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The effects of electrolysis at room temperature on retrogradation of sweet potato starch

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ABSTRACT

The effects of electrolysis at room temperature on formation of sweet potato retrograded starch were studied by photographic method in the paper. The optimal parameters of electrolytic preparation of sweet potato retrograded starch were determined. The ratio between sweet potato starch and water was 10 g/100 mL with addition of NaCl 1.0 g/100 mL, pH value of the solution was 6.0 and the solution was electrolyzed for 30 min at 90 V at room temperature, then it was stored at 4 °C for 24 h after being autoclaved for 30 min at 120 °C, the retrogradation rate of sweet potato starch at this condition was 33.1%, which is 138% higher than that of control group. Four possible reasons are put forward to explain the results.

1. Introduction

Resistant starch is now used as additive for its potential health benefit properties in foods. Resistant starch (RS) has been defined by the European Flair Concerted Action on Resistant Starch (EURESTA) as the starch or products of starch degradation that escape digestion in the small intestine of healthy individuals and may be completely or partially fermented in the colon [1]. Retrograded starch is prepared by certain heat-moisture treatments and may be present in products such as cooled, cooked potatoes and canned peas or beans [2,3]. Some authors regard that retrograded starch is obtained by retrogradation of amylose by autoclave treatment [4–6].

At present, besides autoclave method, other methods had been adapted in producing retrograded starch such as extrusion [7,8], baking [9,10], cooking [11,12], acid-hydrolysis [13] and frying [11,14]. Electrolysis can enhance the energy and electric charge of starch granules to affect surface electrical properties of starch granules, which further affects the water absorption, swelling of starch granules and retrogradation of starch. The electrolysis of starch solution was done at room temperature before pasting of starch to avoid prevention of electrolysis by gelling of starch. At the same time, the effects of electrolysis on retrogradation of sweet potato starch were also investigated by photographic method in the paper. Sweet potato starch is chosen as a material because it contains less protein and fat compared to that of potato, corn, wheat, pea and barley starch [15–20]. Electrolysis was generally used as a process for degradation [21] or oxidation [22] of carbohydrate in literatures; a very few were concerned with retrogradation of starch, and the effect of the salt electrolysis of sweet potato starch at room temperature on its retrogradation was studied in the paper.

2. Materials and methods

2.1. Materials

Sweet potato starch was purchased from Shan Dong Jin-Cheng Limited Company in Shang Dong Province, China.

2.2. Methods

2.2.1. Preparation of sweet potato retrograded starch

The sweet potato retrograded starch was prepared by the process of electrolysis (the voltage parameters were 45, 90, 135, 180, 225 V, and the duration of electrolysis treatment was 0, 30, 60, 90, 120 min at room temperature), pasting of starch (the ratio between starch and water was 10 g/100 mL, and its pH value was 6.0, the paste was heated for 20 min at 95 °C with stirring constantly), autoclaving at 120 °C for 30 min and aging at 4 °C overnight. The electrolysis of mixture of sweet potato and water was performed in a beaker (500 mL) with Pt as anode, and the spacing of 10 mm between two electrodes. During the electrochemical treatment the solution was stirred constantly at room temperature.

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2.2.2. The effects of addition of NaCl on formation of sweet potato retrograded starch

NaCl was dissolved and added in mixture of sweet potato starch and water before electrolysis at 0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6 g per 100 mL, and then the mixtures were treated same as given in Section 2.2.1.

2.2.3. Determination of retrograded starch content

Before determining the retrograded starch content, the samples were washed with excess water for 3 times so as to remove the remaining NaCl. The sweet potato retrograded starch contents were measured according to the analysis procedure provided by the Resistant Starch Assay Kit (Megazyme International Ireland Ltd. Co., Wicklow, Ireland). In brief, to each 100 mg of sample, 4 mL of mixture (pancreatic α-amylase, 10 mg/mL, and amyloglucosidase, 3 U/mL) was added and the whole was incubated in a shaking water bath with 200 strokes/min for 16 h. After incubation, 4 mL of ethanol (99%) was added and the suspension was stirred vigorously (stop reaction), and then centrifuged at 1500 × *g* for 10 min. The supernatant was removed carefully and 8 mL of 50% (v/v) ethanol was added to the residue and stirred in; this was followed again by centrifugation and removal of the supernatant. The 50% ethanol-washing step was repeated once. Two millilitres of 2 M KOH was added to the residue, with gentle stirring in an ice water bath to dissolve the residue for 20 min, at which point 1.2 M sodium acetate buffer (8 mL, pH 3.8) and amyloglucosidase (0.1 mL, 3300 U/mL) were added. Samples were incubated in the water bath (FOSS Tecator AB) at 50 °C for 30 min and centrifuged at 1500 × *g* for 10 min. To 0.1 mL of the supernatant, 3 mL of glucose oxidase–peroxidase–aminoantipyrine (GOPOD; >12,000 U/L glucose oxidase, >650 U/L peroxidase, 0.4 mM 4-aminoantipyrin) was added and the mixture was incubated in the water bath (FOSS Tecator AB) at 50 °C for 20 min. Absorbance was measured using a spectrophotometer (Spectronic Genesys 5, Spectronic Instruments Inc., Rochester, NY, USA) at 510 nm. Sodium acetate buffer (0.1 M, pH 4.5) and glucose (1 mg/mL in 0.2% benzoic acid) were used as a blank and glucose standard, respectively. The measured absorbance was calculated to be % retrograded starch using an equation from the kit manual. The analyses were performed in triplicate.

