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Smart Sustainable Solutions

2D native fibrous vegetable material as textile reinforcement of composites materials

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COVACHIM-M2E

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USP
BioSMat
Materials for Biosystems

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Context

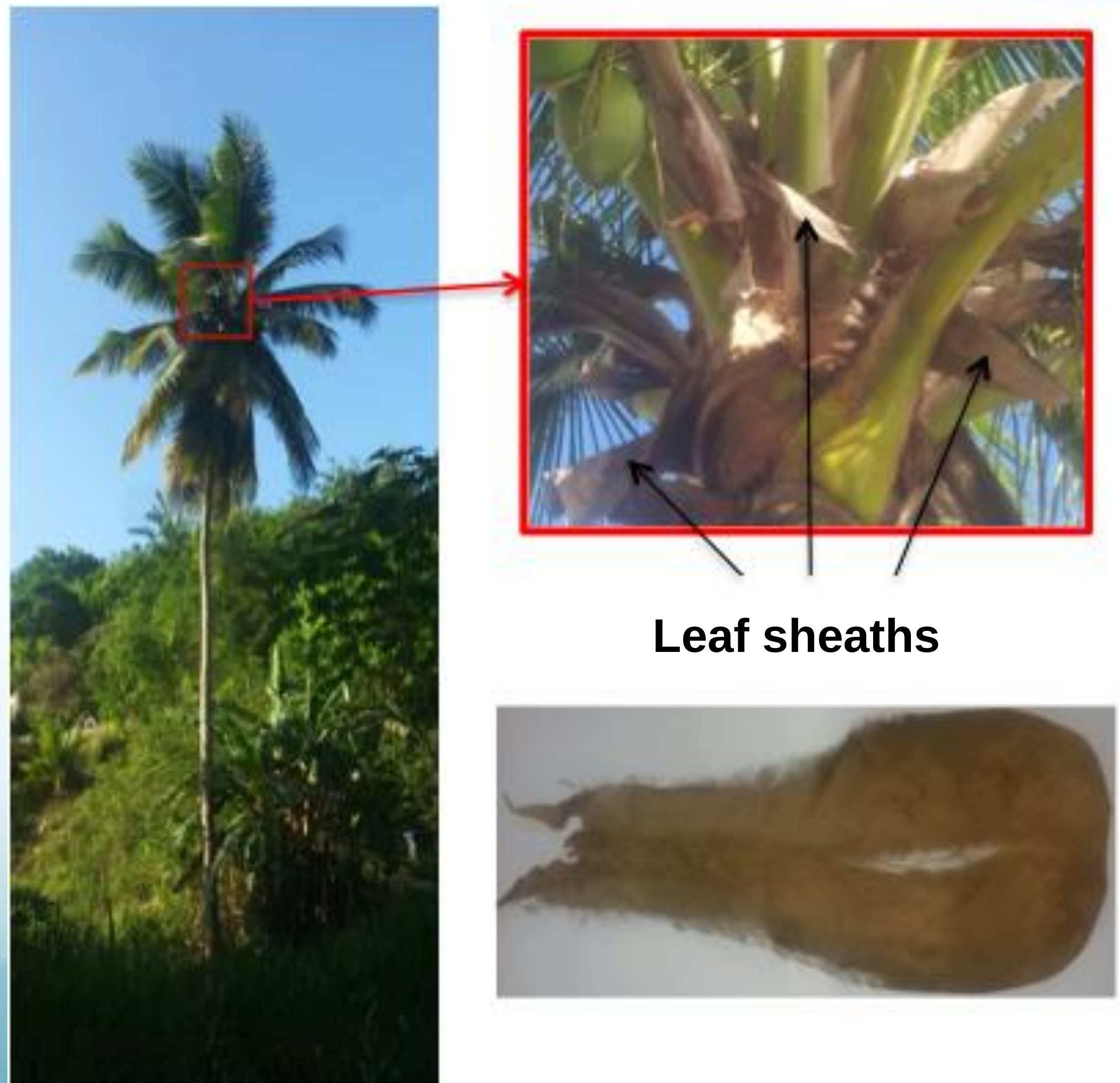
- Environmental, social and economic crisis awareness ➔ development of composites with vegetable fibers as reinforcement.
- Vegetable fibers: renewable, low cost, widely available and low density ➔high specific mechanical properties
- Coconut trees are widely available in Guadeloupe, FWI (15°54’59 N, -61°41’43 W)

