Value-added industrial products from fiber crops

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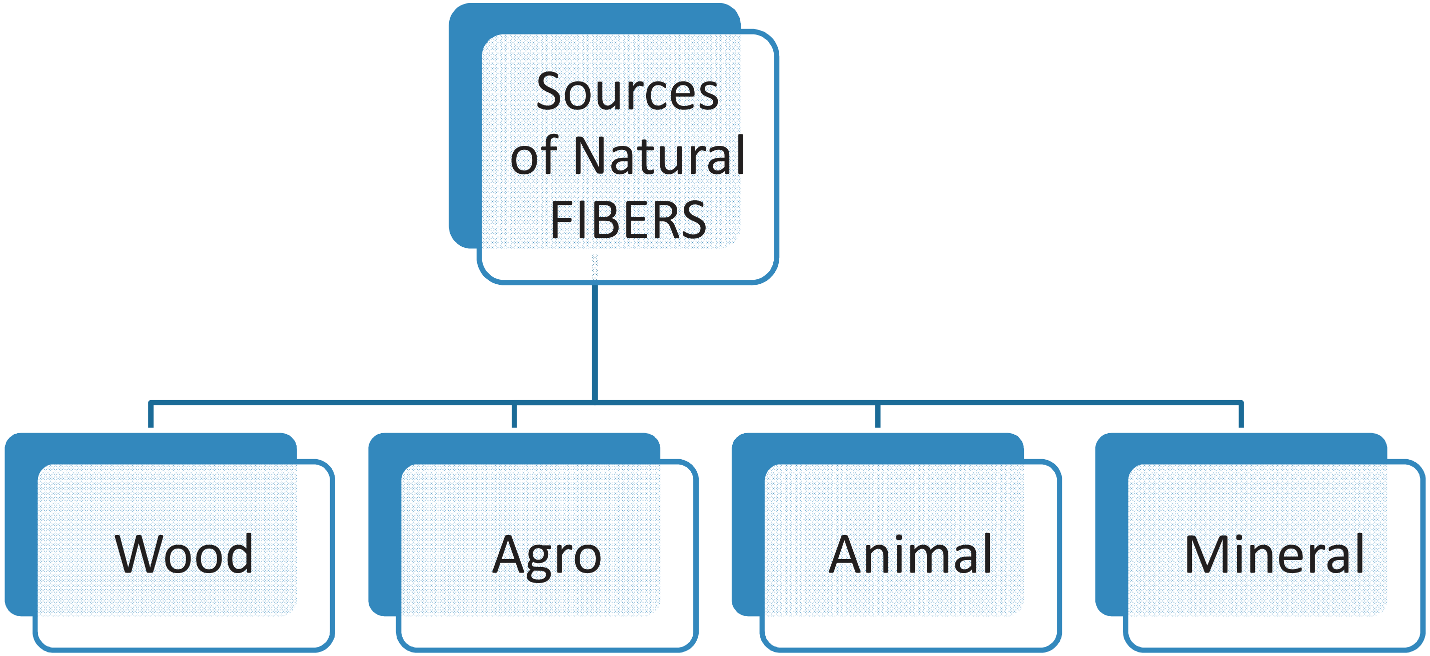
Presentation Outline

- Fibers-Sources and Classification
- Historical review of utilisation of bast fibers
- Modern products from fiber crops
- Composites and biocomposites-terms
- Materials from crops utilised in biocomposites
- Physical and chemical properties of materials from crops
- The Eurostars project
- Advantages-disadvantages of using materials from crops
- Market trends
- Conclusions

Fibers

Fibers are natural or chemical structures that can be spun into yarns.



Wood and plant (agro) fibers are made of cellulose. Animal fibers, like silk and wool, are made of protein.

Each fiber is identified by a generic name. The Textile Fiber Products Identification Act that officially established the generic fiber classifications became effective in 1960.

Classification of non wood cellulose fibers

Bast	Leaf	Seed	Fruit	Stalk
Flax	Sisal	Cotton	Coconut	Bamboo
Hemp	Manila	Kapok		Wheat
Jute	Curaua			Rice
Kenaf	Banana			Grass
Ramie	Palm			Barley
Banana				Corn
Rattan				

Historical review for the use of bast fibers

Applications	Houses in Egypt from clay and straw	Replica of the aircraft used in the WW II. It had the fuselage made of unidirectional, unbleached flax yarn impregnated with phenolic resin	Henry Ford's prototype car	Trabant car with body from cotton and paper	Calfee's creation	NTT DoCoMo's FOMA N701iECO cell phone	LINEO tennis racket
							
	Wall houses in Egypt were made using clay reinforced with straw.	The shortage of aluminium in England led to the use of natural fibers.	Henry Ford had his first prototype car made from hemp fibers.	First production of car made from natural fibers composites.	Number of automotive and bicycle applications.	Cases of cellular phones.	Sporting goods.
Material	**straw**	**Flax + phenolics**	**hemp**	**Cotton + polyester**	**Flax, Hemp, Kenaf, Abaca**	**Kenaf + PLA**	**Flax, Hemp, Kenaf**
Time frame	**3000 years ago**	**1939**	**1942**	**1950-1990**	**2000 onwards**	**2004 onwards**	**2006 onwards**

