Biotransformation of Xylitol Production from Xylose of Lignocellulose Biomass Using Xylose Reductase Enzyme: Review

Nurul Azizah*

* Department of Agroindustrial Technology - Faculty of Agricultural Technology
Brawijaya University, Jl. Veteran – Malang 65145
E-mail: nazizah50@gmail.com

ABSTRACT

Xylitol is a polyol sugar produced from xylose and has a sweet taste. Xylose can be obtained from hemicellulose in lignocellulosic biomass. The types of lignocellulosic biomass that can be used for the production of xylitol include rice straw, sugarcane bagasse, corn cobs, and corn stover. The process of producing xylitol from xylose can be done by biotransformation using enzymes. One of the enzymes that can be used is xylose reductase. The commonly used microorganisms are the group of Candida genus. The maximum production of xylitol from lignocellulosic biomass is between 12.5 - 96.5 g/L. pH, temperature, substrate concentration, and aeration are parameters that influence the increase in xylitol production. The use of xylose can be used in the food, health and pharmaceutical industries.

Keywords: Xylitol, xylose, lignocellulosic biomass, xylose reductase

ABSTRAK

Xilitol merupakan gula poliol yang diproduksi dari xilosa dan memiliki rasa manis. Xilosa dapat diperoleh dari hemiselulosa pada biomassa lignoselulosa. Jenis biomassa lignoselulosa yang dapat digunakan untuk produksi xilitol antara lain adalah jerami padi, bagasse tebu, tongkol jagung, dan limbah (stover) jagung. Proses produksi xilitol dari xilosa dapat dilakukan dengan biotransformasi menggunakan enzim. Salah satu enzim yang dapat digunakan adalah xylose reductase. Mikroorganisme yang umumnya digunakan adalah kelompok genus Candida. Produksi xilitol dari biomassa lignoselulosa maksimal antara 12,5 – 96,5 g/L. pH, suhu, konsentrasi substrat, dan aerasi menjadi parameter yang berpengaruh terhadap peningkatan produksi xilitol. Pemanfaatan xilosa dapat dugunakan dalam industri pangan, kesehatan, dan farmasi.

***Kata Kunci**: Xilitol, xilosa, biomassa lignoselulosa, xylose reductase*

INTRODUCTION

Xylitol is a naturally occurring polyol or penta hydroxy (C5) alcohol sugar (Cortez et al., 2016; Zhang et al., 2018). Xylitol has a sweet taste similar to sucrose (Rafiqul et al., 2015; Dasgupta et al., 2017) and has a calorie content of 40% less than sucrose (Albuquerque et al., 2014). Xylitol has broad commercial applications, including in the pharmaceutical, nutraceutical, food and beverage industries (Dasgupta et al., 2017). Therefore, the market value of xylitol increases significantly. In 2013, the value is estimated at US $ 670 and will increase to US $ 1 billion by 2020 (Zhang et al., 2018). The selling price of xylitol per month is US $ 4.5 - 5.5 / kg and the price for the final product reaches US $ 20 / kg (Ravella et al., 2012).

Xylitol production from xylose (Cheng et al., 2011) by engineering using enzymes (Hassanpour et al., 2017) or so-called biotransformation with the help of enzymes. Xylose itself is a pentose sugar (Sjöman et al., 2008), the most abundant monosaccharide in lignocellulosic biomass along with a bucket (Kwak and Jin, 2017) using sugar with other types such as manose, galactose, arabinose and ramnosa (Albuquerque et al., 2014). The percentage of the amount of xylose in biomass is around 30-40% (Kim et al., 2012). Xylose generally originates from hemicellulose in lignocellulose (Liu et al., 2017).

Lignocellulose is defined as a major structural component in both timber and non-timber plants (Howard et al., 2003). Lignocellulosic biomass is the most important raw material as a new and renewable natural resource that is important for modern industrial societies (Howard et al., 2003; Anwar et al., 2014). Lignocellulosic biomass is composed of three main elements, namely cellulose, hemicellulose, and lignin (Pérez et al., 2002; Howard et al., 2003). Hemicellulose is another source of kabohydrate in lignocellulosic material in addition to cellulose which consists of heterogeneous polysaccharide groups consisting of sugar monomers such as xylose, manose, galactose and arabinose (Naraian and Gautam, 2018).

Lignocellulosic biomass more commonly contains hemicellulose of approximately 25-35% (Anwar et al., 2014). According to Bilal et al. (2017), xylitol is approved as one of the best chemicals derived from lignocellulosic biomass. The conversion of xylose to xylitol has a significant economic role with regard to biomass (Prakash et al., 2011). Therefore, lignocellulosic biomass is needed to produce xylitol.

XILITOL PRODUCTION

Xylitol production can be obtained from xylose reduction in lignocellulosic biomass (Bilal et al., 2017). Some of the main lignocellulosic biomass that can be used for xylitol production include corn, wheat straw, corn waste, wheat bran, miscanthus and others (Rao et al., 2016). **Table 1** shows some of the lignocellulosic biomass found in Indonesia and the microorganisms used for xylitol production.

