Deliverable report

D3.4 An Analysis of "white-spots" in knowledge and technology for lignin innovation

Deliverable Data		
Deliverable number	D3.4	
Dissemination level	Lignocost	
Deliverable name	An Analysis of "white-spots" in knowledge and technology for lignin innovation	
Work package	WG 3	
Lead WP/Deliverable beneficiary	Karolien Vanbroekhoven	
Deliverable status		
Submitted (Author(s))	02/05/2023	Karolien Vanbroekhoven
Verified (WP leader)	02/05/2023	Karolien Vanbroekhoven
Approved (Coordinator)	03/05/2023	Richard Gosselink

Contents

Contents

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Working Group 3

1 Introduction – how to identify white spots in knowledge and technology for lignin innovation?

Since a lot of information related to lignin is publicly available both in literature as in patents, the approach taken to define 'white-spots' in lignin innovation was based on a study undertaken in the framework of IEA Bioenergy task 42, in which lignin derived products are described and potential drivers for their market uptake. Some patent landscape and software analyses have been applied that allows to identify the classes of applications.

2 Approach and suggestions

Based on an early analyses of the patent landscape, a classification in 4 major potential applications for lignin based products was made (Figure 1).

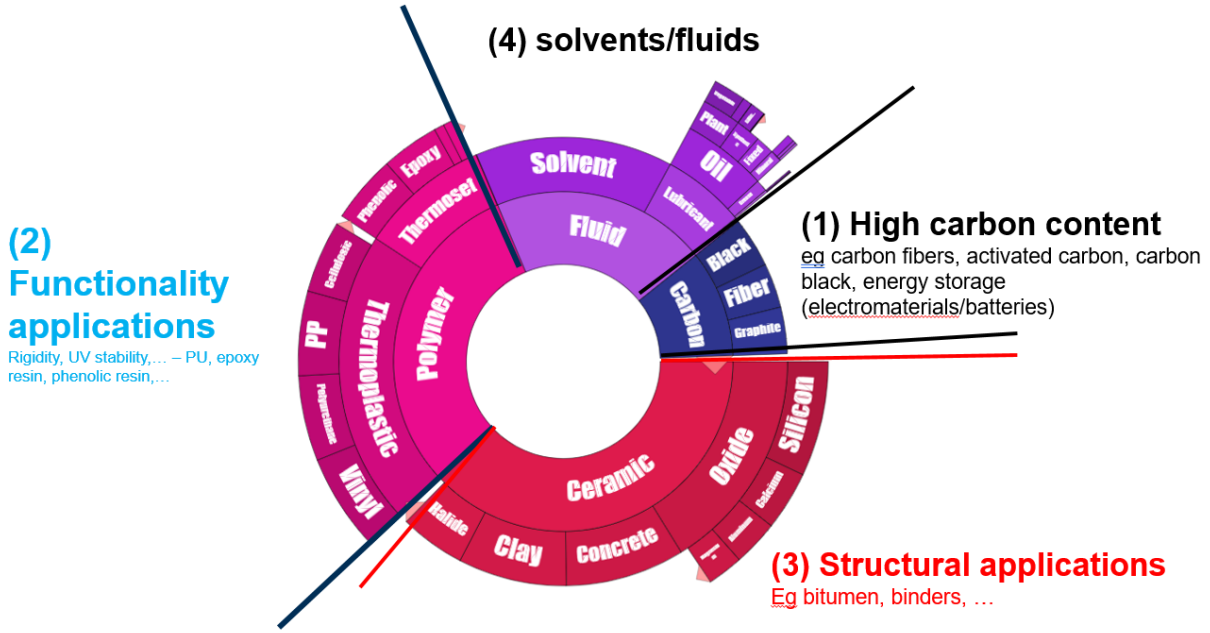

Figure 1: Plot of 4 major potential classes of lignin applications, based on patent landscape analyses.

Some major classes of products including lignin are attributed to the functionality applications like phenolic resins, polyurethanes, polymeric blends. Structural applications relate amongst others to lignin based dispersants. A detailed description of the potential of each of the 4 classes is given in the full report of Task 42 IEA Bioenergy – LignoCOST on lignin valorization [1].