Source: Lucintel , March 2011

Modern products from fiber crops

Automotive	Electrical and electronics	Sporting goods	Construction and furniture	Building	Textiles & accessories
Door panels Seat backs Headliners Dash boards Trunk liners	**Mobile cases Laptop cases**	**Tennis Racket Bicycle Frames Snowboards**	**Door panels Decking Railing Window frames chairs**	**Insulation material Particle-boards MDF**	**Cloths Bags Shoes glasses**
Compression Molding Injection Molding	Injection Molding	Oven cure	Extrusion Compression Molding Injection Molding	Oven cure	

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Source: Lucintel , March 2011

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Cars from Hemp

The Lotus Eco-Elise

The body of the car is made from hemp composite

The Eco One

It is built by experts from Warwick Univer.sity. The body of the high-speed machine is made from hemp and rapeseed oil.

The Sunbeam Tiger Concept

It is a high-speed electric car designed by Ryan Skelley, oventry University

The Formula Three vehicle

It includes hemp, soybean oil, potato starch and recycled bottles.

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http://www.greendiary.com/green-druggy-dream-five-cars-made-in-hemp.html

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Electrical & Electronics with natural fibers

Guitars made from hemp.
http://www.guitarsite.com/news/electric_guitar/guitars_made_from_hemp/

Component speakers from Kenwood electronics, UK
http://www.kenwood-electronics.co.uk/products/car/speakers/component/XR-1800P/

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Construction-Furniture-Sports objects from natural fibers

Insulation materials - Laroche company:
http://www.laroche.fr/upload/090818%20paper%20of%20Laroche%20lecture%20for%20International%20Natural%20fibres%20Congres(3).pdf

Building in France being constructed **entirely of hemp**.
http://www.hort.purdue.edu/newcrop/ncnu02/v5-284.html

http://www.lineo.eu/#!applications
(Flax+epoxy resin)

Hemp chair by Werner Aisslinger. It is made from natural fibers like hemp that have been molded under heat with a special non-toxic, eco-friendly glue
http://inhabitat.com/werner-aisslinger-creates-a-stackable-seating-with-a-modern-form-using-hemp/hemp01/

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Textiles & Accessories from natural fibers

Sunglasses *from natural materials like ash wood, oak veneer, hemp kenaf and flax.*
Read more: [Marius Temming's Chic Eco Sunglasses are Made from Hemp, Kenaf and Flax | Inhabitat - Sustainable Design Innovation, Eco Architecture, Green Building]

Hemp shoes *Read more:*
http://www.thedailygreen.com/living-green/blogs/recycling-design-technology/ipath-hemp-shoes-460809

Hemp Dress by Texture Clothing

Jute products

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What is a composite

Combination of polymer matrix (renewable or non-renewable resources) with organic or inorganic fibers.

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Bio-composites

What is it ?

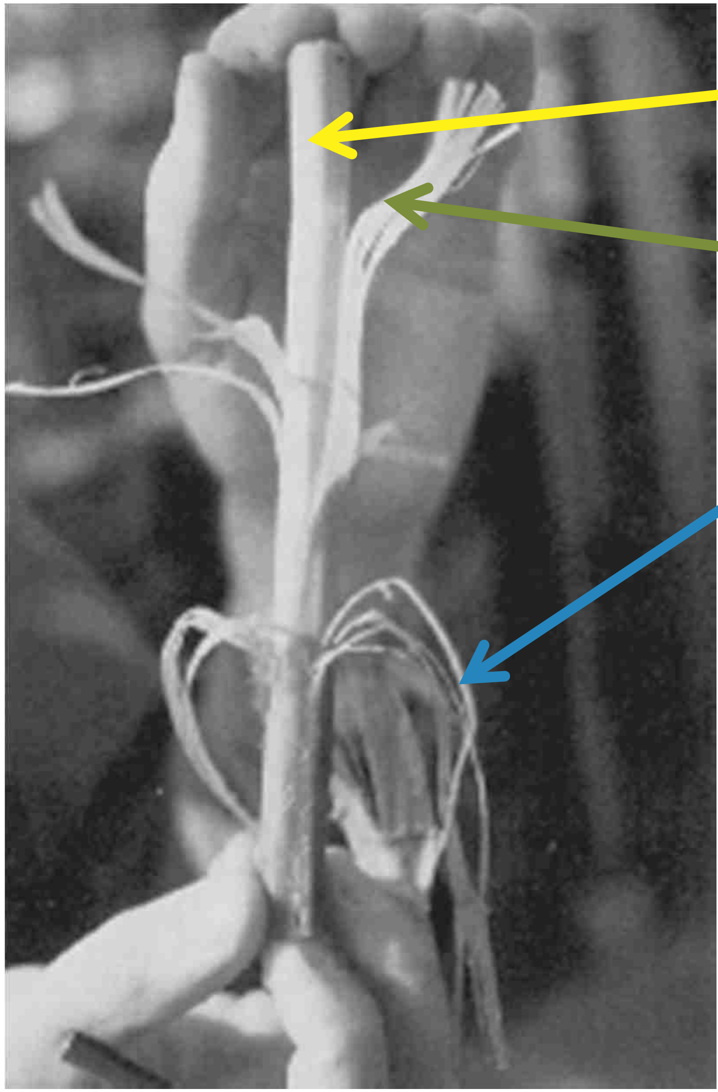
Composites resulted from the combination of a polymer with organic fibers obtained from agricultural and forest resources either as a product or residues.

