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Co-products of sunflower cultivation, a promising source of biostimulatory molecules and construction materials

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Introduction

- **FACCE SURPLUS** call, European Union.

- Project duration: 42 months.

- ◆ From April, 2020 to September, 2023.

- Main objective of the project:

To create a value chain of sunflower biomass.

- Working methodology:

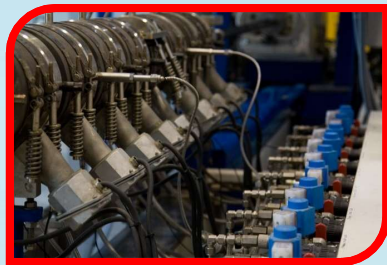
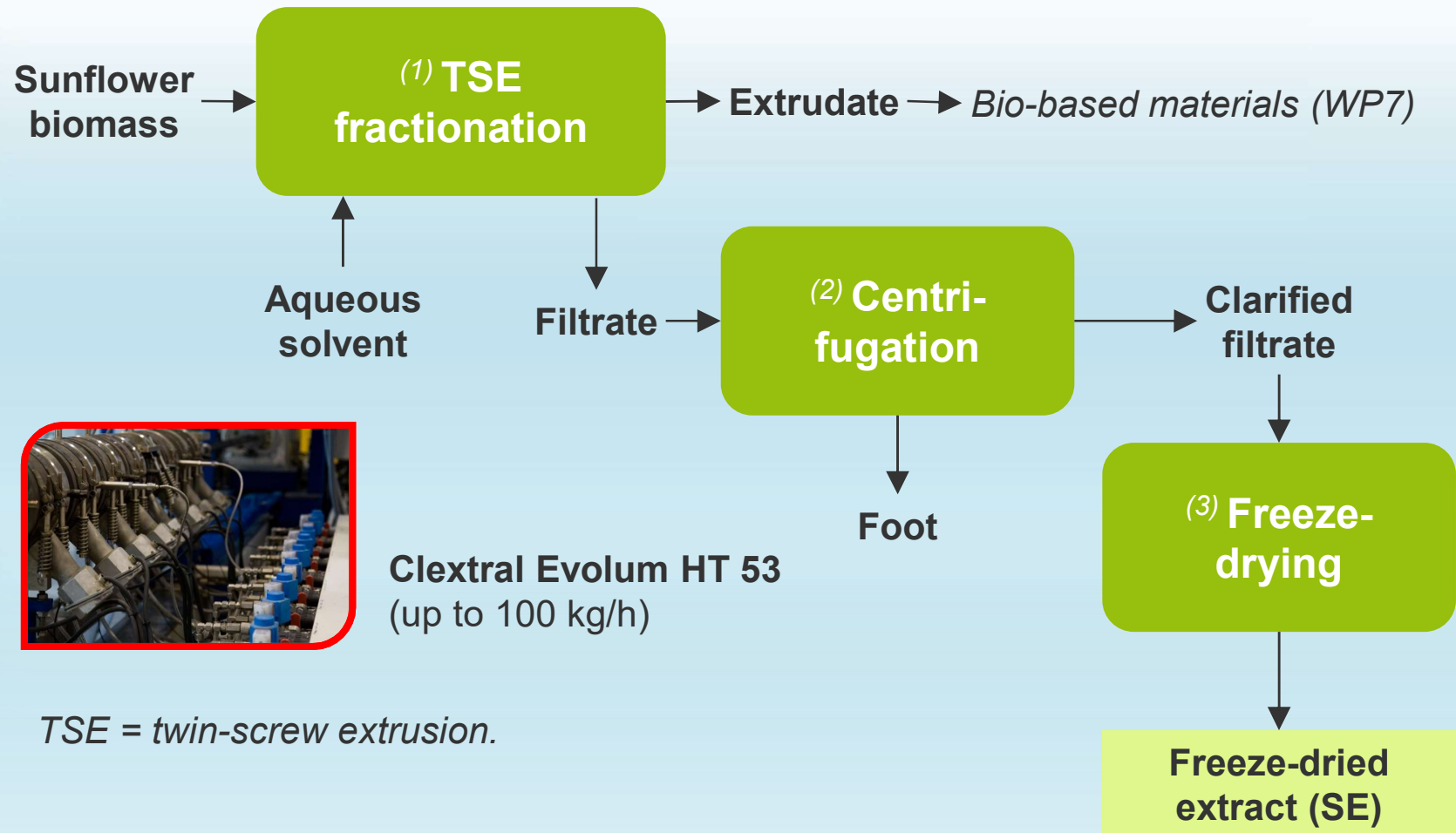
- ◆ Extraction of bioactive ingredients from sunflower co-products (*i.e.*, stalks and heads) through extrusion.
 - Use of the extracts as ecologically-friendly agricultural products.
- ◆ Obtaining bio-based construction materials from the remaining fibrous solid.
 - Generating economical value with a lower environmental footprint.



