

Fire Performance of Thermosetting Resins with Bio-based Additives for Sustainable Flame Retardant Applications

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SCIENTIFIC ABSTRACT

The BIOSAFIRE project investigates the potential use of bio-based additives, including unmodified and chemically modified lignins and tannins, to improve the fire performance of thermosetting resins, offering a sustainable alternative to conventional flame retardants. While the project explores both additives, this study focuses on the effect of lignins when incorporated into conventional polyester and bio-based epoxy resins. The aim is to develop environmentally friendly flame-retardant solutions for high-performance industries, particularly the naval and railway sectors, where fire safety is essential.

Samples were prepared by casting, without interference of fibre reinforcement. The fire behaviour of polyester resins, both with and without commercial flame retardants, was analysed through cone calorimeter tests and Limiting Oxygen Index (LOI) measurements. Additionally, the influence of lignins was assessed in bio-based epoxy resins through cone calorimeter. The results showed that, in some cases, lignin-based additives improved the fire performance of some of the thermoset resins studied.

These findings underscore the complex nature of bio-based additive interactions and their varying effectiveness, highlighting their potential as sustainable alternatives. Future work will focus on optimizing bio-based additives modifications and concentrations to further enhance their fire-resistant properties.

OBJECTIVES

- Ensure compatibility between the developed biobased flame retardants with thermoset matrices.
- Optimisation and adjustment of the final materials composition considering the characterization tests carried out.

WORKING PLAN

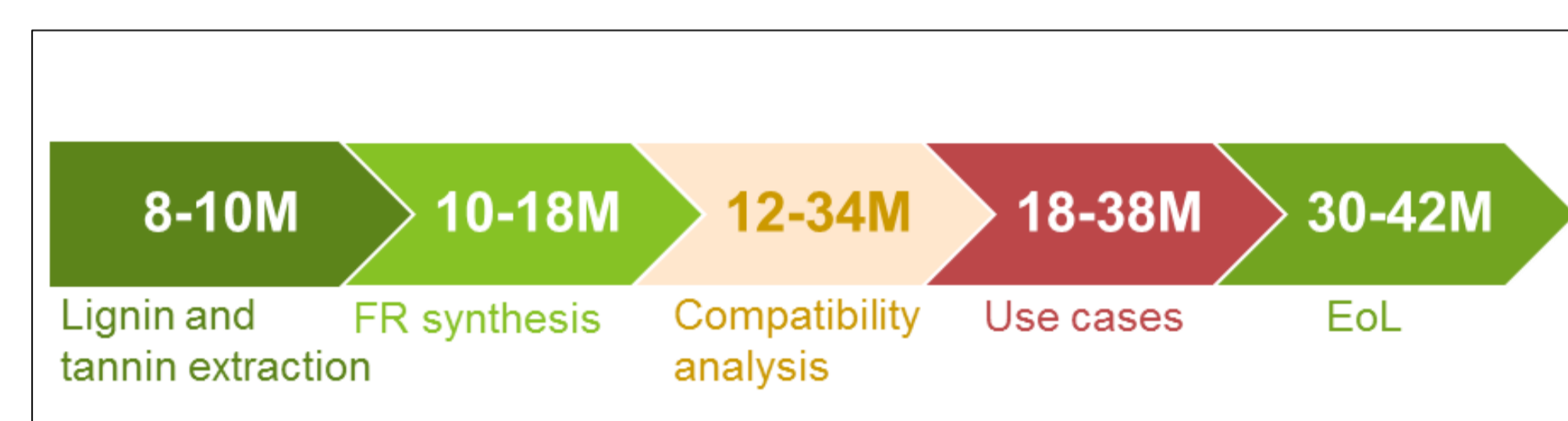


Figure 1. BIOSAFIRE Project Timeline

BIOSAFIRE Project Timeline

The BIOSAFIRE project evaluates from the extraction of raw materials (lignins and tannins) to the study of the end of life of materials (Figure 1), including their chemical modification, compatibility with matrices and the manufacture of demonstrators. It also carries out all the studies established within the SSbD framework.

METHODOLOGY

Manufacture of samples for LOI (Limiting Oxygen Index) and cone calorimeter testing

To manufacture the samples for both the LOI test and the cone calorimeter, two silicone moulds (see Figure 2) have been made with the necessary dimensions for the coupons. Prior to their manufacture, it was determined whether the bioadditives interfere with the curing of thermosetting systems by studying their reactivity using differential scanning calorimetry (DSC). Once their behaviour with thermosetting resins had been verified, the test coupons were manufactured by casting using the aforementioned moulds.