Why we need material from agricultural resources?

Today the materials from agricultural resources have drawn the interest of the scientists and industry because

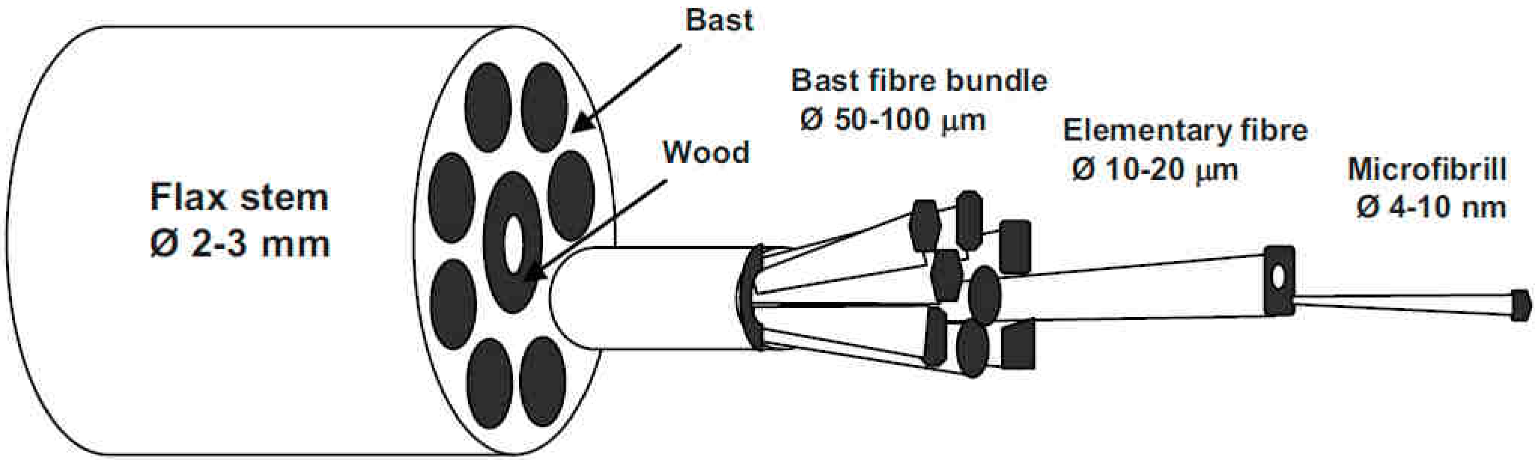
- The environmental awareness is increased
- The fossil resources are greatly depleted
- The land available for forests is not enough to cover the needs of the growing population.

Materials from crops utilised in biocomposites



De Meijer, 1993a
http://extension.oregonstate.edu/catalog/html/sb/sb681/

Structure of bast fibers



J. Kers et.al. Preliminary investigation into tensile characteristics of long Flax Fiber reinforced composite material

Physical properties of bast fibers

The physical properties of some bast fibers that today find application in industrial products are shown in the following table.

Fiber	Density (g/cm^3)	Elongation (%)	Tensile Strength (MPa)	Elastic Modulus (GPa)
Jute	1.3	1.5-1.8	393-773	26.5
Hemp	1.47	-	690	70
Kenaf	1.45	1.6	930	53
Sisal	1.5	2.0 – 2.5	511-635	9.4-22
Coir	1.2	30	593	4.0- 6.0

