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Environmentally friendly preparation of pectins from agricultural byproducts and their structural/rheological characterization

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ABSTRACT

Apple pomace which is the main waste of fruit juice industry was utilized to extract pectins in an environmentally friendly way, which was then compared with chemically-extracted pectins. The water-based extraction with combined physical and enzymatic treatments produced pectins with 693.2 mg g^{-1} galacturonic acid and 4.6% yield, which were less than those of chemically-extracted pectins. Chemically-extracted pectins exhibited lower degree of esterification (58%) than the pectin samples obtained by physical/enzymatic treatments (69%), which were also confirmed by FT-IR analysis. When subjected to steady-shear rheological conditions, both pectin solutions were shown to have shear-thinning properties. However, decreased viscosity was observed in the pectins extracted by combined physical/enzymatic methods which could be mainly attributed to the presence of more methyl esters, thus limiting polymer chain interactions. Moreover, the pectins which were extracted by combined physical/enzymatic treatments, showed less elastic properties under high shear rate conditions, compared to the chemically-extracted pectins.

1. Introduction

Fruit processing in the food industry gives rise to large amounts of by-products. Specially, since the by-products of apple and citrus fruits amount to up to 50% and 25–35% of the processed fruits, their annual wastes are estimated to be $3–4.2 \times 10^6$ and 15.6×10^6 Mton, respectively (Oreopoulou and Russ, 2007). Therefore, there have been great interests in searching for proper disposal methods of apple pomace and citrus peels which are the residue left after juice extraction. Specifically, a main focus has been placed in the utilization of their certain components – pectin as a soluble dietary fiber.

A number of methods have been tried to extract pectins from various sources so far. Pectins are industrially obtained from apple pomace and citrus peels in a chemical way with strong acids such as oxalic (Koubala et al., 2008), hydrochloric (Choi, 1996; Hwang et al., 1998), nitric (Constenla et al., 2002), and sulphuric acids (Garna et al., 2007) which are regarded as conventional acid extraction (Yapo, 2009). Even though these chemical procedures have advantages from an efficient and economical point of view, they may cause environmental problems by producing hazardous contaminants that must be treated. Moreover, with the recent well-being trend, serious consumer concerns about chemical additives become so dominant that the growth rate of natural products in the food industry has begun to rise (Sloan, 2010). Therefore, new 'green' efforts have been made in order to minimize the use of harmful chemicals in the food industry and the processing for pectin isolations is no exception, thereby introducing environment- and human-friendly technology. For examples, enzymatic extraction has been conducted with polygalacturonase (Contreras-Esquivel et al., 2006), (hemi)cellulase (Shkodina et al., 1998; Zykwinska et al., 2008), protease (Zykwinska et al., 2008), and microbial mixed enzymes (Ptichkina et al., 2008). Also, ultrasonic-(Panchev et al., 1988), autoclave-(Oosterveld et al., 1996, 2000), microwave-(Liu et al., 2006), and extrusion-assisted (Shin et al., 2005) treatments have applied to extract pectins from agricultural byproducts such as apple pomace, sugar beet pulp, and orange peels. However, their main research focuses were placed on the yield and/or chemical compositions of pectins extracted by different methods. Even, the combined effects of physical and enzymatic treatments for pectin extraction have not been reported yet to our best knowledge.

In this study, pectin extraction from apple pomace has been studied in an environmentally friendly way with combined physical and enzymatic treatments. Then, their chemical, structural, and rheological properties were characterized and compared with those of chemically-extracted pectins.

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2. Methods

2.1. Materials

Apple pomace obtained from the First Fruits Co. (Seoul, Korea) was used as a source of pectin. After the apple pomace was oven-dried at 80 °C, it was ground and screened with a 50 mesh sieve. The apple pomace powder (7.19% moisture, 2.03% ash, 3.95% protein, 4.30% fat and 82.54% carbohydrate (by difference)) was stored in a plastic bag prior to pectin extractions. All the chemicals and reagents were of analytical grade.

2.2. Pectin extraction

Pectins were extracted from the apple pomace powder in two different ways (chemical and combined physical/enzymatic methods). In the conventional chemical method (Koubala et al., 2008; Rha et al., 2011), apple pomace powder was treated four times with ethanol (85%) for 70 °C for 20 min and filtered with miracloth (Merck KGaA, Darmstadt, Germany). The residue (10 g) was then mixed with oxalic acid/ammonium oxalate (0.25%, pH 4.6, 400 mL), which was maintained at 85 °C for 1 h. The mixture was filtered with miracloth and the filtrate was mixed with three volumes of ethanol (96%). After centrifugation at 14,500 × g for 10 min, the precipitates were washed with 70% and then 96% ethanol, followed by oven-drying (50 °C).