What about using the lignocellulosic textile coconut leaf sheaths as nforcement of polymeric matrices?

Outline

- Materials
- Results:
  - Chemical composition
  - Physico-chemical characteristics
  - Mechanical properties of unitary fibers
  - Mechanical behaviour of 2D native textiles
  - Application in particleboards
- Conclusions and perspectives

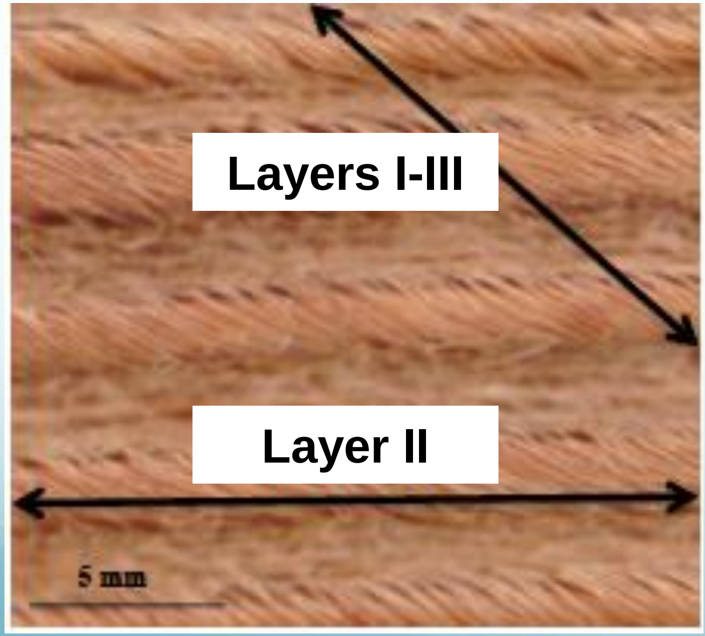
Materials:
coconut leaf sheaths from *Cocos nucifera L.* trees



Materials:
coconut leaf sheaths from *Cocos nucifera L.* trees

- **Collected leaf sheaths washed with water at high pressure (100 bar), soaked in tap water 4 hours and dried in the sun for 1 week.**

- **Forms a 2D native textile.**



Thickness (mm)	Angle I-III/II (rad)
0,23	1,09
0,28	2,36
0,23	0,98
0,27	2,55
0,28	0,79
0,27	2,36
0,23	2,98
0,26	2,36
0,28	2,55
0,28	0,9
0,25	2,36
0,23	2,7
0,04	1,71
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Chemical composition

Cellulose wt%	Hemicellulose wt%	Lignin wt%	Extractives wt%	Litterature
39,22 ± 1,45	**22,17 ± 3,91**	**29,62 ± 0,74**	**0,81 ± 0,06**	**This study**
37,3 ± 5,8	20,3 ± 4,8	32,2 ± 7,1	3,1 ± 0,9	(Maheswari *et al.*, 2012)
43,9	25,7	30,2	–	(Reddy *et al.*, 2010)

+++ cellulose: potential candidates as fibrous reinforcement for polymers (cellulose stiffness approx. 137 GPa)

Lignin: wt% similar to that of other palms ➔ stiffness

!!! Cellulose + hemicellulose ➔ hydrophilic ➔ problem of fibers compatibility with hydrophobic polymers

