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Xylitol Properties and Identification

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Abstract:
Background*: Xylitol is a sugar alcohol that has 5 carbon chains. Xylitol has a function as an antimicrobial, strengthens gums, prevents plaque on the teeth, is antidiabetic, additives in topical preparations, and sweeteners. The advantage of xylitol over sucrose is that it has a fairly low-calorie content with a sweetness equivalent to that of sucrose. Xylitol is classified as a safe sweetener for diabetics because it has a much lower glycemic index value.*
Key Word*: Aplication; Isolation; Properties; Xylitol.*

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Xylitol

Xylitol is a sugar alcohol that has 5 carbon chains. Xylitol has a function as an antimicrobial, strengthens gums, prevents plaque on the teeth, is antidiabetic, additives in topical preparations, and sweeteners. The advantage of xylitol over sucrose is that it has a fairly low-calorie content with a sweetness equivalent to that of sucrose. Xylitol is classified as a safe sweetener for diabetics because it has a much lower glycemic index value. Xylitol is only absorbed about 50% in the small intestine and the rest is fermented in the large intestine.

Xylitol is the top value-added chemical considered by the US department of energy that can be produced from plant biomass[1]. Xylitol-based polyester has been widely developed by scientists as a biodegradable material in tissue engineering applications. Its inert nature and no damaging effects on cells make Xylitol a popular choice as it can be used to make poliol-based polymers [2].

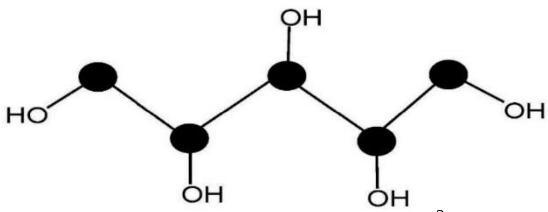

Figure no 1. Xylitol structure [3]

1. Properties of Xylitol

Carried out the synthesis of xylitol from the hydrolyzate of empty oil palm bunches and then carried out the characteristics of the physicochemical properties of xylitol. The xylitol crystals produced in this study are a bit sticky so that the moisture content of the xylitol crystals produced in this study is higher than the xylitol crystals on the market. Heating xylitol at a temperature of 70°C produces moisture content values ranging from 20.61% to 21.97%. While heating at a temperature of 55°C produces a moisture content value of 23.06-24.54%. Lower temperatures bring xylitol to form larger porosity in crystals and the hygroscopicity of xylitol is at a value of 23.44-25.04% which means it is very hygroscopic. The categories for the distribution of the hygroscopicity of a material are as follows [4].

Table no 1. Material hygroscopicity category

Category	Hygroscopicity (%)
Non-Hygroscopic	<10%
Less Hygroscopic	10,10-15%
Hygroscopic	15,10-20%
Very hygroscopic	20,10 – 25%

The high humidity and hygroscopicity of xylitol can be caused by the purity level of xylitol which is not very pure (less than 98%) because it contains by-products such as xylose and glucose. In general, pure xylitol has lower hygroscopicity than sorbitol, fructose, and cornstarch. Xylitol is very soluble in water. The solubility of xylitol in water at various temperatures has been tested and shows the same results, namely having high solubility at each temperature, besides that xylitol is known to be difficult to dissolve in bioethanol[4]. These solubility data are supported by research conducted by Wang et al., in 2013[5]. Xylitol is more soluble in water than in ethanol where the solubility increases when the temperature is increased. The combination of pure ethanol and water as a solvent for xylitol has also been carried out in this study, but the solubility of xylitol still increases when the amount of water in the ratio is higher. Some of the above phenomena are related to the chemical structure of xylitol where this compound has hydrogen bonds in the hydroxyl group which contribute to the solubility of the substance in polar solvents, the viscosity of the material, high boiling point[6].

Xylitol is stable in an alkaline solution of 2.5 mol/L NaOH, 0.6 mol/L $C5H12O5$ where xylitol does not show a chemical reaction[7]. In the thermal stability test, xylitol showed decomposition at lower temperatures than pure PEG which was resistant to heat up to 350°C[8]. The melting point of xylitol becomes metastable at a temperature of 61-61.5°C[8]. Xylitol has a lower melting point than erythritol (104°C or 102-112°C) and sorbitol (90-92°C)[6].

