Banana Peels: A Self-Sufficient Chemical System for the Green and Clean Fabrication of Wood-like Materials

SUPPORTING INFORMATION

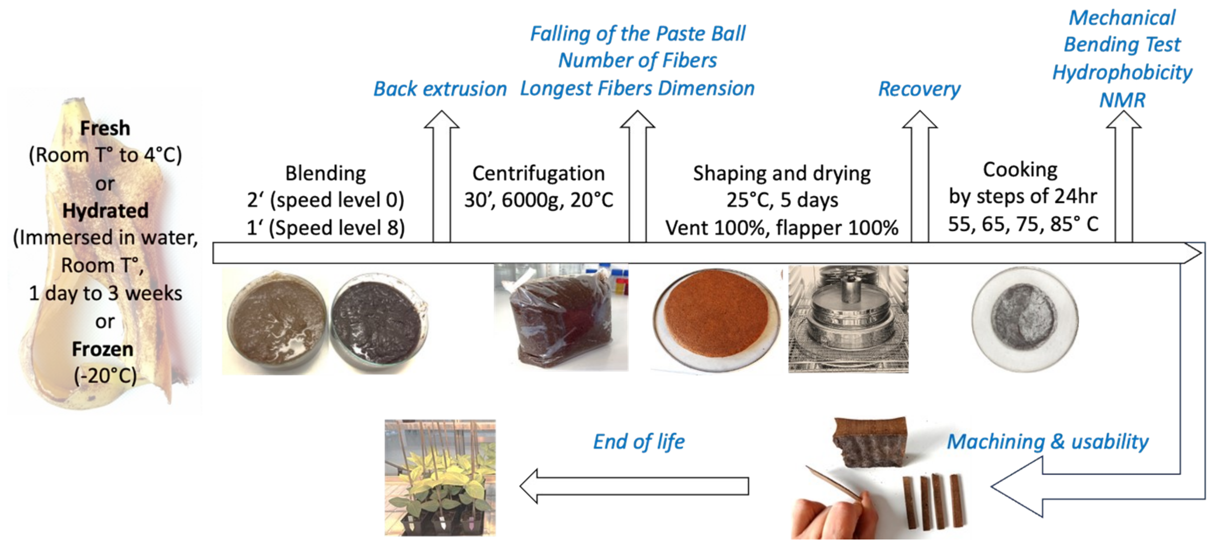
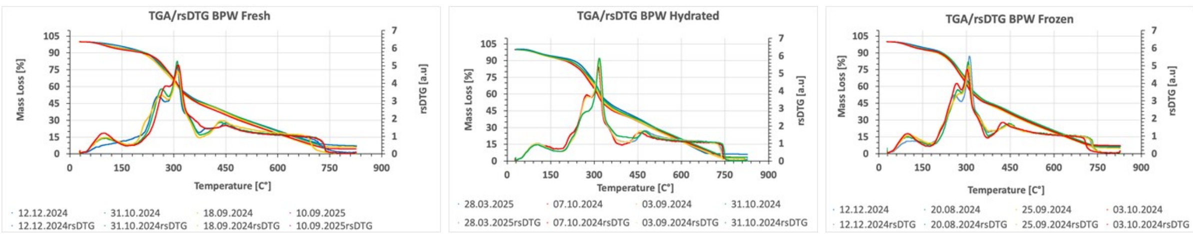


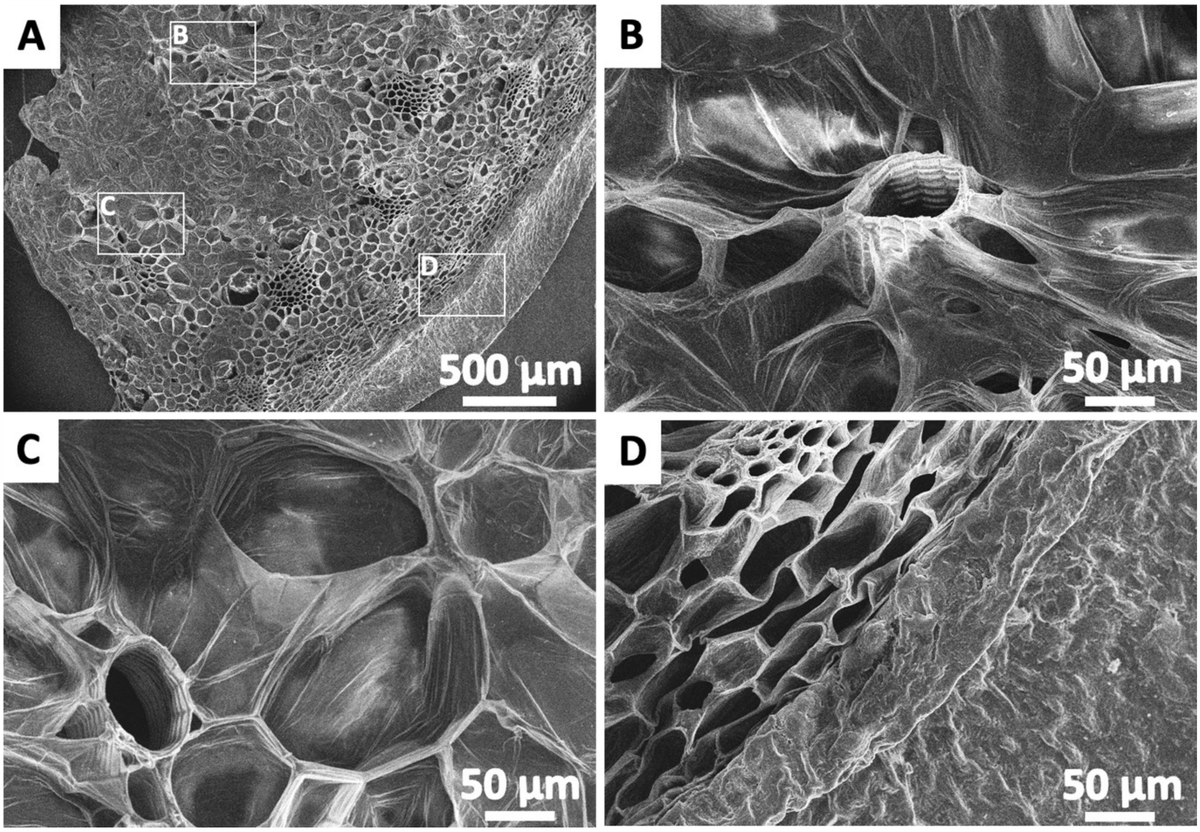
Figure SI_1: The different steps of the process finally adopted to produce wood out of banana peels (BPW). The effects of three pretreatments of the peels were analyzed to identify eventual differences in wood properties. The stages at which, the analysis was made, are indicated in blue.

