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Xylan biopolymer: Sources, Extraction methods and Applications- A Review

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I. Abstract

Biopolymers are considered one of the most important sources of renewable energy in the modern era, due to their significant importance in industrial processes and sustainable development. These natural materials are inexpensive, widely, available sources, and are characterized by their biodegradability, in addition to their multiple benefits and great importance, especially in the food, cosmetic, and pharmaceutical industries. Thise review included a definition of the biopolymer xylan, which is one of the hemicellulosic biopolymers and the second largest source of polysaccharides. Its chemical structure consists of multiple pentose sugar units linked together with side branches containing glucuronic acid and arabinose. The biopolymer xylan appears linear with some simple side branches. Also, some natural sources of xylan and methods of extraction were explained, as well as some studies of its properties and applications in various fields are highlighted.

Keywords: Xylan, antioxidant, Xylan properties, polysaccharides, Biopolymers

II. Introduction

Polysaccharides are bioactive substances found in abundance in plants and living cell walls and are essential components of insect exoskeletons (Galanakis, . 2015).

Given the multiple functional properties of sugars, Multiple only, these sugars have been used in many industries,It is the most abundant raw material because it is extracted from the biomass of living organisms.

Polysaccharides are complex polymers consisting of large numbers of monosaccharides linked together by glycosidic bonds and having branched chains*,* (Ng *et al,*. 2020) .

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Lignocellulosic biomass (LCB) is composed primarily of the biopolymers lignin, cellulose, and hemicellulose, which represent about 85-90% of the total mass. Typically, the proportions in LCB are 60-40% cellulose, 20-40% hemicellulose, and 10-24% lignin (Yogalakshmi,.*et al* 2022).

Hemicellulose is a biopolymer composed of different sugar polymers, which may be hexoses such as galactose, glucose, and mannose, or pentoses including arabinose and xylose, in addition to uronic acids such as glucuronic, methylgalacturone, and
galacturonic acids (Sygula *et al,*.2024).

the main forms of hemicellulose include Xyloglucan, Galactomannan Glucomannan, Glucuronoxylan Arabinoxylan, Xylan

Hemicellulose has a lower degree of polymerization and molecular weight than cellulose, with a molecular weight ranging between 60-70 kDa. This polymer binds lignin to the cellulose fibers and gives the entire structure greater rigidity. Compared to the other components of lignin and cellulose, hemicellulose is more chemically and thermally sensitive, and the higher the temperature, the greater the solubility of its compounds.

Xylan is the most common polysaccharide polymer found in hemicellulose, which account for 10-35% of the total dry weight in hardwoods and 10-15% of the total dry weight in softwoods (Zhang *et al,*. 2021).

male MitchellIn *et al*., (2012) in his study on xylan, he identified it as the main hemicellulosic component found within Secondary cell walls of woody dicots such as poplar and beech, and primary and secondary cell walls of many monocots, such as switchgrass, are relevant to the bioindustry.

As explained scmidt *et a l,* .(2015)Xylan is the main hemicellulosic polymer found in plant cell walls. Along with cellulose and lignin, xylan contributes to the thickness of the cell walls of the fibers, allowing them to maintain the mechanical strength of the stem Zhong *et al*,. (2005), and It forms a large mass that is used in the composition of many products. Agricultural, including human-digestible plants (such as grains and vegetables), animal feed, and trees, for example, represents 20-30% of the dry weight of the secondary cell wall of dicotyledons, including hardwood trees, and may reach 50% of the total mass of feed walls (Scheller and Ulvskov,.2010) .

According to a study presented by Pauly and Keegstra, (2010) Xylan in these tissues may constitute up to 30% of the dry weight of the plant cell wall.

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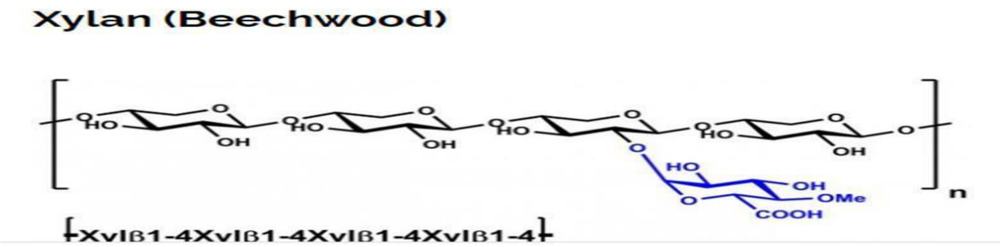
Xylan

Xylan is a heterogeneous polymer with some branching, and is structurally composed of xylopyranosyl residues linked via 1,4-B-D glycosidic bonds ,depending on its sources and extraction method .xylan's chemical composition and properties may vary ,it has been found that methyl-a-D-glucuronic acid and a-D-glucuronic acid can replace O2 or O3positions,while neutral sugar units such as α-L-arabinose, α-d-galactose and α-D-xylose contribute to its structure diversity (Chen,.*et al*2016)

Xylan also contains some different functional groups such as acetyl groups, ferulic acid and coumaric acids , which significantly influence its biological and financial properties(Hsieh and Harris, 2019).

