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Physical properties of pregelatinized and granular cold water swelling maize starches in presence of acetic acid

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ABSTRACT

Pregelatinized (PG) and granular cold water swelling (GCWS) starches are physically modified starches which are used to enhance viscosity at ambient temperature. The main aim of this research was to determine the physical changes of these starches in the presence of acetic acid (0, 500, 1000 and 10,000 mg/kg) as a common organic acid in foods. Native maize starch was converted to PG and GCWS starches using a twin drum drier and alcoholic-alkaline method, respectively. Scanning electron micrographs showed an increase in the size and central hole of the granules in GCWS starch and surface wrinkling of PG starch with increasing acid concentration. Water solubility increased, while water absorption, cold-water viscosity (as measured by a Rapid Visco Analyzer) and freeze–thaw stability of the samples reduced. A reduction in the paste viscosity, consistency, firmness and cohesiveness was observed as assessed using a Texture Analyser. Acetic acid increased the turbidity of GCWS starch but reduced the turbidity of PG starch pastes. The freeze–thaw stability of both samples reduced with addition of acetic acid, which was more pronounced after the first freeze–thaw cycle. These changes were enhanced with increasing acetic acid concentration. The changes caused by the acetic acid to the physical properties of PG starch were more obvious than those with GCWS starch.

1. Introduction

Starch modification involves changing the structure of starch molecules in order to increase the functional properties of the starch. This is generally achieved through chemical, physical, enzymatic or genetic methods. Amongst them, physical methods are more acceptable since they are generally chemical-free and hence considered safer for human consumption (Kaur, Ariffin, Bhat, & Karim, 2012). Two common types of physically modified starches are pregelatinized and granular cold water swelling starches (PG and GCWS starches, respectively). In contrast to native starch, these modified starches can rapidly absorb water and increase the viscosity at ambient temperature. This functionality has made them useful in a range of products including those produced at low temperatures, containing heat sensitive components (e.g. vitamins, flavoring or coloring agents) and instant foods. Cold desserts, instant baby foods, pie fillings, gravies, soups and sauces are examples in which PG and GCW starches are commonly used (Jane, 1992; Chen & Jane, 1994a, 1994b).

PG starch is generally produced by gelatinization of starch followed by rapid drying. During the gelatinization stage, starch granules absorb water and lose their crystalline structure. Depending on the severity of the process, the starch granules may be damaged or completely destroyed. Therefore, water interaction with the starch molecules occurs readily resulting in an increase in the viscosity without heating. PG starch is commonly produced by drum drying, extrusion or spray drying (Anastasiades, Thanou, Loulis, Stapatoris, & Karapantsios, 2002; Mason, 2009). Drum drying is an easy and economical method for production of PG starch which can be achieved using a single or twin drum drier. Generally, starch slurry is poured onto a hot drum and scraped off with a sharp blade. Further drying and milling may be required to achieve an appropriate moisture content and particle size. Drum drying conditions including drum speed and temperature affect the quality of PG starch (Anastasiades et al., 2002; Majzoobi et al., 2011). Nevertheless, some limitations of PG starch including

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grainy texture, insufficient consistency and weak gels have reduced its applications in some foods. These deficiencies are mainly due to the disintegration of the granules, and retrogradation of the wet starch film during drying (Jane, Craig, Seib, & Hoseney, 1986; Rajagopalan & Seib, 1992).

To overcome the limitations of PG starch, GCWS starch has been developed. This type of starch can provide cold water thickening despite maintaining granular integrity. GCWS starches exhibit greater viscosity, more homogeneous texture with higher clarity and have more processing tolerance than PG starches (Eastman & Moore, 1984; Jane et al., 1986; Light, 1990).

There are several methods available for production of GCWS starch. Methods including injection and then nozzle drying of starch slurry (Pitchone, ORourke, & Joseph, 1981) and heating a slurry of starch and monohydric alcohol at high temperature under elevated or ambient pressure (Rajagopalan & Seib, 1992) have been described. Another method is the alcoholic-alkaline treatment at ambient pressure. In this method, sodium hydroxide causes granule swelling and ethanol prevents disintegration (Bello-Pérez, Romero-Manilla, & Paredes-López, 2000; Chen & Jane, 1994a). An alternative method including treating of starch granules with aqueous ethanol and then heating in a rotary evaporator to remove ethanol has been described recently (Zhang, Dhital, Haque, & Gidley, 2012). Although chemicals are used for production of GCWS starch, it is not a chemically modified starch (Jane et al., 1986). GCWS starches can be used in mayonnaise and salad dressings as a thickener or stabilizer and can also be used as a fat replacer by creating desirable texture and mouth-feel (Bortnowska, Balejko, Tokarczyk, Romanowska-Osuch, & Krzemińska, 2014; Jane, 1992).