SI_2:

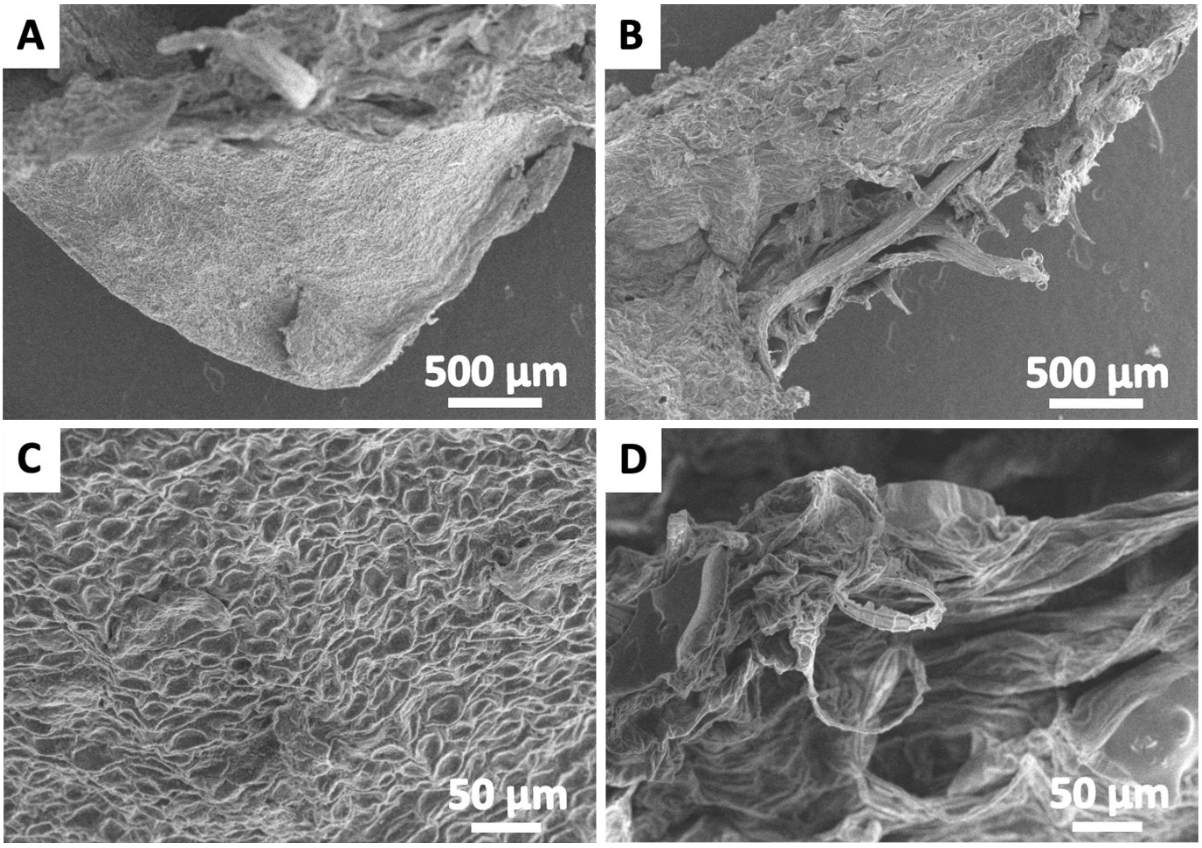
CP and INEPT experiments are complementary and select either rigid or mobile species, respectively. Using an amphiphile system, Nowacka and co-workers modelled the efficiency of both experiments according to the mobility of the involved species [1], when Pérez García *et al.* studied the structure and dynamics of pectic polysaccharides [2]. Fort *et al.* investigated the carbohydrate composition of banana pulp in function of the ripening of the fruit [3]. On the CP spectrum, the main peaks at 73 and 105 ppm correspond to polysaccharides (cellulose, hemicellulose, and starch), as well as the backbone part of pectin. The peak at 172 ppm can be attributed to the C=O of galacturonic acid, acetyl groups, or proteins. Aromatics from proteins or lignin are visible from 130 to 155 ppm. Finally, glycoprotein side chains are present below 45 ppm. Previous authors analyzed such macromolecules with a more in-depth attribution. The INEPT spectrum is simpler and highlights the lipids from 10 to 45 ppm and their C=C unsaturated bonds from 123 to 132 ppm. The variations observed in the spectra highlight the differences in mobility and composition within the samples. The DEPTH spectrum is quantitative and is almost the sum of the CP and INEPT spectra. Additional peaks are present at 134.5 ppm and around 49 ppm. Those are attributed to mobile quaternary carbons.