2.2.4. Determination of the retrogradation rate of sweet potato starch at different stages of preparation

The groups of sweet potato starches with different treatments were washed five times to eliminate NaCl in starch before determining retrogradation rate of starch, the procedure of determining was same as given in Section 2.2.3.

2.2.5. Optical micrographs taken in the course of preparing retrograded starch of sweet potato

The starch resolution was moved to the slide observed by microscope (OLYMPUS IX71); all optical micrographs were taken in 400× magnification.

3. Results and discussion

3.1. Optimizing the electrolysis conditions of preparation of retrograded sweet potato starch

3.1.1. The effects of electrolytic voltage on formation of sweet potato retrograded starch in electrolysis

Table 1 shows the effects of electrolytic voltage on formation of sweet potato retrograded starch in electrolysis for 1.5 h.

Table 1
The effects of voltage on formation of sweet potato retrograded starch.

Voltage (V)	Yields of sweet potato retrograded starch (%)
0	7.7
45	21.3
90	23.1
135	17.3
180	9.7
225	0.5

The results show that the rates of retrogradation of sweet potato starch increase as electrolytic voltage increased when voltage is below 90 V, and above that, they decrease as voltage increase. Electrolyzing of sodium chloride solution produces hydrogen, chlorine and sodium hydroxide; hydrogen and chlorine spill out of water, and only sodium hydroxide remains in water and some of them may combine with starch. The OH^- on the surface of starch serves two functions for retrogradation of starch, one is promoting water absorption and crystal melting of starch, which causes more swelling of starch ball and more leaching of amylase so that the retrogradation rate is increased, the other is accelerating starch hydrolysis under alkaline conditions, which leads to reduce starch retrogradation rates by decreasing amount of starch involved in retrogradation. The balance of these two functions controls the rate of starch retrogradation. 90 V is the proper parameter to electrolyze mixture of sweet potato starch and water so as to form retrograded starch.

3.1.2. The effects of electrolysis time on formation of sweet potato retrograded starch

Fig. 1 shows the effects of electrolysis time on formation of sweet potato retrograded starch in electrolysis at 90 V.

The results show that the retrogradation rates of sweet potato starch increase as electrolysis time prolongs before it reaches 30 min, but decrease after that, indicating that too long a time electrolysis might enhance decomposition of sweet potato starch, the reason was same as given in Section 3.1.1. Thus 30 min is the optimum electrolysis time.

3.1.3. The effects of NaCl addition on formation of sweet potato retrograded starch in electrolysis

Table 2 shows the results of effects of NaCl addition on formation of sweet potato retrograded starch in electrolysis at 90 V for 30 min.

The results show that addition of NaCl improves the formation of sweet potato retrograded starch greatly; the most was addition of 1.0 g/100 mL, and the retrogradation rate of sweet potato starch reaches to 33.1%; that is 138% higher than that of control group.

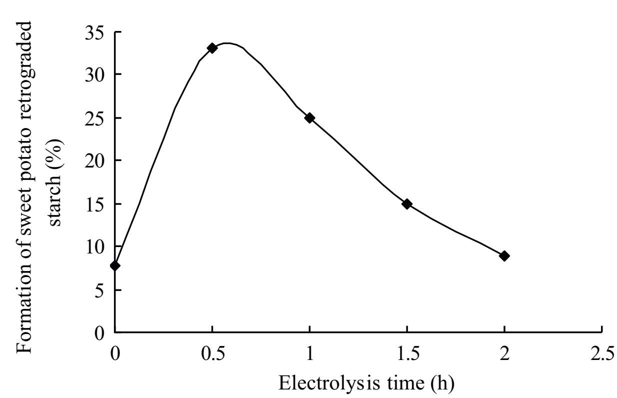

Fig. 1. The effect of electrolysis time on formation of sweet potato retrograded starch.