Tropical agro-wastes for environmentally friendly non-load bearing bio-composites and comparative analysis with wood panels

MANSOUR Souha[1,2], VIRETTO Amandine[1,2], THEVENON Marie-France[1,2], BRANCHERIAU Loïc[1,2]

[1]CIRAD, UPR BioWooEB, F-34398 Montpellier, France.
[2]BioWooEB, Univ Montpellier, CIRAD, Montpellier, France.
souha.mansour@cirad.fr

Keywords: tropical biomasses from West Africa, agricultural waste, biocomposite materials

Context

This work is part of the BIO4AFRICA project (H2020-No 101000762) which aims to diversify incomes in rural areas of Africa through sustainable and locally replicable solutions. The project focuses on developing technologies adapted to the environment and improving traditional techniques in African rural contexts with the local biomass available to develop bio-sourced materials for habitat.

In this context, five agricultural residues issued from Côte d'Ivoire and Senegal were selected to produce composite panels for building applications as non-load-bearing materials. The selected biomasses are oil palm empty fruit bunches, rice husks, cocoa pods, millet stalks, Typha. All the listed biomasses have no nutritional value and their use in such applications is beneficial, first economically and second to reduce waste and solve the induced health and environmental problems (Veloso et al., 2021); they are left on plantation sites (Abdul et al., 2012) which is the main cause of many diseases in the Western Africa area. They are available in large quantities, seasonal, and present different inherent properties.

Objectives

The objective of this study is the development of materials that represent environmental responsibility and are well-suited for use in tropical climates. It is important to take into consideration the significance of creating durable materials capable of withstanding the challenging conditions often found in tropical regions. Equally important, we are committed to minimizing the environmental impact associated with the entire production chain of these materials. This encompasses sourcing sustainable raw materials, employing eco-friendly manufacturing processes, and implementing waste reduction strategies.

This study is separated into three parts. Firstly, the characterization of the biomasses, then the fabrication and characterization of the composites, all while studying the effect of fiber/binder ratio and the intrinsic properties of the biomasses. Secondly, the role of the particle size will be studied and its effect on the panels' properties. Lastly, the research will explore the possibility of substituting the traditional binder used in the first two parts, which is melamine urea formaldehyde, with bio-sourced binders, ultimately striving for the development of 100% bio-sourced composites.

All the panels produced during this work will be compared with commercial wood panels used at the moment as non-load-bearing materials in the habitat sector. Characterization tests will be conducted on both the biocomposites produced and the wood panels to facilitate a comprehensive and distinct comparison between the two.

Material and methods

Biomass preparation

The biomasses sourced from Senegal and Ivory Coast underwent an initial drying process at 80°C for 24 hours to remove moisture content. Following this, they were subjected to milling using the Retsch SM100 mill with a 6 mm sieve. Due to the large size of these materials, this milling step was essential to reduce the size for the analysis of the biomasses and their incorporation in the composites.

Biomass characterizations

The characterization process involved several distinct steps. Initially, the biomasses underwent a sieving procedure using the Endecotts sieve shaker model EFL 2000 (sieve from 5 mm to 0.1 µm). This sieving aimed to establish a granulometric distribution, which holds significance for the subsequent phase of the study.

