawed at room temperature for 6 h and centrifuged at 1950*g* for 10 min. The percentage of water separated was measured and expressed as the syneresis (%) (Schmitz et al., 2006).

2.5. Preparation of potato starch gels

Amino acids (1%, 5% and 10% on a starch weight basis, % w/w) were weighed and placed into beaker. Distilled water (50 ml) was added and then mixed with 3 g potato starch. The potato starch suspension (6%, w/w) with different levels of amino acids were obtained. The gels were prepared by heating starch suspension at 95 °C for 20 min in a water bath with manual stirring and then poured into the weighing bottle (40 mm in diameter and 25 mm in depth). The samples were sealed with plastic wrap to prevent moisture loss and stored at 4 °C overnight.

2.6. Colour measurement

Colour measurements of gels were performed in a Hunter Lab Ultra Scan XE colorimeter (Hunter Lab Co., Ltd, Reston, VA, USA) at ambient temperature. The equipment was standardized with a standard-white reflection plate (Hansen, Jackson, Wehling, Wilson, & Graybosch, 2010). The colour parameters (L^*, a^* and b^* values) were recorded. L^* is the parameter that measures lightness (0 = black, 100 = white), a^* is red or green colour (negative = green, positive = red), and b^* is blue or yellow colour (negative = blue, positive = yellow). The Hunter L^*, a^* and b^* values were determined in triplicate.

2.7. Gel strength measurement

Gel strength was measured by a TA.XTPlus Texture Analyzer (Texture Technologies Corp, Scarsdale, NY, USA) and analyses were made using return to start model with a cylindrical probe (*P*/0.5, 12.7 mm in diameter), which was programmed to move downwards for a compression ration of 40% of the original height at a speed of 2 mm/s and a pre-test speed of 1 mm/s, a post-test speed of 5 mm/s as well as a trigger force of 5 g. All measurements were carried out in triplicate. The maximum force (*N*) required to compress the sample was recorded as gel strength.

2.8. Dynamic rheological testing

Dynamic rheological testing was performed on an AR2000ex Rheometer (TA Instruments, New Castle, DE, USA) equipped with 40 mm diameter parallel plate system. The gap size was set at 1 mm. The strain and angular frequency (2% and 5 rad/s), which were obtained from stress and frequency sweep in the linear range, were set for all determination. Starch suspensions of 20% (w/w) concentration added with amino acids were loaded onto the pettier of rheometer and the outer edge of the starch suspension was covered with a thin layer of silicone oil to minimize evaporation loss. The starch samples were heated from 20 °C to 100 °C at the rate of 1 °C/min. Storage modulus (G′) was obtained.

2.9. Statistical analysis

Results of colour and TPA were reported as mean values ± standard deviation (SD). For data analysis, the analysis of variance (ANOVA) was performed using a SPSS package (SPSS 17.0 for Windows, SPSS Inc, Chicago, IL, US). Differences among the mean values of various treatments were made using Duncan's multiple range test ($P < 0.05$).

3. Results and discussion

3.1. Swelling power and solubility

Fig. 1a shows that the amino acids with zero net charge (Phe and Met) had no significant effect on swelling power of potato starch ($P > 0.05$). However, addition of charge-carrying amino acids (Lys, Arg, Asp, Glu) resulted in a decrease of swelling power of potato starch. As the concentrations of charge-carrying amino acids in starch increased, its swelling power decreased gradually. Like its swelling power, the solubility of potato starch was also decreased as the charge-carrying amino acids were added (Fig. 1b). However, there was no significant change in starch solubility ($P > 0.05$) when Phe and Met were added into starch. The solubility