SI_3: Thermogravimetric analysis of all samples per family. We did not observe any significative distinction from one family to another. All graphs fit in between that of samples 03 and 31.10.2024.



SI_4: Dried section of a banana peel observed by SEM. (A) showing the different constituting tissues from the parenchyma (inner part of the peel) on the left to the epiderma and its cuticle (external) on the right. (B-D) zoom in of area delineated in (A). Note the presence of conductor vessels (B&C) and the density of the cuticle (D).



SI_5: Dried fracture made in a banana peel observed by SEM showing (A) the peel (bottom) and a fibre (top) extruding from the parenchyma. (B) Fibres of different sizes extruding from the parenchyma. (C) zoom on cutille. (D) zoom in on a disrupted conductor vessels.

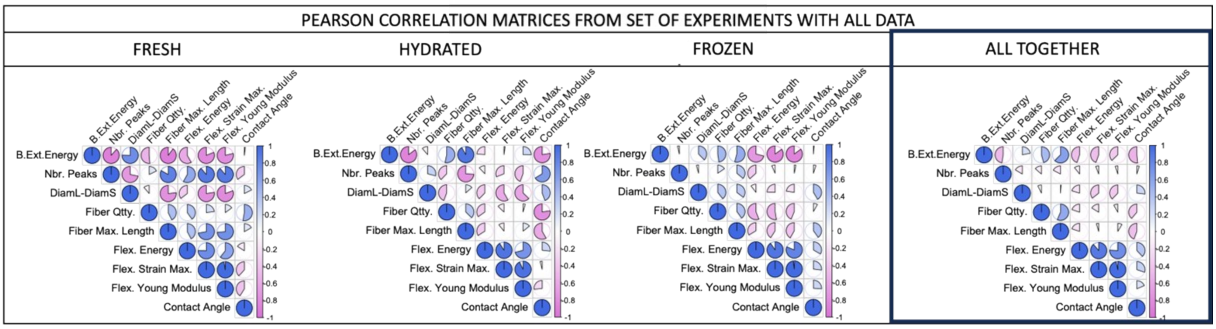


Figure SI_6: Pearson correlation matrices. The highest correlations between the different analyses within each family are the highest for the *Fresh* banana peels. Indeed, for the *Fresh* family, we can predict how the BPW would behave right from the beginning of the process, right after the blending. If we can make some tentative guesses for *Frozen* samples, it is not possible for *Hydrated*. As seen altogether, it is pretty hard to determine the outcome.

	Bending Rupture Moduli [Mpa]		
Moisture % dry weight	Chestnut	Eastern Spruce	Longleaf Pine
5	84	97	139
10	60	77	103
20	50	51	71
25	42	43	62

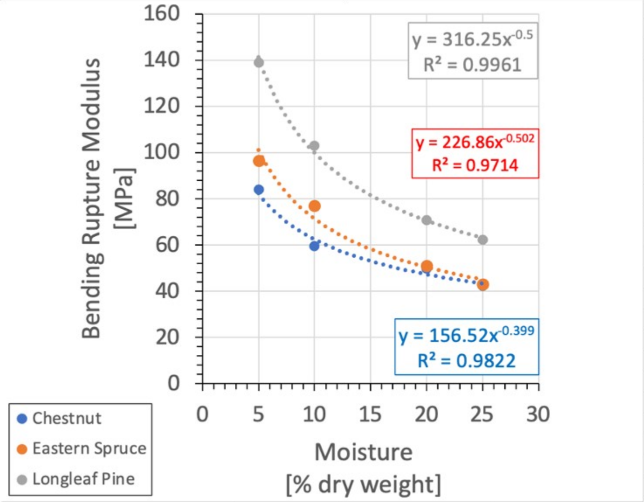


Figure SI_7: Moisture impact on bending moduli of some natural woods. Adapted from [4] to find equations ruling the relation between moisture and bending moduli using excel (version 16.78.3). Using data given in [4], we have made the graphic in Figure SI_9. We see for instance that for Eastern Spruce the relation between bending stress at rupture and moisture is defined by the equation:

[4] $$y = 227x^{-0.502}$$

When applied to spruce, this relation gives values of 65, 48 and 43 MPa respectively for 12, 23 and 28% moisture. Thus, to calculate the theoretical value of the Young modulus at different moisture percentage, we use the relation:

