DEVELOPMENT AND PILOT PRODUCTION OF SUSTAINABLE BIO-BINDER SYSTEMS FOR WOOD-BASED PANELS

Deliverable 5.3 – final draft

LCA of proposed resins

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Publishable summary

The SUSBIND project

The SUSBIND consortium develops, produces and tests bio-based adhesives as an alternative to adhesives based on a formaldehyde resin as currently used for wood-based panel boards in furniture mass production. SUSBIND aims at producing these bio-based adhesive systems with leading wood board manufacturers for two product types: P2 particleboard (PB) and medium density fibreboard (MDF). The resulting bio-based adhesive system aims to outperform current conventional adhesive systems by means of a significantly lower carbon footprint, while also reducing emissions toxic to humans.

This study

SUSBIND consortium partners have developed a novel bio-based resin based on a carbohydrate feedstock: fructose. Along with fructose, the resin consists of hydroxymethylfurfural (HMF) and bis(hexamethylene)triamine (BHT). The new Fructose-HMF-BHT resin has shown promising technical performance in lab-scale testing.

The goal of this life cycle assessment (LCA) is to provide a first estimate of the carbon footprint of adhesive systems based on the Fructose-HMF-BHT resin in P2 PB and MDF boards. Both maize- and wheat-based fructose are assessed. The analysis shows which parts of the life cycle contribute most to its carbon footprint. In addition, we include a comparison to the benchmark state-of-the-art petrochemical adhesive systems (urea-formaldehyde; see prior SUSBIND Deliverable 5.1).

Because SUSBIND aims to develop a bio-based resin with a lower carbon footprint at TRL 5 (compared to conventional petrochemical resins at TRL 9), the analysis aims to estimate the resin's environmental performance at TRL 5. However, since the resin is still in development, there are important uncertainties in the data used for the LCA that should be kept in mind when interpreting the results. These include:

- The formulation of the Fructose-HMF-BHT resin is still subject to change, as testing with different formulations (and processing conditions) is ongoing.
- The current production process for Fructose-HMF-BHT resin operates at a small scale, which means the process is not optimised for minimal energy use.
- It is not yet known whether the use of Fructose-HMF-BHT resin will affect downstream processes, such as the use of hydrophobic agents or hardeners, and whether board pressing times/energy use will be affected.
- The technical performance analysed at lab-scale has not yet been confirmed with tests of P2 PB and/or MDF boards.

In the present analysis, assumptions are used to overcome these limitations and provide a first comparison to the state-of-the-art petrochemical resin. In the remainder of the SUSBIND project, more information is expected to become available on these topics, which can be taken into account in subsequent analyses.

Function and functional unit

The SUSBIND consortium aims to develop an adhesive system for two types of board products, particle board (PB) of Type P2 and medium density fibreboard (MDF). For each of these boards a functional unit is defined:

- Functional unit for PB: An adhesive system for P2 PB measuring 450 by 550 by 14 mm, meeting the performance requirements.

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- Functional unit for MDF: An adhesive system for MDF measuring 450 by 550 by 12 mm, meeting the performance requirements.

'Adhesive system' is defined in this assessment as all components of the board which are not wood. This includes the resin and any additives which contribute to attaining the functional requirements. The assumption behind this definition is that the wood use (type and quantity) will not change when switching from conventional to a bio-based adhesive. The energy use required to produce the board (to press resin and wood chips together etc.), as well as wood production and (pre)treatment is outside the scope of this analysis, with the assumption that switching from conventional to bio-based adhesive will not influence this energy use. For end-of-life, incineration without energy recovery is assumed. These assumptions will be checked later in the SUSBIND project.

Analysis

This LCA is focused on the production of the proposed Fructose-HMF-BHT resin. Data on the formulation and process conditions was supplied by WoodK+. This was supplemented by a first estimate on the process' energy use at TRL 5 by CE Delft. For the bio-based feedstock, both wheat-derived fructose and maize-derived fructose are included (in line with the recommendations from Deliverable 5.2).

The downstream parts of the boards' life cycle are assumed to be similar to the benchmark UF adhesive systems and are unchanged from previous analyses (particularly Deliverable 5.1). This means:

- Adhesive and board production are assumed identical to the benchmark/reference UF adhesive, e.g. in terms of the use of hardeners, hydrophobic agents or other additives.
- The technical performance of the Fructose-HMF-BHT resin is assumed to be identical to the benchmark UF adhesive on a dry solids basis (based on preliminary testing by WoodK+). Therefore, during board production the same dry solids amount of adhesive is added when using the Fructose-HMF-BHT resin and when using the reference urea-formaldehyde (UF) resin.
- For the boards' end-of-life, incineration without energy recovery is assumed. For the end-of-life phase the CO_2 emissions of the adhesive (when the furniture is incinerated) are taken into account. In the bio-based system these emissions will not be counted as they are short-cycle (biogenic) CO_2 emissions.

