# Mould resistance of insulation boards made from tropical wood fibre residues

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## Context and objectives

An energy-efficient transition to a better sustainable building industry is required to develop a circular economy by reducing the pressure on ecosystems. A key strategy is to optimize the use of available plant biomass by enhancing the recovery of residual resources from biomass processing (Chaudhary et al 2025), aiming to reduce waste and contribute to the development of value-added materials with lower environmental impact (Mujtaba et al 2025). The development of renewable and environmentally friendly materials can improve the energy efficiency of buildings and construction. Therefore, the development of efficient and long-lasting thermal insulating structural objects is highly desirable (He et al 2020). One of the most significant solutions to reduce operational energy use relies on the insulation of the building envelope, which confers benefits in both heating and cooling energy use (Cetiner and Shea 2018). Wood residues from timber harvesting and processing operations are excellent green and low-cost alternatives to inorganic materials for insulation panel development. Their low embodied energy and potential moisture buffering capacity improve indoor environmental quality (Cetiner and Shea 2018). However, the effect of moisture content modifies the resulting mechanical performance (De Ligne et al 2022) and biological durability (Brischke and Alfredsen 2020).

This study investigates the technological potential of fibre insulation board panels manufactured using main wood residues from the Guyanese timber industry, which is considered an eco-friendly and low-cost alternative to inorganic materials. However, such tropical resources remain understudied, and the thermo-hygric conditions of French Guiana impose significant constraints on bio-based materials, affecting their durability and performance over time. Specifically, this work aims to assess the mould resistance of insulation boards using seven Guyanese wood species to improve the understanding of the physical behaviour of these wood-based composites in tropical climates and to support their wider application in sustainable construction.

## Materials and methods

*Selection and sampling of wood species for fibre board production*

The different residual fibres of interest for the production of insulation boards were selected based on their availability, physical, chemical, and biological resistance properties, and their potential future exploitation in French Guiana (ONF 2022; Gérard et al 2019a-b; Beauchêne et al 2021a-b). Seven wood species, presented in Tab. 1, were selected and classified according to the following three resource typologies. Commercial reference fibres were provided by STEICO (indicated in the manuscript as “commercial reference”- Commercial), consisting of a blend of pulpwood fibres treated with ammonium phosphate.

Tab. 1: List of the tested wood-fiber insulation panels, according to their fiber nature and the material density.

| Resource typologies | Reference | Wood species | Fibre modality | Panels Density (in kg.m$^{-3}$) |
|---|---|---|---|---|
| Commercial wood species (i) | Dg | *Dicorynia guianensis* | Wood | 211.58 ± 20.65 |
| | Sr | *Sextonia rubra* | Wood | 214.48 ± 24.31 |
| | Lp | *Lecythis persistens* | Wood | 228.52 ± 21.24 |
| | Lp-bark | *Lecythis persistens* | Wood + Bark | 246.49 ± 17.21 |
| Future plantation forests (ii) | Bg | *Bagassa guianensis* | Wood | 203.58 ± 31.21 |
| | Bg-bark | *Bagassa guianensis* | Wood + Bark | 221.77 ± 26.19 |
| | Sa | *Simarouba amara* | Wood | 172.72 ± 14.11 |
| | Sa-bark | *Simarouba amara* | Wood + Bark | 200.06 ± 21.06 |
| Agricultural clearings (iii) | Co | *Cecropia obtusa* | Wood | 219.43 ± 25.88 |
| | Co-bark | *Cecropia obtusa* | Wood + Bark | 193.62 ± 20.66 |
| | Vm | *Virola michelii* | Wood | 230.16 ± 40.70 |
| | Vm-bark | *Virola michelii* | Wood + Bark | 196.56 ± 16.28 |

*Fibre preparation and chemical characterization*

All wood fibre fractions were oven dried at 60 °C for 24 - 48 h until to reach RH < 15 %. Then, they underwent the same two-stage procedure: (i) pre-shredding suing a single-rotor shredder with knives on the rotor and an 8 mm grid (Decoval®, France) was used to obtain a fraction with a relatively homogeneous particle size distribution, with the majority of particles smaller than 8 mm; (ii) Impact grinding technology using a shredder (Electra®, France) steel hammers combined with a 2 mm grid and coupled to a suction system, extracting the shredded material and eliminate ultrafine particles, was used to reach a particle size ranges from 0.1 to 1 mm. Then, the chemical composition of all the wood fibres (soluble, hemicellulose, cellulose, lignin, and ash fractions) was determined by the Van Soest method (Van Soest 1990), according to the NF V 18-122 (2013) standard.

