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Xanthan Gum—Bio-Based Raw Material for Wood Adhesive

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Abstract

Due to their lower environmental impact, ease of accessibility, low cost, and biodegradability, bio-renewable sources have been used extensively in the last several decades to synthesize adhesives, substituting petrochemical-based adhesive. Vegetable oils (including palm, castor, jatropha, and soybean oils), lactic acid, potato starch, and other bio-renewable sources are all excellent sources for the synthesis of adhesives that are being taken into consideration for the synthesis of "eco-friendly" adhesives. Due to their widespread use, accessibility, affordability, and biodegradability, biobased raw materials like carbohydrates used to synthesize wood and wood composite adhesive have gradually replaced petrochemical-based adhesive. Recently, xanthan gum, a naturally occurring polymer, has drawn the interest of scientists as a potentially petroleum source replacement. It possesses specific rheological characteristics, excellent water solubility, and stability to heat, and can be used as a binder, thickener, suspending agent, and stabilizer. Xanthan gum increases the adhesive strength in addition to increasing the viscosity of water-soluble adhesives. This article discusses xanthan gum as a potential substitute for traditional raw materials derived from petroleum that is used as a raw material for adhesives.

Keywords

Xanthan Gum, Bio-Polymer, Adhesive, Wood, Carbohydrates

1. Introduction

In general, the majority of polymeric coatings and adhesives are made from fossil feedstocks. However, switching from fossil feedstocks to renewable resources is necessary because of rising prices for oil and global warming. The utilization of renewable feedstock as a source of raw materials for the manufacture of monomers and their polymeric coatings and adhesives has recently attracted more scientific attention [1]. Researchers have a great interest in traditionally bio-based binders, such as starch [2] [3] [4] [5] [6], soy protein [7] [8] [9] [10] [11] or renewable rubber [12] [13] [14] [15], use of modified vegetable oils or lignin derivatives [16]-[22], and various cellulosic materials [23]-[32] for application in adhesive field. Cellulose is the most abundant renewable biomaterial among these biopolymers [33] and has a natural affinity for self-adhesion, which makes it a potential material in adhesion science. The presence of free hydroxyls in the cellulose structure of carbohydrates makes them an important potential replacement for petrochemical-based polymers. Additionally, as the most prevalent biopolymer with biodegradability, film-forming capabilities, favorable chemical-mechanical and thermal characteristics, and most significantly, adhesive properties, it can benefit in the development of higher performance adhesive. Free hydroxyl groups provide the site for chemical modification which can be used for tailor-made applications [34] [35].

2. Xanthan Gum Structure and Properties

Xanthan gum is an exopolysaccharide produced by bacteria through fermentation engineering of carbohydrates. It has distinctive rheological properties, good water solubility, stability to heat, acid, and alkali, as well as good compatibility with various salts, and can be used as a thickening, suspending agent, emulsifier, and stabilizing agent [36]. In xanthan gum, 1,4-linked B-D-glucose residues are linked to alternate D-glucosyl residues by a trisaccharide side chain. The backbone of the polymer is similar to that of cellulose. The side chains are β -D-mannose- 1,4- β- D-glucuronic acid 1,2- α -D-mannose, where the internal mannose is mostly O-acetylated and the terminal mannose may be substituted by a 4,6-linked pyruvic acid ketal as shown in **Figure 1** [37].

An anionic polysaccharide, xanthan gum has a very high molar mass of above 2000 kg/mol, but it can also be as high as 13,000 - 50,000 kg/mol. Its primary chain is made up of glucose units that are separated by mannose and glucuronic acids [38]. Xanthan gum dissolves in both hot and cold water. Xanthan gum is stable over a wide pH range. According to DIN 38412-L25, xanthan gum is a naturally occurring polymer and is totally biodegradable. Paints employ xanthan gum to provide the desired thixotropic index and viscosity. Printing pastes, colours, texture coatings, and adhesives are a few further technical applications for xanthan gum's rheological properties [39].

3. Xanthan Gum-Based Wood Adhesives

A microbial exopolysaccharide with broad applications, xanthan gum is created through carbohydrate fermentation engineering. It can be employed as a thickening, suspending agent, emulsifier, and stabiliser because of its distinctive rheological properties, good water solubility, good stability to heat and acid and alkali, and good compatibility with various salts [40] [41].

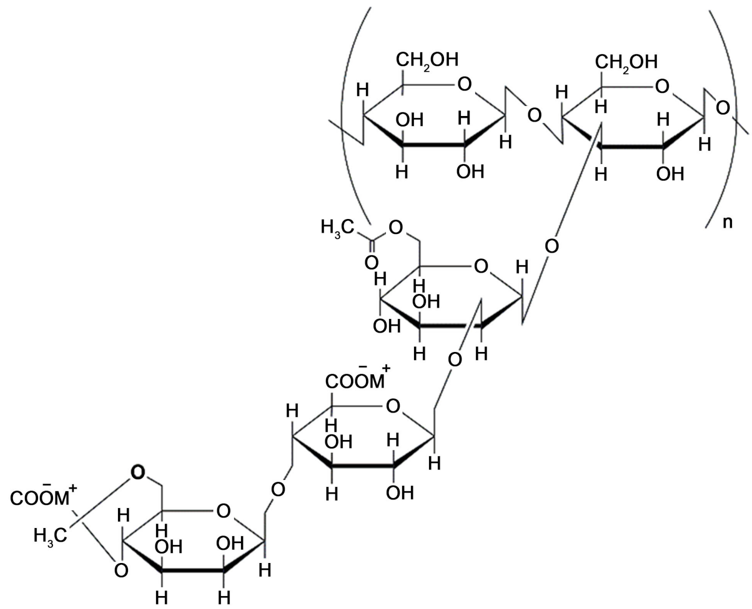

Figure 1. Structure of xanthan gum [37].