[5] $$y_1 = y_2\left[\frac{x_1}{x_2}\right]^{-0.502}$$

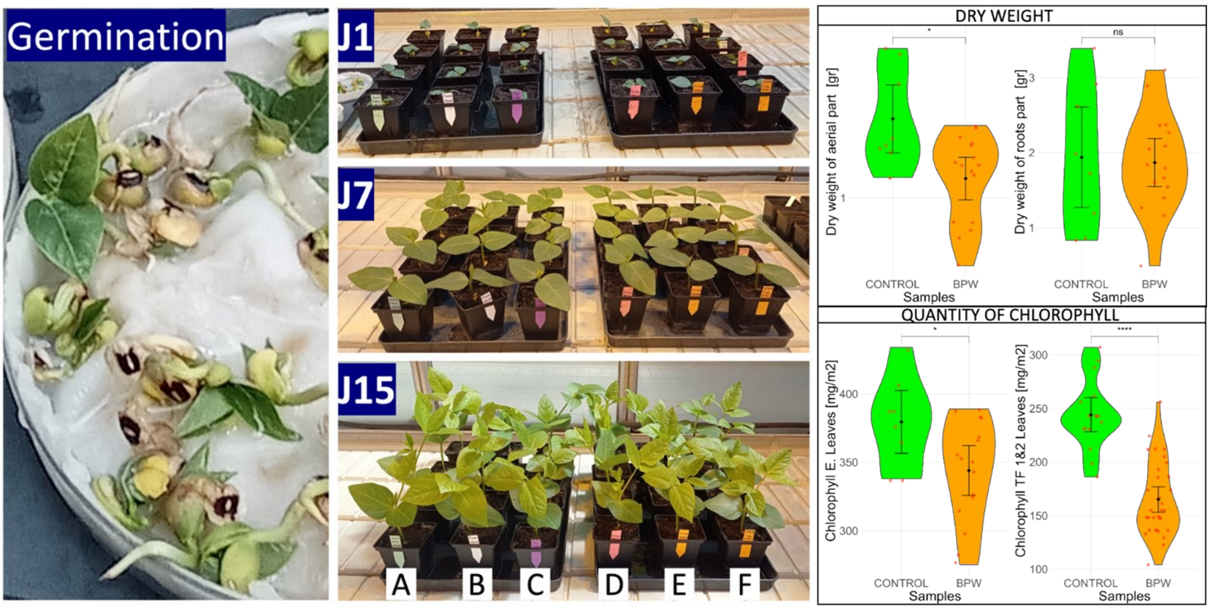


Figure SI_8: Test for end of life of Banana Peel Wood in the environment. We observe an impact of the BPW on *Vigna unguiculata* plant development. The presence of BPW slows down aerial plant growth, with lower chlorophyll accumulation. Left, germinated *Vigna unguiculata* seedlings before planting in soil. Center, *Vigna unguiculata* plants at one day (J1), seven days (J7) and fifteen days (J15) of growth on soil. Rows A, B, D, E, F are plants cultivated with six BPW cubes. Row C correspond to control plants. Right, top, dry weight of aerial and root parts of plants, bottom, chlorophyll content of embryonic leaves (E) and trifoliated leaves (TF). Significant difference between control plants and plants grown on PBW were analyzed using ANOVA followed by Tukey post-hoc test (for 95% family-wise confidence level $p < 0.05$ was considered significant (0 '***'; 0.001 '**'; 0.01 '*'; < 'ns').

Figure SI_9: Test of *Vigna unguiculata* seedling and growth directly on BPW. The seeds develop and plants grows palish and rickety but follow the otherwise normal development. When soil is added (Day 44) the plants recover their normal green color very fast.

Fig. SI_10: Electric guitar with humbucker pickup contour in BPW.

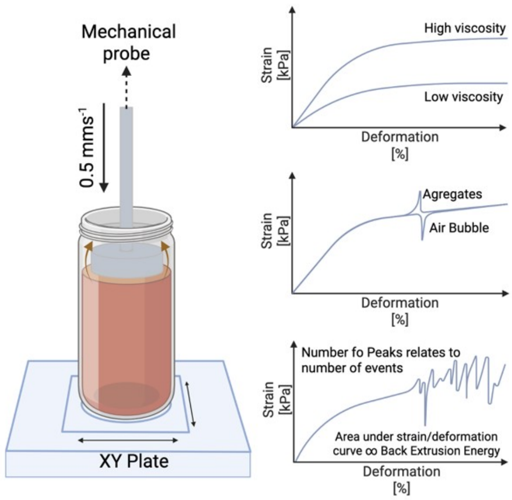


Figure SI_11: Back-Extrusion scheme. On the left the setup consisted of: 1° a transparent plastic vial in which the complex liquid is set to be analyzed, 2° the cylindrical probe of diameter smaller than the vial, mounted on the mechanical bench. The probe is put into contact with the liquid and the test is started.

To better understand the origin of signals recorded in force/displacement (or strain/deformation) mode, we used alginate solution at different concentrations (2%, 6%, 10%, corresponding to viscosities of 2 Pa.s, 164 Pa.s, 793 Pa.s) to get a simplified and controlled model of the liquid to be tested. Alginate solutions were prepared by dissolving the alginate powder in water under mechanical stirring and letting it sit (up to 4 days for the more concentrated solutions) until it reached stability and homogeneity, and all air bubbles were out of the solution. We recorded the data to check the effect of viscosities.

Afterwards, we introduced air-bubbles by mechanical stirring and retested the solutions to record their effect.

Independently, we created jellified alginate beads to model inhomogeneities in the solution (average diameter: 1,935 mm) by dropping a 2% alginate solution into CaCl2 0,1M solution with a 0,3 mm diameter syringe under low stirring. The beads were then gently mixed in the alginate solutions and those were retested by back-extrusion.

The impacts of viscosity, air bubbles and beads were thus clearly revealed and are schemed on the right side. In the present study we only made use of the number of peaks and the area under the curve to compare different samples.

Stress versus strain curves were analyzed as follows: the area under curve, which presents some relation to the energy necessary to press the probe into the grind was calculated on Microsoft Excel (version 16.78.3) table using the equation [1]:

[1] $$Area = \sum_{Min\%}^{79\%} \{[A(n+1) - A(n)] * [B(n+1) + B(n)]/2)\}$$

Where A(n) are the values of strain and B(n) the values of stress recorded on the mechanical bench.

