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Prebiotic potential of oligosaccharides: A focus on xylan derived oligosaccharides

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ABSTRACT

Xylan is available abundantly in nature as a major constituent of hemicellulose, a component of lignocellulosic biomass. Agricultural wastes such as straw, stalk, cob, hull, husk, bagasse and pulp of hardwood represent a major source of xylan. Xylooligosaccharides (XOS), the hydrolysis product of xylan is substrate for colonic commensal bacterial population, acting as potential prebiotic. Its fermentation produces short chain fatty acids, improves gut epithelial health and regulates metabolic process. These oligosaccharides possess bound phenolics including ferulic acid, coumaric acid, thus imparting additional antioxidant effect and immunomodulatory activity. This paper deals with xylan based oligosaccharides with an emphasis placed on the need of oligosaccharides and discusses in detail the health benefits of xylooligosaccharides.

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1. Introduction

With increased consumer awareness, there is distinct change in understanding of role of food in human health promotion. Scientific investigations have also moved from primary role of food as source of energy, body forming substance to their biological activity on human health. The term “functional food” was first used in Japan, in the 1980s, for food products fortified

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with special constituents that possess advantageous physiological effects (Prapulla & Aachary, 2011; Hardy, 2000; Shahidi, 2009). Functional foods can be considered as basic nutrition foods which have demonstrated physiological benefit (Shahidi, 2009). Functional food includes: i) food with natural bioactives ii) derived food e.g. prebiotics and iii) bioactives added to food as supplements e.g. probiotics, antioxidants (Grazek, Olejnik, & Sip, 2005). Table 1 provides the definition of probiotics, prebiotics and synbiotics with some examples from this type of functional foods.

Prebiotics are non-digestible or of low digestibility food ingredients which selectively stimulate growth of limited number of species of gut microbiota, conferring health benefits to host (Roberfroid et al., 2010; Vitali et al., 2012). It includes oligosaccharides and polysaccharides which are: 1) resistant to gastric acidity and hydrolysis by mammalian enzyme, 2) fermented by intestinal microflora, and 3) selectively stimulate growth of intestinal bacteria (Roberfroid, 2007; Broekaert et al., 2011). Cited examples of prebiotics include inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), isomaltooligosaccharides, soybean oligosaccharides and lactulose (Macfarlane, Macfarlane, & Cummings, 2006). Xylooligosaccharides (XOS) are a new class of prebiotics and consists of xylobiose, xylotriose and so on (Vazquez, Alonso, Dominguez, & Parajo, 2000; Chapla, Pandit, & Shah, 2012). They are naturally present in fruits, vegetables bamboo, honey and milk and can be produced from xylan rich lignocellulosic wastes. Table 2 summarizes source, chemical characteristics, production process and marketed products of different prebiotic oligosaccharides.

Lignocellulosic materials (LCM) are most abundant biomass and made up of: cellulose, a linear polymer of 1→4 linked β-glucose units; hemicellulose, a heteropolysaccharide comprising of monosaccharides (pentoses and hexoses); and lignin, All these constituents make a major portion of the plant cell wall material (Parajo, Vazquez, & Alonso, 2000; Kobayashi & Fukuoka, 2013). Annually tons of such biomass such as of corn stover, sugarcane bagasse, rice and wheat straw, pomace, peel are generated as a result of various post-harvest and processing activities of grains, fruits and vegetables (Van Dyk, Gama, Morrison, Swart, & Pletscheke, 2013); most of this material is discarded, reducing the nutritional value of food (Martinez et al., 2012). Moreover, these agricultural wastes are rich in bioactives which can be incorporated into foods to increase the nutritional value and functional properties (O'Shea, Arendt, & Galaghar, 2012, Carvalho, Neto, Fernandes da Silva, & Pastore, 2013).

Bioconversion of these LCM to usable products require fermentation (Zha & Punt, 2013) and pretreatments including mechanical (Cadoche & Lopez, 1989), chemical (Nguyen et al., 2010; Ramadoss & Muthukumar, 2014) and biological (Yin et al., 2011; Canam, Town, Iroba, Tabil, & Dumonceaux, 2013) to produce higher value added products such as single cell protein, monosaccharides, xylitol, biofuel, aromatic compounds.

Hemicellulose (25–35%) is most abundant polymer only after cellulose (45–55%) found in plant cell walls, in close association with lignin (Ebringerova & Heinze, 2000). Hemicelluloses have β-(1→4)-linked backbone and include xyloglucans, xylans, mannans and glucomannans, and β-(1→3, 1→4)-glucans (Scheller & Ulvskov, 2010). Xylans have a linear β-(1→4)-D-xylopyranan backbone with various substituents including arabinofuranosyl, glucopyranosyl and uronic acid derivatives, ferulic and coumaric acid, acetyl and phenolic acids which are either ether or ester substituted to the hydroxyl group of xylose units, as shown in Fig. 1. Depending on the botanical source and the method of extraction employed, xylans of various structural complexities can be obtained; also, different tissues of same plant may show diversity in their structure and function (Suzuki, Kitamura, Kato, & Itoh, 2000, Jensen, Johnson, & Wilkerson, 2013). Most commonly xylans are classified based on the substituents as shown in Fig. 2. These long chain carbohydrates and their oligosaccharides are major components of dietary fiber (Holloway, Tasman-Jones, & Bell, 1980) and play an important role as prebiotics (Otieno & Ahring, 2012).

According to IUP-IUPAC, oligosaccharides are defined as oligomers composed of 2–10 monosaccharide residues. Oligosaccharides are low molecular weight carbohydrate residues and are classified as digestible or nondigestible (Mussatto & Mancilha, 2007). As opposed to α-linkages which are digestible by human digestive enzymes, the anomeric carbons in nondigestible oligosaccharides have β-linkages and thus are resistant to hydrolysis by human digestive enzymes in most cases, except galactosides (e.g. lactose). Generally, the larger the molecular weight of the bulk sucrose substitute, the weaker the intensity of sweetness. Most oligosaccharides are water soluble, have sweet taste (0.3–0.6 times of sucrose), good mouth feel and low calorific value (1.5 Kcal/g); hence they are used as bulking agent in food production to enhance other food flavors (Roberfroid & Slavin, 2000). The functional properties of oligosaccharides to be used in processed foods should be similar to that of sucrose in providing bulk properties and a good sweetness.

The focus of the review is to inform readers about need and role of XOS based prebiotics to manage the gastrointestinal tract (GIT) ecosystem, antioxidant activity and positive effects on immune system. Wherever found feasible, examples and selected citations have been given to demonstrate the application of XOS and other oligosaccharides prebiotics to manage the GIT ecosystem thereby improve the health and

Table 1 – Definition and examples of probiotics, prebiotics and synbiotics.

Name	Definition	Examples	References
Probiotics	Selected, viable microbial dietary supplements which in sufficient quantity confer health benefit to host	Bifidobacterium spp., Lactobacillus spp., etc.	Sanders, 2008
Prebiotics	Non-digestible or low digestable food ingredients which selectively stimulate growth of limited number of species of gut microbiota, conferring health benefits to host	Lactulose, fructooligosaccharides, Inulin etc.	Grazek et al., 2005
Synbiotics	Combination of prebiotic with probiotic, where prebiotics selectively favors the probiotic	Oligofructose and Bifidobacteria	Schrezenmeir & de Vrese, 2001