



Effect of acetic acid on physical properties of pregelatinized wheat and corn starch gels



Mahsa Majzoobi^{a,b,*}, Zahra Kaveh^a, Asgar Farahnaky^{a,b}

^aDepartment of Food Science and Technology, School of Agriculture, Shiraz University, Shiraz, Iran

^bARC Industrial Transformation Training Centre for Functional Grains and Graham Centre for Agricultural Innovation, Charles Sturt University, Wagga Wagga, NSW, Australia

ARTICLE INFO

Article history:

Received 11 May 2015

Received in revised form 26 September 2015

Accepted 28 September 2015

Available online 30 September 2015

Keywords:

Acetic acid
Pregelatinized starch
Corn starch
Wheat starch

ABSTRACT

Pregelatinized starches are physically modified starches with ability to absorb water and increase viscosity at ambient temperature. The main purpose of this study was to determine how different concentrations of acetic acid (0, 500, 1000, 10,000 mg/kg) can affect functional properties of pregelatinized wheat and corn starches (PGWS and PGCS, respectively) produced by a twin drum drier. With increasing acetic acid following changes occurred for both samples; cold water solubility (at 25 °C) increased, water absorption and apparent cold water viscosity (at 25 °C) reduced, the smooth surface of the starch particles converted to an uneven surface as confirmed by scanning electron microscopy, cohesiveness, consistency and turbidity of the starch gels reduced while their syneresis increased. It was found that in presence of acetic acid, PGWS resulted in higher water absorption and apparent cold water viscosity and produced more cohesive and turbid gels with less syneresis compared to PGCS.

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1. Introduction

Instant or pregelatinized starch (PG) is a physically modified starch with wide applications in food products (Majzoobi et al., 2011; Sajilata & Singhal, 2005). The main advantage of PG is related to its ability to absorb water and swell rapidly in cold water and enhance viscosity, while to obtain similar properties from native starch, it should be heated in water to reach gelatinization temperature (above 60 °C). Therefore, PG is more useful than native starch in heat-sensitive products and the products which require viscosity at low temperature such as cold desserts, salad dressing, mayonnaise and instant foods such as baby foods, dried soups and cake mix. Time, energy, labor, equipment use, production cost and flavor loss associated with high processing temperature can be saved by using PG starch (Adedokun & Itiola, 2010; Bortnowska et al., 2014; Vallous, Gavrielidou, Karapantsios, & Kostoglou, 2002).

The PG starch is produced by rapid drying of gelatinized starch mainly by drum dryer, extrusion and spray dryer (Singh, Kaur, & McCarthy, 2007; Vallous et al., 2002). Other methods for production of PG starch are also available including ohmic heating and

cooking of starch in aqueous ethanol (Qiu, Li, Chen, Liu, & Yin, 2014; Singh et al., 2007). Amongst these methods, drum dryers (single or twin drums) is commonly used as a cost-effective industrial method capable of producing large pregelatinized starch particles which are mainly used as texturizing starch. In this method starch suspension in water is dried over the surface of a hot rotating drum and then scraped off by means of a sharp blade. Drum temperature and speed, starch slurry concentration and type of drum dryer (single or twin) affect the properties of the PG starch. Generally, a smoother and more viscous starch paste is obtained from twin drum dryer compared to single drum dryer (Anastasiades, Thanou, Loulis, Stapatoris, & Karapantsios, 2002; Vallous et al., 2002).

In many food systems in which PG starch is used, organic acids are added or present naturally. Acetic acid, ascorbic acid, citric acid and malic acid are examples of common organic acids in food products. They are usually added to adjust pH, provide taste and flavor or to act as a natural antimicrobial agent (Majzoobi & Beparva, 2014).

Previous studies have shown that the organic acids have some effects on physicochemical properties of native and some modified starches and hence affect their functional properties. Degradation of native wheat (Majzoobi & Beparva, 2014) and cassava starches (Vallès-Pamiès et al., 1997) in the presence of ascorbic acid and hence viscosity reduction have been documented. Hirashima, Takahashi, and Nishinary (2005) determined the effects of acetic acid, malic acid, citric acid, lactic acid, tartaric acid and ascorbic

Abbreviations: PG, pregelatinized starch; PGWS, pregelatinized wheat starch; PGCS, pregelatinized corn starch.

* Corresponding author at: ARC Industrial Transformation Training Centre for Functional Grains and Graham Centre for Agricultural Innovation, Charles Sturt University, Wagga Wagga, NSW, Australia.

E-mail address: majzoobi@shirazu.ac.ir (M. Majzoobi).

acid on native corn starch paste and reported that the amylose and amylopectin chains were hydrolyzed by addition of the organic acids resulting in viscosity reduction at low pH values. Majzoobi, Radi, Farahnaky, and Tongdang (2012) investigated the effects of ascorbic acid on physicochemical properties of native wheat starch and showed that the ascorbic acid had some degradation effects on starch molecules mainly after gelatinization.

Recently, we studied the effects of other organic acids such as malic, citric, acetic and lactic acids on native and cross-linked wheat starches and it was found that these acids, even at low concentrations, could change some of the functional properties of the samples (Majzoobi & Beparva, 2014; Majzoobi, Beparva, Farahnaky, & Badii, 2014a, 2014b). In addition, we reported that PG wheat starch produced more viscous and firmer paste compared to the PG corn starch in the presence of different levels of ascorbic acid (Majzoobi, Kaveh, Farahnaky, & Blanchard, 2015).

