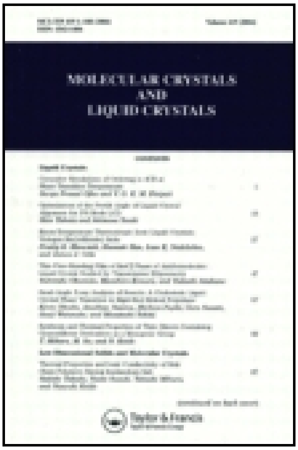

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Plant Fibres in Composites. Comparative Results between Hemp, Kenaf and Flax Fibres. Preparation of Raw Material and Final Products

Pietro Cappelletto [a] , Francesco Mongardini [a] , Marina Brizzi [a] , John Skinner [b] , Giles Sebe [b] , James Hague [b] & Pietro Pasini [c]

[a] Istituto Poligrafico e Zecca dello Stato, via Salaria 971, Roma, 00138, Italy

[b] Biocomposites Centre, University of Wales, Bangor, GwyneddLL572UWUK

[c] Tecnagri, via Faentina 106, Ravenna, 48100, Italy

Version of record first published: 24 Sep 2006

Mol. Cryst. and Liq. Cryst., 2000, Vol. 354, pp. 391-399
Reprints available directly from the publisher
Photocopying permitted by license only

Plant Fibres in Composites. Comparative Results between Hemp, Kenaf and Flax Fibres. Preparation of Raw Material and Final Products

PIETRO CAPPELLETTO[a], FRANCESCO MONGARDINI[a], MARINA BRIZZI[a], JOHN SKINNER[b], GILES SEBE[b], JAMES HAGUE[b] and PIETRO PASINI[c]

[a]*Istituto Poligrafico e Zecca dello Stato, via Salaria 971, Roma, 00138 Italy,* [b]*Biocomposites Centre, University of Wales, Bangor, Gwynedd, LL572UWUK and* [c]*Tecnagri, via Faentina 106, Ravenna, 48100 Italy*

In the future, composite materials based on plant fibres will have increasing importance in our life. They are light, recyclable, environment friendly. Plant fibres can substitute the artificial fibres in many industrial products even if manmade fibres at present still perform better. Nevertheless, appropriate dry-mechanical treatment of raw material can improve plant fibre characteristics; subsequent chemical treatments are able to induce fibre modifications that increase their resistance when utilised in composite products.

This paper will describe the hemp, flax and kenaf dry-mechanical preparation system; results on treatment yield and characteristics of different fractions will be given for each species.

Afterwards, the composites preparation system will be described and results of fibre behaviour in composite products will be illustrated and discussed.

Keywords: plant fibres; composites; hemp; flax; kenaf

INTRODUCTION

In the future, composite materials based on plant fibres will have increasing importance in our life. They are light, recyclable, environment friendly. Plant fibres can substitute the artificial fibres in many industrial products even if manmade fibres at present still perform better. Nevertheless, appropriate dry-mechanical treatment of raw material can improve plant fibre characteristics;

subsequent chemical treatments are able to induce fibre modifications that increase their resistance when utilised in composite products.

Recently several new crops have been proposed in order to diversify the European production of agricultural goods. Special attention has been paid to fibre crops, since the fibre market in Europe heavily depends on import from non-EU countries. Table 1 shows the quantity of the most important fibres (appropriate for composite materials) that are imported in the EU, together with their average market price. Prices of fibres obtained from crops grown in Europe will have to compare and even rival with these values in order to be accepted by potential users.

TABLE 1 Imports of fibres in the European Union - 1997 (source FAO)

	quantity t/year	average price $/t
abaca	15 325	1 450
coir	41 120	421
jute	22 659	483
sisal	45 394	738

FIBRES FOR COMPOSITES IN EUROPE

This study focuses on three types of fibre which can be produced in Europe, one issued from an agricultural residue, i.e. linseed straw (*Linum usitatissimum*) and the other two produced by nonwood plants, i.e. hemp (*Cannabis sativa*) and kenaf (*Hibiscus cannabinus*) (Table 2).