Carbon footprint results

Below, Figure 1 shows a breakdown of the carbon footprints of the different adhesive systems studied. The graph shows the results in gram CO_2 eq. per piece of P2 PB (left) or MDF (right); note that the dimensions of the pieces of boards are not the same (see 'Function and functional unit' above). For both board types, we show the results for the UF benchmark (from Deliverable 5.1) and the Fructose-HMF-BHT adhesive system produced from either wheat- or maize-derived fructose.

Figure 1 highlights a few key findings:

- The largest contributor to the estimated carbon footprint of the Fructose-HMF-BHT adhesive system is the production and end-of-life (EOL) of BHT. BHT production accounts for 32% to 40% of the total carbon footprints of the adhesive systems for P2 PB and MDF, respectively. In the EOL BHT is also a large contributor, since it contains fossil carbon. It contributes between 14% and 17% of the total carbon footprint.
- The contribution of the fructose solution to the total carbon footprint of the adhesive system is also substantial (about 20-30%). This is due to the fact that more fructose is used in the adhesive than was assumed in the Deliverable 5.2 and because more adhesive is required per piece of board, due to the lower d.s. content of the Fructose-HMF-BHT adhesive system.

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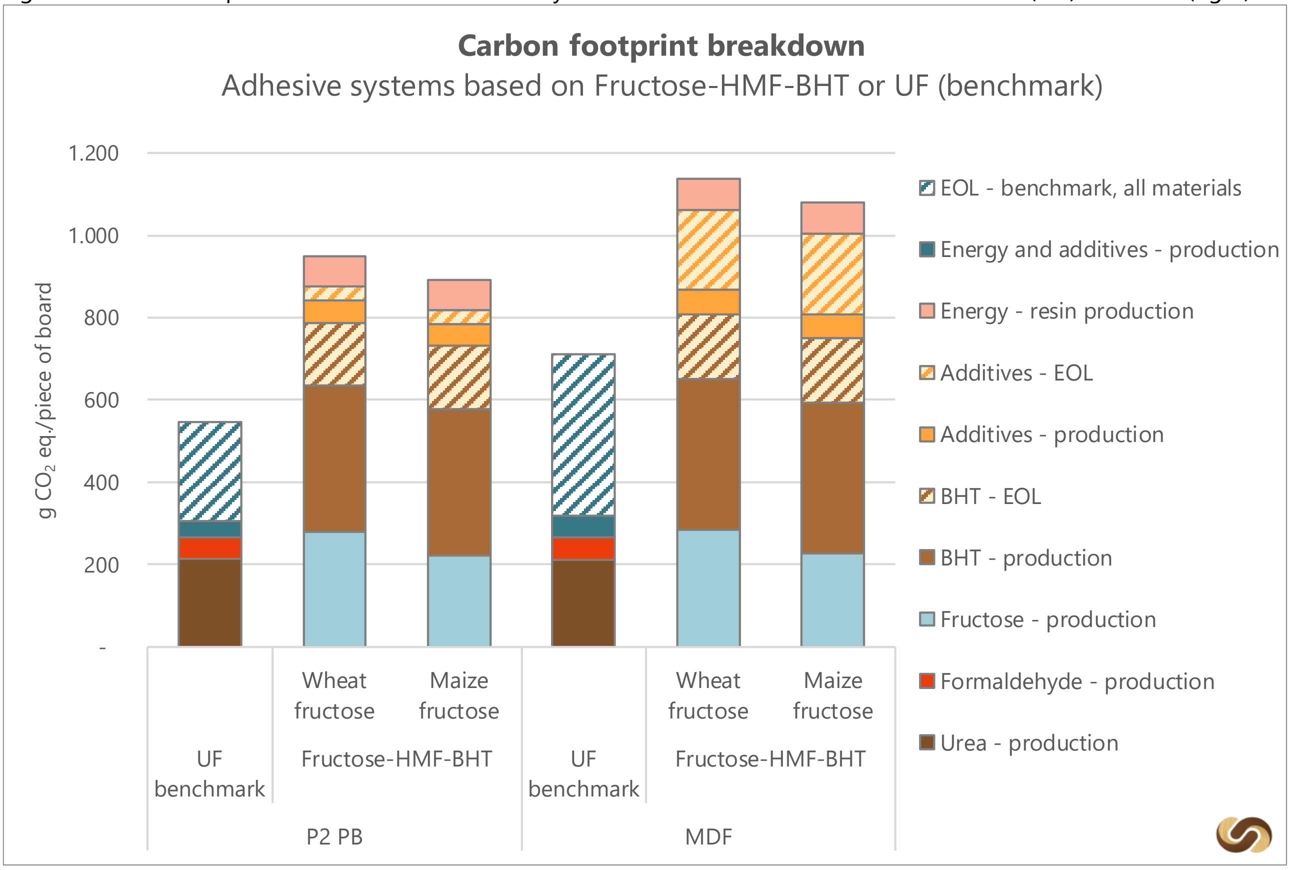
- Fructose derived from maize has a lower carbon footprint than fructose derived from wheat. In the adhesive systems studied here, the carbon footprint reduction by using maize-derived fructose instead of wheat-derived fructose is about 6% and 5% for P2 PB and MDF, respectively.
- The dry solids (d.s.) content of the Fructose-HMF-BHT adhesive is 61% (WoodK+ information), which is somewhat lower than the reference UF resin. Since we assumed 1 kg d.s. of Fructose-HMF-BHT can replace 1 kg d.s. of UF resin, more ('wet weight') Fructose-HMF-BHT resin is required overall.