3.1. Blending with PVAc

The benefits of the xanthan-based carpenter glue include quick drying times, good cold and water resistance, strong bonding strengths, and good creep resistance [42]. The adhesive of this invention consists primarily of polyvinyl acetate as the main adhesive, xanthan gum as a thixotropic thickening agent, polyvinyl alcohol as a tackifying agent, and a mixture of wood flour and glyoxal as water-repellent agents for the dry adhesive [43] [44]. Xanthan gum used in the present invention is a polysaccharide produced from a microorganism, Xanthomonas campestris, and is composed of mannose, glucose, and glucuronic acid. By adding to the Ethylene-vinyl acetate (EVA) emulsion, the EVA emulsion can be thickened and pseudoplasticity can be imparted. Moreover, the thickening effect is stable over time [45]. Polyvinyl alcohol (PVA) is water-soluble but has high adhesive strength and initial adhesiveness (initial tack) to low-penetration materials such as glass, plastics, and metals. Furthermore, xanthan gum has the effect of increasing the adhesiveness of PVA, in addition to the effect as a thickener, and has pseudoplastic properties. Therefore, the adhesive strength and initial adhesiveness of the invention product to the low-penetration material can be increased. Xanthan gum has the property of increasing not only the viscosity of water-soluble vinyl acetate (VAc) derivatives, but also the adhesive strength. It has been found that when applied to a vertical smooth surface of a low-penetration material such as glass, plastics or metal, the viscosity can be prevented from dripping [46]. The aqueous adhesive contains 15% to 75% by weight of the PVA, and contains the carboxylic acid-containing polymer or a neutralized product thereof, a cellulose derivative, and xanthan gum [47].

The water-based thixotropic adhesive gel contains: water, PVA, or wherein a portion of the PVA is replaced with polyvinylpyrrolidone, xanthan gum to impart thixotropic properties to the gel. The gel has a thixotropic index which permits the viscosity of the adhesive to break down when a flexible tube or squeeze bottle dispenser is finger-pressed while having a sufficiently low viscosity to allow for easy extrusion from an orifice having a diameter of about 0.06 to 0.15 in. When pressure is released, after the desired amount of adhesive has come out of the dispenser, the adhesive quickly reverts to very close to its original gel state so that it does not run on a vertical surface of porous or semiporous material such as paper [48] [49]. The invented starch adhesive had advantages of short curing time and good adhesive strength, was especially suitable for corrugated board, and could dramatically increase strength of corrugated board [50].

3.2. Chemical Modification-Grafting

The physical, chemical, and mechanical properties of starch were changed by the use of grafting, a fundamental technique. One of the best ways to improve starch's mechanical properties was to graft the polymerization of synthetic polymers onto a starch backbone [51]-[60]. Recently, scientists and industries have become more interested in the graft polymerization of vinyl acetate (VAc) monomer on starch and its usage in wood adhesives [61] [62] [63] [64] [65]. The biobased raw materials xanthan gum, guar gum, and cellulose copolymerized with VAc were used to synthesize biobased modified white latex, as well as a method for synthesizing it. The prepared bio-based modified built-in white emulsion has good film-forming performance, strong adhesive strength, and a broad application range, according to the formulation and technique of the present invention [66] [67]. The xanthan gum is easily dissolved in water to form colloid, has a super-bonded banded spiral copolymerization structure, and can be woven into a net structure in space; however, the branched chains of the xanthan gum molecules have more functional groups, and when a network structure is formed, the steric hindrance between the branched chain functional groups is overcome, the dynamic balance of the network structure is maintained, and the stable state is difficult to maintain; the fiber reinforcing agent is uniformly dispersed in the reticular structure formed by the xanthan gum, which is beneficial to improving the strength of the reticular structure and plays a role in supporting and reinforcing the reticular structure woven by the spiral copolymer of the xanthan gum [68].

4. Conclusion

In conclusion, xanthan gum has demonstrated that it is a possible raw material for the production of adhesives. It looks very promising both as a rheological modifier and as a reactive component for grafting reactions. Natural resource scarcity, increasing environmental concerns, and stricter regulations have not only encouraged but also encouraged adhesive manufacturers to explore for more environmentally friendly and renewable alternatives. One step in this direction is definitely the incorporation of xanthan gum, one of the most commonly accessible natural polymers, to our adhesives. It possesses distinct rheological characteristics, good water solubility, and heat stability. It can be utilized as a binder, thickener, suspending agent, and stabilizer. Some chemical businesses began their bio-based research years ago, and some even promote bio-based application as a future strategy.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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