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Measurement of functional properties and health promoting aspects-glucose retardation index of peel, pulp and peel fiber from *Citrus hystrix* and *Citrus maxima*

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ABSTRACT

The objective of this study was to evaluate some functional properties of peel, pulp and peel fiber from *Citrus hystrix* and *Citrus maxima* (red and white var), in order to use them as potential dietary fiber sources in the enrichment of foods. These components were analyzed for their functional properties and *in vitro* health promoting properties. Water holding capacity, oil holding capacity, emulsion activity and emulsion stability of *C. hystrix* and *C. maxima* (red and white var) samples were found in the range between 5.18–8.08 mL water/g sample, 1.26–2.45 mL oil/g sample, 29.06–40.68% and 72.12–96.30%, respectively. Glucose retardation index of samples were in the range of 10.43–16.31%, at 180 min. In starch digestion process, all the citrus sample powders showed greater reduction of glucose in dialysate at 20–180 min. Photomicrographs on surface morphology of peel and peel fiber were made by Scanning Electron Microscope (SEM), FTIR spectrum was also recorded for functional group analysis.

1. Introduction

Dietary fiber is a common component of food products which consists of variety of non starch polysaccharides such as cellulose, hemicelluloses, pectin, β-glucans, gums and lignin (Elleuch et al., 2011) and those are taken as foods due to their beneficial effects on food nutritional properties (Fernandez-Lopez, 2008). Consumption of dietary fiber plays a significant role in the prevention, reduction and treatment of chronic diseases such as bowel, gastrointestinal disorders, obesity, diabetes, cardiovascular disease, cancer and also promoting physiological functions including reduction in blood cholesterol level and glucose attenuation (Figuerola, Hurtado, Estevez, Chiffelle, & Asenjo, 2005; Mehta, 2005; Marlett, 2001). By-products from fruits, vegetables, and whole grains are promising sources of dietary fibers and functional compounds (Larrauri, 1999; Jensen, Koh-Banerjee, & Hu, 2004). The recommended dietary fiber intake of 25–30 g/day could help to overcome the fiber deficit in the diet and has been related to several physiological and metabolic effects (Drzikova, Dongowsky, Gebhardt, & Habel, 2005; Fernandez-Gines, Fernandez-Lopez, Sayas-Barbera, Sendra, & Perez-Alvarez, 2003).

Dietary fiber can delay gastric emptying and reduce or delay the uptake of carbohydrates from the small intestine

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result of which lowers blood concentrations of glucose and prolongs satiety after a meal and can also reduce the uptake of cholesterol and lower the LDL cholesterol (Galisteo, Duarte, & Zarzuelo, 2008). In addition, fiber can be fermented by bacteria in the large bowel resulting in the production of short chain fatty acids which can be absorbed by the body (Theuwissen & Mensink, 2008). When plant fibers are added to food products it could retard starch digestion, adsorb glucose, reduce glucose absorption, and also control postprandial serum glucose level (Chau, Huang, & Lee, 2003). The physiological effects are related to the physicochemical and functional properties of dietary fiber such as water holding capacity, oil holding capacity, emulsion activity, swelling power and soluble index (Tungland & Meyer, 2002). Those physiological effects of fiber depend on a complex mixture of structural, chemical and physical properties (Blackwood, Salter, Dettmar, & Chaplin, 2000). The importance of dietary fibers in diet therefore leads to a trend to find new sources of fibers as ingredients for the food industry.