Consider Lu *et al*,. (2021) Xylan is a biocomponent of hemicelluloses of great importance, which, represents Content 10-35% of the total dry weight in hardwoods and 10-15% of the total dry weight in softwoods



Chemical structure of xylan compound)

(Zhang *et al,.2022)*

Sources of xylan

Arabinoxylan is abundant in nature, where it constitutes the largest proportion of plant biomass residues after cellulose. Xylan is the main component of grasses, such as cereal residues, weeds, shrubs, and wheat straw(SimmonsIn*et al* ., 2016).

A study presented by Palaniappan *et al,*. (2017) Extract xylan from bran Rice and finger millet.

Explain Manaf *et al*,. (2018) The possibility of using acid hydrolysis to analyze hemicellulose compounds to obtain Xylan derivatives and Hemicellulose is the major component of the secondary cell walls of dicotyledonous plants, and as a major component of wood, it is one of the

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most abundant biopolymers on Earth, and hasXylan and lignocellulosic biomass residues were produced from agricultural waste and industrial process residues.In the remains and peels of fruits such as pineapple Banerjee *et al*., (2018), and is considered Woods such as birch, acacia, beech and aspen are most important Sources of xylan include sorghum stalks, rice, corn cobs, rye, barley, and oat hulls (Thakur et *al* .,2019)

Arabinoxylan is also extracted from sugarcane residues and is considered a biomass. Lignocellulosic is an inexpensive raw material with abundant and diverse sources, and is renewable, making it possible to use it in many renewable and environmentally friendly bio- industries

(Khaleghipour *et al* , . 2021).

Properties of Xylan

1-Viscosity

Viscosity is one of the most important physical properties of biopolymers, including Xylan . Viscosity depends mainly on temperature, molecular weight solution concentration, pH, and ionic strength. Analyses have confirmed that hemicellulose (Xylan) contains a large number of hydroxyl groups with high affinity for water. This affects the functional properties of xylan-coated papers, but it can facilitate the chemical modification of xylan to improve its hydrophobic properties and expand its application areas. (Nechita et al, 2021).

Xylan has the general properties of insolubility in water, solubility in alkaline solutions, easy acid hydrolysis, high negative optical rotation, non-r educing action towards Fehling's solution, and degree of acetylation(Roman et al., 2023).

2- Solubility

Xylan exists in the form of complex molecules and xylanIt is not completely soluble in water, but it can be extracted from plant hemicellulose tissues by alkaline solutions (Kishani.,*et al* 2016) .

Studies have shown that arabinoxylan from softwood exhibits partial and limited solubility in aqueous media(kishani *et al* ,. 2019).chemical and enzymatic extraction including acidic and alkaline hydrolysis , have been used to improve xylan solubility (Oriez *et al*,. 2020).

3- Fourier transform infrared spectroscopy (FTIR))

Bouramdane *et al*,. (2022) employed Fourier transform infrared spectroscopy to study Structural alterations and assess deterioration in Moroccan softwood cedar.

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The use of Fourier infrared spectroscopy helped in identifying the functional groups within xylan , such as hydroxyl, carbonyl and methyl groups present in the structure of the xylan biopolymer were identified, which give a specific range of vibrations for each group (Wen *et al,*.2024)

4- Thermogravimetric analysis (TGA)

Knows the analysisThermogravimetric analysis (TGA) is a quantitative analytical technique that monitors sample mass changes a from 1 mg to several grams while heating in a furnace up to 1600 °C under a controlled flow (Saadatkhah *et al*., 2020)

Thermogravimetric analysis (TGA) is one of the most common methods for studying the thermal decomposition of compounds. This method relies on heating a precisely weighed amount of the sample material to be studied. The weight of the sample is measured at each period and at specific time intervals. The resulting curve represents the relationship between weight(mass) and temperature (Adnan Al-Habash, 2018).

Xylan applications

A study presented by Noaman *et al* ,. (2008) and Oliveira *et al.,* (2010) That hydrogels Xylan-based nanoparticles have many important properties such as regeneration, tunable functions, and biocompatibility.

Most importantly, Xylan has innate immune defense that inhibits cell mutations, and anti-inflammatory properties, for cancer and antioxidants while other polysaccharides such as cellulose, starch, and lignin lack these physiological properties. Since Xylan is a renewable, biocompatible, and relatively cheap raw material, it is of great interest as a carrier for advanced drug delivery. Most investigations have used Xylan hydrogels to load drugs, and some studies have addressed the potential of Xylan in drug encapsulation (Daus and Heinze,. 2010).

Xylan by-products can be used as renewable materials with tunable functions and biocompatibility in the fields of pharmaceuticals, cosmetics and food. Xylan has the properties of innate immune defense, the ability to inhibit cell mutations, the presence of anticancer and antioxidant properties, and is more efficient than many other polysaccharides (Gao*et al*., 2016).