Figure 1 Carbon footprint breakdown for adhesive system based on Fructose-HMF-BHT in P2 PB (left) and MDF (right)



Note: Results exclude climate change impact of land use change

Conclusions and recommendations

The SUSBIND project aims to develop a bio-based adhesive system for P2 PB and MDF that achieves two main environmental goals: 1) a 5% lower carbon footprint (TRL 5 for bio-based compared to TRL 9 for the petrochemical benchmark) and 2) lower human health impacts compared to the benchmark. In this analysis, the environmental performance of a novel, partly biobased Fructose-HMF-BHT resin which is currently in development in SUSBIND was assessed, focusing primarily on the carbon footprint performance.

The current analysis is based on our current best understanding of the Fructose-HMF-BHT adhesives and various assumptions. However, as SUSBIND progresses and the novel resin production and application is better understood and optimised further, new insights may change the analysis and its results. Any conclusions drawn at this stage should therefore be considered preliminary.

The present analysis leads to the following (preliminary) conclusions regarding SUSBIND's two environmental goals:

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- The **carbon footprint** of the adhesive systems based on the Fructose-HMF-BHT resin developed within SUSBIND is currently estimated at about 890 to 900 g CO_2 eq. / piece of P2 PB and 1080 to 1140 g CO_2 eq. / piece of MDF. The lower values correspond to the use of maize-derived fructose; the higher to the use of wheat-derived fructose.
  - Based on these results, the Fructose-HMF-BHT adhesive systems have a higher carbon footprint than the benchmark state-of-the-art UF adhesive systems (see Deliverable 5.1). The benchmark carbon footprint values are 550 g CO_2 eq. / piece of P2 PB and 710 g CO_2 eq. / piece of MDF.
  - The carbon footprint of the Fructose-HMF-BHT adhesive systems is strongly determined by the use of fossil-based BHT, which has a high carbon footprint (during production and end-of-life).
  - If Fructose-HMF-BHT resins were implemented in P2 PB and MDF on a large scale, potential emissions due to land use change can increase the carbon footprint of the adhesive systems by between 8% and 24%.
- Regarding **human health impacts**, Fructose-HMF-BHT adhesive systems are expected to perform substantially better in the use phase of the boards than UF-based adhesives since they do not use formaldehyde.

In the upcoming period leading up to the next LCA report (Deliverable 5.4), different steps can be taken to reduce uncertainties and/or lower the carbon footprint of the Fructose-HMF-BHT adhesive system. The following options have been discussed within the consortium:

- **Optimising the resin/adhesive formulation**. Reducing BHT content can most strongly lower the carbon footprint of the novel resin. In addition, reducing the use of hydrophobic agents (or using a bio-based alternative) can lower the carbon footprint of the entire adhesive system, even more so for MDF than for PB.
- Evaluating the **amount of adhesive** required. The current carbon footprint analysis assumes the amount of (dry solid) adhesive required is the same for Fructose-HMF-BHT and UF. This assumption may lead to an over- or underestimation of the carbon footprint and should be revisited when the formulation has been developed further.
- Assessing changes in **board pressing energy use**. Similarly, it is not known yet to what extent the novel Fructose-HMF-BHT affects the board pressing times and energy use compared to UF. An initial analysis in Deliverable 5.1 suggested that this may be a critical factor in the overall carbon footprint.
- Checking the relevance of **other benchmark resins**. As discussed in Section **Fout! Verwijzingsbron niet gevonden.**, other resin types such as MUF or pMDI may also be relevant benchmarks for specific applications or if the market sets higher standards for formaldehyde emissions from boards. These other resins are expected to have a higher carbon footprint than UF.

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