The number of peaks were calculated on Microsoft Excel (version 16.78.3) by first determining changes of tendencies in the set of stress values (increase/decrease) and allocating a value C of -1 or +1 in a third data column using the equation [2]:

[2] $$C(n) = SI(B(n) > B(n+1);1;-1)$$

Finally, the number of peaks was calculated with the equation [3] :

[3] $$Nbr.Peaks = \sum_{Min\%}^{79\%} ABS[D(n) - D(n+1)]$$

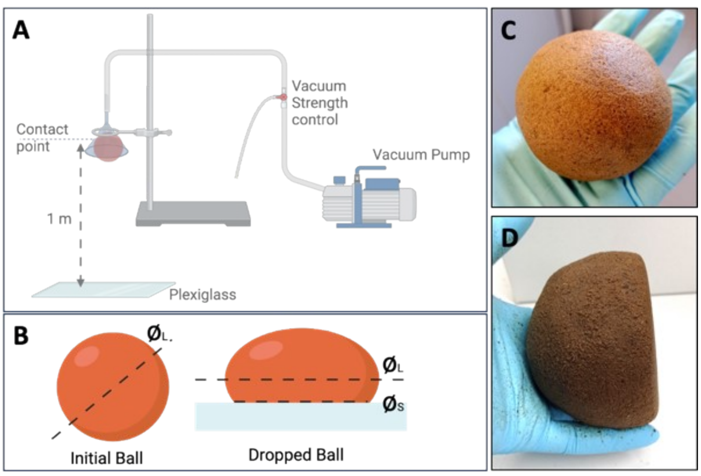


Figure SI_12: DropBall test setup and definitions. The DropBall test is used by builders to address earth to the best application and/or to supplement it with clay [Web.Ref. 1]. They let a ball of clay fall to the floor from the navel height and look how it deforms and whether, and how, it cracks. This test gives them a qualitative indication of the cohesiveness and viscosity of the earth ball. We transposed this test to this project to characterize the BP paste before drying and cooking. For this, we constructed a setup to make the test easier to handle, fix the distance to 1 m for all samples and easily take the measurements needed. (A) set up: A funnel, linked to a vacuum pump and equipped with an in-lab 3D printed vacuum distributor, is set up reversed at one meter above the ground. A transparent plexiglass is set on the floor. A vacuum strength controller allows adapt the vacuum to the paste. The initial paste ball (C) is placed in the funnel and the vacuum is turned on and off as soon as the paste is sucked into the funnel to release it. The final ball (D) is measured for its largest diameter $\varnothing_L$ and the impact diameter $\varnothing_S$ (B).

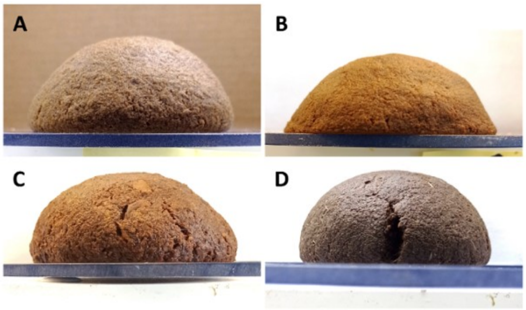


Figure SI_13: Final paste balls. A) Ball with $\varnothing_L > \varnothing_S$ indicated that the paste has an intermediate viscosity and relative cohesion. B) $\varnothing_L = \varnothing_S$ indicated that the paste has a low viscosity and relative cohesion. C) Ball with $\varnothing_L > \varnothing_S$ presenting several fine cracks indicated that the paste has an intermediate viscosity and relatively low cohesion. D) Ball with $\varnothing_L > \varnothing_S$ presenting several large cracks indicated that the paste has an intermediate viscosity and relatively low cohesion.

SI_TABLE 1			
	Density [g.cm^3]	**Maximal Stress [MPa]**	**Young Modulus [GPa]**
Natural Woods (12% Humidity)			
MAHOGANY CAILCEDRAT	0.78	86	11.6
AFRICAN MAHOGANY	0.57	77	11.8
BALSA	0.14	24	5.1
BULLETWOOD	1.1	170	24.4
OAK	0.74	105	13.3
ASIAN BLACK EBONY	1.1	250	18.0
ASIAN VEINED EBONY	1.2	250	18.0
SPRUCE	0.45	78	11.9
EUROPEAN WALNUT	0.66	117	11.8
GUM	0.61	51	0.092
RUBBER TREE	0.65	82	11.8
LARCH	0.6	90	11.8
BIRCH	0.6	95	10.2
ROSEWOOD PARA	1.04	183	26.1
UTILE	0.62	91	13.2
WAMBA	0.87	169	16.1
YELLOW MERANTI	0.54	98	14.1
Data extracted from CIRAD-Tropix 7			
BPW (28% Humidity)			
FRESH	**1.1**	19	1.447
HYDRATED	**1.1**	33	2.450
FROZEN	**1**	24	1.920
Best BPW	**1.2**	45	3.034

SI_Table 1: Top: Densities and flexion mechanical specifications of different natural wood as given on CIRAD Tropix 7 [5]. Bottom: same information on BPW for comparison.

SI_TABLE 2									
	Fresh Dried Peel			**03.10.2024**			**31.10.2024**		
STAT	χ^2/DoF 0.007; R2 0.98, RMSE 0.04, It 25			χ^2/DoF 0.021; R2 0.97, RMSE 0.15, It 28			χ^2/DoF 0.021; R2 0.97, RMSE 0.15, It 28		
Peak N°	Area	Mass Loss [%]	Mass [mg]	Area	Mass Loss [%]	Mass [mg]	Area	Mass Loss [%]	Mass [mg]
1 moisture	2.12	4.42	1.91	6.02	8.27	3.80	4.58	7.40	3.49
2 soluble sugars, pectins and hemicellulose I	5.95	12.42	5.37	0.39	0.53	0.24	2.00	3.23	1.52
3 Hemicellulose II	18.50	38.59	16.69	26.64	36.63	16.81	19.93	32.18	15.18
4 amorphous cellulose and starch	4.94	10.30	4.46	4.41	6.06	2.78	6.53	10.54	4.97
5 crystalline cellulose	0.36	0.76	0.33	1.25	1.72	0.79	3.67	5.92	2.79
6 high-temperature lignin degradation	10.73	22.39	9.68	30.44	41.85	19.21	22.08	35.65	16.81
Ashes		11.12	4.81		4.94	2.27		5.06	2.39
TOTAL	42.60	100	43.25	69.14	100.00	45.90	58.79	100.00	47.16