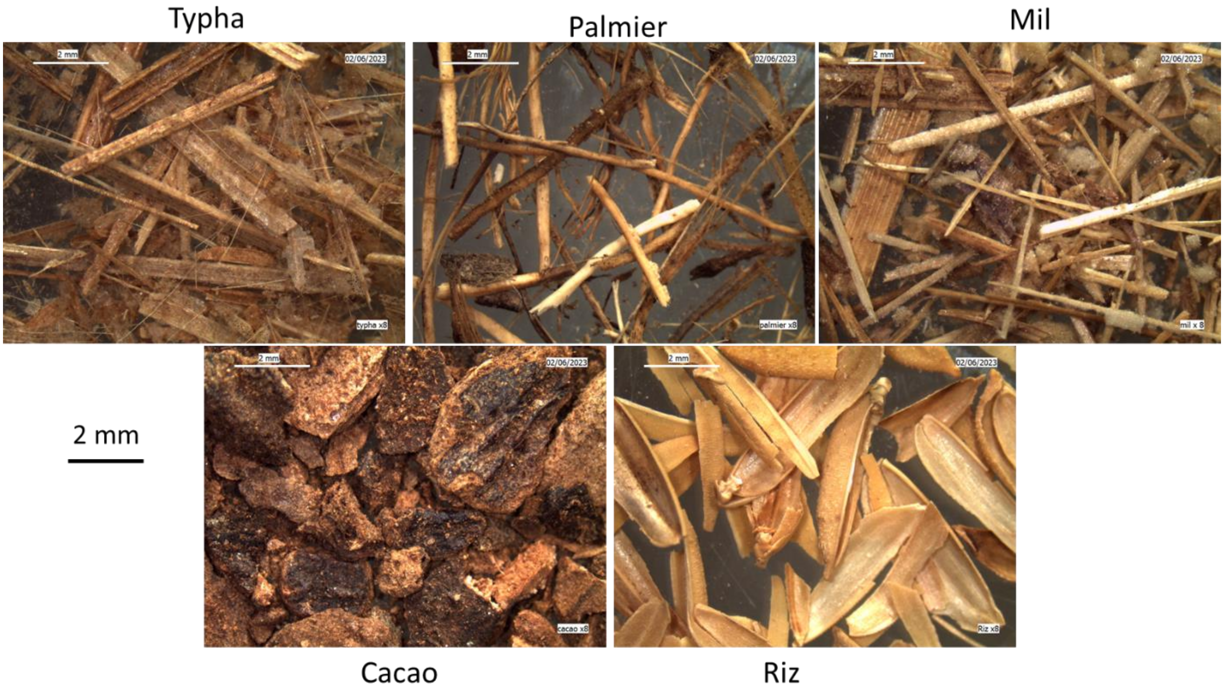

Fig. 1 : Microscopic view of the five biomasses (x8)

Following this, a thermogravimetric analysis was conducted using the Mettler Toledo Thermal Analysis instrument. This analysis involved subjecting the biomasses to a temperature range from 30 to 800 °C, with a heating rate of 10 °C/min, in two different atmospheres: air and nitrogen. The third test encompassed the determination of chemical composition through the ANKOM 200 fiber analyzer. To prepare for this assessment, the biomasses were ground to a size of 1 cm and then placed in filter bags. This procedure facilitated the determination of cellulose, hemicellulose, and lignin quantities and ratios in the materials. In addition to these major components, ash and humidity contents were also evaluated to determine the global chemical composition. Subsequently, Near-infrared spectroscopy, performed using PerkinElmer's Spectrum Two™ equipment, was employed to study the constituents of the fibers. A correlation could be made between these two methods which determine the chemical composition. To assess durability in the face of termite infestation, a dedicated screening test was conducted on raw biomass according to the method of Boer et al. (2021). Finally, the last carried out analysis on the produced grounded fibers will be the measurement of color.

Composites formulation

A heating hydraulic press (MIB, 100T) will be utilized for the production of panels measuring 40×40×1 cm. The grounded fibers were blended with Melamine Urea Formaldehyde (MUF) as binder which requires a temperature of 120°C to react.

Expected results

Following the fabrication of the panels, an extensive characterization process will follow, delving into various aspects as physico-chemical, mechanical, thermal and biological properties. These include an examination of their density, porosity, coloration, resistance to termites and fungi, thermal conductivity, fire resistance, mechanical strength, acoustic properties, and their response to water absorption. It is anticipated that the results obtained will likely differ from those observed in the case of wood panels; however, this comparative analysis will elucidate the distinctions between the two types of composite materials.

Regarding the fiber-to-binder ratio, it is anticipated to range between 80/20 and 60/40, with preliminary indications suggesting that the 80/20 ratio may yield more efficient outcomes. It is essential to note that particle size and the nature of the biomass used will significantly influence the final properties of the biocomposite materials.

In the subsequent phase, natural binders will be incorporated in order to replace MUF, but the expectation is not necessarily that they will outperform. Instead, the aim is to assess if the values achieved are within a close range of efficiency. If this proves to be the case, the preference will lean toward the utilization of a 100% bio-sourced material, aligning with sustainability goals.

References

Abdul H.P.S., Jawaid M., Hassan A., Paridah M.T., Zaido A. (2012) Oil Palm Biomass Fibres and Recent Advancement in Oil Palm Biomass Fibres Based Hybrid Biocomposites. Composites and Their Applications, June 2014. https://doi.org/10.5772/48235

Boer F.D., Valette J., Commandré J., Fournier M., Thévenon M. (2021) Slow Pyrolysis of Sugarcane Bagasse for the Production of Char and the Potential of Its By-Product for Wood Protection. Journal of Renewable Materials, 9(1), 97–117. https://doi.org/10.32604/jrm.2021.013147

Veloso M.C.R., Scatolino M.V., Gonçalves M.M.B.P., Valle M.L.A., de Paula Protásio T., Mendes L.M., Junior J.B.G. (2021) Sustainable valorization of recycled low-density polyethylene and cocoa biomass for composite production. Environmental Science and Pollution Research, 28(25), 32810–32822. https://doi.org/10.1007/s11356-021-13061-y