Xylooligosaccharides (XOS) are low molecular weight oligosaccharides (LMWs) which are indigestible sugars composed mainly of multiple units of the pentose sugar xylose which is of great importance due to its physical and chemical properties. XOS are known to be unaffected by gastric and intestinal enzymes and thus pass through the upper digestive tract undigested and reach the large intestine where they are metabolized by microorganisms. Therefore these substances are important in enhancing the diet fortified with XOS and work to enhance human health in several

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ways due to the defensive and immune properties, which has increased the demand for foods containing On these materials (Farid *et al*., 2019)

Xylan has gained increased interest due to its unique properties. It has been found that its sweetness is equivalent to that of sucrose. It can also be used as a substitute for sucrose in the food industry due to its low calories and slow or limited digestion, which contributes to reducing nutritional stress in diabetics (Li *et al*.,2019)

The biopolymer Xylan is of great interest as an environmentally friendly alternative and renewable source of raw materials in many industries. Xylan is an important component of lignocellulosic biomass and agricultural waste. Xylan offers multiple biological activities, such as antioxidant, antimicrobial, antiviral, and antitumor, so it is widely used in the pharmaceutical industry. (Qasem *et al.,*2021)

Xylan is used in many industrial applications due to its versatility and multiple molecules, such as the food industry, the feed industry, the pharmaceutical industry, and packaging materials (NešicIt *et al* ., 2020) is also used in bakeries to improve The quality of the grain flour, and it has a wide therapeutic range, as it is very useful in the pharmaceutical field as a drug carrier, such as micro and nano particles (Annu and Ahmed, 2021)

Xylan is biodegradable and non-toxic, and has been shown to have beneficial effects on overall health and the body's resistance to disease in particular Yan *et al*. , 2022)

It is also used as an additive to plastics to increase their strength and biodegradability (Curry *et al*., 2023)

A technology based on Xylan hemicellulose modified with vegetable waxes has been developed as an excellent barrier against water and moisture And oils (Barriers *et al*., 2023)

The presence of a large number of active groups (hydroxyl, carboxyl, and carbonyl) in the structural unit of xylan hemicellulose compounds facilitates their modification through a series of chemical reactions whereby the functional properties of xylan are improved, making them more suitable for use in various applications (Barriers *et al*., 2023).

Xylan as an antioxidant

Antioxidants are chemically defined as stable molecules capable of delaying or preventing the oxidation of other molecules. They have the ability to donate an electron to any free radical, halting its activity. The presence of these chemical compounds in any diet at low concentrations delays the onset of oxidation through various mechanisms, including the removal of free radicals. They can also be defined as compounds used to preserve food and delay its spoilage.

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Nutritionally, antioxidants are known as compounds that can be added to foods in very small concentrations and lead to hindering or preventing the oxidation of vital compounds such as carbohydrates and fats, especially unsaturated fats (Jafri *et al.,*2022).

The occurrence of oxidative reactions is associated with the presence of an excess of free radicals, which enhances harmful oxidation processes in the body. It has been found that the high content of plants in compounds with antioxidant properties capable of capturing free radicals (carotenoids, phenols, flavonoids, anthocyanin derivatives, unsaturated fatty acids, vitamins, enzymes and cofactors) prevents the occurrence of oxidation processes, so interest in using them in treatment has increased(Davies2000)

Many studies have shown that since ancient times, humans have used many plants, such as herbs, grains, and other plant products, to treat many diseases and for cosmetic purposes (Shiddamallayya *et al.,* 2015).

Oxidative stress is a concept widely used in medical science, and plays an active role in the pathophysiology of very common diseases, such as diabetes, hypertension, preeclampsia, atherosclerosis, and kidney failure. Acute oxidative stress, Alzheimer's disease, and Parkinson's disease. Through oxygen metabolism, cells generate reactive oxygen species (ROS), which can be harmful. Under normal conditions, the rate and capacity of oxidant formation are balanced by the rate of their removal. However, an imbalance between oxidants and antioxidants leads to oxidative stress. High levels of ROS in biological cells significantly affect their function, leading to cell dysfunction, aging, or disease (Rodrigo *et al.* , 2009) .

costa *et al* ., (2010) In his study, xylan showed different biological activities due to its properties and composition. The chemical composition and presence of multiple active groups, including these groups (hydroxyl, carboxyl and carbonyl) found in the structural unit of the Xylan compound, makes it important for the human body due to the benefits it provides in fighting free radicals and reducing oxidative damage to cells.

Xylan acts as an antioxidant due to its rich composition of phenolic and cyclic compounds .Xylan is used in the development of nutritional supplements used to enhance the body's ability to combat free radicals and reduce the damage resulting from the formation of these compounds inside

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the body, which occurs due to oxidation during metabolic processes.(Silveira et al, 2012).

Anti-free radical activities of this type of sugars have been revealed according to a study presented by Bauer *et al.* ,(2012)Because it contains phenolic compounds and antioxidants.

As shown OliveiIn *et al.,* (2014) his study, he found that Xylan plays an important role in the integrity of the plant cell wall and increases From the resistance of this wall to enzymatic digestion Thus, it helps in preserving plant tissues against pathogens..

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34

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