Citrus fruits (*Citrus hystrix* and *Citrus maxima*) are important fruit tree crops and are consumed in high quantities all over the world in the natural and peeled forms and as a juice. It contains many nutrients including vitamin C, A and B, minerals, dietary fiber and many secondary metabolites such as dietary phenolics, flavonoids, limonoids and carotenoids (Roussos, 2011). The addition of citrus fiber in the meat products will improve the oxidative stability and prolong their shelf life by preventing the lipid peroxidation due to the presence of associated bioactive compounds *i.e.* polyphenols (Sayago-Ayerdi, Brenes, & Goni, 2009) and also decrease the residual nitrite level (Fernandez-Gines et al., 2003). After the juice extraction process, the residues comprising of peel, pulp, rag and seeds are usually discarded as feed (Bampidis & Robinson, 2006). Citrus peel could be considered to be a potential source of pectin (pectin also belongs to fiber family) and fiber which are composed of white, spongy and cellulosic tissue (Terpstra, Lapre, Vries, & Beynen, 2002). Many epidemiological studies proved that peel of citrus fruits effectively lower the plasma and liver cholesterol level and decrease the level of serum triglyceride, serum total cholesterol, liver total lipids, and liver cholesterol (Chau, Chen, & Lin, 2004; Terpstra et al., 2002). Citrus fruit peel by-products can be a promising source of dietary fiber and functional compounds (Larrauri, 1999; Chau et al., 2003). The peel fiber derived from orange fruit involve in the improvement in intestinal function and health (Chau, Sheu, Huang, & Su, 2005).

The physicochemical properties, *in vitro* hypoglycemic effects of fibers from various fruits and vegetables have been evaluated to explore their potential applications and physiological activities (Chau & Huang, 2003; Chau et al., 2004; Fuentes-Alventosa et al., 2009; Al-Sheraji et al., 2011). The physicochemical properties (water holding, oil holding, emulsion activity, emulsion stability, swelling power and soluble index) of the three samples (peel, pulp and peel fiber) from *C. hystrix* and *C. maxima* were found to be high. This fiber powder could therefore be promising sources of dietary fiber. Since the method of processing of agricultural byproducts determines the functionality of dietary fibers, the aim of the present work was to evaluate potential hypoglycemic effects by several *in vitro* tests. The influence of these samples on the availability and diffusion of glucose and enzymatic degradation of starch were discussed. The potential role of the peel and pulp in lowering postprandial serum glucose level are discussed in this study.

2. Materials and methods

2.1. *Sample collection*

The fruits of *C. hystrix* and *C. maxima* (red and white) were collected from Mayiladuthurai, Nagai district, Tamil Nadu. The fresh fruit samples were separated into peel and pulp. The peel was divided into two parts. One part of the peel and pulp samples were dried at room temperature and another part of the peel was subjected to treatment for preparing the peel fiber (Larrauri, 1999). The peels were washed in hot water (90 °C for 5 min, peel:water 1:2). Later the residue was pressed to reduce excess moisture and dried at 65 °C for 24 h. The dried samples were ground into fine powder using electric blender and stored in a separate container at 4 °C until further analysis.

2.2. *Chemicals*

All the chemicals used in this study were of analytical grade. α-Amylase (A3176-1MU) from Porcine pancreas, D-glucose, starch from potato, xanthan gum, guar gum, dialysis bag (cut off molecular weight of 12,000), glucose assay kit (GAGO20-1KT) were purchased from Sigma Chemicals Co., (St. Louis, MO, USA). All the other chemicals were obtained from HiMedia Laboratories (Mumbai, Maharashtra, India). The water was treated by arium 67,316 reverse osmosis (Sartorius Stedim Biotech GmbH, Goettingen, Germany). All the spectrophotometric measurements were carried out using UV 100 (Cyberlab, Westborough, MA, USA).

2.3. *Structural analysis—Scanning electron microscopy (SEM)*

Powder samples of peel, and peel fiber from *C. hystrix* and *C. maxima* (red and white) were examined by SEM. Powdered samples were loaded over conducting double sided carbon tape and sputter coated with gold palladium and scanned by using ICON analytical, FEI QUANTA 200.

2.4. *Functional group analysis—Fourier transform infrared spectroscopy (FTIR)*

FTIR data were obtained using the BRUKER TENSOR 27 FTIR spectrophotometer. The spectrum was recorded in the Attenuated Total Reflectance (ATR) mode in the range from 600 to 4000 cm^{-1}.

2.5. *Proximate composition*

The moisture content of fruits samples (peel, pulp and peel fiber) were determined using Moisture Analyzer MA35 (Sartorius AG, Germany) at 105 °C. Micro-Kjeldahl method was employed to determine the total nitrogen and a nitrogen-protein conversion