In the thermal test conducted by Gunasekara et al in 2016, the xylitol solution which underwent four heating (at a temperature of 115°C) and 3 cooling cycles showed a change in the color of the solution to become browner. From this test, it can be seen that the xylitol solution has the potential to change color if heated at a temperature of 10°C higher than the melting point of xylitol and the heating time is quite long. Xylitol has a high boiling point of 216 °C[6]. The following is an illustration of the color change of a heated xylitol solution

Figure no 2. Discoloration of the xylitol solution after heating[9]

2. Source of xylitol

Xylitol can naturally be sourced from a variety of fruit, vegetable, and plant biomass containing xylan or hemicellulose such as cashew bagasse[10], corn cobs[11], oil palm empty fruit bunches[12], bagasse of cane sugar, straw, and several types of nuts. To obtain pure xylitol, it is necessary to go through several extraction processes, the results obtained are not comparable to the long process carried out so that it can be said that this process is less effective.

There are also ways to synthesize xylitol through chemical processes and biotechnology.

Tabel no 2. Fermentation Condition in pada Syntesis of Xylitol

Reference	Hydrolyzed raw material	Synthesis process	Microorganisms	Xylitol yield from xylose (g/g)	Fermentation method/condition
Li dkk., 2015	Corn cobs	Biotechnology	*Candida tropicalis*	75,14%	At temperature 48,01°C and pH 5,57
Kresnowati dkk., 2016	Oil palm empty bunch	Biotechnology	*Debaryomyces hansenii* ITB CC R85	0.102+- 0.007 g/g	pH 5 and initial concentration 6 x 10^7 cells/mL
Wang dkk., 2011	Corn cobs	Biotechnology	*Candida tropicalis*	71,4%	At temperature 30°C for 48 hours, pH 6
Walsh dkk., 2018	straw wheat	Biotechnology	*Candida guillermondii*	86,9%	At temperature 30 °C for 8 hours, pH 7
Silva dkk., 2020	Sugarcane	Biotechnology	*Scheffersomyces amazonensis*	68% with purity 98%	At temperature 30 °C for 84 hours, pH 5,5
Kumar dkk., 2018	Corn cobs	Biotechnology	*Candida tropicalis*	85%	-

a) Biotechnology

In general, the synthesis of xylitol through biotechnology will be related to the fermentation process by yeast or bacteria at a lower level. Biotechnology uses fungi, yeasts, or microorganisms at lower levels than bacteria in the fermentation process and can produce xylitol products[13,14]. This process is more effective and efficient to obtain xylitol products.

The most widely used yeasts as agents for xylitol production include Candida tropicalis, Candida guillermondii, Scheffersomyces amazonensis, and Debaryomyces hansenii. This synthesis process starts from the hydrolysis of xylose from hemicellulose, then detoxifies the hydrolysis results and proceeds to the xylitol production stage by the fermentation process. In the process of hydrolysis of xylose from hemicellulose, there are several important parameters that need to be considered, such as pH, temperature, reaction time, and other additives. Research conducted by showed that hydrolysis of corn cobs using an autoclave for 3 hours at 50°C at pH 4.5 resulted in 22% higher xylose compared to untreated.

The addition of acid can affect the final yield of xylose. Obtaining high xylose (up to 70%) using dilute nitric acid with a concentration of 0.05% [15] or dilute sulfuric acid can also be an option[16]. In the study of [14] there were also additional materials used and affecting the results of xylose, including xylanolytic enzyme inducers. In this study, a combination of corn cobs and wheat bran in a ratio of 7: 3 was used, nitrogen source to produce xylanase and xylosidase and the addition of surface active substances. The reaction results produce by-products such as ethanol, glycerol[16] acetic acid[12], furfural, 5-HMF, phenol[16] or nitrate salts hydrolyzed using nitric acid[15]. The product formed is likely to interfere with the course of fermentation by negatively inhibiting microbial growth, so it needs to be removed.