Introduction

- Five partners from France and Belgium.
 - ◆ Three academic partners:
 - **Toulouse INP** (France) → Twin-screw extrusion fractionation of sunflower co-products, and bio-sourced materials from remaining solid.
 - Ghent University (project leader) and KU Leuven (Belgium) → Evaluation of the bioactivity of extracted molecules when applied to plants.
 - ◆ Two industrials partners:
 - Ovalie Innovation (France) → Provider of sunflower co-products, and end-user.
 - Oleon (France and Belgium) → Formulation of biostimulatory products, and end-user.

Sunflower biomass fractionation



Clextral Evolum HT 53
(up to 100 kg/h)

TSE = twin-screw extrusion.

Optimisation of the extrusion procedure

- Operating parameters studied:
 - ◆ Incoming solid particle size,
 - ◆ **Screw profile in the liquid/solid separation zone,**
 - ◆ Filling ratio of the machine,
 - ◆ **pH of the extracting solution,**
 - ◆ Number of injection points,
 - ◆ **Total liquid-to-solid (L/S) ratio.**

- Results from optimal configuration:
 - ◆ Extraction yield equal to 64.4% (w/w).
 - ◆ Yield in proportion to the initial water-soluble compounds.
 - ◆ Results obtained in one single pass in the twin-screw machine for greater economic efficiency.

SE extracts as biostimulatory products

- Addition of SE to Arabidopsis (*Arabidopsis thaliana* L.) seedlings grown *in vitro* → Dose-dependent response:
 - ◆ Severe growth inhibition at high concentrations.
 - ◆ Small but significant increase in leaf area at a dose of 5 g SE freeze-dried powder per liter.
 - ◆ Improvement in the salt stress tolerance by reducing the production of reactive oxygen species (ROS) (e.g., hydrogen peroxide) by about 30%.
 - Presence of antioxidant agents in SE: polyphenols, carbohydrates, proteins, etc.
 - Activation of ROS-eliminating enzymes.
- Results very recently published in **Frontiers in Plant Science** → DOI: [10.3389/fpls.2022.837441](https://doi.org/10.3389/fpls.2022.837441).

Chemical composition of residual solid (RS)

- Chemical composition (% of dry matter):

Chemicals	Content (%)	
Minerals	7.6±0.4	
Lipids	4.5±0.1	
Proteins	3.2±0.1	
Cellulose	42.5±0.8	NATURAL FIBRES (63.5%)
Hemicelluloses	9.1±0.1	
Lignins	11.9±0.2	
Water-solubles	8.1±0.5 ¹	