*Table 3. 1 Main products from **lignin platforms** ordered in macro-categories, their industrial use, technologies and processes. The products in the grey cells, which have a greater market exploitation and/or innovation perspectives, have been selected for a detailed description in the present document.*

Macro-category	Product	Sub-product/application	Sector	Preferred lignin type	Technologies	Ref.	TRL
Polymeric Materials	Dispersants	Lignin-based Asphalt	Building	Lignosulfonates and kraft (alkali-oxidated)	Blends with Asphalt	[17-28]	5
		Concrete modifier			Almost direct use	[14, 29-35]	5
		Drilling muds modifier	Oil extraction	Lignosulfonates	Almost direct use	[37-42]	5
		Agricultural chemicals	Agriculture	Lignosulfonates and kraft (alkali-oxidated)	Almost direct use of a selected molecular weight range of pure lignin	[12-16]	7
		Dyes	Textile, Cosmetic				
		Carbon black in battery electrodes	Automotive				
	Phenolic resins	Panels	Building, Furnishings	Kraft, Organosolv, Soda	Phenolic unit activation and polymerization (partial substitution of traditional resins)	[7, 43-88]	8
		Plywood, Laminates	Building, Furnishings				
		Food packaging	Packaging				
	Polyurethane	Foam	Building, Furnishings, Automotive	Kraft, Organosolv, Soda	Polyol reactivity improv. and di-isocyanate reaction (lignin polyol chains extension: hydropropylation, glycerol and glycerol deriv. grafting, etc.)	[89-138]	6
		Panels	Building				
		Coatings	Building, Electronic				
		Rubber replacing	Apparel				
	Blends with PE, PP, PET, etc.	Coatings, Plastic	Food, Animal feed, Agriculture	Kraft, Organosolv, Soda	Blends improving the existing technology	[139-156]	9
		Displays	Electronic				
Electro-chemical applications	Energy storage applications	Additive in electrodes, flow-batteries, supercapacitors	Building, automotive	Lignosulfonates	Lignosulfonate-functionalized graphene hydrogels, Lignosulfonate with single-walled carbon nanotubes and cellulose hydrogels	[157-165]	5
BTX (Benzene, Toluene, Xylenes)	Chemicals	Solvents, Monomers, Fuels	Industry (synthesis, solvents, etc.), Automotive, Transport	Kraft (biomass)	Pyrolysis, Hydrothermal treatments, Hydrodeoxygenation, Separation	[169 - 223]	4-6
Fuels	Hydrocarbons	Automotive fuels (light hydroc.)	Automotive, Transport	Kraft, Organosolv, Soda (biomass)	Pyr., Gasification, sequential Pyr/HDO	[224-255]	5
		Jet-fuels (Alkyl benzene related)	Aircraft, Transport				5
	Aromatic rich pyr. oil (petroleum like)		Refinery products (fuels, chemicals)				5
	Syngas (CO, H2, CH4)		Power production				9
Carbon Fibres			Automotive, Steel repl.	Kraft, Organosolv, Soda	Lignin modif. (filaments), blends (PAN, other poly.)	[256-259]	5
Activated carbon/Biochar		Agricultural amendment	Agriculture	Lignosulfonates, Kraft, Organosolv, Soda	Pyr., Gasification	[1-3, 6, 8-10, 12, 14, 29, 50, 52, 54, 73, 86, 125, 221-224, 253, 256, 258]	6-8
Aromatic lignin monomers	Quinones	Solvents, Polym. building block	Industry (synthesis, solvents, etc.)	Kraft, Organosolv, Soda	HTU (acid and alkali cat), HDO + Separation and Purification Technologies		3-5
	Benzylic aldehydes	Solvents, Polym. building block	Industry (synthesis, solvents, etc.)				5
	Phenols	Solvents, Polym. building block	Industry (synthesis, solvents, etc.)				5-7
	Aromatic alcohols	Solvents, Polym. building block	Industry (synthesis, solvents, etc.)				5
	Vanillin	Spice production	Food	Lignosulfonates	Lignin oxidation (Borregaard process)		9
Mixed organic acids	Short chain acids, di-acids, -OH acids	Solvents, Polym. building block	Industry (synthesis, solvents, etc.)	Kraft, Organosolv, Soda	Lignin oxidation process + Sep. In addition, Pur. Technol.		5

When looking to the overall patent analyses, China has most of the patent applications however these patents do not appear close to market exploitation.

3 Conclusions and outlook

The main obstacles still hindering the development of industrial initiatives are often linked to non-technological barriers like environmental analyses to demonstrate economic feasibility and sustainability; the building of value chains that cross-operate together at the regional to world scale level; changing and highly stringent legislation. On the other hand, applications where lignin is used and that incorporate the inherent functional advantages that nature has to offer like better resistance to environmental stresses, antioxidant and thermal stability do have a big potential for further development. In quite some cases, the need for making this product easier to handle and get it to resemble more to a typical chemical by further modification/depolymerization/fractionation will lower the technological risks. In any case, a market that matures in terms of lignin supply, pricing, and quality and that allows this resource to become commodity and ensure security of supply will for sure help to overcome the last barriers for further product development.

Reference

(1) Mastrolitti, S., E. Borsella, A. Giuliano, M.T. Petrone, I. De Bari, R. Gosselink, G. van Erven, E. Annevelink, K.S. Triantafyllidis, H. Stichnothe (2021) Sustainable lignin valorization – Technical lignin, processes and market development. Edited by: IEA Task 42 & LignoCOST. 195 pp. https://task42.ieabioenergy.com/publications/sustainable-lignin-valorization/