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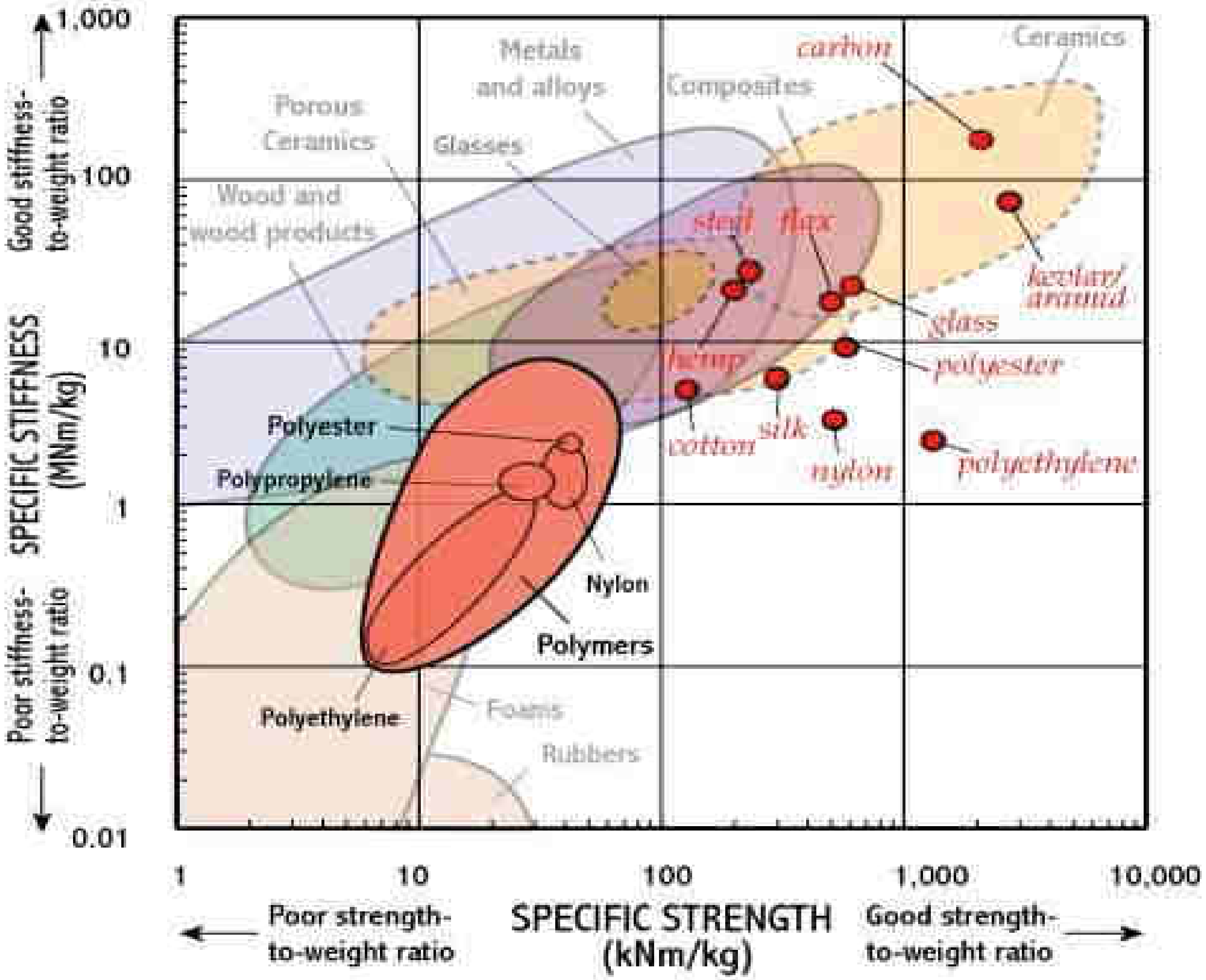
Mechanical strength of fibers from crops



http://www.learneasy.info/MDME/MEMmods/MEM30007A/polymers/polymers.html

Chemical composition of fibers

Fibrous material	Cellulose	Hemicellulose	Lignin	Extractives	Ash
Flax	78.5	9.2	8.5	2.3	1.5
Hemp	68.1	15.1	10.6	3.6	2.5
Kenaf	60.8	20.3	11.0	3.2	4.7
Coniferous	48.0	15.0	25.3	11.5	0.2
Deciduous	52.8	21.8	22.3	2.7	0.4

Source: Danforth International, and TAPPI

Chemical composition of core material of kenaf & hemp

Chemical composition	Kenaf core	Hemp core
water	7-10%	10%
Cellulose	51-52%	45-52%
Hemicelluloses	-	15-20%
Lignin	17%	20-30%
Ash	2.9-4.2%	4-5%

Source: KEFI company, Italy

Eurostars project

- **Title:** Green composites and 3D objects
- **Subject:** Development of green composites (particleboards, MDF and 3-D objects) suitable for a wide range of applications from **hemp and kenaf**. The adhesives used for the production of PBs and MDF are based on tannin and lignin while the composites intended for the production of 3-D objects are manufactured from chitosan or/and poly(butylene succinate).
- **Partners**
  - CHIMAR HELLAS S.A. - GR
  - HempFlax Exploitative BV - NL
  - Valbopan Fibras de Madeira S.A - PT
- **Sub contractors**
  - AUTH (Chemical and Physical departments) - GR
  - CRES - GR
- **Total Duration:** 7/11/2011 – 6/11/2014 **(**36 months)

Participant’s interactions

Kenaf material configurations

Hemp material configurations

HEMP FLAX (Hemp)

\+

CRES (Kenaf)

CHIMAR → (Resin) → VALBOPAN

CHIMAR / AUTH

CHIMAR → Particleboards

VALBOPAN → MDF

CHIMAR / AUTH → 3D Objects

The role of CHIMAR

CHIMAR is a private research institute serving the wood-based panels industries. The company develops and licenses know-how for adhesives, impregnation syrups and various chemicals (hardeners, fire retardants, etc).