In many foods in which PG or GCWS starches are used, organic acids are either added or present naturally. Acetic acid, the main acid in vinegar, is a frequently used organic acid in the formulation of salad dressing, mayonnaise and many other foods. It provides a sour taste, and an acidic flavor, reduces pH and can act as a natural antimicrobial agent. Previous studies have shown that organic acids can alter some of the functional properties of different starches. Molecular degradation of cassava starch has been reported after addition of L-ascorbic acid (Sriburi, Hill, & Mitchell, 1999). Hirashima, Takahashi, and Nishinary (2005) reported a reduction in the native maize starch viscosity with addition of acetic acid. Similar findings were reported for native rice starch when acetic acid was added during cooking (Ohishi, Kasai, Shimada, & Hatae, 2007). It has been shown that L-ascorbic acid can degrade the molecular structure of native and cross-linked wheat starches (Majzoobi, Beparva, Farahnaky, & Badii, 2014a; Majzoobi, Radi, Farahnaky, & Tongdang, 2012). It has been reported that these acids caused some molecular degradation which consequently affected the physiochemical properties of both starches, however, native starch was more sensitive to the acids. It has been shown that malic, lactic and citric acids can alter some of the physico-chemical properties of native and cross-linked wheat starches (Majzoobi & Beparva, 2014; Majzoobi, Beparva, Farahnaky, & Badii, 2014b). Under identical conditions, the effect of lactic acid on physicochemical properties of the samples was greater than acetic acid. Similarly, malic acid had greater effects than citric acid on the functional properties of the starches. Recently, the effects of L-ascorbic acid on PG maize and wheat starches were investigated and it has been shown that the viscosity of the samples reduced in the presence of L-ascorbic acid. It was found that the cold water viscosity and gel texture of PG wheat starch was less affected by the acid compared to PG maize starch (Majzoobi, Kaveh, Farahnaky, & Blanchard, 2015).

From the literature it was concluded that the organic acids used in various foods can affect the functional properties of native and some modified starches depending on the type of starch and the acid used. Therefore, understanding the effects of organic acids on the physicochemical properties of starch is important and can give useful information about the functionality of starch in foods and the quality of the final products.

To the best of our knowledge, there is no published paper showing the effects of acetic acid on the functional properties of PG and GCWS maize starches. Therefore, the main aim of this research was to determine how acetic acid at various concentrations can affect some physical properties of PG and GCWS maize starches.

2. Materials and methods

2.1. Materials

Native food grade maize starch in the form white powder with 10.69% moisture, 0.43% protein, 0.18% ash, 0.72% fat (determined using Approved Methods of the AACC, 2000) and 28.90% amylose determined by the iodine method (Morrison & Laignelet, 1983) was purchased from Mahshad Company (Yazd, Iran). Food grade ethanol (96% purity) was donated by Parsian Company (Shiraz, Iran). Glacial acetic acid (100% purity), sodium hydroxide (NaOH) and hydrochloric acid (HCl) were obtained from Merck (Darmstadt, Germany).

2.2. Production of PG starch using a twin drum drier

Slurry of maize starch in distilled water (10%, w/w) was prepared and stirred using a plastic spoon for 2–3 min at ambient temperature. The slurry was dried at 158 °C over a twin-drum drier (Benton Harbor, USA) with a clearance of 0.4 mm and rotating speed of 5 rpm (Majzoobi et al., 2011). The dried starch film was collected and milled using a laboratory mill and sieved to obtain a white powder with an average particle size of 200 ± 50 μm. PG starch with a moisture content of 6.93% was packed in a glass jar, capped and stored at 22 °C.

2.3. Production of GCWS starch by alcoholic-alkaline method

The procedure described by Chen and Jane (1994a) was followed to produce GCWS starch. Starch (100 g, dry basis) was suspended in 500 g of ethanol solution (40%, w/w) and stirred using a magnetic stirrer. Then 300 g NaOH (3 M) was added gradually to the suspension and stirred for 15 min. After that 900 g of ethanol solution (40%, w/w) was slowly added to the suspension followed by stirring for 10 min. The sample was left to sit until the starch settled to the bottom. The supernatant was decanted and the starch was washed with ethanol solution (40%, w/w) and neutralized with HCl (3 M in absolute ethanol) and further washed with 60% and 90% (w/w) ethanol solutions. The sample was then dehydrated with absolute ethanol and dried at 80 °C for 3 h. The dried starch with moisture content of 5.02% (dry basis) was sieved to obtain a white powder with an average particle size of 200 ± 50 μm and stored in a screw capped glass jar at ambient temperature for further tests.

2.4. Starch treatment with acetic acid

Different amounts of acetic acid including 0, 0.5, 2.5, 5.0 and 50 mg were added to distilled water (50 mL) followed by the addition of starch (5 g) to each solution. The acid to starch ratio in the prepared dispersions were 0, 100, 500, 1000 and 10,000 mg/kg, respectively. For pH and turbidity tests and microstructual studies, the starch suspensions were stirred for 30 min at 25 °C using a magnetic stirrer. For cold-water solubility and cold-water