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Influence of pectinase treatment on the physicochemical properties of potato flours

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ABSTRACT

Untreated and pectinase-treated potato flours from Atlantic and Superior cultivars were characterised to identify the effects of pectinase treatment on their physicochemical properties. Steam-cooked potato whole-tissues were treated with and without pectinase to prepare the dehydrated potato flours. Untreated and pectinase-treated potato flours were investigated with respect to morphology, chemical composition, starch leaching, swelling power, gelatinization, and pasting viscosity. Upon viewing with scanning electron microscopy and light microscopy, the pectinase-treated (relative to untreated) potato flours revealed that the retrograded starch materials were present in intact parenchyma cells, apparently exhibiting granular structures. Their protein and ash contents were reduced through pectinase treatment. While starch leachate contents were lower for the pectinase-treated potato flours, the opposite trend in swelling powers was observed. Pectinase-treated potato flours exhibited higher melting temperatures and pasting viscosities than untreated counterparts. Overall, the modification of potato flour morphology by pectinase treatment may result in alteration of physicochemical properties of potato flours.

1. Introduction

Potato (*Solanum tuberosum* L.) with a worldwide annual production of 374 million tons in 2011 (NPC, 2013) is one of the most important carbohydrate sources in the human diet and a versatile commodity yielding potato-based products and starch for example (Borodoloi, Kaur, & Singh, 2012; Šimková, Lachman, Hamouz, & Vokál, 2013).

Potatoes are available in the fresh state only for a few months, because they are only single-cropped for one year in most countries (Kaur, Singh, Ezekiel, & Sodhi, 2009). Stored potatoes are exposed to potential risks (e.g., excessive weight loss, spoilage by pathogens, and sprout growth) even under good storage conditions, resulting in the decline in their yield and end-use quality (Kaur et al., 2009). To resolve the difficulties in potato storage and expand the utilisation of potato in the food industry, a substantial portion of cultivated potatoes is processed, using treatments such as freezing, frying/freezing, dehydrating, and canning. Particularly in USA, per capita consumption of processed potato products in 2010 was estimated to be about 2.1 times that of fresh potatoes (NPC, 2013).

Relative to frozen and frozen/fried potato products, dehydrated potato products (potato dice, flake, and granule) tend to be underutilised in industrial applications (Anantachote, 2009; NPC, 2013). Among the dehydrated potato products, nevertheless, potato granules appear to be widely used for preparation of the potato-based foods due to their availability, convenience, low cost, and storage stability (Anantachote, 2009). Potato granules are commonly prepared via a series of processes, i.e., cooking, mashing, freezing, thawing, dehydration, granulation, and drying (Ooraikul, 1977). Similar to potato granules, potato flours (prevalent in Republic of Korea) are produced through blanching or cooking, drying, grinding, and sieving (Park & Kang, 2004; Youn et al., 2002). Potato granules and, to a lesser extent, flours have been employed as an ingredient in extruded potato snacks, reconstructed potato chips, instant potato soups, instant mashed potato (NPC, 2013). Retrograded potato starches (a main component in potato granules and flours) following partial or complete starch gelatinisation by pre-treatment (e.g. blanching, cooking) of potato whole-tissues (Ooraikul, 1977; Park & Kang, 2004; Youn et al., 2002) have limited use as ingredients in other foods.

Potato granules and flours commonly exhibit reduced viscosity development during heating, sticky paste characteristics, cohesive and gummy gel properties, and poor resistance to amylolytic enzymes (Kaur et al., 2009; Lu et al., 2011). To further expand the utilisation of potato granules and flours, their physical functionalities must be improved. There have been recent attempts to develop potato granules with ungelatinised potato starches in order to moderate the glycaemic response of dehydrated potato

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products (Aguilera, Cadoche, López, & Gutierrez, 2001; Anantachote, 2009). Their strategies were that individual parenchyma cells (including granular starches) from potato whole-tissues were isolated through dissolution and/or decomposition of pectic substances (cementing parenchyma cells together) with chemicals (acid–alkali, or alkali-chelating agent) and pectinase (Aguilera et al., 2001; Anantachote, 2009). Anantachote (2009) reported that pectinase (relative to alkali-chelating agent) treatment was more effective and efficient for the isolation of potato parenchyma cells. Although both studies well elucidated the morphological characteristics of isolated potato parenchyma cells by hot-stage light and field-emission scanning electron microscopy, only limited information is still available on their physical functionalities. Compared to commercial potato granules with retrograded starches, also, the dehydrated potato parenchyma cells with granular starches are may only have limited utilisation.

Utilizing pectinase, the objective of this study was to prepare and characterise individual parenchyma cells (i.e., pectinase-treated potato flour) from cooked potato whole tissues. To identify the effects of pectinase treatment on potato flour properties, the characteristics of the pectinase-treated potato flours were compared with those of untreated potato flours (mimics of commercial potato granules or flour).