The process of removing by-products can be carried out using an ion exchange resin method where the ionized compound will be attracted and then move to the opposite charge. From this process, sodium nitrate salts are lost up to 60%. Ion exchange resins are known to be effective in the process of removing by-products from ionized compounds compared to non-electrolyte compounds[1516]also carried out the process of removing by-products (detoxification) in the synthesis process using CaO, H3PO4, activated charcoal, and NaOH. Preparation of raw materials, optimal time, temperature, and pH will help reduce the formation of by-products so that no detoxification is needed [14,15]. Factors that affect the amount of xylitol obtained is the initial concentration of cells used, wherein the research of[12], a high initial cell concentration refers to higher xylitol yields at optimal pH, sufficient oxygen, and aeration conditions when fermentation. Another thing that needs to be considered in this final process is that the aeration level given is recommended not to be too high because it can cause xylitol to be oxidized to xylose so that the final level of xylitol is lower[15].

Tabel no 3. Xylitol Yield in Chemical Synthesis

Reference	Process	Catalyst	Xylitol Yield (%)
Du dkk., 2020	chemical process	Nickel Philosilicate	95
Rohini and Hebbar 2021	chemical process	Zinc Oxide Doped Copper	19,87
Payormhorm, 2017	chemical process	TiO_2	6,45

b) Chemistry

The production of xylitol by chemical processes is usually carried out by catalytic hydrogenation of xylose at high hydrogen temperatures and pressures. Until now, many catalysts have been tested for use in the xylitol synthesis process, including nickel catalysts[17]. The nickel catalyst evaporated with ammonia (NI-EA) at an optimal temperature of 800°C produced a higher amount of xylose than some other nickels. In this process, the higher the reduction temperature used, the higher the xylose (98%). However, the selectivity in producing xylitol is not affected by the nickel catalyst but is influenced by the hydrogen pressure used. This hydrogenation chemical reaction requires high temperature and pressure in the process.

Research conducted by[18], regarding photocatalytic with a catalyst used in the form of copper nanoparticles doped with zinc oxide which has a good opportunity in converting high-value chemicals from biomass derivatives. Evaluation of xylose into xylitol or erythritol where the reaction was carried out in a reactor illuminated by UVA-LED light. This reaction is also relatively environmentally friendly and energy-efficient.

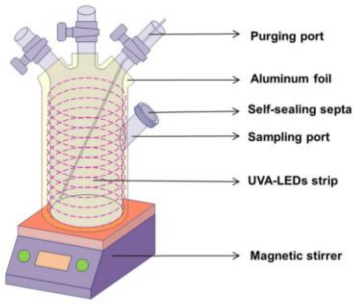

Figure no 3. Photocatalytic Reactor

The process is carried out by flowing nitrogen gas for 10-15 minutes then the solution is inserted into the tool with constant stirring at 300 rpm for 7 hours to produce 4% xylitol, while in the same research method but there is a difference in the catalyst, namely TiO2, it produces 6.45% xylitol[19]. [19]showed that the addition of surfactants to TiO2 catalysts can increase the surface area and help produce high amounts of xylitol, arabinose, and formic acid. In this photocatalytic process, some of the important things to note are the hydrogen donors in the process. In research[18] only glycerol was used as a hydrogen source without adding hydrogen from the outside where this hydrogen is very important in the conversion of xylose to xylitol[18].

Sources of xylitol are found in various kinds such as fruits, vegetables, wheat, and mushrooms, in amounts <1%. Currently, xylitol is produced by the chemical reduction of xylose on an industrial scale. Due to the high purity of xylose, a chemical reduction process is required to avoid the formation of by-products. Extensive purification of xylose is unavoidable before chemical reduction takes place [20]

Plants are one of the natural producers of xylitol. The main source of xylitol can be found in wood, but research is lacking. Then it is also extracted from fruits and vegetables by obtaining the solvent extract. The maximum concentration of xylitol comprises about 1% of dry weight[21].