*Fibre insulation board production*

Wood fibre insulation panels were manufactured using a process defined and adapted by Vignon (2020) and Bossu et al (2023). They are composed of the natural fibres (93 % in mass) and synthetic bicomponent fibres (polypropylene / low density polyethylene, 6 mm-long, made by FiberVisions and supplied by STEICO France), representing 7 % of mass at the beginning of the process. All the fabrication process is illustrated in Fig. 1. After fabrication, the panels (450 × 450 × 25 mm$^3$) were conditioned at 20± 2 °C, 65 ± 5 °C % RH and cut into test specimens of 50 × 50 x 25 mm$^3$ using a sliding table saw. The stabilized samples were weighed to determine their density before being subjected to durability tests.

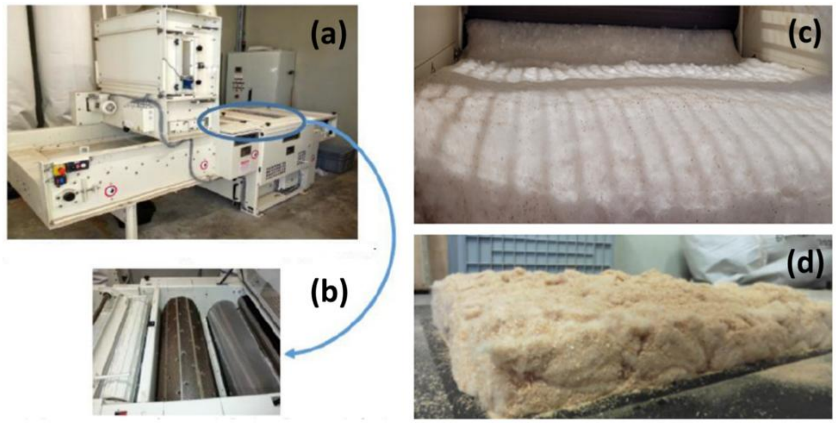


Fig. 1 : Device used for insulation fiberboard production and processing steps: (a) Laroche napper opener, (b) rotating spiked roller for carding and air-stream opener, (c) example of the opening of synthetic fibers, (d) wood / synthetic fibers mixture mat before consolidation by hot-pressing.

*Mould resistance test*

The mould resistance tests were adapted from the guidelines of the ASTM D3273-00 (2005) standard, with some adjustments regarding the type of fibreboard material and selection of wood-destroying fungi. For each modality, three samples extracted from three different panels ($50 \times 50 \times 25$ mm$^3$, 1 sample per panel) were exposed to *Aspergillus terreus* [AT - Thom, 1918], grown on malt/agar medium [malt 40 ± 0.5 g.L$^{-1}$ (Difal, France), agar 20 ± 0.5 g.L$^{-1}$ (Biomérieux, France)], cultivated in the laboratory in Petri dishes on malt-agar culture medium, conditioned at 22 ± 2 °C, 65 ± 5 % RH, in the dark. For comparison, reference massive wood samples using *Pinus sylvestris* sapwood and *Fagus sylvatica* (50 × 50 × 25 mm, L × R × T) were also tested under the same conditions. The samples were conditioned at 20 ± 2 °C, 65 ± 5 % RH until stabilization, their moisture content was determined as well as their theoretical anhydrous mass. Then, the samples were sterilized by γ-rays (25-50 kGγ) before being exposed to the mould (Fig. 2a). *Aspergillus terreus* inoculum was scraped and diluted in distilled water (2 petri dishes / 400 mL). Then, 2000 µL of the spore suspension (Fig. 2b) was evenly spread over the surface of the panel sample using a sterile pressurized dispenser (Fig. 2c). Pulverized samples were placed in the middle of a glass bottle on a malt agar culture medium surface, as illustrated in Fig. 2d.