On the other hand, another way to extract apple pomace pectins was based on combined physical and enzymatic treatments with distilled water (Min et al., 2010, 2009) (Fig. 1). The apple pomace powder was suspended in distilled water at a concentration of 10% (w/v) and mixed with agitation for 1 h at room temperature. After the suspension was filtered with miracloth, the residue was mixed with distilled water (10%, w/v), homogenized for 3 min, and then autoclaved at 121 °C for 10 min. After cooling at room temperature, it was followed by an enzymatic treatment with Viscozyme® L (Novozymes, Bagsvaerd, Denmark). The viscozyme with 1.2×10^{-4} fungal β-glucanase unit was added to the suspension, which was maintained at 40 °C and boiled to stop the enzymatic reaction after 1 h. Then, the reaction mixture was dialyzed (8000 Molecular weight cutoff, Spectrum Laboratories Inc., CA, USA) against distilled water for 24 h. After freeze-drying, the samples were stored in a plastic bag before further experimental analysis.

2.3. Analysis of degree of esterification

The degree of esterification (%) was calculated from the molar ratio of methanol to galacturonic acid (Klavons and Bennett, 1986; Smout et al., 2005). For methanol analysis, pectins were dissolved in distilled water (0.1%, w/v) and the total volume was adjusted to 50 mL by adding potassium hydroxide (25 mL, 1.0 N) before they were incubated at ambient temperature for 30 min. After the pH was adjusted to 7.5 with phosphoric acid, the solution was diluted with distilled water. Alcohol oxidase (1 unit, Sigma–Aldrich Inc., MO, USA) was added to 1 mL of the diluted solution and incubated at 25 °C for 15 min. Then, 2,4-pentanedione in 2.0 M ammonium acetate and 0.05 M acetic acid (2 mL) was added,

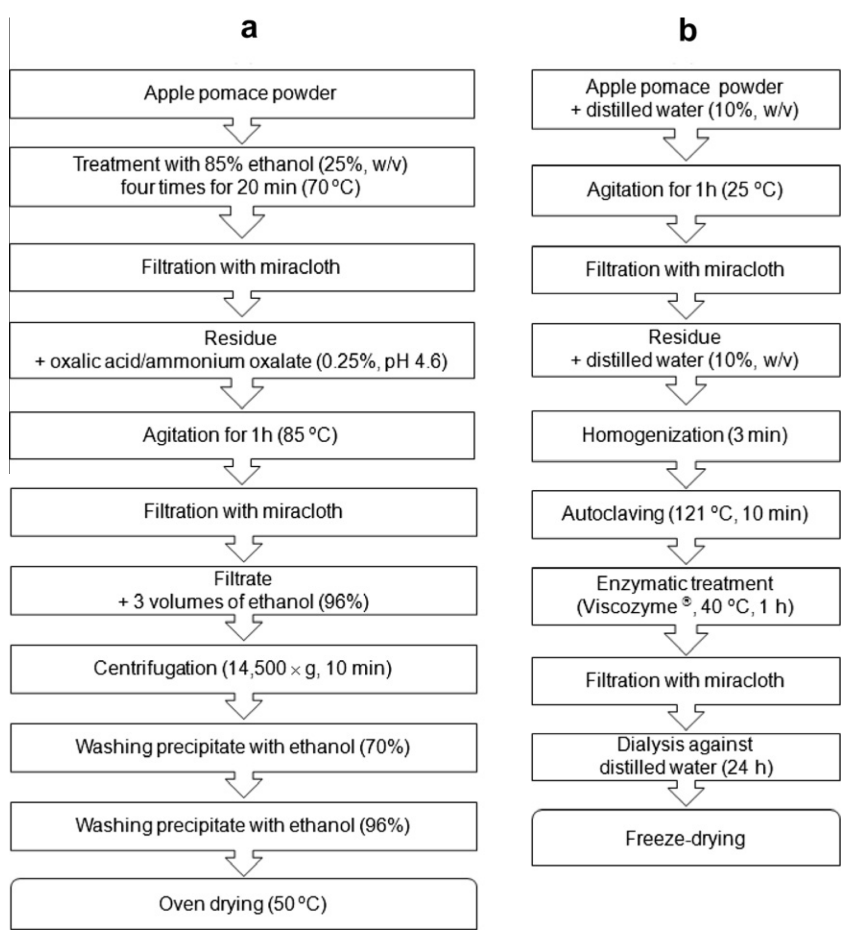

Fig. 1. Schematic of pectin extraction from apple pomace in (a) chemical and (b) environmentally friendly ways.