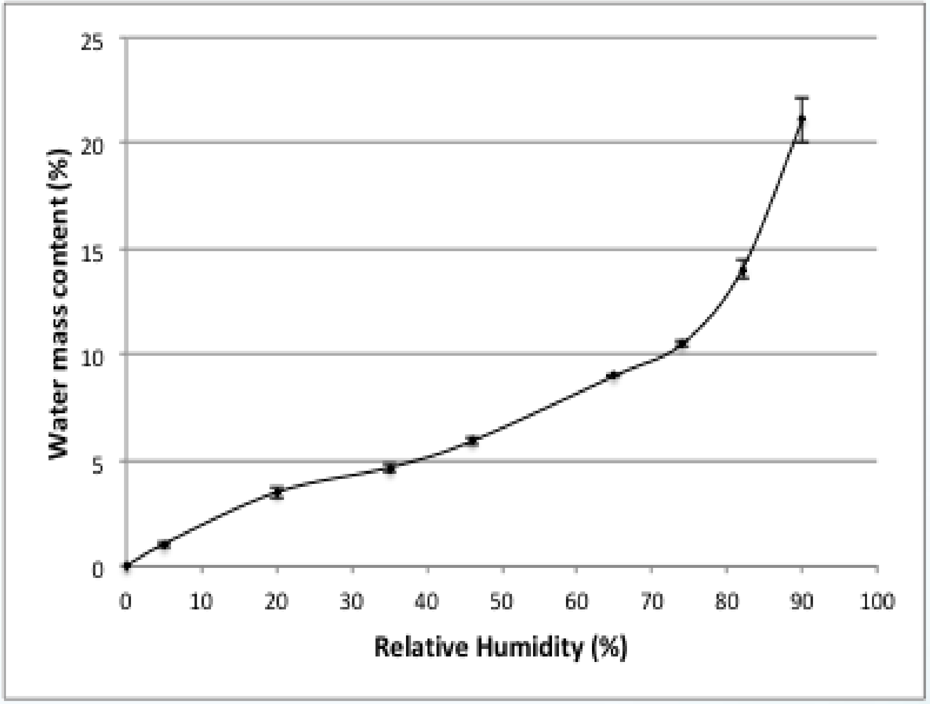
Physico-chemical characteristics

Water sorption isotherms

Moisture content of (9.53 ± 0.03)%: leaf sheaths are less hydrophilic than sisal, jute, abaca and pineapple fibers (Li et al. 2007, Faruk et al. 2012)

➔ **better dimensional stability of composites reinforced with coconut leaf sheath fibers and a more stable fiber / matrix interface**