TABLE 2 Present situation of linseed, hemp and kenaf production in the EU

	acreage ha/y	tonnage t/y	yield of raw material t/ha
linseed straw	252 284	from 378 426 to 630 710 (potential)	1.5 - 2.5
hemp	22 670	from 226 700 to 340 050	10 - 15
kenaf	only experimental fields	non relevant	8 - 12

The three plants require different growing conditions and have different harvesting time (Table 3).

TABLE 3 Growing and harvesting season for flax, hemp and kenaf in Europe

	planting	harvesting	better adapted to
linseed straw	March/April or October	June/July	northern Europe
hemp	March/April	August/September	northern and southern Europe
kenaf	April/May	September or after winter frost	southern Europe

PREPARATION OF FIBRES

Previous research [1, 2] demonstrated that when dealing with fibrous nonwoody plants, it is necessary to apply a preliminary dry-mechanical treatment, prior to further processing.

The objectives of the preliminary treatment are:

- to **separate** the different parts of raw material into uniform fractions
- to **concentrate** the fibrous matter
- to **eliminate** foreign substances

Previous research [3] demonstrated also that when the straw or the stalks undergo a retting-like process, then the dry mechanical pre-treatment is more efficiently applied (Table 4). Retting-like process are all those modifications that can be obtained by natural agents (like rain, frost, humidity, fog, sun) when leaving the plants (standing or not) in the field for some time. The retting-like processes are not very specific and controlled as the traditional retting process that is applied to fibre in the textile chain. Nevertheless, they are much more convenient, especially from an economical point of view, when fibres are utilised for a product with lower added value, as in the composite industry.

TABLE 4 The most efficient retting-like and harvesting methods for fibre plants destined to the composite manufacturing chain

crop	retting	harvesting
linseed straw	dew retting	after seed harvesting, crop residues (i.e. the straw) are cut and left in the field for 20-30 days. Afterwards straw is roundbaled
hemp stalks	dew retting	after ripening, and if necessary after seed harvest, stalks are cut and left in the field for 20-30 days. Afterwards they are roundbaled
kenaf stalks	winter retting	stalks are left standing in the field, are frost killed and then are cut and roundbaled (February-March)

Tecnagri prepared the raw material, according to the retting-like and harvesting methods described in Table 4.

Then, the Centro Tecnico Industriale of Istituto Poligrafico e Zecca dello Stato applied the dry mechanical pre-treatment to the samples of linseed straw, kenaf and hemp stalks.

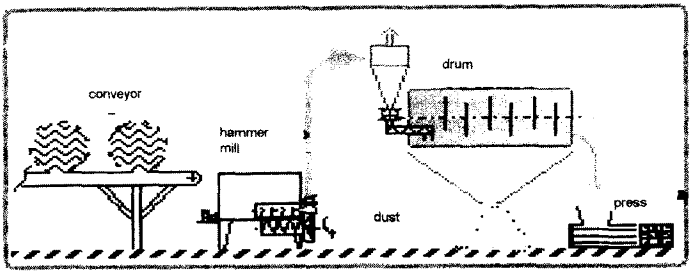

FIGURE 1 Separation and dry-cleaning system for the preparation of plant fibres

Figures 1 and 2 illustrate the dry-mechanical pre-treatment system and the pilot plant in Rome where the trials had been carried out.