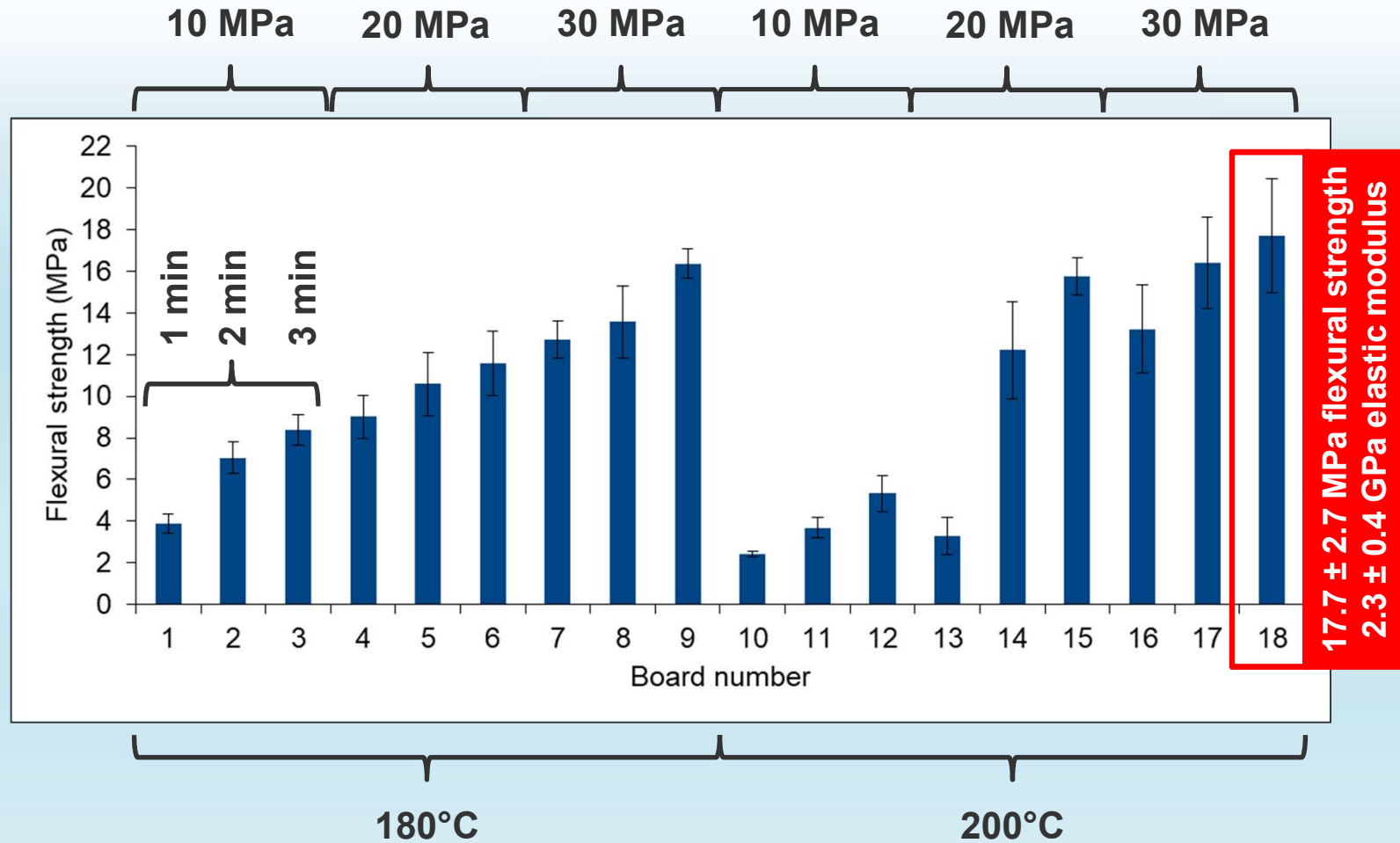
¹ 21.1±0.3% of dry matter in the starting material.