➔ **improved mechanical properties**



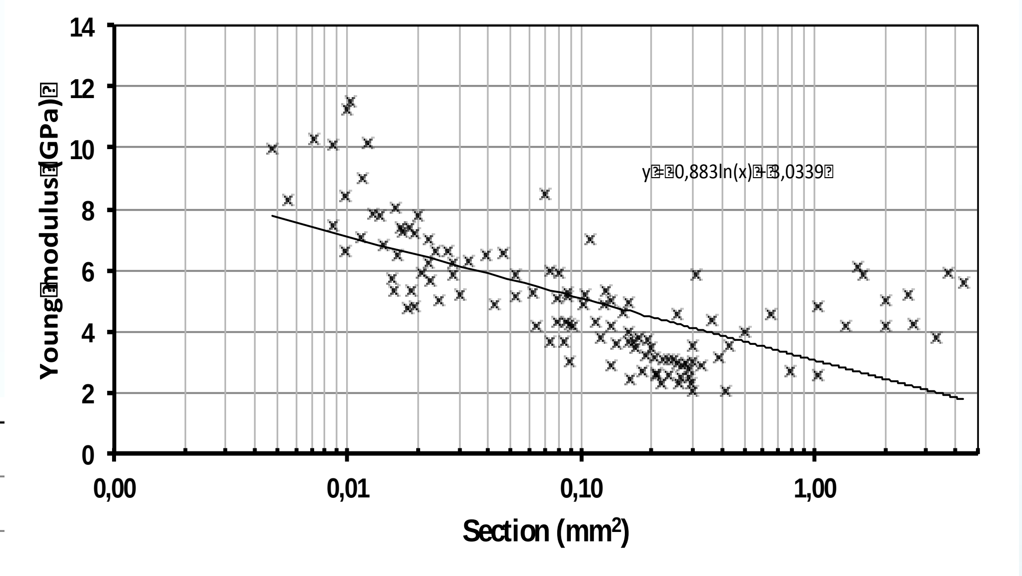
Specific density = (0.97 ± 0.01) g/cm^3

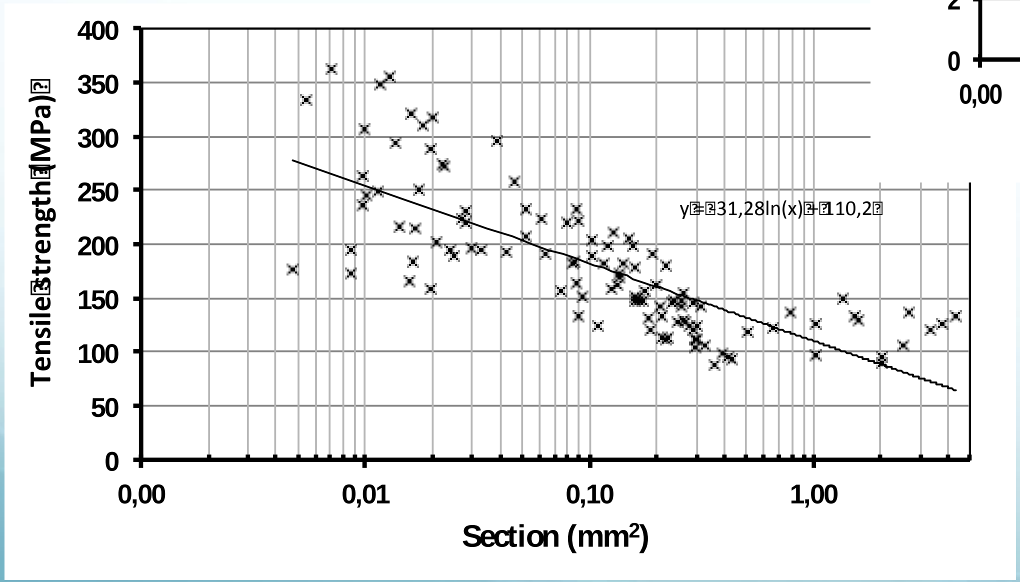
Lower than that of most other vegetable fibers and glass (Li et al. 2007, John & Anandjiwala, 2008)

➔ **Competitive reinforcement in composites engineering (light, renewable and biodegradable)**

Mechanical properties of unitary fibers coming from 2D native textile

As showed in literature, logarithmic decrease of tensile strength and Young modulus according to the section of unitary fibers.

