Stems from amaranth (*Amaranthus cruentus*), an original agricultural by-product for obtaining low-density insulation blocks and hardboards for building applications

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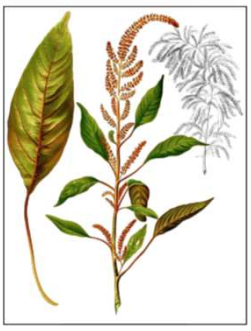
Introduction

- *Amaranthus cruentus*, an annual herb native to temperate and tropical regions (cultivated for the nutritional properties of seeds).
- A promising raw material for the biorefinery of whole plant (all parts potentially usable for food and non-food applications).
- Seeds contain: - A lipid fraction (7-8%), rich in squalene of vegetal origin (5-6%) → **FOOD SUPPLEMENT**, **COSMETICS** [1].
  - Proteins (15%) → **BREAD FLOURS**, **BIOCIDAL AND ANTIOXYDANT ACTIVITIES** [2].
  - Starch (up to 55%) → **INJECTION-MOULDING APPLICATIONS**.
- This study especially aims to investigate the possible uses of stems for **material applications**.



Amaranthus cruentus

Results and discussion

- Structure of stems was studied from ten samples: pith fraction was estimated to 24% (w/w).
- Difference in density between bark and pith fractions ⇨ Continuous separation possible through (i) **grinding** and (i) **blowing**.

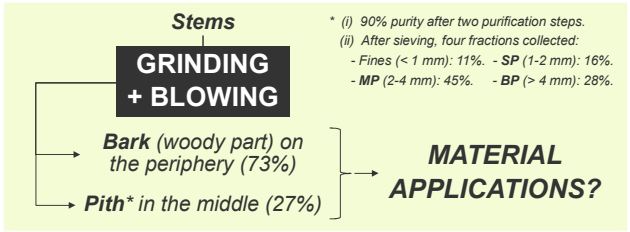
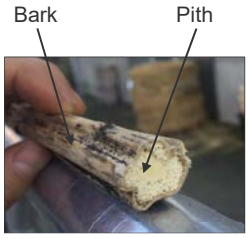


Tableau 1. Characteristics of insulation blocks.

Pith particles	d (kg/m³)	σ_f (kPa)	λ (mW/m.K)
SP	116 ± 1	15.8 ± 1.9	57.5 ± 0.6
MP	100 ± 5	23.0 ± 3.3	54.8 ± 1.5
BP	**89 ± 2**	**84.5 ± 8.2**	**56.0 ± 1.4**
Mix (all fractions)	130 ± 3	59.3 ± 4.5	60.3 ± 1.5

d, density; σ_f, flexural strength ; λ, thermal conductivity.



Cross section of stem

- Alveolar structure for pith particles ⇨ Low bulk density (47 kg/m³ for 4-16 mm particle size) ⇨ Raw material for **thermal insulation**.
- Cohesive materials produced through compression molding (87 kPa, 30 sec, 25 ºC), thanks to the addition of 10% starchy binder.
- **Best compromise between flexural and heat insulation properties with the big pith particles (BP), *i.e.*, > 4 mm (Table 1).**
- High lignocellulose content for the bark (Table 2) ⇨ Potential for the production of **hardboards (HB)** through **hot pressing**.
- From a previously **extrusion-refined bark** using water at a 4.0 liquid/solid ratio, a cohesive HB was obtained with no external binder added (NB) (Table 3) ⇨ Adhesive ability of some chemicals inside bark (free sugars, hemicelluloses and lignins).
- Bending properties much improved with **plasticized cake from amaranth seeds (A)** added ⇨ External binder (starch + proteins).
- **Best flexural properties obtained when adding 20% A (Table 3) ⇨ A2 board is a viable, sustainable alternative for current building wood-based materials, *e.g.*, plywood, chipboard, OSB, MDF, etc.**

Insulation blocks from pith

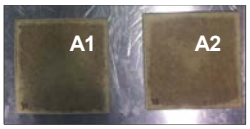
Tableau 2. Chemical composition of bark (% of dry matter).

Component	Cellulose	Hemicelluloses	Lignins	Minerals	Water-solubles
Content	43.6 ± 0.7	17.6 ± 0.4	20.3 ± 0.6	9.3 ± 0.3	14.8 ± 0.9

Tableau 3. Density, flexural properties and water resistance of hardboards produced from extrusion-refined bark using hot pressing (200 ºC mold temperature, 19.6 MPa applied pressure, and 5 min molding time).

Board number	Binder type	Binder content (%)	d (kg/m³)	σ_f (MPa)	E_f (GPa)	TS (%)	WA (%)
NB	No binder	0	1244 ± 35	19.8 ±1.6	2.4 ± 0.2	71 ± 4	56 ± 2
A1	A	10	1279 ± 47	32.4 ±2.6	2.9 ± 0.3	77 ± 4	60 ± 1
A2	**A**	**20**	**1318 ± 47**	**35.8 ± 2.9**	**4.2 ± 0.2**	**87 ± 8**	**69 ± 2**

E_f, elastic modulus; TS, thickness swelling after 24 h immersion in water; WA, water absorption after 24 h immersion in water.



Hardboards from bark

Conclusion

- *Amaranthus cruentus*, a promising raw material for the **biorefinery** of whole plant.
- Stems, composed of (i) a **bark** on their periphery (76% w/w), and (ii) a **pith** in their middle (24% w/w): both usable for **material applications**.
- Possibility to separate mechanically and continuously these two fractions thanks to a fractionation process developed recently: grinding plus blowing.
- Low density for pith particles: usable as **thermal insulating materials** inside buildings (in the form of insulation blocks molded with 10% starchy binder).
- ***Optimal insulation block (BP) ⇨ Light and insulating while preserving good machinability and promising mechanical properties.***
- **Extrusion-refined bark** successfully used for the manufacture of **hardboards** (*i.e.*, dense fiberboards) using **hot pressing**.
- ***Optimal hardboard (A2) ⇨ Viable option for replacing current wood-based building materials, e.g., floor underlayers, interior partitions, etc.***
  - *According to NF EN 312 standard, board already usable for interior fittings (including furniture), in dry environment (P2 type board).*
  - *With much improved water resistance (10% max TS), could be used as a P7 type board (board working under high stress, used in humid environment).*

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