The role of CHIMAR in the project:

- Synthesis of resins based on tannin or/and lignin suitable for the production of paricleboards (PB) & medium density fiberboards (MDF).
- Production of PBs from **hemp and kenaf** chips at various densities.
- Development of composites for 3D objects from poly(butylene succinate) and chitosan enforced with fibers and shives from hemp and kenaf

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Resins synthesized by CHIMAR for the Eurostars project

- Urea - formaldehyde
- Phenol – formaldehyde with partial phenol replacement by lignin and glyoxalated lignin.
- Tannin + hardener

Production of particleboards

Production process

1. Drying of chips at a moisture content of 3-5%
2. Gluing: Mixing of the chips with the resin
3. Formation of the panel (mat)
4. Pressing under certain temperature and time
5. Testing and Evaluation of panels

Production of kenaf chips & fibers at CHIMAR premises

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Production of particleboards at CHIMAR premises

Drying of chips in the oven

Measuring the moisture content of chips

Preparation of the glue mix

Mixing chips with resin

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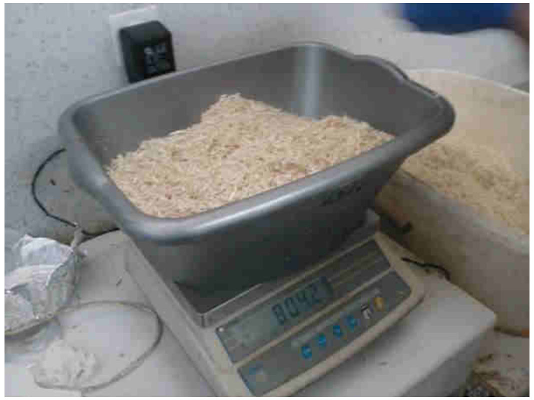
Production of particleboards at CHIMAR premises



Weighing the required amount of glued chips

Mat formation

Pressing of panels

Panels

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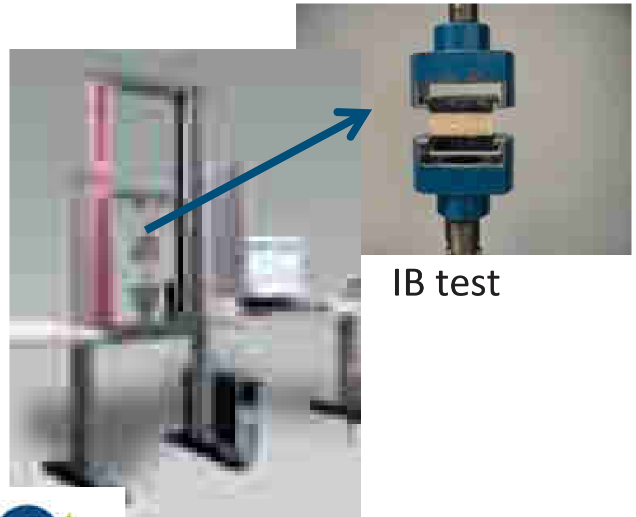
Testing of particleboards

Property	European standard
Internal Bond (N/m^2)	EN 319
Modulus of rupture (N/m^2)	EN 310
Thickness swelling, %	EN 317
Moisture content, %	EN322
Formaldehyde content, mg/100g wood	EN120 (Perforator method)


IB test


MOR test


Perforator test

PB-successful results so far

- Production of PBs with various substitution levels of wood by hemp bonded with resins based on lignin, at the density of 650kg/m^3.
- Panels totally from hemp or kenaf at the densities of 650, 500 and 400kg/m^3.

Such panels can be used for indoor lightweight constructions (furniture, insulation panels, etc)

VALBOPAN – MDF panels

Valbopan has used both fibers and chips of hemp as wood fibers substitutes in the production of MDF panels

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Testing of MDF panels

Property	Test method
Density, Kg/m^3	EN 323
Swelling in thickness 24h, %	EN317
Internal bond N/mm^2	EN319
Bending strengh N/mm^2	EN310
Modulus of elasticity in bending N/mm^2	EN310

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MDF - Results so far

- 25% of wood fibres replaced by hemp material
- Panels with low densities (570, 600, 650, 680 kg/m^3)

Problems faced

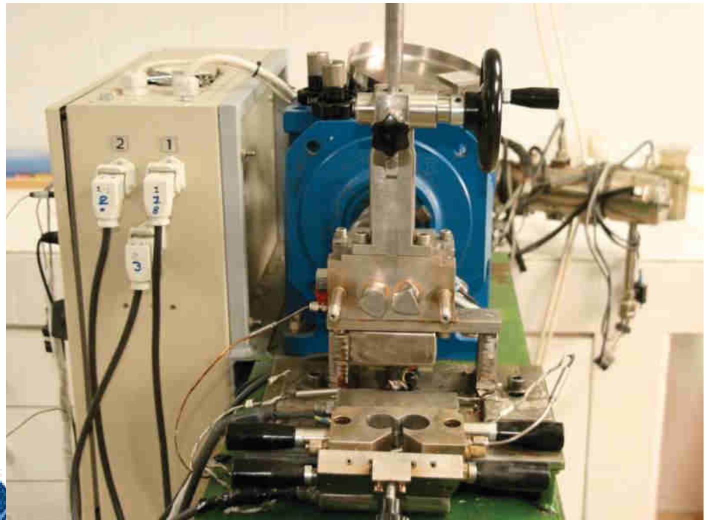
Hemp fibers are too long compared to wood fibers for MDF and mechanical problems came up during their use (they blocked the fan).