These studies have shown that the effects of various organic acids on starches are not the same and some organic acids are more capable of depolymerizing starch than others. For example, at constant weight concentration, malic acid was more effective than citric acid in changing the functional properties of native and cross-linked wheat starches. The robustness of the starch against organic acids also depends upon the origin and type of modification (Majzoobi et al., 2014a, 2014b). Such effects have not been reported for other organic acids including acetic acid on pregelatinized starches.

The main purpose of this study was to investigate the effects of different concentrations of acetic acid which are commonly used in various foods, on physical properties of PG wheat starch (PGWS) and PG corn starch (PGCS) gels. The results may be useful for further applications of these starches in food products.

2. Materials and methods

2.1. Materials

Native corn starch was purchased from Mahshad Starch Company (Yazd, Iran) and had 10.69% moisture, 0.43% protein, 0.18% ash, 0.72% fat (determined based on Approved Methods of the AACC, 2000) and 28.90% total amylose (all on dry basis) determined by the iodine method (Morrison & Laignelet, 1983). Native wheat starch with 8.06% moisture content, 0.14% protein, 0.27% ash, 0.66% fat determined based on Approved Methods of the AACC (2000) and 27.25% total amylose (all on dry basis) determined by the iodine method (Morrison & Laignelet, 1983) was supplied by Fars-Glucosin Company (Marvdasht, Iran). Glacial grade acetic acid 100% (product code 1.93002.0521) was purchased from Merck (Darmstadt, Germany).

2.2. Production of PGWS and PGCS

Suspensions of native wheat and corn starches in distilled water (10 %, w/w) were prepared separately and dried over the hot surface (158 °C) of a twin drum drier (Benton Harbor, USA) with a clearance between the drums of 0.4 mm and rotation speed of 5 rpm. The dried starch film was collected, milled using a laboratory mill and sieved to obtain an average particle size of $200 \pm 50 \mu\text{m}$ (Majzoobi et al., 2011). The moisture contents of the PGWS and PGCS were 7.11% and 6.93%, respectively. The samples were packed in glass jars and stored at ambient temperature.

2.3. Preparation of starch in acid suspensions

Pregelatinized starch (5 g) was added to acetic acid solutions (50 mL) with concentrations of 100, 500, 1000 and 10,000 mg/kg

(dry basis). These suspensions were used for further experiments except apparent cold water viscosity measurement. For this experiment, 2.5 g starch was added to 25 mL of the above acid solutions in a Rapid Visco Analyser (RVA) aluminum canister. Control samples were prepared in the same way without addition of acetic acid.

2.4. Determination of the pH

The starch suspensions were stirred for 30 min at 25 °C using a magnetic stirrer. The pH of the samples was measured at 20 °C using a calibrated digital pH meter (Starter 3000, OHAUS, USA).

2.5. Determination of cold water solubility and water absorption

The suspensions were stirred for 30 min or 24 h at 25 °C using a magnetic stirrer and then centrifuged for 10 min at 1200g. The supernatant was collected and weighed. The supernatant was dried in an air forced oven at 110 °C for 4 h. Cold water solubility was calculated according to Eq. (1) (Eastman & Moore, 1984).

Cold water solubility (%)

$$= \frac{\text{Weight of dissolved solids of the supernatant}}{\text{Weight of the dry solid of the sample}} \times 100 \quad (1)$$

Knowing the weight of supernatant and the concentration of acetic acid in the sample, the approximate weight of acetic acid in the supernatant was calculated and subtracted from the cold water solubility of the starch.

The pellet was collected, weighed and dried at 110 °C until a constant weight (about 4 h). Water absorption was determined using Eq. (2).

Water absorption (g/g)

$$= \frac{\text{Weight of wet pellet} - \text{weight of dry pellet}}{\text{Weight of the dry solid of the sample}} \quad (2)$$

The approximate weight of acetic acid in the pellet was calculated based on the pellet weight and was subtracted from the water absorption of the starch.

2.6. Determination of the morphological properties of the starches

Starch suspensions were frozen at $-20 \text{ }^\circ\text{C}$ before being transferred to a freeze dryer (Dena Vacuum, Esfahan, Iran). Then about 0.1 g of the freeze-dried sample was fixed on an aluminum stub using double sided adhesive tape and sputter coated with gold to avoid charging effects under the electron beam. Then the samples were observed using a scanning electron microscope (Model Leica Cambridge, UK) at 20 kV and a working distance of 7.5–9.5 mm.

2.7. Determination of apparent cold water viscosity of the starches

The RVA (RVA, StarchMaster 2, Perten, Australia) was used to determine apparent cold water viscosity of the samples at 25 °C. The suspension was first mixed manually using the RVA plastic paddle for 1 min and then the canister was placed inside the instrument and stirred using the paddle at 960 rpm for the first 20 s and then at 160 rpm for the rest of the experiment. The apparent viscosity of the samples after 15 min stirring at a constant temperature (25 °C) was reported.

2.8. Determination of textural properties of the starches

Each suspension was stirred for 10 min at 50 rpm using a digital mixer (Model RZR 2102 Control, Germany) at 25 °C. Then 50 g of the suspension was weighed into a cylindrical glass container

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