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Table 1. Production of xylitol from several types of lignocellulosic biomass using different microorganisms

Lignocellulosic Biomass	Microorganisms	Used Xylose (g/L)	Xilitol Yield (g/L)	References
Rice Straw	*Candida guilliermondii*	85	66,1	Mussatto and Roberto, 2003
	Candida tropicalis	45,8	31,1	Huang et al., 2011
Cane Bagasse	*Candida guilliermondii*	77,26	50,5	de Arruda et al., 2011
	Debaryomyces hansenii	100	71,2	Prakash et al., 2011
Corncob	*Candida tropicalis*	116,7	96,5	Li et al., 2012
Corn stover	*Pichia stipitis*	21,5	12,5	Rodrigues et al., 2011

In general, the production of xylitol from xylose by microbial is done using the help of yeast. Yeast is considered as a powerful and efficient producer of xylitol compared to bacteria and fungi (Pal et al., 2016). Based on Table 1, the maxillation of xylitol from xylose is maximum in corncobs using *Candida tropicalis*, which is 82.69%. Table 1 also shows the types of microorganisms most commonly used are *Candida tropicalis* and *Candida guilliermondii*. According to Ikeuchi et al. (1999), in general, microorganisms derived from the genus Candida are the most widely used microorganisms to produce xylitol. Meanwhile according to Pal et al. (2016), most yeasts such as *Candida* spp., *Hansenula polymorpha*, and *Debaryomyces hansenii* are used in xylitol production.

Biotransformation of Xylose to Xylitol

Bioconversion of xylitol from xylose using yeast is considered as an alternative to large scale commercial chemical processes because the biological route requires lower energy (López-Linares et al., 2018). The metabolism of xylose to xylitol by yeast is reduced using the enzyme xylose reductase (Cortez et al., 2016). The reduction of xylose to xylitol by the enzyme xylose reductase can be seen in **Figure 1**. Xylose is obtained from the process of collecting xylose into xylitol bioconversion. Xylose is reduced by using NADH or NADPH using the enzyme xylose reductase to xylitol (Pal et al., 2016). NADH or NADPH in this case works as a cofactor to catalyze the approval of carbonyl groups (reductase or dehydrogenase) (Chin et al., 2009).

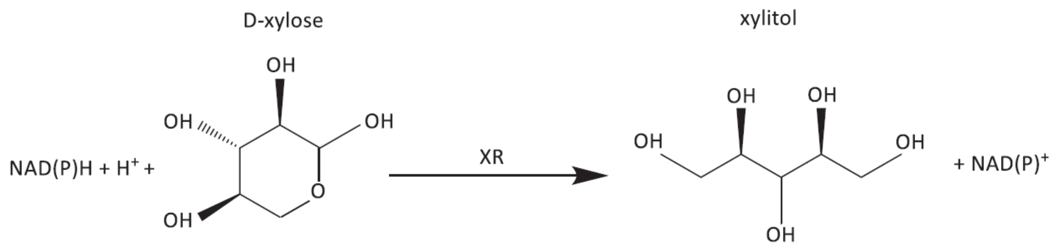

Figure 1. Reducing Xylose to Xylitol with Xylose Reductase (XR) Enzyme (Hassanpour et al., 2017)

Xylitol can be produced in large quantities through xylose reductase engineering with xylose as a reactant and xylitol as an enzymatic product needed to be produced. The purpose of engineering xylose reductase is to engineer the specificity of xylose reductase substrate while maintaining its activity against natural substrates, in this case xylose (Hassanpour et al., 2017). Other efforts that can be done to increase the yield or productivity of xylitol are by increasing the heterologous gene xylose reductase to higher activity or increasing the amount of gene contribution (Pal et al., 2016).

Xylitol Production Process Parameters

In xylitol production, it is important to consider parameters that are questioned in the production process (Tamburini et al., 2015). Some parameters that contribute to the productivity of xylitol include carbon and nitrogen sources (Rao et al., 2016; Dasgupta et al., 2017), pH, temperature, substrate concentration, and aeration (Pal et al., 2016; Rao et al., 2016; Dasgupta et al., 2017). Aeration or availability of oxygen is a factor that plays an important role in the accumulation of xylitol, because it affects the activity of the xylose metabolism enzyme, in this case the xylose reductase enzyme (Pal et al., 2013, 2016).

XILITOL APPLICATION

Xilitol applications can generally be used in various fields, namely the food industry (Kim et al., 2010), health (López-Linares et al., 2018), the pharmaceutical (pharmaceutical) and chemical industries and have an application value and potential market important (Qi et al., 2017) as mentioned in the introduction. Xylitol has several properties related to its function, namely low energy content, anti karyogenicity, tooth rejuvenation, prevention of otitis, upper ear and respiratory infections, and others (Rao et al., 2016).

Xylitol, in the food industry, has been popularly used in formulations of various foods and confectionery products, such as sugar-free bread and gum products. That is because xylitol provides a sweet taste, rapid cooling effect and as a low-energy sweetener (Zhang et al., 2018). Xylitol is used to replace sucrose because it is considered to be able to reduce calorie reduction in cupcake, cookie, chocolate, and chewing gum production (Albuquerque et al., 2014).

CONCLUSSION

Xylitol is produced from hemicellulose biomass lignocellulose by changing xylose. The enzymatic biotransformation of xylose into xylitol using the xylose reductase enzyme. Microorganisms that are commonly used are the *Candida* genus group. Maximum xylitol production from lignocellulosic biomass is between 12.5 - 96.5 g / L with xylose material between 21.5 - 116.7 g / L. The maximum biotransformation process can reach 82.69%. The parameters that influence the production of xylitol are pH, temperature, substrate concentration, and aeration. Utilization of xylose in the food industry can be used to replace sucrose because of its lower calorie content.

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