The problem will be faced by reducing the size of the normal fibers or using other types of fibers provided by the HempFlax company.

Composites for 3D objects

Production process

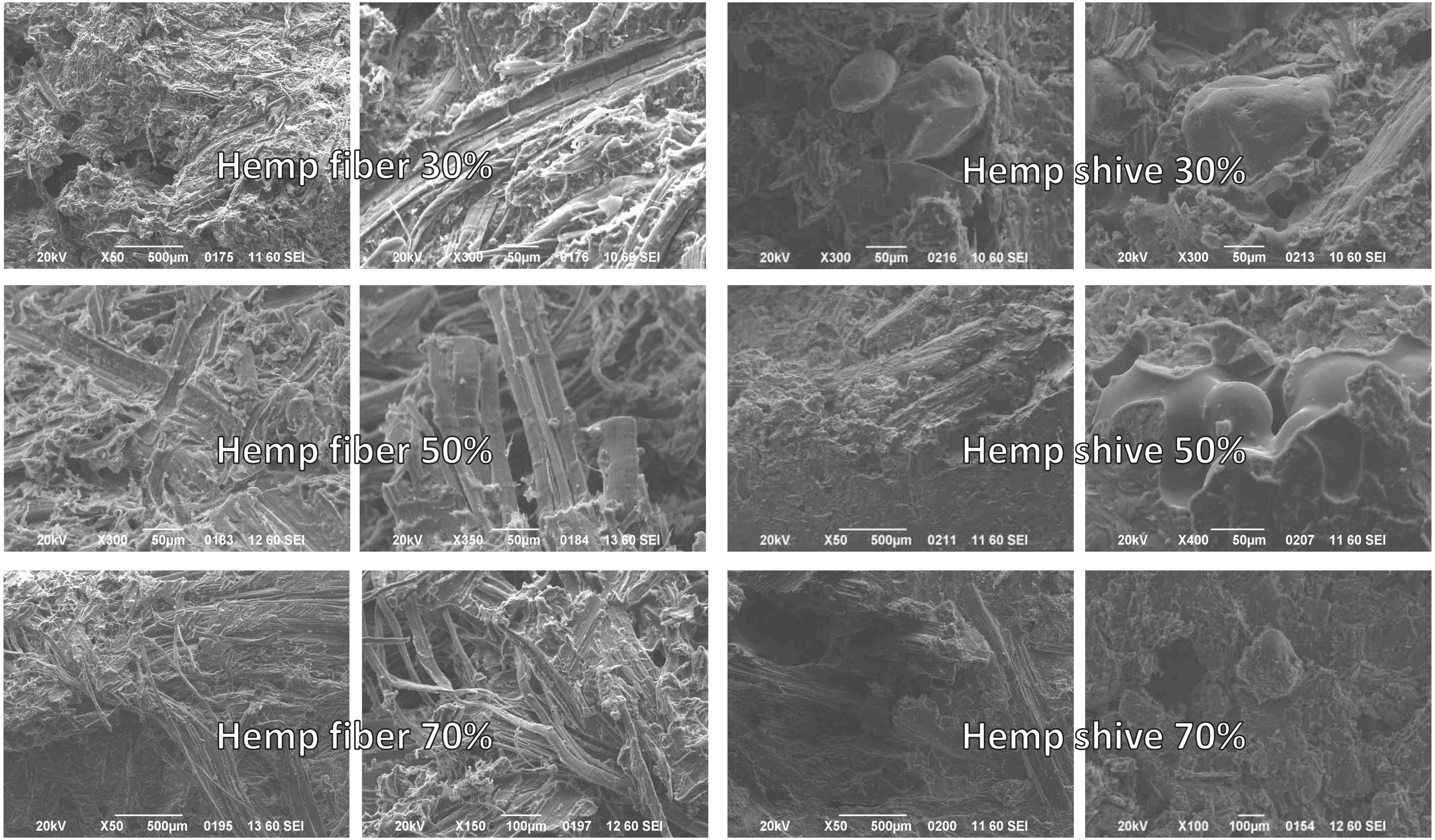
- Composites were prepared in a twin-screw co-rotating reomixer from PBSu and hemp fibres and shives, as reinforcing materials. Conditions: Temperature 130°C, time 10 min.
- Hemp fibers had 0.5cm length and <40 μm diameter
- Hemp shives had <800 μm diameter
- In each case, the concentrations of fibres and shives in the composite were: 15, 30, 50, 60 and 70%.