Xylitol content of various vegetables and fruits juice carrot (10 mg), chestnut (14 mg), banana (21 mg), carrot (86.5 mg), onion (89 mg), lettuce (96.5 mg), pumpkin (96.5 mg), spinach (107 mg), white mushrooms (128 mg), eggplant (180 mg), raspberry (268 mg), cauliflower (300 mg), strawberries (362 mg), yellow plums (935 mg)), lingon berry (64 mg), canberry (37 mg), bilberry (38 mg), sea buckthorn (91 mg), rowan berry (160 mg), and apple (128 mg).[21].

4. Xylitol Identification

Xylitol can be identified by several methods including differential scanning calorimetry and thermogravimetry, structural interpretation, GC-MS.

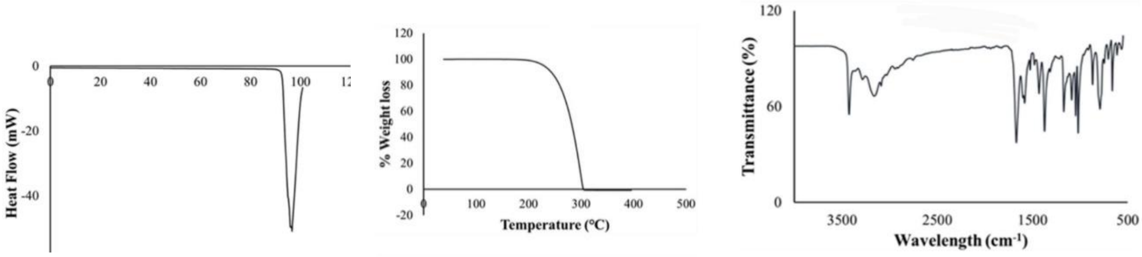

Figure no 4. Identification of Xylitol by a) DSC b) Thermogravimetry c) FTIR [22]

Differential scanning calorimetry and thermogravimetry Figure (A) below shows a DSC scan of xylitol where the sharp endothermic peak corresponds to the melting temperature. Figure (B) shows that the decomposition of xylitol was recorded at 240.59℃ with a final decomposition temperature of around 306.73. The DSC thermogram obtained indicates that the pharmaceutical excipients used in the formulation may have adverse interactions[22].

Structural Interpretation of infrared spectroscopy with Fourier transformation can be used by all optimally prepared excipients and the resulting spectrum is shown in Figure 4 where the determination of the peaks of xylitol bound by OH stretching was observed at 3354cm and 3284 cm, intense CH peaks at 1418 cm. In this analysis, it is shown at the peak of the vibration which describes the presence of certain functional groups present in pharmaceutical excipients

5. Xylitol Application

The application of xylitol in various industries has grown very rapidly, such as in the chemical industry. Brazil is the world's largest fiber exporter, which accounts for 50% of total world production. About 90% of its composition is fermentable sugars such as xylose and glucose sourced from corn and bagasse[1].

In the food industry, xylitol has a sweet taste that is equivalent to sucrose, this is due to its use in food products that are used as a substitute for sugar. The browning/ Maillard reaction between reducing sugars and amino acids has an important value in the chemical stability of foods and provides a unique aroma and taste. Xylitol which does not brown is due to the absence of free aldehyde or ketone groups. Xylitol can avoid microbial contamination because it acts as a sweetener as well as a preservative for food products. Xylitol is preferred over other sweeteners as a formula for baby food[21].

Tabel no 4. Xylitol Application in The Pharmaceutical Field

Reference	Function	Content
Szel dkk., 2015	Anti-irritant and anti-inflammatory	8,26% dan 16,25%
Korponyai dkk., 2017	Skin moisture booster	5%
Asgari dkk., 2018	Inhibits the growth of *S.pneumoniae.*	5%- 7,5%
Bahador dkk., 2012	Reduce cariogenic, especially in bacteria S*treptococcus mutans* and *streptococcus sobrinus*	70%
Xu dkk., 2016	*Human respiratory syncytial virus* (hRSV)	3.13 mg/mL
Jain dkk., 2016	Reduced biofilm biomass (*S. epidermidis*), inhibited biofilm formation (*S. aureus* dan *P.aeruginosa*) and decreased growth of planktonic bacteria (S. *epidermidis, S. aureus,* and *P. aeruginosa)*.	5% dan 10%
Hardcastle, 2017	Mucolytic mucus rhinosinusitis	5%

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