SI_Table 2: Data extracted from deconvolution of reversed first derivative thermogravimetric (rsDTG) curves of dried fresh banana peel (dried in oven at 70°C under pulsed air) and samples 03.10.2024 and 31.10.2024 chosen as representatives of all TGA analysis of the twelve samples which ever family.

Environmental impacts

The objective of this part is to assess the potential environmental impacts of Banana Peel Wood (BPW) and to compare them with those of conventional wood products, such as sawn wood and wood fiberboards. This comparison aims to evaluate its potential for reducing emissions and enhancing carbon storage using a minimized methodology of Life Cycle Assessment (LCA)[1]. IA (ChatGPT, Emmy and Gemini) was used for this analysis in a human controlled manner.

Energy consumption for fabrication:
At laboratory scale, the production of a batch of material (corresponding to ~270 cm³) involves several electromechanical devices. Energy consumption was calculated based on nominal power and operating times.

Stages	**Mixing**	**Degassing**	**centrifugation**	**Drying & Baking**	**TOTAL**
Nominal power [kW]	1.68	0.45	2.00	2.50	
Time [h]	0.05	0.50	0.50	216.00	**217.05**
Energy [kWh]	0.084	0.225	1.00	**540**	**541.31**
The total energy consumption ~541 kWh for a produced material volume of 2.71×10^{-4} m³, which corresponds to a specific consumption of **Elab ≈ 2.0 GW/m³** with 99% due to the drying and baking stage.					

Industrial Scale Extrapolation
Baking/drying alone accounts for over 99% of the total energy consumption, highlighting the non-representative energy profile of the experimental setup. Indeed, the laboratory-scale oven used (Memmert UF75, usable volume of 74 L) was largely underutilized. For an initial volume of 1.86×10^{-3} m³, the effective fill rate was only about 0.0025%. This extreme underuse of the usable volume explains the very high specific energy consumption measured in the laboratory. In an industrialized scenario, considering a 1 m³ oven or dryer operating continuously with a realistic occupancy rate of 80% and assuming an energy demand of the same order of magnitude per cycle, the specific consumption for the baking/drying step would be reduced to approximately **677 kWh/m³**—a reduction of more than three orders of magnitude compared to the laboratory scenario.

Impact on Climate Change
The impacts on climate change were calculated based on specific energy consumption and electricity emission factors.

		Climate impact	
Emission Factors Used		**French electricity mix g CO_2-eq·kWh^{-1}**	**World global average electricity mix g CO_2-eq·kWh^{-1}**
		40	520
Scenari	**Specific Consumption [kWh·m^{-3}]**	**kg CO_2-eq·m^{-3}**	**kg CO_2-eq·m^{-3}**
Laboratory	2.0×10^6	8×10^4	1.04×10^6
Industrialized	675	27	351

[1] ISO 14040, 2006; ISO 14044, 2006. For extensive description see [6]

Biogenic Carbon Storage

The final material (BPW) contains biogenic carbon from banana peels, immobilized in the solid matrix. After 9 days of baking and drying, deconvolution of ATG data indicated a residual amount of water of ~6%. According to default values from the IPCC report, approximately 50% of the dry matter consists of carbon. Thus, with a BPW density of 948.15 kg/m³, the stored carbon mass is estimated at 471.1 kg C per m³ of material. To convert this carbon mass into CO_2 equivalent, the molar mass ratio of CO_2 to carbon is used:

$$\text{"}CO_2\text{-eq (kg/m}^3\text{)"} = 471.1 \times 44/12 \approx 1{,}727 \text{ kg } CO_2\text{-eq/m}^3$$

BPW stores approximately **1,727 kg CO_2 equivalent per cubic meter**, reflecting the material's potential for biogenic carbon sequestration.

Energy Loss Associated with the Anaerobic Digestion Pathway of banana peels

Data from our study:

Initial weight of fresh banana peels: 4.371 kg (4371 g)
Dry matter in fresh peels (16%[7]): 0.699 kg
Final weight of BPW: 0.256 kg (256 g)
Moisture content in BPW: 6%
Volume of BPW produced: ≈0.00027 m³ (270 cm³)
Density of BPW: 948.15 kg/m³

Standard relations used:

Volume of CH_4 produced per kg of dry matter: 0.322 m³ CH_4/kg DM
Recoverable electrical energy: 3.5 kWh/m³ CH_4

Result from our study:

Volume of CH_4 produced: = 0.225 m³ CH_4
Loss of potential recoverable electrical energy: =0.788 kWh

Our result transposed into kWh per m³ of BPW generated

Energy loss per m³ of BPW: ≈ 3077 kWh/m³ BPW

Reference Industrial Wood Materials

Two industrial wood materials were considered: softwood sawn timber and medium-density fiberboard (MDF). Data are sourced from Buchanan & Levine (1999) and the IPCC (2006).