Figure 2. Silicon moulds. Right: LOI Test coupons; Left: Cone calorimeter coupons

LOI test (OXYGEN LEVEL INDEX TEST - EN ISO 4589-2)

- This test measures the minimum oxygen percentage needed to support a material's flame.
- Samples made by casting: 150 x 10mm
- The thickness of the samples tested is around 3.8mm
- Two 5s pilot flame application to ignite the edge of the coupons



Figure 3. LOI Test

Cone calorimeter (ISO 5660-1:2015 + AMD.1:2019)

- This test measures key fire properties, like heat release rate (HRR), maximum average rate of heat emission (MARHE), ignition time...
- Samples made by casting: 100 x 100mm
- Radiation: 50 kW/m²
- Distance (cone-sample): 60mm



Figure 4. Cone Calorimeter Test

RESULTS

Material + 30 phr FR	LOI
Polyester- REF	18
Lignin 1 (15% N)	20,5
Commercial Lignin	21
Tannin 1 (25.7% N)	21,5
Tannin 2 (7.6% N)	20,5
Tannin 3 (21.1% N)	21
Tannin 4 (7.2% N)	20,5
Tannin 5 (6.7% N)	20,5

Figure 5. LOI Test results for polyester resin

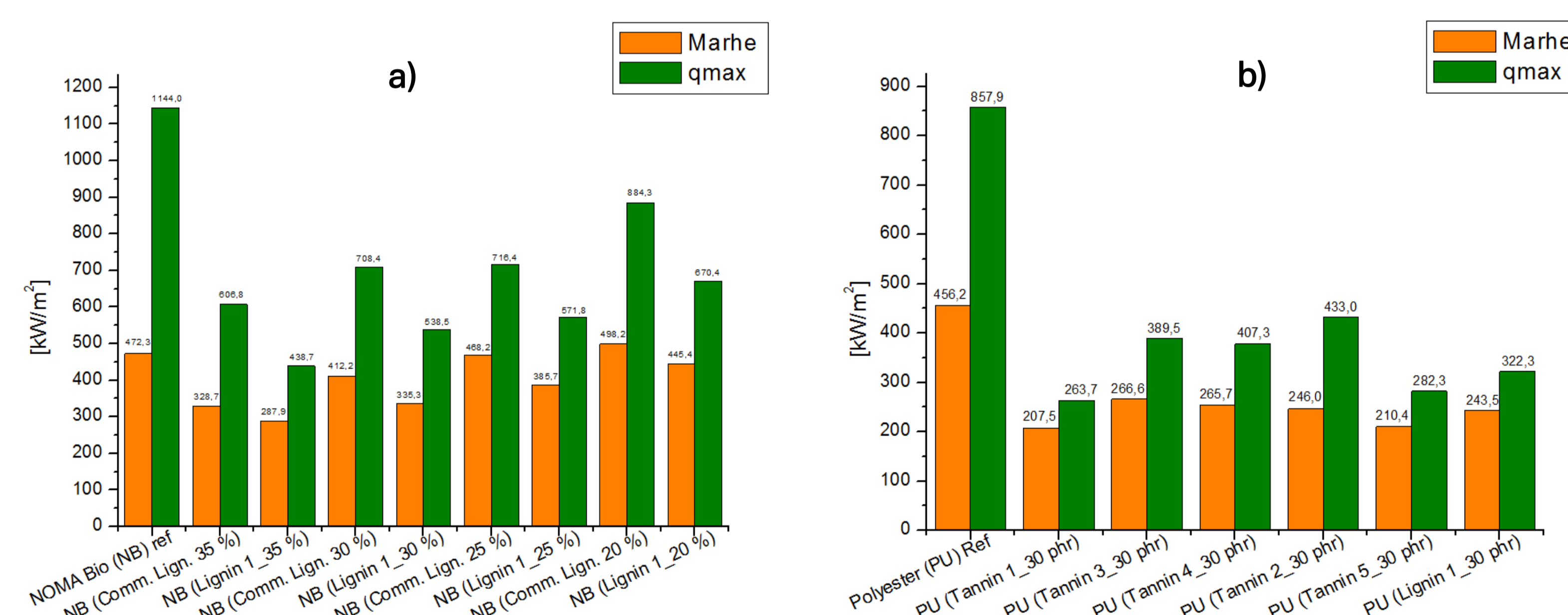


Figure 6. Cone Calorimeter Test Results. a) Epoxy Biobased; b) Polyester

CONCLUSIONS

LOI Test:

- Formulations show a consistent increase in LOI with increasing lignin content.
- Polyester + Tannins → N-content does not affect significantly the samples behaviour

Cone Calorimeter Test:

- Epoxy resin shows better behaviour with N-modified lignin
 - The higher the lignin content, the better fire behaviour
- Polyester Samples → Tannin with lower N-content → similar results to Tannin with 25%N



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