To cite this version:

Evon, Philippe and de Langalerie, Guyonne and Labonne, Laurent and Merah, Othmane and Talou, Thierry and Ballas, Stéphane and Véronèse, Thierry *Innovative low-density blocks from amaranth pith for the thermal insulation of buildings.* (2019) In: 15th International Conference on Renewable Resources & Biorefineries (RRB15), 3 June 2019 - 5 June 2019 (Toulouse, France). (Unpublished) .

Innovative low-density blocks from amaranth pith for the thermal insulation of buildings

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Amaranth is an annual herb native to temperate and tropical regions. Cultivated by Native Americans for the nutritional properties of its seeds, the latter are very digestible and also an interesting source of starch and proteins. For the future, amaranth appears as a promising raw material for the biorefinery of whole plants, all parts of the plant being potentially usable for different food and non-food applications.

This study especially aims to investigate the possible uses of pith from stems for material applications. For that, plants from the *Amaranthus cruentus* variety were cultivated in 2018 near Auch (Gers, France). Stems were manually harvested at plant maturity. Representing up to 90% w/w of the aerial part of amaranth plant, stems were then dried in a ventilated oven to facilitate their conservation. They are composed of a bark on their periphery and a pith fraction in their middle. The structure of stems was studied from ten samples, and the pith fraction was estimated manually to 27% w/w. Due to the difference in density between bark and pith fractions, a fractionation process associating grinding and blowing steps made possible the continuous separation between bark and pith.

As for sunflower and corn, amaranth pith particles have an alveolar (*i.e.* a microporous) structure similar to that of expanded polystyrene, and they reveal a very low bulk density (*e.g.* 48-52 kg/m^3 for 4-16 mm particle size, and 58-61 kg/m^3 for 1.25-2.50 mm particle size), making them a promising raw material for the thermal insulation of buildings. Cohesive and low-density insulation blocks were successfully obtained from amaranth pith, primarily mixed with a starch-based binder, through compression moulding at ambient temperature. Different operating conditions were tested, especially including (i) the size distribution of amaranth pith particles, (ii) the binder content, and (iii) the filling level of the mould. All produced samples were then characterized in terms of (i) density, (ii) bending and compression properties, and (iii) thermal insulation properties (measured through the hot wire method). All insulation blocks revealed low density, ranging from 90 to 140 kg/m^3. Such innovative materials could be sustainable and viable options for the thermal insulation of buildings.

INNOVATIVE LOW-DENSITY BLOCKS FROM AMARANTH PITH FOR THE THERMAL INSULATION OF BUILDINGS

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Introduction

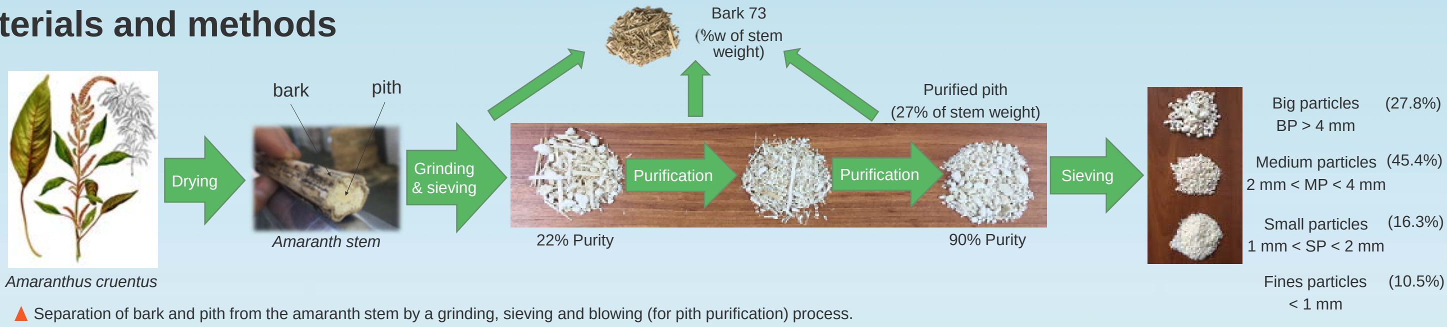
- *Amaranthus cruentus*, an annual herb from temperate and tropical regions.
- Seeds are cultivated by Native Americans for their **nutritional properties**.
- Stems are composed of 2 parts : **bark** in periphery and **pith** in the middle.
- **Alveolar structure** of the pith similar to expanded polystyrene (EPS).