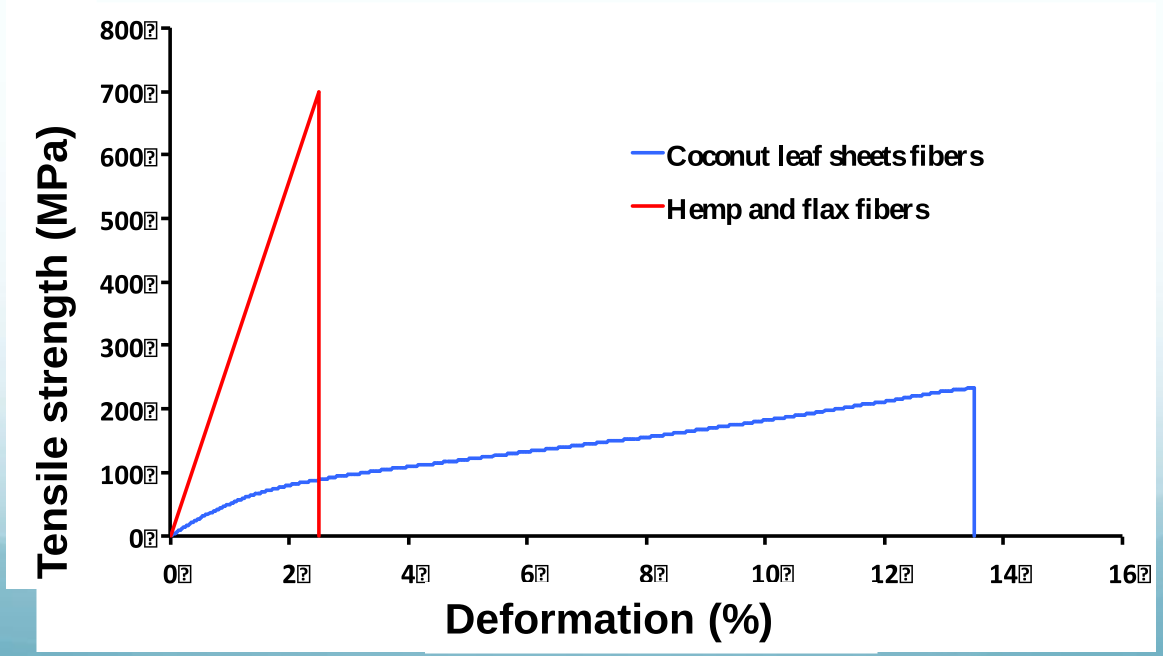




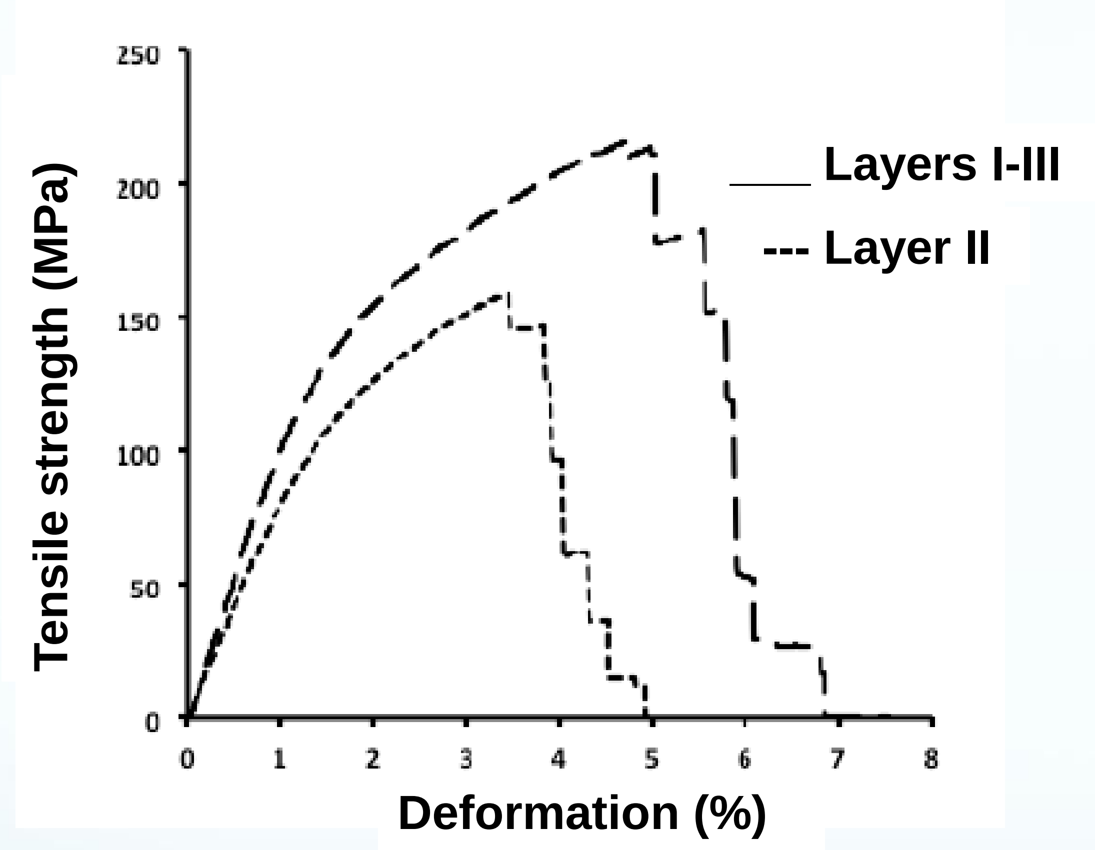
Mechanical properties of 2D native textile