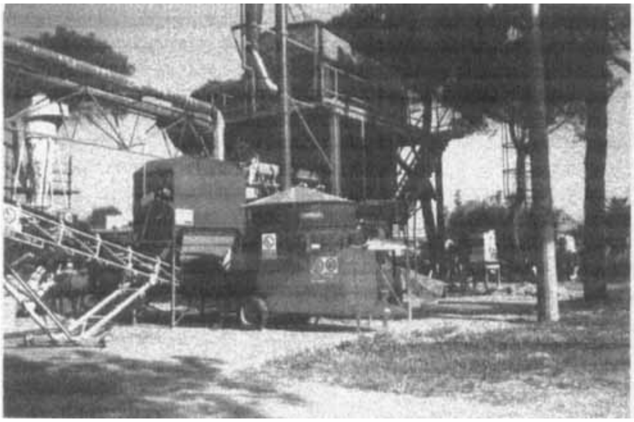

FIGURE 2 Centro Tecnico Industriale IPZS - Roma. Separation and dry-cleaning pilot plant for the preparation of plant fibres

Results of this treatment are shown in Table 5. All trials for the three species were carried out with the same operating conditions. Obviously, improvements in separation and cleaning performances can be obtained by regulating the equipment according to the different plants.

In case bast fibres of shorter length will be requested, it is possible to add another hammer mill to the dry-mechanical treatment system.

TABLE 5 Dry-mechanical pre-treatment results

	linseed straw		hemp stalks		kenaf stalks	
	fraction percentage %	degree of purity %	fraction percentage %	degree of purity %	fraction percentage %	degree of purity %
bast	63	70	28 - 33	88	30 - 35	97 - 99
core	28	99	64 - 68	95	55 - 60	95 - 98
dust	9		6 - 10		2 - 4	

Linseed straw gave the higher percentage of bast, while the dust percentage is almost equivalent for all the plants. Accordingly, the core fraction is higher for the kenaf and the hemp stalks.

Table 5 also shows the pre-treatment efficiency, which is excellent for the kenaf (both for bast and core) and the linseed and hemp core; indeed the purity of these fractions is higher than 95%. On the contrary, the system proved not to be completely satisfactory for the separation of the linseed bast fibre (only 70% purity).

MECHANICAL PROPERTIES OF PLANT FIBRE REINFORCED COMPOSITES: COMPARATIVE RESULTS BETWEEN HEMP, KENAF AND FLAX.

At the BioComposites Centre hemp fibre-reinforced polyester composites were prepared using a Resin Transfer Moulding technique and the flexural and impact properties determined as a function of fibre loading. These hemp composites were then compared with 29% wt kenaf and flax composites prepared in the same conditions.

Experimental

Hemp (*Cannabis sativa*), kenaf and flax fibres were used in the form of nonwoven mats and the samples were moulded with a laboratory Hypaject MK

II model machine (from Plastech, UK) connected to a 500 mm x 300 mm x 3 mm mould. The fibres were equilibrated in a climatic room, at 23 °C and 50% H.R., before moulding. Panels were produced according to an industrial process used for the manufacture of glass fibre-reinforced car parcel shelves. The resin used was the same unsaturated polyester resin Crystic PD9029 (from Scott Bader). This polyester was cured with 2% wt Trigonox 524 (mixture of acetyl acetone peroxide and tert-butyl peroxybenzoate, from Akzo) as catalyst and 0.6% wt of 1% cobalt solution (NL 49 ST, from Akzo) as accelerator. The mould temperature was 30 °C at the beginning of the resin injection which was performed at a pressure of 2 bar, with vacuum assistance. The composites were post-cured for 16 h at 80 °C before testing.

Flexural tests were performed according to BS 2782: Part 10: Method 1005: 1977, using an Instron universal testing machine Model 1195 (50 KN max. capacity), at a crosshead speed of 10 mm per minute. Flexural stress was calculated at rupture. Charpy impact strength of unnotched specimens were calculated according to BS 2782: Part 3: Method 359: 1984, using a Zwick pendulum impact tester

Results

Figures 3-5 represent the flexural and impact properties of hemp fibre-reinforced polyester composites as a function of fibre weight fraction. Properties of 29% wt kenaf and flax composites are also reported.

Error bars represent the mean value ± the maximum standard deviation observed with hemp, kenaf and flax respectively.

