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

Ph. Evon^{1(*)}, G. de Langalerie^{1,2}, L. Labonne¹, O. Merah¹,
T. Talou¹, S. Ballas², T. Véronèse²

¹ Laboratoire de Chimie Agro-industrielle (LCA), Université de Toulouse, ENSIACET, INRAE, Toulouse INP, Toulouse, France

² Ovalie Innovation, Auch, France

* e-Mail address (corresponding author): Philippe.Evon@ensiacet.fr (Ph. Evon)

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**.

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 (ii) **blowing**.

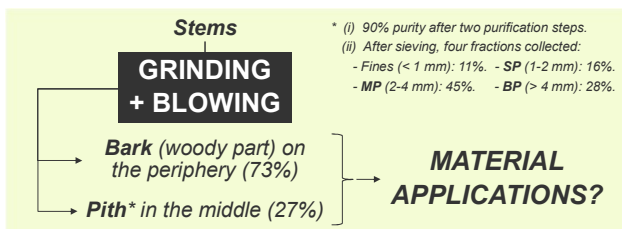


Tableau 1. Characteristics of insulation blocks.

Pith particles	d (kg/m ³)	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

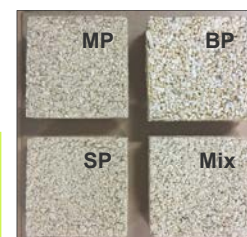
d, density; σ_f , flexural strength; λ , thermal conductivity.



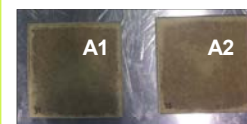
Amaranthus cruentus



Cross section of stem



Insulation blocks from pith



Hardboards from bark

- ▶ 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 °C), 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.**

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 °C mold temperature, 19.6 MPa applied pressure, and 5 min molding time).

Board number	Binder type	Binder content (%)	d (kg/m ³)	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.

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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