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XYLITOL ON DENTAL CARIES: A REVIEW

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ABSTRACT

Xylitol is a pentahydroxy sugar-alcohol which exists in a very low quantity in fruits and vegetables (plums, strawberries, cauliflower, and pumpkin). On commercial scale, xylitol can be produced by chemical and biotechnological processes. Chemical production is costly and extensive in purification steps. The precursor xylose is produced from agricultural biomass by chemical and enzymatic hydrolysis and can be converted to xylitol primarily by yeast strain. Hydrolysis under acidic condition is the more commonly used practice influenced by various process parameters. Biotechnological xylitol production is an integral process of microbial species belonging to Candida genus which is influenced by various process parameters such as pH, temperature; time, nitrogen source, and yeast extract level. It is a functional sweetener as it has prebiotic effects which can reduce blood glucose, triglyceride, and cholesterol level. Dental caries is an infectious microbiologic disease of the tooth that results in localized dissolution and destruction of calcified tissues. Xylitol has been shown to reduce dental caries when mixed with food, chewing gums and milk. Dental caries are prevalent in acidic pH where Streptoccocus mutans (MS) ferment resulting in demineralization of tooth, where as Streptococcus mutans cannot ferment xylitol thus it reduces MS by altering their metabolic pathway and enhance remineralization and helps arrest dentinal caries. Reduction in caries rate is greater, when xylitol is used as the sugar substitutes. This review discusses the taste acceptability of xylitol in milk as a step towards measuring the effectiveness for the reduction of dental caries.

Keywords: Xylitol, Carbohydrates, Caries, Remineralisation, Demineralization, Streptoccocus mutans

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INTRODUCTION

Xylitol is a naturally occurring sugar-alcohol having five carbon atoms and five hydroxyl groups and present in a very small quantity in fruits such as plums, strawberries, and raspberries and vegetables such as cauliflower, pumpkin, and spinach. Commercial production of xylitol is based on hydrogenation of xylose in a nickel-catalyzed process which is an energy and cost demanding. Therefore, some alternative biotechnological processes have been studied, especially those involving yeasts from Candida genus. Currently, xylitol market lies between 20,000 and 40,000 tons per year with an economic value ranging between 90 and 340 million dollars.[1, 2, 3]

Xylitol has applications for at least three types of industries, namely, food (for dietary especially in confectioneries and chewing gums), odontological (due to its anticariogenicity, tooth rehardening, and remineralization properties) and pharmaceutical (for its tooth friendly nature, capability of preventing otitis, ear and upper respiratory infections, and its possibility of being used as a sweetener in syrups, tonics, and vitamin formulations).[3] However, the foremost utilization is for the prevention of dental caries as it inhibits the growth of microorganisms responsible for tooth decay.[4,5,6] Besides this, it is accepted for consumption for diabetics and helps in treatment of hyperglycemia as its metabolism is independent of insulin.[4] Furthermore, it is also considered to be a functional food due to its prebiotic nature.[7] Its market value is increasing day by day and is estimated to be $340 million per year with a selling price of $4-5 kg-1.[3]

It can be produced either by chemical hydrogenation of xylose or by biotechnological processes. The chemical process is difficult, costly, and energy intensive. One of the alternatives is bioconversion of renewable biomass sources which requires hydrolysis followed by bioconversion of xylose from crude hydrolysate to xylitol employing specific microbial strains for fermentation.[8,9] The precursor xylose is produced from agricultural wastes by enzymatic or chemical hydrolysis and can be converted to xylitol mostly by yeast strains which present the possibilities of economic production by reducing required energy when compared to chemical production. Biomass pre-treatment under acidic conditions is the most commonly used practice and is influenced by various process parameters. Various microbial growth inhibitors are produced during acid hydrolysis that decrease xylitol production from xylose, a detoxification step is, therefore, crucial. As a cheap raw material, agricultural wastes are considered as potential sources for its bioproduction.