Testing of composites

- Tensile strength
- Elongation
- Impact strength
- TGA, DSC, SEM, FTIR and XRD analysis
- Biological decomposition (hydrolysis by enzymes and soil)

SEM Images



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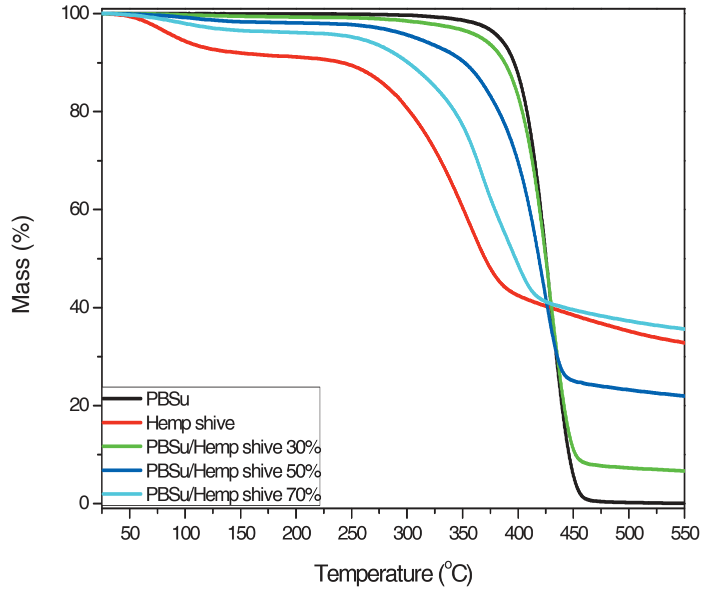
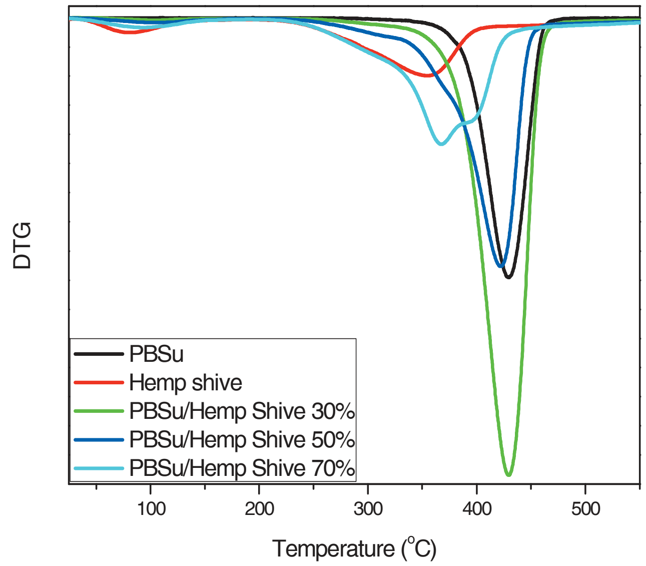
TGA study results





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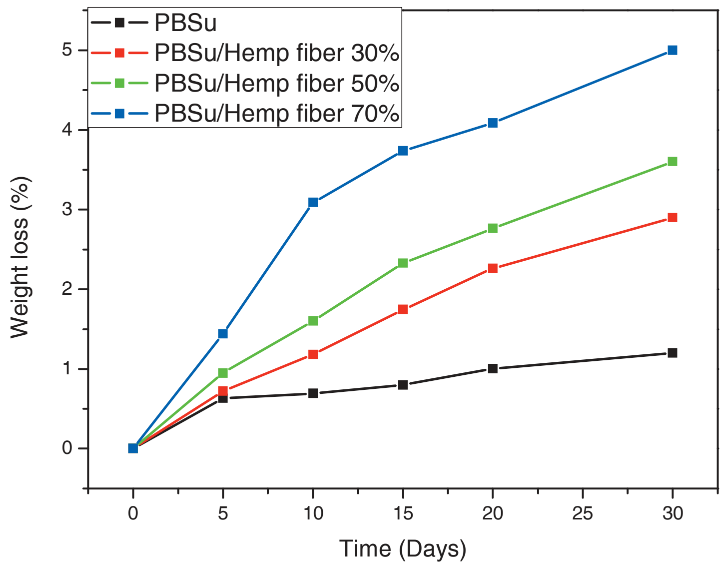
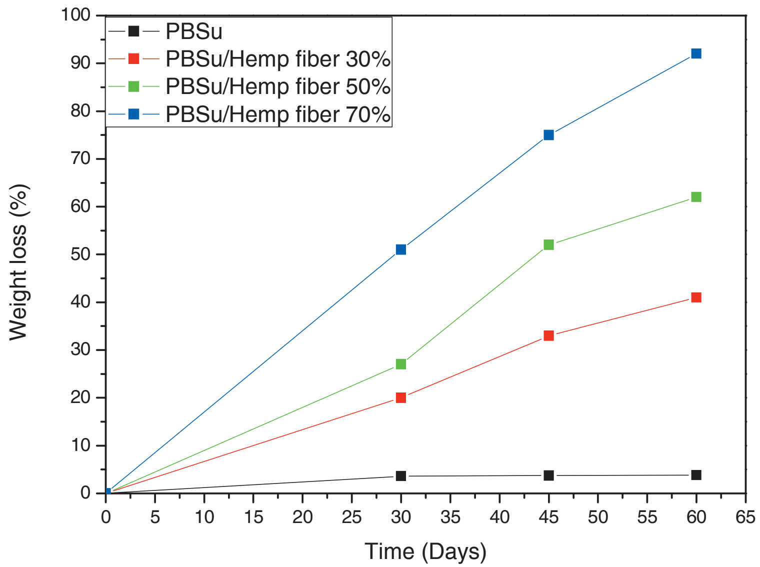
Biological decomposition



Enzymatic hydrolysis



Decomposition in soil

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Composites - Results so far

- Tensile strength:< than pure PBSu, although still good
- Elongation: < than pure PBSu
- Impact strength : < than pure PBSu
- The higher the percentage of hemp the lower the thermal stability of the composite and the sooner their biological decomposition.
- The decomposition is faster in soil than the enzymatic hydrolysis.