Comparison of the stress-strain curves typical of hemp, flax to those of coconut leaf sheath fibers:
➔For coconut leaf sheath fibers, the non-linear region begins at around 60 MPa following a short linear zone characteristic of the plastic, ductile and tenacious behavior of these fibers.

➔ Potentially interesting reinforcements for improving the impact properties of composites compared to flax and hemp fibers (Defoirdt, 2010).



Mechanical properties of 2D native textile



The direction in which the fibers are stressed influence their tensile strength

The stress-strain curves of raw leaf sheaths have a similar appearance to that observed for individual fibers:

- a linear zone
- followed by a nonlinear region.

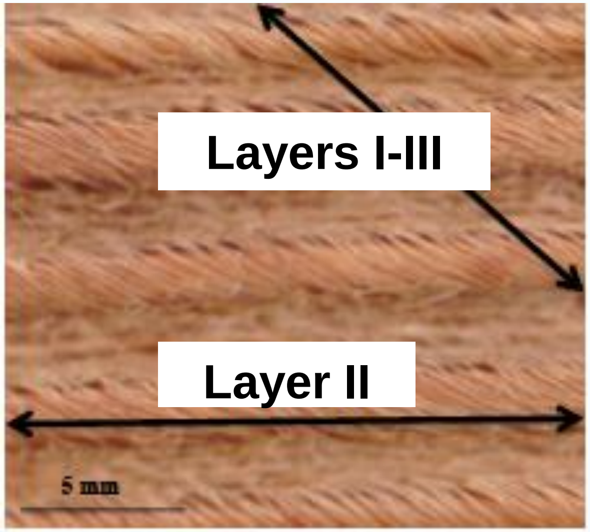
➔ Stepwise rupture of the sheaths in textile form resulting in a gradual breakage of the fibers.

Modeling of mechanical properties of 2D native textile

Tensile strength in the preferred direction of the fibers:

- Layers I – III (fine and medium fibers)

- Layer II (large fibers)