Sawn softwood:

Density: 550 kg/m³
Carbon fraction: 50%, equivalent to 275 kg C/m³ ≈ 1,008 kg CO_2 eq/m³
Production energy consumption: 0.4–1.0 GJ/m³ (111–278 kWh/m³)

Medium-Density Fiberboard (MDF):

Density: 700 kg/m³
Carbon fraction: 50%, equivalent to 350 kg C/m³ ≈ 1,283 kg CO_2 eq/m³
Production energy consumption: 3–5 GJ/m³ (833–1,389 kWh/m³)

Comparison of carbon storage and energy consumption between industrial wood materials and BPW.

Entity	Density [kg/m³]	CO_2-eq stored [kg/m³]	Consumed energy for fabrication [kWh/m³]	Energy lossed (non-methylation) [kWh/m³]
BPW (Industrial)	948	1,740	675	3,077
Sawn softwood	550	1,008	111-278	0
MDF	700	1,283	833-1,389	0

End of lives

BPW: At the end of its life cycle, banana peel wood (BPW) can be energetically valorized through several pathways, depending on its properties (carbon content, residual moisture, etc.). Below is an analysis of potential options, along with estimates of recoverable energy for each pathway, based on available data and realistic assumptions.

Natural Wood: At the end of its life, natural wood is primarily used for thermal or electrical energy through direct combustion or conversion into pellets, densified logs, or biofuels.

The lower calorific value (LCV) of dry wood is approximately 16–18 MJ/kg (4.5–5 kWh/kg), depending on moisture content. In France, about 22% of wood waste is energetically valorized (2.5 million tons per year).

Wood-Based Materials (Panels, Plywood, Engineered Wood): Wood-based materials (particleboard, OSB, plywood) can be energetically valorized if they are not recyclable, especially if treated or contaminated. Their calorific value is similar to natural wood but may vary due to binders or chemical treatments.

Process	**BPW** Estimated values **(MWh/m³)**	**Natural Wood** **(MWh/m³)**	**Wood-Based Materials** **(MWh/m³)**	**Energy Form**
Direct Combustion	~3.7	~2.27	~2.49	Heat, Electricity
Gasification	~3.00	~1.98	~2.18	Syngas (Heat, Electricity)
Pyrolysis	~3.20	~1.84	~2.02	Bio-oil, Charcoal
Carbonization	~1.35	~0.85	~0.93	Charcoal
Incineration	~3.20	~2.13	~2.33	Heat, Electricity
Anaerobic Digestion	Low	Low	Very Low	Biogas (Methane)
Composting	Low	Low	Very Low	N/A (Soil amendment)

Dependence on Fossil Resources Beyond Climate Impact

Beyond its climate cost, industrial wood materials structurally rely on the use of fossil-based energy and inputs (mechanized forestry, transport, thermal drying, synthetic resins), which are accounted for in life cycle assessments (LCAs) but draw on finite, non-renewable resources. However, it is now widely acknowledged that the sole "climate change" indicator fails to capture the challenges posed by fossil resource depletion and the long-term sustainability of production systems (Guinée et al., 2002; Hauschild et al., 2018).

In this context, a material like BPW—based on the valorization of residual biomass and potentially compatible with low-carbon energy processes—aligns with a logic less dependent on fossil resources. This dimension, not fully captured by the CO_2-eq indicator alone, underscores the importance of broadening the analysis to include other impact categories, particularly resource depletion.

DATA TABLES

Data 1: mean values obtained characterizing the grind of the last 12 last experiments

LIQUID GRIND						
Backextrusion						
TYPE	EXPERIMENT	Number of samples	Mean Energy	Stand. Error.	Number of peaks	Std. Error
	Date		[kJ.m^{-3}]	[kJ/m3]		
Frozen	20.08.2024	6	12.4	2.3	1918	167
Hydrated	03.09.2024	4	12.1	2.3	1185	116
Fresh	10.09.2024	4	9.1	0.6	1559	30
Fresh	18.09.2024	4	4.5	0.6	2054	240
Frozen	25.09.2024	4	6.0	1.0	1676	151
Frozen	03.10.2024	4	18.6	3.9	1654	124
Hydrated	07.10.2024	4	8.6	1.2	1365	99
Hydrated	31.10.2024	4	2.6	1.0	1574	227
Fresh	31.10.2024	4	6.0	0.1	1744	56
Fresh	12.12.2024	4	10.1	0.3	1504	105
Frozen	12.12.2024	4	13.5	3.2	1262	71
Hydrated	28.03.2025	4	2.3	0.1	1791	83

Data 2: mean values obtained characterizing the paste of the last 12 last experiments

PASTE										
		Ball Drop Data			Fibers length			Fibers Quantity		
TYPE	EXPERIMENT	Number of samples	Φ_L - Φ_S	Std. Error	Number of samples	Length	Std. Error	Number of samples	Quantity	Std. Error
	Date		[mm]	[mm]		[mm]	[mm]		[Area %]	[Area %]
Frozen	20.08.2024	5	4.73	2.37	15	35.1	6.8	5	22.96	5.71
Hydrated	03.09.2024	5	5.41	1.00	15	45.7	6.6	5	16.04	4.83
Fresh	10.09.2024	5	3.60	1.95	15	32.2	0.6	5	12.14	1.56
Fresh	18.09.2024	4	0.07	0.09	15	24.5	3.1	3	14.78	0.65
Frozen	25.09.2024	4	2.02	0.98	15	31.3	9.7	3	23.11	5.85
Frozen	03.10.2024	4	4.63	3.42	15	45.4	6.3	3	30.25	4.95
Hydrated	07.10.2024	4	0.28	0.73	15	28.7	4.4	3	25.14	7.98
Hydrated	31.10.2024	4	2.23	1.35	15	12.0	3.3	3	6.44	1.84
Fresh	31.10.2024	4	2.57	1.35	15	30.7	0.8	4	27.67	9.45
Frozen	12.12.2024	4	4.75	1.32	15	13.9	0.6	4	9.43	2.46
Fresh	12.12.2024	4	1.74	1.58	15	39.8	4.2	3	22.38	1.73
Hydrated	28.03.2025	4	6.13	1.18	15	13.0	5.7	4	11.59	2.92

Data 3: mean values obtained characterizing the BPW of the last 12 last experiments.