Hot pressing of RS

- 1 Molding conditions tested:
 - ◆ Mold temperature: 180°C, and 200°C.
 - ◆ Applied pressure: 10 MPa, 20 MPa, and 30 MPa.
 - ◆ Molding time: 1 min, 2 min, and 3 min
- 2 Addition of sunflower protein isolate (SPI) as an exogenous natural binder:
 - ◆ Isolate obtained from industrial cake:
 - Alkaline extraction (denaturing conditions) plus isoelectric precipitation.
 - Protein content: 96% dry matter.

→ ***Cohesive formaldehyde-free boards.***

1 Flexural strength of boards without SPI

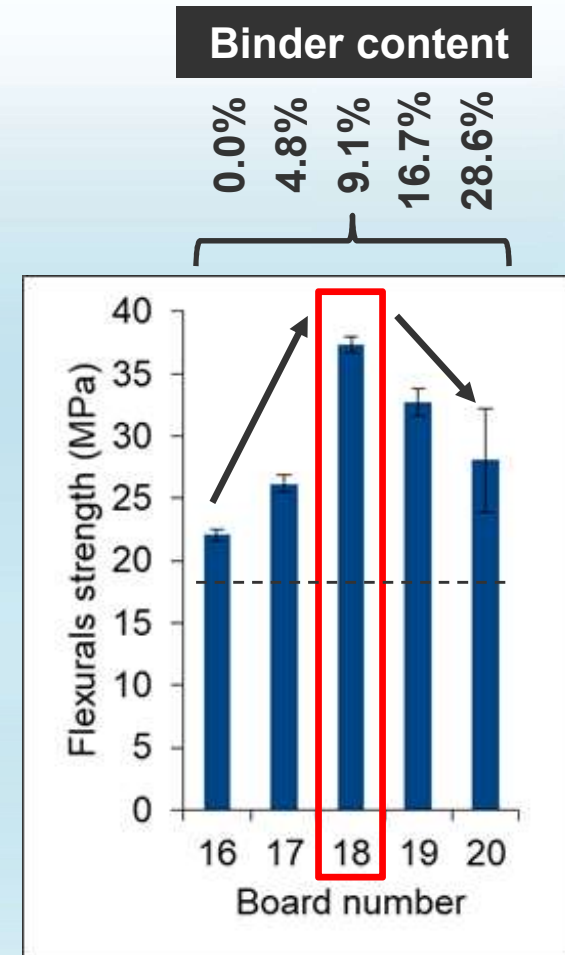


Conclusions about self-bonded boards

- Cohesive **self-bonded** panels produced from the only solid raffinate.
 - ◆ Contribution of proteins, hemicelluloses, lignins and residual water-solubles to binding.
- Influence of thermopressing conditions on the board's properties:
 - ◆ Increase with the applied pressure and the molding time.
 - ◆ Increase with the mold temperature at 30 MPa applied pressure.
- **Optimal molding conditions:**
 - ◆ 200°C mold temperature.
 - ◆ 30 MPa applied pressure.
 - ◆ 3 min molding time.

2 Molding under optimal conditions with SPI

- Optimal binder content: 9.1% (w/w).
 - ◆ Sufficient for optimal wetting of the fiber external surface.
- With more binder content, co-existence of two solid phases:
 - ◆ Interface fragility,
 - ◆ Decrease in flexural strength.
- Optimal flexural properties:
 - ◆ 37.3 MPa flexural strength,
 - ◆ 4.6 GPa elastic modulus.



Conclusions about boards with SPI

- Adding SPI makes optimal board much more mechanically resistant.
 - ◆ +111% for flexural strength.
- 1,270±17 kg/m³ density → **Hardboard.**
- **Type P2 board according to NF EN 312.**
 - ◆ Interior fittings (including furniture) used in dry environment.

Characteristic	Optimal board	Recommandation ¹
Flexural strength (MPa)	37.3±0.7	13 min
Elastic modulus (GPa)	4.6±0.2	1.8 min
Internal bond strength (MPa)	0.85±0.02	0.45 min
Shore D surface hardness (°)	68±2	None

¹ NF EN 312 standard.

