ERA CoBioTech

BioTech Research & Innovation Hack

2021

ERA CoBioTech Funded Projects at A Glance: WooBAdh

Environmentally-friendly bioadhesives from renewable resources

PART OF EUROPEAN BIOTECH WEEK

INNOVATION IS IN OUR GENES

WooBAdh

Feasibility of replacing formaldehyde in wood adhesives by natural components derived from wood or other vegetable matter

Research in the WooBAdh project focused on enzymatic, chemical and electrochemical modifications of phenolic fractions of different raw materials to produce bioadhesives that do not contain formaldehyde in their formulation, avoiding the emission of VOCs

Replacement of formaldehyde in wood adhesives with bio-based solutions for the wood board production

Formaldehyde-based synthetic adhesives largely dominate the field of wood and fibreboard binders. Acceptable levels of formaldehyde emission from wood-based panel products have been continuously reduced over the last decades, this fact, together with consumer demand for non-hazardous products, are the main driving force to replace formaldehyde in wood adhesives with natural components derived from wood or other plant materials. The project has developed new bioadhesives capable of offering an alternative to the current emission challenges faced by the wood board sector, focusing on different modifications of phenolic groups of lignin and tannins. Biotechnological approaches based on enzymatic systems combined with several different chemical approaches for the production of bioadhesives were also considered. From an environmental point of view, the Life Cycle Assessment (LCA) methodology has been applied and the main environmental impacts associated with the production of bioadhesives have been assessed. The project results have provided value-added bio-adhesives from renewable resources, making a contribution to the development of innovative and environmental solutions in the field of green adhesives.

Analytical characterization and enzymatic/chemical/electrochemical modification of natural substrates for wood bio-adhesives production

The materials (tannin and lignin fractions, including modified ones) were analytically characterised using up-to-date methods such as SEC, MN, MW, polydispersity. Elemental composition (CHONS) and chemical composition (ash, moisture, saccharide content, lignin purity, tannin purity) were determined by NREL technical protocols as well as by published analytical methods: NMR methods (31P-NMR after in situ labelling for identification and quantification of functional hydroxyl groups), 2D-NMR (HSQC 13C/1H, 500Mhz), and ATR-FT-IR. After this first characterisation, chemical, electrochemical and enzymatic modifications have been carried out in order to activate/functionalise the bio-based fractions. Subsequently, different cross-linking reactions using amino groups as main cross-linking agents have been considered for the formulation of formaldehyde-free bioadhesive alternatives. Once the bioadhesives were developed, automated bond evaluation system (ABES), dielectric analysis (DEA) and dynamic mechanical analysis (DMA) were used to determine the curing parameters considering various temperature and pressure ranges. ABES was considered as the reference method; DEA was considered as a method that overestimates the curing process and more accurately describes the beginning of the curing process; and DMA was considered as a method that underestimates the curing process and is more accurate in determining the end of the curing process. Finally, to assess the environmental impacts associated with the different bioadhesive alternatives, the Life Cycle Assessment methodology has been used as the main tool to evaluate the environmental burdens of these production chains.

Main results

The topic of the project is relevant for the EU economy. The EU wood-based panel industry has an annual turnover of about 22 billion euros, creates more than 100,000 direct jobs and has more than 5,000 companies in Europe. The use of waste by-products (lignins, tannins) from pulp and paper mills and 2G biorefineries for the production of bioadhesives foresees the application of the circular economy, extending the biorefinery concept. The valorisation of waste streams/by-products into bioadhesives benefits different sectors of society, from the wood board industry to consumers. The results achieved in the project have provided new green materials for wood-based industries following EU legislation and regulation, new approaches for the valorisation pathways of lignocellulosic fractions, better understanding of their chemical and structural characterisation, new emerging cost reduction technologies following circular economy criteria and better wood products, with lower carbon footprint and content of potentially toxic materials.

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Future prospect

Adhesives obtained from natural resources having a lower environmental impact could be considered more socially acceptable than formaldehyde-based binders. From an environmental point of view, the use of both, renewable resources for producing the bioadhesives, and the lower emissions of volatile organic compounds (VOC), provides a sustainable approach to be applied in wood industries. On the other hand, the use of residual / by-products streams for the performance of bioadhesives alternatives, provides a new approach and productive framework in the wood industry, thus favoring, not only the reduction in the generation of residual streams, but also an effective recovery that provides a product with high added value that will be used in the process itself for the manufacture of the wooden boards, thus integrating the concept of circularity and sustainable production. Another important aspect of the project is the bio-adhesives evaluation from an economical perspective. It is necessary to analyze the replacement of chemical binders with bioadhesives from an economic and environmental perspective considering the whole value-chain from supply networks to final users. This approach has been applied, after defining the optimal formulation of the bioadhesive and evaluating its properties at small scale. Value-adding production of bioadhesives from renewable resources by a cost-effective process, and its integration into the material flow of an existing wood industry, is essential for the development of innovative and environmental solutions in the field of green adhesives.