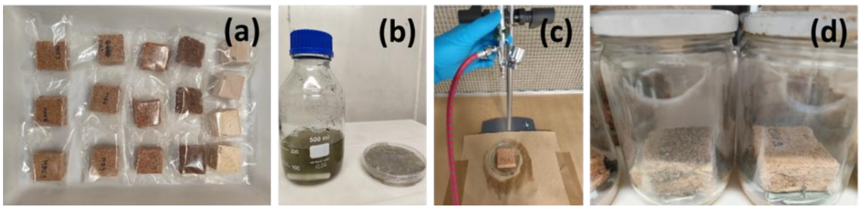


Fig. 2 : Protocol used for mold resistance tests: (a) γ-rays sterilization of all the insulation fiber board samples before being exposed to mold; (b) Preparation of the Aspergillus terreus mycelium suspension diluted in distilled water (2 petri dishes/ 400 mL); (c) Spraying of 2mL of Aspergilus terreus mycelium suspension on the surface of the insulation fiber board sample; (d) Sprayed insulation fiber board samples and control samples were placed in the middle of glass bottle on a malt-agar culture medium surface during 6 weeks, in the dark within a conditioned room at 27 ± 2 °C - RH > 75 %.

The test devices were then incubated in the dark in a conditioned room at 27 ± 2 °C and RH > 75 % for six weeks. The presence of a mould zone on each surface of the sample was observed and evaluated every week. Distilled water was sprayed onto the sample to add moisture and favour mould colonization. At the end of the test, all the tested samples were cleaned by carefully removing mould, weighed, and then dried at 103 ± 2 °C for 24 h. Finally, the final weight was recorded to determine the moisture content of the 6-weeks incubated samples and the weight loss (dry basis) due to mould exposure. Finally, a visual rating was assigned to all tested samples depending on the degree of mound growth according to the ASTM D3273-00 (2005) standard.

## Results and discussion

Tab. 2 presents the chemical composition (in %, w/w dry basis) of all the fibre modalities used for the elaboration of insulation board materials. These results show that tropical fibres have a lower content of hemicelluloses and a higher content of inorganic compounds than temperate woods. It should be emphasized that the introduction of bark into the samples significantly modified their composition, increasing the hemicellulose or lignin content. Moreover, commercial wood and future plantation wood species generally present higher contents in lignin and extractives, and lower content in hemicelluloses than those of agricultural clearings wood species.

Tab. 2: Chemical compositions of the different fibre modalities used in the production of fibre insulation panel, and of the wood species used as biological degradability virulence controls.

| | | | **Contents in chemical constituents (in %, w/w dry basis)** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Resource typologies | Wood species | Fibre modality | Hemicelluloses | Cellulose | Lignin | Soluble | Inorganics | Extractives |
| Commercial wood species (i) | *Dicorynia guianensis* | Wood | 10. 25 ± 0.07 | 52.55 ± 0.21 | 31.05 ± 0.07 | 4.95 ± 0.50 | 1.15 ± 0.35 | 4.70 |
| | *Sextonia rubra* | Wood | 8.30 ± 0.28 | 55.50 ± 0.07 | 25.30 ± 0.30 | 9.80 ± 1.70 | 1.30 ± 0.10 | 7.20 |
| | *Lecythis persistens* | Wood | 6.40 ± 0.57 | 60.90 ± 1.20 | 22.40 ± 0.4 | 9.30 ± 1.00 | 1.10 ± 0.20 | 4.80 |
| | *Lecythis persistens* | Wood + Bark | 8.00 ± 0.14 | 60.10 ± 0.42 | 16.50 ± 0.10 | 8.10 ± 0.90 | 1.20 ± 0.10 | 6.10 |
| Future plantation forests (ii) | *Bagassa guianensis* | Wood | 10.70 ± 0.28 | 54.10 ± 0.42 | 22.10 ± 0.28 | 12.20 ± 0.07 | 1.00 ± 0.28 | 10.10 |
| | *Bagassa guianensis* | Wood + Bark | 11.80 ± 0.50 | 54.30 ± 0.35 | 22.00 ± 1.30 | 11.00 ± 0.10 | 1.10 ± 0.50 | 12.40 |
| | *Simarouba amara* | Wood | 8.90 ± 0.35 | 57.30 ± 0.14 | 27.10 ± 0.30 | 5.30 ± 0.00 | 1.50 ± 0.10 | 6.30 |
| | *Simarouba amara* | Wood + Bark | coming soon | coming soon | coming soon | coming soon | coming soon | coming soon |
| Agricultural clearings (iii) | *Cecropia obtusa* | Wood | 12.20 ± 1.13 | 58.50 ± 1.34 | 16.50 ± 0.10 | 12.20 ± 0.30 | 0.80 ± 0.20 | 3.30 |
| | *Cecropia obtusa* | Wood + Bark | 12.00 ± 0.21 | 60.60 ± 0.71 | 20.10 ± 0.40 | 6.20 ± 0.40 | 1.30 ± 0.10 | 15.70 |
| | *Virola michelii* | Wood | 12.30 ± 0.77 | 60.70 ± 0.99 | 16.20 ± 0.10 | 10.10 ± 0.20 | 0.90 ± 0.40 | 4.20 |
| | *Virola michelii* | Wood + Bark | 12.10 ± 0.28 | 58.90 ± 0.00 | 19.10 ± 0.40 | 9.00 ± 0.40 | 1.10 ± 0.10 | 4.10 |
| Control | *Fagus sylvatica* | Wood | 21.71 ± 0.40 | 55.39 ± 0.40 | 13.30 ± 1.70 | 8.00 ± 0.20 | 0.10 ± 0.00 | 1.50 |
| Control | *Pinus sytlvestris* | Wood | 16.38 ± 0.35 | 49.00 ± 1.20 | 28.22 ± 0.70 | 1.78 ± 0.20 | 0.30 ± 0.10 | 4.32 |