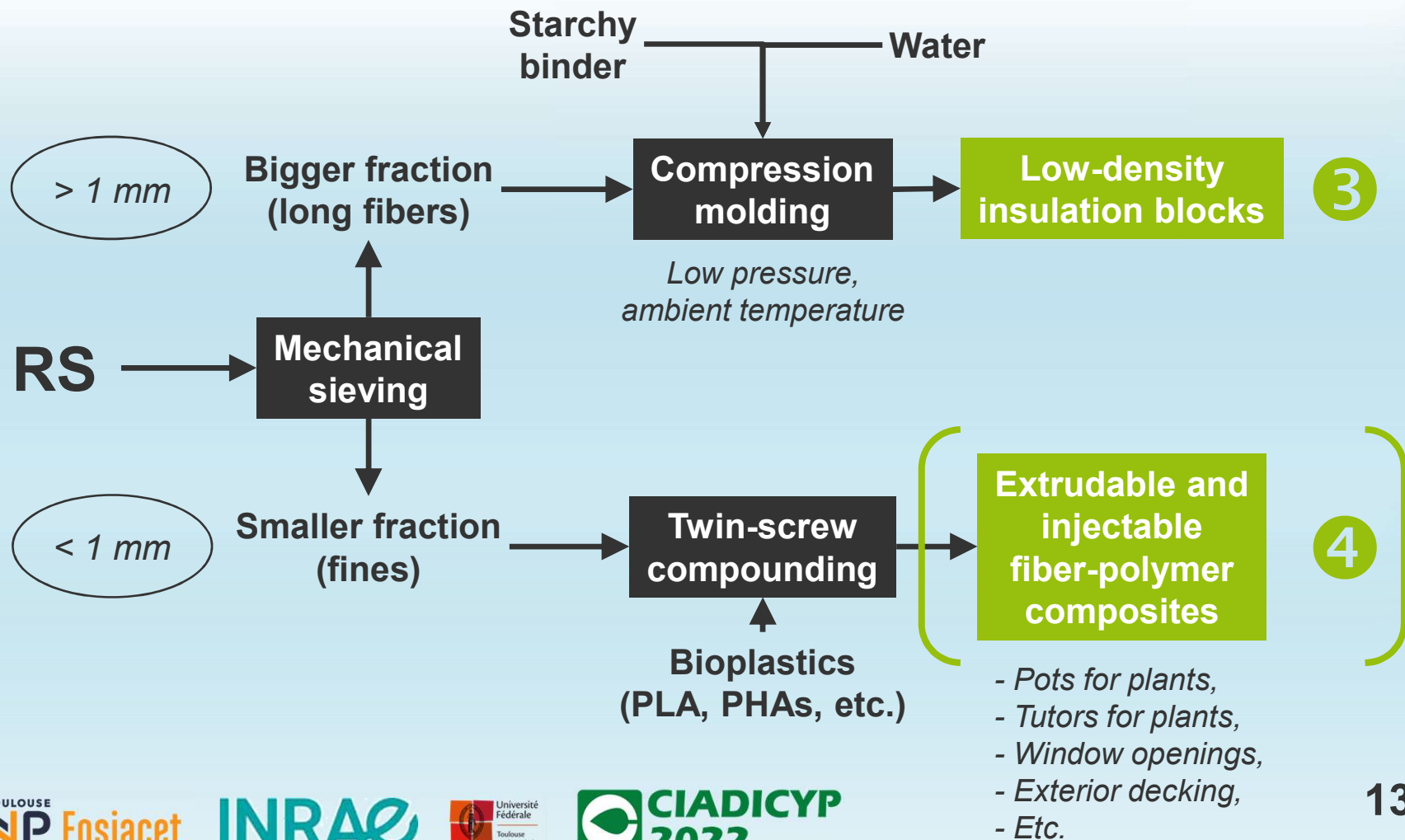
Conclusions about boards with SPI

- Alternative to commercial wood-based boards such as plywood, chipboard, OSB, MDF, etc.
- No formaldehyde emission.
- Thickness swelling (TS) ($169 \pm 16\%$) to be improved.
- Reduction in TS possible after post-treatment:

Post-treatment	TS (%)
Coating with drying oil (linseed oil)	123 ± 6 (-27%)
Coating with varnish	118 ± 12 (-30%)
Cooking (220°C, 10 min)	33 ± 10 (-80%)

- Type P3 and P4 boards: TS lower than 21% required.