Such composites are suitable as biodegradable pots for the sowing of plants.

Advantages & disadvantages of using material from fiber crops

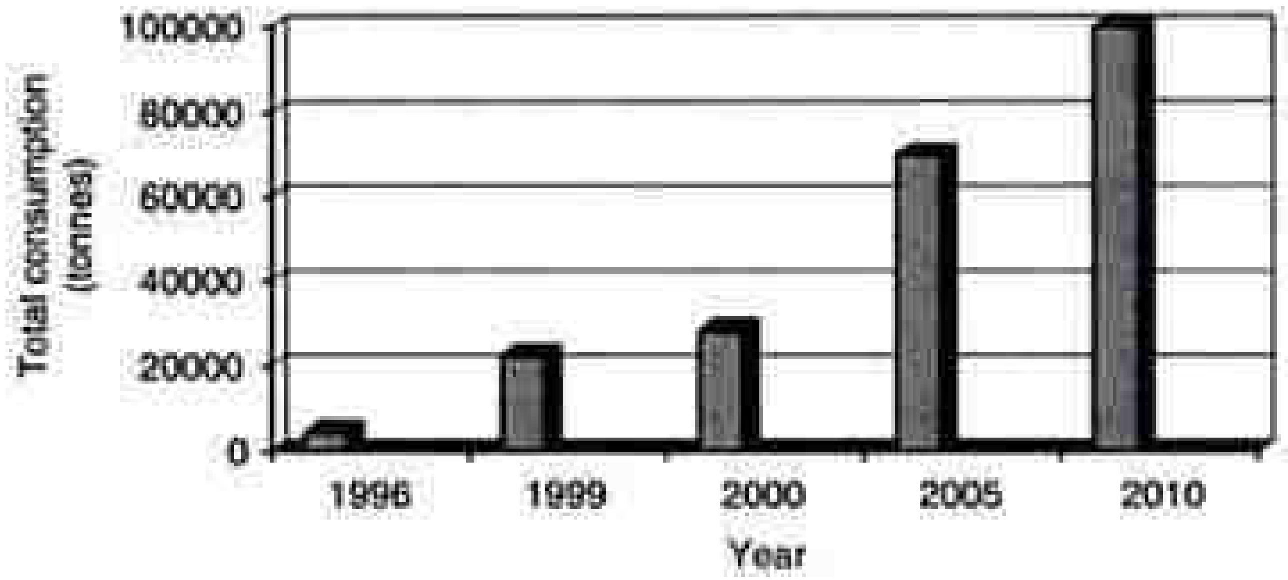
ADVANTAGES

- Renewable organic products
- Have excellent mechanical and physical properties
- Need low energy
- Show CO_2 neutrality
- No dermal issue for their handling
- Do not pose a bio-hazard upon disposal
- Non abrasive
- Expose great formability
- Light weight (less than ½ the density of glass fibers)
- Good thermal and acoustic insulation properties
- available on a worldwide basis

DISADVANTAGES

- Dimensional changes
- Swelling
- Shrinkage
- Organisms with specific enzyme systems hydrolyze the carbohydrate polymers into specific polymers

European market of natural fibers



Total consumption of natural fibers

In the European market, the use of the natural fibers suffered depletion during 1950 to 1996, registering a significant increase for the period 2000 to 2005

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Market trend for bio-composites

According to the U.S.-based market research company Lucintel:

- The **global market** for natural fiber composites reached a total value of **US$2.1 bn in 2010**
- The demand for natural fibers and resins will continue to grow rapidly. **By 2016,** the natural fiber composite market is expected to reach **US$ 3.8 bn. (10% CAGR)**
- Major reasons for using natural fibers: to reduce weight, achieve a better environmental balance, reduce costs, and manufacture complex structural elements.

The **sales** of natural fibers for use as reinforcement materials in composites in **Europe** were **20,000 tons in 2010** and this number can increase to 40,000 - 50,000 tons by 2015. *(report in the latest issue of Technical Textile Markets —a quarterly publication from the global business information company Textiles intelligence)*

Conclusions

The industrial exploitation of bast fiber crops like jute, hemp, kenaf, sisal, coir, etc., not only offers valuable raw materials for biocomposites but also contributes to the protection of the environment (absorption of CO_2) and gives economic potential to the countries under development.

The biocomposites have gained crucial importance during time and many studies regarding them are in development.

Although today many products are already available on the market, some certain subjects regarding the materials from crops have to be faced like:

- Availability at industrial quantities year round

- Price competitive to the materials they replace (like wood)

Thank you for your attention

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http://www.chimarhellas.com

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