Tab. 3 reports the mould resistance of all wood fibre insulation board modalities and control samples to *Aspergillus terreus*. The results follow the same tendency than those observed with *Pycnoporus sanguineus*. The Dg, Sr, Lp, and Lp-bark panel modalities, which all belong to the industrial dense wood by-products group, appear to be more resistant against mould colonization compared to all the other materials classified as “sensitive to mould infestation”. It confirms that the content of hemicellulose, lignin and extractives has an important effect on water absorption (moisture content) and the resulting mould sensitivity (Findlay and Savory, 1954). Additionally, the visual aspect of mould infestation was slightly different among all the insulation panels and the massive wood control samples. This observation could be attributed to variations in the surface structure of the specimen, which affect spore attachment and germination (Gobakken et al 2010).

## Conclusion and perspectives

The most important wood properties involved in the mould resistance of solid wood and wood-based materials seems to be related to the lignin composition of the cell wall, availability of nutrients, amount and composition of extractives, and presence of moisture-regulating components. Finally, the length of time an experiment on mould growth is conducted significantly influences the likelihood of mould development, as extended incubation periods increase the risk of infestation. Therefore, future research could incorporate long-term outdoor testing using matched samples to enable a direct comparison with the laboratory findings presented in this study.

Tab. 3: Moisture content, classification of mould growth according to ASTM D3273-00 (2005), and most representative visual appearance of wood insulation panels and control samples, after 6 weeks of *Aspergillus terreus* exposure (AT).

| *Aspergillus terreus* | | | |
|---|---|---|---|
| Reference | Final Moisture Content (%) | Classification number for mould growth, according to ASTM D3273-00 (2005) standard criteria | |
| | | Scale* | Comments |
| Dg | 44.45 ± 1.63 | 2 | Moderate sensitivity to mould infestation |
| Sr | 48.50 ± 1.51 | 2 | Moderate sensitivity to mould infestation |
| Lp | 39.83 ± 3.26 | 1 | Resistant to mould infestation |
| Lp-bark | 44.13 ± 3.43 | 2 | Moderate sensitivity to mould infestation |
| Bg-bark | 55.66 ± 9.46 | 4 | Sensitive to mould infestation |
| Sa | 78.83 ± 9.40 | 4 | Sensitive to mould infestation |
| Co | 68.34 ± 6.41 | 4 | Sensitive to mould infestation |
| Co-bark | 61.21 ± 6.38 | 4 | Sensitive to mould infestation |
| Vm | 45.84 ± 7.94 | 4 | Sensitive to mould infestation |
| Vm-bark | 60.12 ± 0.65 | 4 | Sensitive to mould infestation |
| Ps-control | 35.02 ± 3.01 | 4 | Sensitive to mould infestation |
| Fs-control | 46.10 ± 6.99 | 4 | Sensitive to mould infestation |
| Commercial | 129.79 ± 3.62 | 4 | Sensitive to mould infestation |

* According to the ASTM D3273-00 (2005), 0 = no visible mould or discoloration; 1 = some traces of fungi only visible under the microscope; 2 = mould/discoloration on up to 25 % of the total surface area; 3 = mould/discoloration on > 25 % up to 50 % of the total surface area; 4 = mould/discoloration on more than 50 % of the total surface area.

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