Dry fractionation scheme of RS



Tapped densities after mechanical sieving

- Important inhomogeneity in the particle size for RS.
- After mechanical sieving, increase in homogeneity of both fractions:
 - ◆ Low density in bulk for the bigger fraction.
 - ◆ Smaller fraction in the form of fines (*i.e.*, flour).

Material	Tapped density (kg/m ³)
RS	98.2±1.1
Bigger fraction (> 1 mm) // 56% (w/w)	65.0±0.4
Smaller fraction (< 1 mm) // 44% (w/w)	109.1±1.5

Chemical composition of sieved fractions

- Despite very different morphologies, small difference in chemical composition between both fractions.
- Richness in natural fibres in both cases.**

Chemicals (% of dry matter)	Bigger fraction (> 1 mm)	Smaller fraction (< 1 m)
Cellulose	47.3±0.1	46.3±0.1
Hemicelluloses	10.1±0.3	4.1±0.3
Lignins	13.9±0.1	15.1±0.5
Water-solubles	12.2±0.4	9.6±0.3

71.3% NATURAL FIBRES

65.5% NATURAL FIBRES

3 Insulation materials from bigger fraction

- In the low range of the conventional insulating materials.

	Material	Density (kg/m ³)	Conductivity (mW/m K)	Resistance (m ² K/W) ¹
	Bigger fraction in bulk	65.0 ± 0.4	47.7 ± 0.2	1.05 ± 0.01
	O11>1-66%	128.0 ± 0.3	48.8 ± 0.5	1.03 ± 0.01
Conventional insulating materials	<i>Expanded polystyrene</i>	20.0	32.0	1.56
	<i>Glass wool</i>	27.5	35.0	1.43
	<i>Rock wool</i>	35.0	38.0	1.32
	<i>Cellulose wadding</i>	50.0	38.0	1.32
Innovative bio-based materials	<i>Sunflower pith block</i>	43.0	39.0	1.28
	<i>Coriander straw block</i>	155.0	55.6	0.90

¹ Thermal resistance for a 5 cm thickness insulating material.

Conclusions about insulation blocks

- Low-cost compression molding process with very low pressure (100 kPa) applied at ambient temperature.
- Use of a starchy binder with physical curing as natural adhesive.
- Possible applications in the building sector.
- **For equivalent thermal resistance as expanded polystyrene (1.56 m² K/W), need for a thicker insulation block:**
 - ◆ 7.6 cm instead of 5 cm (*i.e.*, + 51%).

Main conclusions

- **BioSUNmulant, a value chain of sunflower created.**
- Fractionation of sunflower biomass possible in a continuous mode using a twin-screw extruder:
 - ◆ Aqueous extracts (SE) and residual solid (RS).
- Bioactive ingredients extracted from sunflower co-products through twin-screw extrusion (SE):
 - ◆ **Biostimulatory molecules.**
- Different types of **construction materials** from RS:
 - ◆ Free-formaldehyde hardboards (RS plus SPI).
 - ◆ Thermal insulation blocks with low density and low thermal conductivity from bigger fraction only.
 - ◆ Fiber-polymer composites from smaller fraction (to continue).



Thank you for your attention

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https://www.researchgate.net/profile/Philippe_Evon

Submit a paper into the Special Issue of **Coatings** (IF 2.881)

"Natural Fiber Based Composites II"

https://www.mdpi.com/journal/coatings/special_issues/fiber_basedII