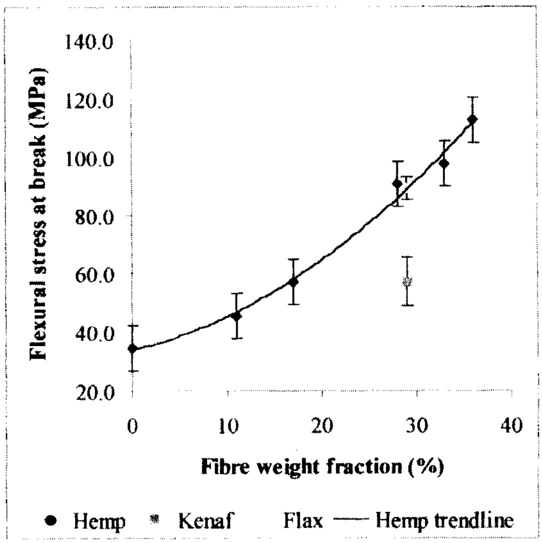

FIGURE 3 Flexural stress at break as a function of fibre weight fraction.

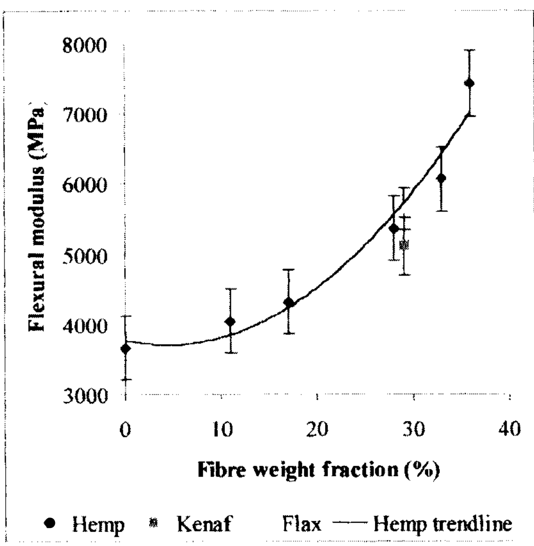

FIGURE 4 Flexural modulus as a function of fibre weight fraction.

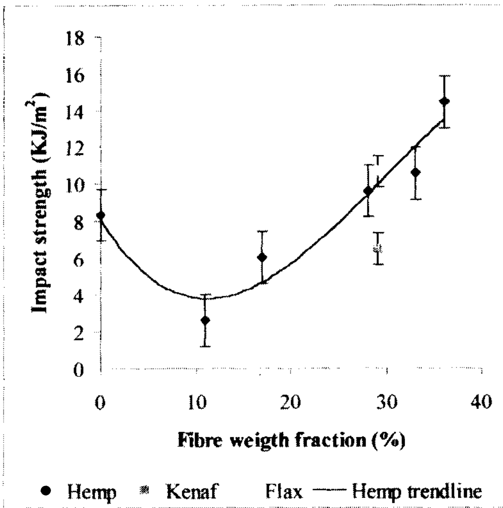

FIGURE 5 Unnotched impact strength as a function of fibre weight fraction.

Hemp and flax composites exhibited similar flexural and impact properties, suggesting a similar reinforcing capacity for both types of fibre. Kenaf however, led to a composite with much lower flexural stress at break and impact strength, the flexural modulus being only inferior.

References

[1] P. Cappelletto, *Kenaf. SIVA's separation system* (European Seminar on Kenaf, Bologna Italy 1995) proceedings.

[2] P. Cappelletto and F. Mongardini, Industrial systems for preparation of cellulose fibers: IPZS experience (Flax and other bast plants Symposium. Non-Textile Applications, Poznan Poland 1997) proceedings.

[3] P. Cappelletto, F. Mongardini, M. Sannibale, M. Brizzi and P. Pasini, Mechanical treatment of field retted oilseed flax and hemp. Resulting fibers can restore recycled fibers quality (1st Nordic Conference on Flax and Hemp Processing (NORDFLAX), Tampere Finland 1998) proceedings, page. 127–140.