Aims of the study :

1. To optimize a fractionation process for the **separation of bark and pith.**
2. To develop a process for producing thermal **insulation blocks from pith.**

Materials and methods

1



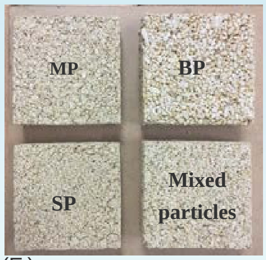
▲ Separation of bark and pith from the amaranth stem by a grinding, sieving and blowing (for pith purification) process.

2

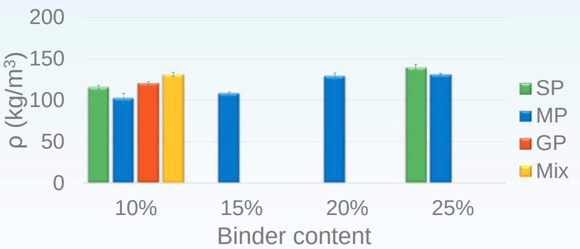
Name	Particle size (mm)	Ratio binder*/pith
BP10	> 4	0.10
MP10	2 – 4	0.10
MP15	2 – 4	0.15
MP20	2 – 4	0.20
MP25	2 – 4	0.25
SP10	1 – 2	0.10
SP25	1 – 2	0.25
Mix	-	0.10

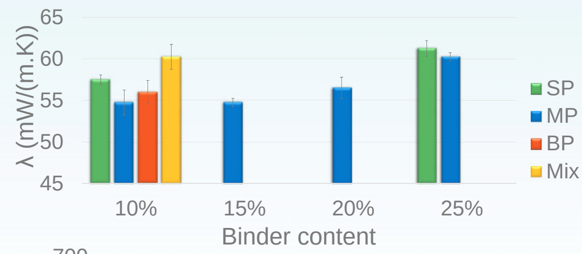
*Starch-based binder

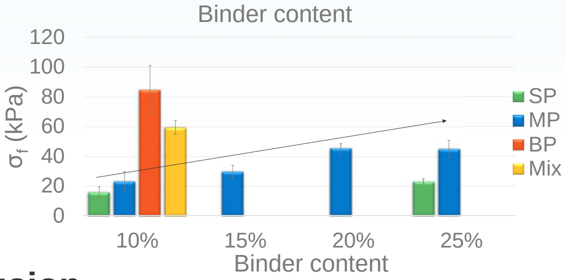
1. **Formulation of blocks**
2. **Compression molding (25° C)** 8.7 kPa ; 5 mn
3. **Drying (50° C)** To remove the added water for the dissolution of the binder
4. **Characterizations** Density (ρ) ; Thermal conductivity (λ) Bending properties : Bending stress (σ_f) and elastic modulus (E_f)

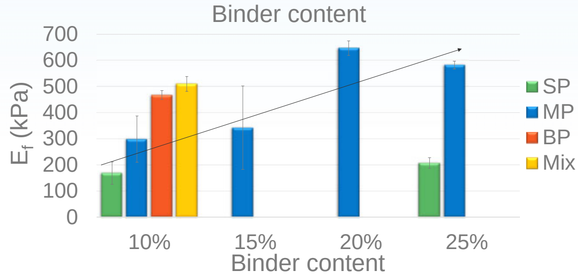


Results and discussion









	ρ (kg/m³)	λ (mW/m.K)	σ_f (kPa)	E_f (kPa)
Amaranth pith	**102.4 ± 5.9**	**54.8 ± 1.5**	**21.0 ± 6.7**	**299.0 ± 88.5**
Sunflower pith [1]	32.0 ±1.92	35.3 ± 1.6	49.6 ± 6.0	422.0 ± 93.9
Corn pith [2]	75.4 ± 2.2	44.4 ± 0.5	29.1 ± 7.7	< 200
EPS	17.6 ± 0.4	28.0 ± 0.0	97.0 ± 4.3	2478.3 ± 82.2

[1] M. Abdellahi, *Contribution to the elaboration and characterization of a 100% bio-based thermal insulating panel, using sunflower pith for building applications.* (2016)

[2] A. Ben Rhouma, *Development and characterization of bio-based composite materials for building industry with low environment impact and corn stem based.* (2017)

Conclusion

- Optimization of the separation process between bark and pith.
- Production of low density (102-142 kg/m³) pith blocks bounded by starch.
- Mechanical properties raise with particle size and binder ratio.
- Conversely, thermal insolation ability of blocks is reduced.
- Optimal block (MG10) : light and insulating while preserving good machinability and mechanical properties.