It is a non-nutritive sweetener that has demonstrated effectiveness for preventing dental caries.[10] It has been introduced in different foods for children's including gum, candies, gelatin, sorbets, syrups and other products including multivitamins, lozenges, tooth paste, and oral rinses. Studies have demonstrated that daily ingestion of 5g of xylitol in different format reduces the level of dental caries. Reduction of dental caries can be explained by the effect of xylitol on cariogenic bacteria.[11] Xylitol has the same sweetness and bulk of sucrose but with fewer calories.[12] Snacks made with xylitol are well accepted.[13] The perception of flavours in milk is one of the human infant's earliest sensory experiences, and there is support for the idea that this early experience with flavours has an effect on milk intake and on later food acceptance.[14]

This review discusses the taste acceptability of xylitol in milk as a step towards measuring the effectiveness for the reduction of dental caries.

NATURE AND OCCURRENCE OF XYLITOL

Xylitol (C5 H12 O5) is a naturally occurring pentose sugar alcohol used as sweetener. It was first synthesized in 1891 by German and French scientists. During the next five decades, it got very little attention, however sugar shortage during World War II prompted the search for new sweetener. Sweetening power of xylitol is equivalent to sucrose; however, other polyols possess less sweetness than sucrose. It has one-third caloric content than conventional sugar and thus has potential to replace sucrose in low caloric products. The special properties of xylitol find use in food and pharmaceutical industries. It occurs as an intermediary product of carbohydrate metabolism in humans and animals. About 5-15 g xylitol is produced per day in human adults. It is present in some fruits and vegetables in a very low quantity.

LIGNOCELLULOSIC BIOMASSES FOR BIOPRODUCTION

Lignocellulosic biomasses (LBs) are wide spread, abundant, renewable, cost-effective, and economical sources of polysaccharides which can be used for xylitol production. These sources include agricultural, agro-industrial, and forestry residues. These residues contain lignocellulose as organic matter which is mainly composed of cellulose (34-50%), hemicellulose (19-34%), lignin (11-30%), and smaller amounts of pectin, protein, extractive, and ashes. Composition of these components differs with the source of plant species, age, and growth conditions. Most abundant heterogeneous polymer of LBs is hemicellulose which comprises of pentoses (xylose and arabinose), hexoses (mannose, glucose, and galactose), and sugar acids. In contrast to cellulose, hemicellulose is not chemically homogeneous. Xylans are the most abundant hemicelluloses. Xylans of many plant materials are heteropolysaccharide with homogeneous backbone chain of 1, 4-linked β -D-xylopyranose units. In addition to xylose, xylan may contain arabinose, glu- curonic acid, or its 4-O-methyl ether, and acetic acid, ferulic acid, and p-coumaric acids. The compositions of branches depend on the source arabinofuranosyl, A-1, 2, or 4 are glucuronic acid substituents. They can thus be positioned homoxylan as linear, arabinoxylan, and glucuronoxylan glucuronoarabinoxylan. Xylans from different sources, such as grasses, cereals, softwood, and hardwood differ in their composition. Birchwood xylan contains 89.3% xylose, arabinose, 1%, 1.4% glucose, and 8.3% anhydrouronic acid. Rice bran xylan contains 46% xylose, arabinose 44.9%, galactose 6.1%, glucose 1.9%, and 1.1% anhydrouronic acid. Wheat arabinoxylan contains 65.8% xylose, 33.5% arabinose, 0.1% mannose, galactose 0.1%, and 0.3% glucose. Corn fiber xylan is one of the heteroxylans complex with linked β (1, 4)-xylose. It contains 48-54% xylose, arabinose 33-35%, 5-11% galactose, and 3-6% glucuronic acid. Almost 80% of the xylan backbone is highly substituted with monomeric side chains of arabinose or glucuronic acid linked to 0-2 and/or 0-3 of xylose residues, and also by oligomeric side chains containing arabinose, xylose, and galactose. The heteroxylans which are interconnected to form a network in which the cellulose microfibrils are embedded are strongly influenced by diferulic cross-bridges. Structural wall proteins might be cross-linked together by isodityrosine bridges and with feruloylated heteroxylans, thus forming an insoluble network.