2. Materials and methods

2.1. Materials

Potatoes from Atlantic and Superior cultivars were the sources of potato flours prepared in this study. Potatoes (cultivated in June, 2013) were obtained from Dr. Se-jin Hong of the Department of Horticulture at Gangneung–Wonju National University (Gangneung, Republic of Korea) and stored at 4 °C and relative humidity of 90% until use. Pectinase (endo-polygalacturonase from *Aspergillus niger*, activity >1 U/mg), pancreatin from porcine pancreas (8× USP/g), Congo red, and ruthenium red were purchased from Sigma–Aldrich Co. (St. Louis, MO). Amyloglucosidase (3300 U/mL), total starch assay kit, and glucose oxidase–peroxidase assay kit (GOPOD) were obtained from Megazyme International Ltd. (Bray, Ireland). All chemicals and reagents used in this study were of analytical grade.

2.2. Preparation of potato flours

Potato flours were prepared using an existing method for dehydrated potato granules (Ooraikul, 1977). Washed and peeled potatoes were cooked for 30 min using a steam-cooker (DG 1218 CB; Bomann, Kempen, Germany), and cooled to ambient temperature (~24 °C). The cooked potatoes were mashed with a conventional potato masher, and frozen at −25 °C for 48 h. The frozen potato mashes were thawed at 25 °C for 3 h, and then, dried at 50 °C for 48 h with a forced convection drier (FD-600 M; Jeio Tech Co., Seoul, Korea). The dried potato mashes were ground with a cyclone sample mill equipped with 50-mesh sieve (Cyclotec 1093; FOSS, Eden Prairie, MN), passed through a 60-mesh standard sieve, and stored in Teflon sample bottles at ambient temperature prior to further analysis.

2.3. Preparation of pectinase-treated potato flours

The frozen potato mash, outlined in the section of "*Preparation of potato flours*," was thawed at 25 °C for 3 h. The resultant potato mash (200 g, wet basis or w.b.) was put into 350 ml of 100 mM citrate buffer (pH 3.5) containing ascorbic acid (400 ppm), and incubated until the mashed potato suspension reached 50 °C. Then, pectinase (0.5 U/mL) was added to the suspension, and the reaction mixture was incubated at 50 °C for 3 h under continued stirring (100 rpm) with an overhead stirrer (MS-3060; Misung Scientific Co. Ltd., Yangju, Korea) (Anantachote, 2009). After 3 h, the reaction mixture was passed through a series of standard sieves (20 and 140 mesh). While potato materials on a 20-mesh sieve (potato tissue residues) were discarded, those (designated as a pectinase-treated potato flour) on a 140-mesh sieve were washed with deionised water (DIW) on the sieve to remove free starch granules and pectin/parenchyma cell wall hydrolysates. The resultant pectinase-treated potato flours were washed again with absolute ethanol, recovered using a Büchner funnel, dried at 50 °C for 24 h, and stored in Teflon sample bottles at ambient temperature prior to further analysis.

2.4. Field-emission scanning electron microscopy (FE-SEM)

Potato flours were dusted onto the double-sided adhesive carbon tape of aluminium specimen stubs, and coated with a 20-nm layer of gold:palladium (60:40). Their morphological characteristics were observed using a field-emission scanning electron microscope (JSM-6700F; Jeol Ltd., Tokyo, Japan) at an accelerating voltage of 5 kV and 600 times magnification.

2.5. Light microscopy (LM)

Potato flours were stained independently with aqueous solutions of Congo red (1.0%, w/v) and ruthenium red (0.02%, w/v) to visualise their parenchyma cell walls and pectic substances, respectively (Vallet, Chabbert, Czaninski, & Monties, 1996). Potato flours (100 mg, dry basis or d.b.) were dispersed in DIW (2 mL), followed by the addition of a dye solution (2 mL). The mixtures were held at ambient temperature (~24 °C) for 5 min, and then washed with DIW until the supernatant became colourless. To localise starch materials within potato flours, also, Congo red-stained potato flours were further treated with 1 mL of I_2/KI solution (0.2 g I_2 + 2.0 g KI in 100 mL of DIW) (Morrison & Laignelet, 1983), and washed with DIW to remove excessive I_2–KI solution. The aqueous dispersions of the stained potato flours were mounted onto slide glasses, and viewed using an inverted light microscope (Axiovert 100; Carl Zeiss Microimaging, Inc., Thornwood, NY) at 100 times magnification.

2.6. Chemical composition

Moisture, protein (%N × 6.25), lipid, and ash contents of potato materials were analysed according to AACC Methods 44–19, 46–08, 08–01, and 30–26, respectively (AACC, 2000). Carbohydrate contents were calculated by subtracting the sum (%, d.b.) of protein, lipid, and ash contents from 100. Total starch contents were assayed using a total starch assay kit according to AACC Method 76–13 (AACC, 2000). Apparent amylose contents were determined with the colorimetric method outlined by Morrison and Laignelet (1983). Phosphorus contents were analysed via inductively coupled plasma-atomic emission spectroscopy (ICP-AEC) (Anderson, 1996).

2.7. Starch leaching and swelling power

Potato flours (0.5 g, d.b.) were mixed with DIW (25 mL) in a 50-mL centrifuge tube. Potato flour suspensions were heated for 30 min (with periodic vortexing) at pre-determined temperatures (25, 40, 55, 70, 85, and 100 °C), and cooled for 20 min in a tap water bath. Swollen potato flours were recovered by centrifugation (2500*g*, 30 min), and the supernatants were carefully poured into a 50-mL volumetric flask. The tubes were inverted and allowed