$$P = \sum_i p_i f_i$$

P = property of 2D native textile

i = fine, medium or large fibers

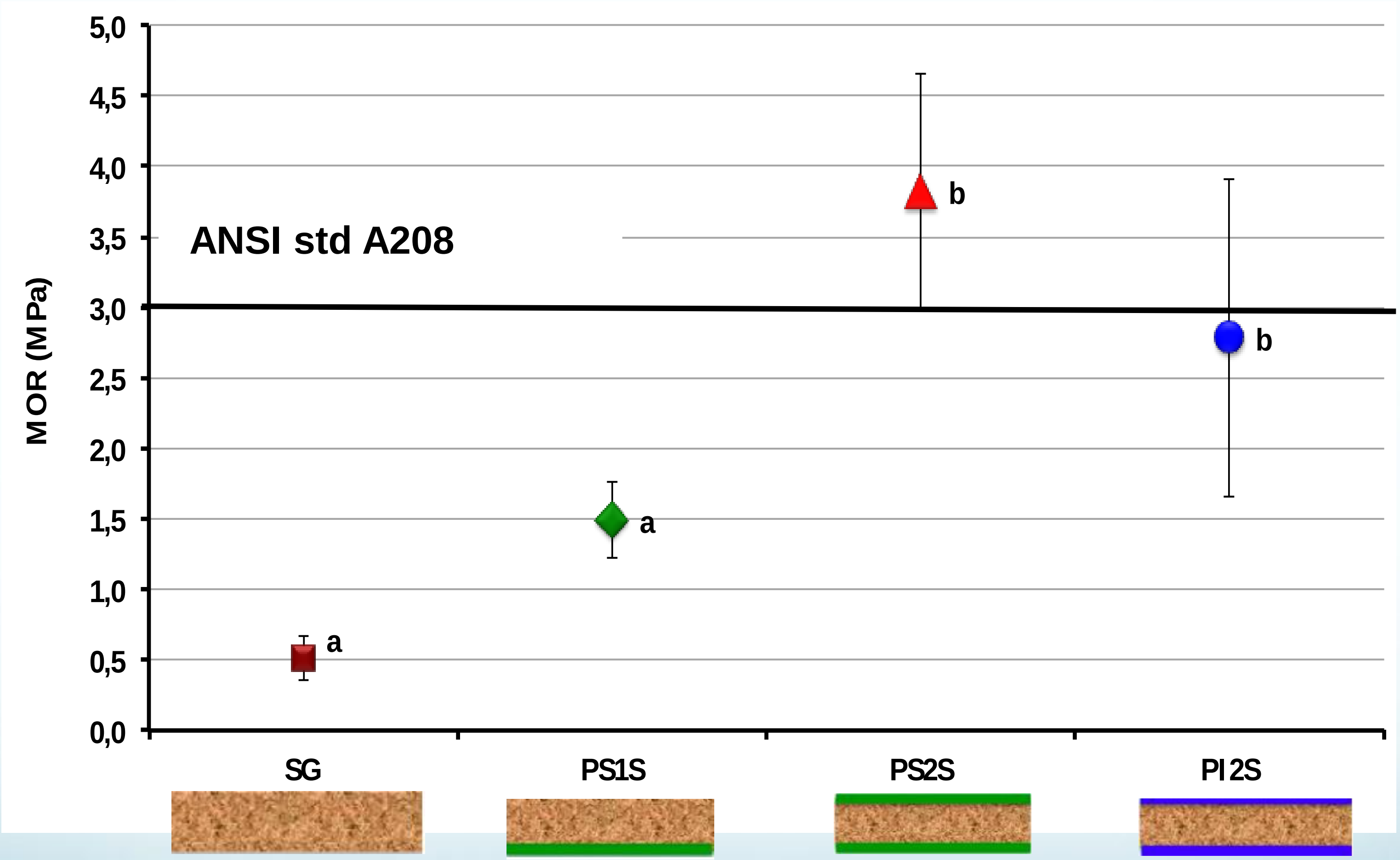
p_i = property of unitary fibers i

f_i = surface fraction of unitary fibers i

	Tensile strength (MPa)		Young modulus (GPa)	
	exp	theor	exp	theor
Layers I-III	193 ± 30	179 ± 44	7.8 ± 1.2	5.2 ± 1.4
Layer III	133 ± 30	131 ± 25	7.4 ± 0.7	4.2 ± 1.2

Good agreement between experimental and modeling data

Application: composites particleboards reinforced by 2D native textile



- ➢ **PS2S meets the mechanical requirements recommanded by ANSI A208 for low density particleboards**

Conclusions & perspectives

- **2D native textile coconut leaf sheaths is a complex, heterogeneous but predictive material.**
- **Potentiality of natural materials as reinforcement of polymeric matrices (particleboards).**
- **Ecofriendly materials, viable characteristics.**
- **Durability? compatibility with other matrices?**
- **Applications in automotive or housing area?**

Deeper studies on mechanical, acoustic and thermal behaviours

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Thank you for your attention!!!

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