A variety of other plant biomasses has also been evaluated as a source of raw materials such as corn[8], sugarcane bagasse, spent brewing grain, olive tree pruning, soyabean hull, palm oil empty fruit bunch fibre, rice straw, banana peel, mongbean hull, peanut hull, oat hull, and coffee husk. These are organic in nature and are of great significance for sustainable development in contrast to renewable nonorganic materials and fossil carbohydrates.[3]

ROLE OF CANDIDA SPECIES AS MODEL ORGANISMS FOR XYLOSE METABOLISM

Candida species are utilized for xylitol production as they have well-developed pentose phosphate pathway (PPP) and can grow on xylose only which is a single substrate and energy source. The oxidative phase of PPP produces pentose phosphates from hexose phosphates provides NADPH which is required for its biosynthesis. The non-oxidative phase produces hexose phosphates and triglycerides from pentose phosphates. Candida tropicalis is one of the most successful organisms for xylitol production. Its industrial importance is due to its high uptake of xylose, xylitol production capability, and alkane and fatty acids degradation in its peroxisomes.[2,8]

Cheng et al. (2009) optimized pH and acetic acid concentration for bioconversion of hemicellulose from corncobs to xylitol by Candida tropicalis.[19] It was produced by Candida tropicalis W103 from corncobs subsequently by acid hydrolysis, detoxification by boiling, over liming, and solvent extraction. It was observed that glucose in hydrolysate enhanced the growth of Candida tropicalis while acetic acid at high concentration had inhibitory effect. The inhibition by acetate can be eliminated by adjusting pH to 6 prior to fermentation. Under these optimal conditions, a maximum xylitol concentration of 68.4 g L-1 was achieved after 72 h of fermentation, giving a yield of 0.7 g xylitol g L-1 xylose and a productivity of 0.95 g L-1 h-1.

The fermentation of mixtures of D-glucose and D-xylose by the Candida tropicalis NBRC 0618 has been studied by Sanches et al. (2008) under the most probable conditions. Synthetic culture medium was used in all the experiments, with an initial substrate concentration of 25 g L-1, a constant pH of 5.0 and a temperature of 30o C.[20] From the experiments, it was concluded that the highest yield in xylitol production was obtained from the mixtures with higher percentage of D-xylose, with an overall xylitol yield of 0.28 g g-1. Arrizon et al. (2011) produced xylitol and bioethanol from sugarcane bagasse, coffee husks, and agava tequilana bagasse by utilizing s. ceriavisae, C. magnolia, and C. tropicalis. Among them C. tropiclis was found to be best for xylitol production.[21]

DENTAL CARIES

This is the disease that dentist deals with more than 90% of secretions, or metabolic products of microorganisms, have the time. According to acidogenic theory, dental decay is caused by acids produced by microbial enzymatic action on ingested carbohydrates. These acids will decalcify the inorganic portion of the tooth; then the organic portion is disintegrated, creating cavities. The proteolysis theory, on the other hand, claims that the organic portion of the tooth is attacked first with certain lytic enzymes. This leaves the inorganic portion without a matrix support, causing it to be washed away, creating cavities. In a third theory, microbiotic the ability to chelate calcium from tooth substances, leaving the organic matrix to be disintegrated. Each of these theories fails to explain all ramifications of the disease, but all three agree on the following.[1] For the decay process to be established there must be:

1. Host (tooth)

2. Parasite (plaque microorganisms)

3. Medium, (carbohydrates in the diet)

4. Time

ROLE OF XYLITOL IN REMINERALISATION

When xylitol is incorporated in milk, chewing gums or any other food products there was no fermentation of bacteria since there was no acidic nature. This resulted in the stimulation of salivary secretion thus alkaline environment was produced in the oral cavity. So the oral pH increases resulting in the remineralisation of tooth thus helping in the prevention of dental caries.[14]

Sugar substitutes:

Xylitol is commonly used sugar substitute especially in chewing gums. A non fermentable sugar acts as a carrier or reservoir for calcium phosphate.[15] A study showed that sugar free gum containing xylitol produces superior remineralisation.[16] The abilities of xylitol and Sorbitol to remineralise early enamel caries seem to be similar.[17]

Chewing gums:

Xylitol as chewing gums are effective method for caries prevention when chewed for long period they stimulate saliva and have washed off effect on debris. They can also be used to carry desired medicaments to the tooth, thus having beneficial effect. It has been observed that the effect of xylitol along with calcium lactate improved remineralisation.[18]

CONCLUSION

Milk with xylitol is well accepted by both children and adults. Relevant effect of xylitol in milk on cariogenic bacteria has been reviewed. The beneficial effect of milk along with xylitol demonstrate that xylitol in milk has an anti- caries effect and further research have to be carried out to demonstrate this anti-cariogenicity activity of milk along with xylitol.

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