BANANA PEEL WOOD										
Mechanical Test in Flexion										
TYPE	EXP.	Nbr. of samples	Flexion Energy	Std. Error	Max. Flex. Stress	Std. Error	Strain at Max Stress	Std. Error	Young Modulus	Std. Error
	Date		[kJ/m3]	[kJ/m3]	[MPa]	[MPa]	[%]	[%]	[GPa]	[GPa]
Frozen	20.08.2024	**5**	249.14	2.57	25.13	2.23	1.76	0.095	1.93	0.15
Hydrated	03.09.2024	**7**	226.62	6.89	30.05	5.67	1.62	0.22	2.43	0.29
Fresh	10.09.2024	**4**	83.77	5.26	11.23	6.92	1.42	0.31	1.02	0.53
Fresh	18.09.2024	**4**	198.29	6.46	26.19	5.97	1.45	0.22	2.21	0.31
Frozen	25.09.2024	**4**	248.80	3.28	34.89	1.49	1.41	0.10	2.92	0.14
Frozen	03.10.2024	**6**	94.59	4.65	10.36	5.36	1.84	1.84	0.93	0.45
Hydrated	07.10.2024	**8**	326.19	3.61	34.82	3.61	1.99	0.20	2.39	0.35
Hydrated	31.10.2024	**4**	397.29	4.59	45.12	2.27	1.78	0.14	3.03	0.21
Fresh	31.10.2024	**4**	212.77	1.92	18.52	1.10	2.07	0.15	1.32	0.09
Frozen	12.12.2024	**4**	200.25	2.96	23.85	3.36	1.66	0.11	1.89	0.31
Fresh	12.12.2024	**4**	181.29	2.56	13.58	0.57	2.27	0.20	0.95	0.02
Hydrated	28.03.2025	**4**	169.43	3.73	18.92	1.035	1.76	0.37	1.40	0.27

		Contact Angle		Density		
TYPE	EXPERIMENT	Nbr. of samples	Contact Angle	Std. Error	Density	Std. Error
	Date		[°]	[°]	[g/m^{-3}]	[g/cm3]
Frozen	20.08.2024	**5**	24.914	2.57	25.13	0.04
Hydrated	03.09.2024	**7**	22.662	6.89	30.05	0.07
Fresh	10.09.2024	**4**	8.377	5.26	11.23	0.10
Fresh	18.09.2024	**4**	19.829	6.46	26.19	0.03
Frozen	25.09.2024	**4**	24.88	3.28	34.89	0.03
Frozen	03.10.2024	**6**	9.4587	4.65	10.36	0.08
Hydrated	07.10.2024	**8**	32.619	3.61	34.82	0.04
Hydrated	31.10.2024	**4**	39.729	4.59	45.12	0.01
Fresh	31.10.2024	**4**	21.277	1.92	18.52	0.01
Frozen	12.12.2024	**4**	20.025	2.96	23.85	0.04
Fresh	12.12.2024	**4**	18.13	2.56	13.58	0.02
Hydrated	28.03.2025	**4**	16.94	3.73	18.92	0.03

Data 4: mean values per family for all characterizations

MEANS VALUES PER FAMILY

LIQUID GRIND

Backextrusion

TYPE	Mean Energy	Stand. Error.	Number of peaks	Std. Error
	[kJ.m^{-3}]	[kJ.m^{-3}]		
FRESH	8.52	0.94	1656.80	58.40
HYDRATED	5.60	0.37	1858.60	110.07
FROZEN	11.04	2.30	1566.69	124.37

PASTE

	Ball Drop Data		Fibers length		Fibers Quantity	
TYPE	Φ_L - Φ_S	Std. Error	Length	Std. Error	Quantity	Std. Error
	[mm]	[mm]	[mm]	[mm]	[Area %]	[Area %]
FRESH	2.31	1.38	31.88	1.85	17.82	2.99
HYDRATED	3.51	1.06	24.82	5.01	14.80	4.39
FROZEN	4.03	2.02	31.41	5.84	21.44	4.75

BANANA PEEL WOOD

Mechanical Test in Flexion

TYPE	Flexion Energy	Std. Error	Max. Flex. Stress	Std. Error	Strain at Max Stress	Std. Error	Young Modulus	Std. Error
	[kJ.m^{-3}]	[kJ.m^{-3}]	[MPa]	[MPa]	[%]	[%]	[GPa]	[GPa]
FRESH	169.03	4.05	17.38	3.64	1.80	0.22	1.37	0.24
HYDRATED	279.88	4.71	32.23	3.15	1.79	0.23	2.31	0.28
FROZEN	198.19	3.37	23.56	3.11	1.67	0.54	1.92	0.26

	Contact Angle		Density	
TYPE	Contact Angle	Std. Error	Density	Std. Error
	[°]	[°]	[g/m^{-3}]	[g/cm3]
FRESH	80.44	3.71	1.06	0.04
HYDRATED	90.38	4.45	1.15	0.04
FROZEN	76.95	3.96	1.05	0.05

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[Web.Ref. 1] REBAt Bio "Caractériser les terres pour un usage dans le bâti" https://www.youtube.com/watch?v=AWRb66SUWnY