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Review

Advances in the pectin production process using novel extraction techniques: A review

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ABSTRACT

The heteropolysaccharide known as pectin has found a myriad of functional and nutritive uses within the food and, increasingly, in other related industries. Extraction is a critical unit operation in recovering this compound from its *in situ* state in the cell walls of various plant-based food processing side streams. Although well established, growing demand has exposed certain inadequacies of the mainstream pectin extraction technique—notably efficiency and product consistency, thus prompting research interest towards ameliorating the process by an adoption of a number of novel technologies. Microwave and ultrasound energy appear to be the more likely candidates, but so are enzymatic-augmentation of the extraction process and the use of subcritical water to replace acidified water as solvent, among others. Yet this paper takes an objective approach in evaluating these new methods; for all their advantages, high cost, amidst other drawbacks, still prohibits their use in industry. Furthermore, optimization of process parameters are crucial to better understanding the chances of process scale-up, and this has been the current stage of efforts in the area. The present review discusses the nuances involved in using these non-conventional technologies for its extraction, including advantages and drawbacks. Prospects of their industrial integration are also conjectured.

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1. Introduction

Following their isolation, many naturally-synthesized cellular components of plants, animals, and microorganisms help meet some human nutritive and functional needs (Puri, Sharma, & Barrow, 2012). A number of these useful compounds occur as biopolymers, mainly polysaccharides and a few proteins (collectively called hydrocolloids, being water-loving polymers). Pectin is a native polysaccharide in the cell wall and middle lamellae of many land-growing plants, especially those of fruits and vegetables. Historically, the compound was dubbed 'pectic acid' from the Greek word $\pi\eta\chi\tau\varepsilon\varsigma$, meaning coagulated material, by the French scientist Henri Braconnot, who first isolated pectin from vegetables in 1825 (Muzzarelli et al., 2012; Yanakieva, Kussovski, & Kratchanova, 2012). Although ubiquitous in the planta, pectin in citrus, apple, sugar beet and sunflower are considered of special industrial interest (Table 1). This is due to the availability of the biomasses and the physicochemical quality presented by their pectins. Moreover, the properties of extracted pectin are known to vary with the plant source, and the extraction and post-extraction treatment conditions.

The sugar acid, D-galacturonic acid (GalA)—an oxidized form of D-galactose, constitutes the main monomeric unit of the rather complex pectin molecule. The GalA units are linked by α-1→4 galacturonosyl linkages; however, these natural link are often interrupted by L-rhamnose units bearing side-chains, which causes a discontinuity in the linear conformation of the poly-(GalA) chain. Some of the carboxyl group on the continuous poly-(GalA) chain of pectin are esterified by methyl groups informing variation in the degree of methyl esterification (DE or DM). This results in its classification as high methoxyl (HM) and low methoxyl (LM) pectins, depending on whether DE is greater or less than 50%, respectively (WHO/FAO, 1981). Homogalacturonans (HG), rhamnogalacturonan-I (RG-I), and substituted galacturonans (SG or RG-II) are the three main structural classes of pectin (Ridley, O'Neill, & Mohnen, 2001). The biosynthesis of pectin is also known to be complex and its understanding is currently characterized by much speculation (Caffall & Mohnen, 2009; Ridley et al., 2001).

Such diverse microstructural and macromolecular properties of pectin form the basis for its various food and non-food applications, which includes their reported health-promoting benefits and bioactivities (Endress, 2011; Yamada, Kiyohara, & Matsumoto, 2003). For example, pectins with low-molecular weight and chemically modified structures are said to instil satiety-inducing effects, selective cytotoxicity leading to anti-colon cancer activities, enhancement of cardiovascular health, and insulin and gastric inhibitory polypeptides (GIP) reduction (Almeida et al., 2015; Brown, Rosner, Willett, & Sacks, 1999; Hasselwander, 2008; Maxwell, Belshaw, Waldron, & Morris, 2012; Rabbani et al., 2001, 2004). Texturizing applications of pectin in food and similar systems, including gelling, viscosity enhancement, and colloid stabilizing, are fundamentally related to its in-solution (gels or dispersions) behaviour, the basis of which have been previously discussed (Lopes da Silva and Rao, 2006). Food sectors like dairy, bakery, and nutraceutical and functional foods (Anton & Artfield, 2008; Bierhalz, da Silva & Kieckbusch, 2012; Burnside, 2014; Li & Nie, 2016; Phillips & Williams, 2009; Rababah, Al-u'datt, & Brewer, 2015; Ramaswamy & Basak, 1992; Schmidt et al., 2015; Tromp, de Kruif, van Eijk, & Rolin, 2004; Zhuang, Sterr, Kulozik, & Gebhardt, 2015) as well as pharmaceutical domains like drug delivery (Liu, Fishman, & Hicks, 2007), exploit pectin. The book chapter by Endress (2011) provides a great overview of the basis of its current as well as prospective functionalization for nutritive and texturizing purposes.

Utilizing pectin, however, begins with its isolation from the parent plant material. This entire pectin production process is well documented in literature and is summarised in Fig. 1; it broadly includes a raw material pre-treatment stage, an extraction operation, and a post-extraction stage (Gentilini et al., 2014; Kai, Yan, Sijin, Xiaojun, & Xiaosong, 2008; Kratchanova, Panchev, Pavlova, & Shtereva, 1994; Lopes da Silva & Rao, 2006; May, 1990). However, one of the questions raised regarding the conventional pectin production process, particularly the extraction step, is whether or not the valorisation of fruit and vegetable processing by-products is really worth energy and economic demands that are currently associated with the practice (Casas-Orozco, Villa, Bustamante, & González, 2015). Asides this resource conservationist's viewpoints, the extended heating duration required, also raises the question of whether the process duration can be reduced, thereby resulting in better quality and with somewhat consistent physicochemical properties of pectin. To this end, several sustainable and quicker alternative approaches to extracting natural compounds from biological materials have emerged. Some prominent outcomes of adopting these novel methods include shorter extraction

Table 1
Comparison of some commercial and non-commercial sources of pectin.

Source/utilized segment	Content (% dry wt)	Probable natural class of pectin[a]	References
Conventional			
Citrus peel	30–35	HM	Lopes da Silva and Rao (2006)
Apple pomace	15–20	HM	Lopes da Silva and Rao (2006)
Sugar beet pulp (post-sugar extraction)	15–30	HM	Michel, Thibault, Mercier, Heitz, and Pouillaude (1985); Peng et al. (2015)
Sunflower seed head	5–25	LM	Miyamoto and Chang (1992); Wiesenborn et al. (1999)
Unconventional			
Cranberry, onion, garlic, banana, mango, pumpkin, peach, rapeseed, papaya	0.1–28	LM and HM	Alexander and Sulebele (1973); Jeong et al. (2014); Kalapathy and Proctor (2001); Maran and Prakash (2015); Pagán, Ibarz, Llorca, Pagán, and Barbosa-Cánovas (2001)

[a] LM – low methoxyl; HM – high methoxyl.