1. Cradle-to-gate Life Cycle Assessment of bio-adhesives for the wood panel industry. A comparison with petrochemical alternatives (doi.org/10.1016/j.scitotenv.2020.140357) The purpose of this study was to environmentally analyse the production of four different bio-adhesives as alternatives to the most conventional fossil resins used in the production of wood panels. The bio-adhesives proposed for analysis derived from different available renewable biopolymers such as protein (soy) and lignin (Kraft and Organosolv), as well as tannin.
2. Environmental benefits of soy-based bio-adhesives as an alternative to formaldehyde-based options (https://doi.org/10.1007/s11356-021-12766-4) This report includes the environmental profiles of soy-based adhesives taking into account the Life Cycle Assessment (LCA) methodology. In addition, in order to increase their potential to replace synthetic resins, a sensitivity analysis of the main contributors to environmental damage was performed, thus giving an open guide for further research and improvement. This study aims to provide innovative alternatives and new trends in the field of environmentally friendly bio-adhesives for the wood panel industry.
3. Evaluation of starch as an environmental-friendly bio-resource for the development of wood bio-adhesives (10.3390/molecules26154526)This manuscript investigates the environmental profile associated with different wood bio-adhesives based on the functionalization of starch as a renewable alternative to formaldehyde resins. Considering that this is a process under development, the conceptual design of the full-scale process will be addressed through process modelling and the environmental profile will be assessed using life cycle assessment methodology.
4. Recent developments in bio-based adhesives from renewable natural resources (https://doi.org/10.1016/j.jclepro.2021.127892) The aim of this study is twofold: (i) to critically analyze the available reports on the formulation of bio-based adhesives for the manufacture of wood panels, evaluating the different renewable raw material options, and (ii) to identify the advantages, disadvantages and difficulties encountered that hinder further development.
5. Organosolv lignin for Non-Isocyanate Based Polyurethanes (NIPU) as Wood Adhesive (10.32604/jrm.2021.015047) A non-isocyanate-based polyurethane (NIPU) wood adhesive was produced from organosolv lignin. The formulation of this new lignin-based NIPU adhesive was chemically characterised by MALDI ToF mass spectrometry and by FTIR spectrometry analyses.
6. The effect of ageing on bonding performance of plasma treated beech wood with urea-formaldehyde adhesive (https://doi.org/10.1007/s10570-021-03687-z) In this study, fresh and aged wood specimen both, untreated and plasma treated, were investigated.
7. Bioresource heat resistant coatings by cross-linking of proteins with triethyl phosphate. (10.3390/polym9060206) The paper deals with using wheat protein hydrolysate, namely SOLPRO 508 and casein reacted with triethyl phosphate (TEP) for the preparation of high-temperature resistance coatings.
8. Development of polyvinyl acetate adhesive bond strength when gluing veneer (https://doi.org/10.26614/les-wood.2020.v69n02a04) This article presents the development of the shear strength of two polyvinyl acetate (PVAc) adhesives: Mekol D_3 and Mekol SPECIAL when bonding veneer depending on pressing time.
9. Bio-based adhesive mixtures of pine tannin and different types of lignins (10.15376/biores.15.4.9401-9412) In this study, several different biobased tannin-lignin-hexamine adhesive mixtures were prepared and compared in a lap-joint shear strength test.
10. Tannin and lignin sources availability for the holistic replacement of synthetic wood adhesives in the European Area. It reports the availability of tannin and lignin based bio-adhesives for wood boards.
11. Cross-country comparison on environmental impacts of particleboard production in Brazil and Spain (https://doi.org/10.1016/j.resconrec.2019.104434) The purpose of this study is to analyse and compare the environmental performance of particleboard production in both countries

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12. Biosourced heat-resistant coatings by cross-linking of proteins with triethyl phosphate DOI: 10.1016/j.porgcoat.2019.105403. using wheat protein hydrolysate and casein reacted with triethyl phosphate (TEP) for the preparation of high-temperature resistance coatings.
13. Natural Tannins as New Cross-linking Materials for Soy-based Adhesives DOI:10.3390/polym13040595, Feasibility of using three types of natural tannins (quebracho, mimosa and chestnut tannins) as cross-linking materials for soy adhesive was studied.
14. Oxidized Demethylated Lignin as a Bio-Based Adhesive for Wood Bonding DOI: 10.1080/00218464.2019.1710830. Study of the demethylation and periodate oxidation of lignin.
15. Preparation and Properties of a Novel Type of Tannin-based Wood Adhesive DOI: 10.1080/00218464.2020.1863215. A novel biomass-based wood adhesive was prepared with commercial Mimosa tannin extract and glycerol diglycidyl ether (GDE) by convenient mechanical mixing
16. Characterization of Condensed Tannin Non-Isocyanate Polyurethane (NIPU) Rigid Foams by Ambient Temperature Blowing DOI:10.3390/polym12040750. Ambient temperature self-blowing mimosa tannin-based non-isocyanate polyurethane (NIPU) rigid foam was produced, based on a formulation of tannin-based non-isocyanate polyurethane (NIPU) resin.
17. Soy Protein Isolate Non-Isocyanates Polyurethanes (NIPU) Wood Adhesives DOI: 10.32604/jrm.2021.015066. Soy-protein isolate (SPI) was used to prepare non-isocyanate polyurethane (NIPU) thermosetting adhesives for wood panels by reacting it with dimethyl carbonate (DMC) and hexamethylene diamine.
18. Curing characterization of tannin-hexamine adhesive by automated bonding evaluation system, dielectric analysis, and dynamic mechanical analysis. DOI: 10.15376/biores.16.3.6174-6185. In this study, an automated bonding evaluation system (ABES), dielectric analysis (DEA), and dynamic mechanical analysis (DMA) were used to determine the curing parameters of biobased pine tannin-hexamine adhesive.

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