Progress Report

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TASK 2.4 RAW MATERIALS CHARACTERISTICS OF FIBRE PLANTS IN EUROPE

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I. Executive Summary

The project 4 F CROPS deals with crops for food, feed, fibre and fuel. The project is coordinated by Dr. Eftinia Alexopoulouů (CRES), Greece. At the Institute of Natural Fibres and Medicinal Plants work on the project is coordinated by Prof. Dr. Ryszard M. Kozlowski and Eng. Maria Mackiewicz-Talarczyk.
The main aim of the 4F CROPS project is to survey and analyze all the parameters that will play an important role in successful non-food cropping systems in the agriculture of EU27 alongside the existing food crop systems.

The main aim of the work within task 2.4 Raw materials characteristics was to evaluate the physical, chemical, mechanical properties and quality parameters of bast fibrous plants (flax, industrial hemp) as a raw material for the specific semi-finished or final products.

It provides the base for categorization of those crops per end-use, for each end use of bast fibrous plants the favourable characteristics has been listed. It allows for prioritizing crops according to the degree of fulfilling.

Presented results have been sourced mainly from the results of many years research of the Institute of Natural Fibres as well are based on our previous involvement in the European Commission project IENICA.
The reason for this work is that the natural raw material characteristics vary widely in terms of physical and chemical composition, size, shape, moisture content, bulk density, fibres length, etc. These variations can make it difficult (or costly) to supply the relevant industries with material of consistent quality year round. The proper and complete characteristic of the raw materials such as straw, fibre, yarn for specific semi-finished and finished products should provide the background enabling the supply of the relevant industries with material of consistent and appropriate quality year round.

II. Background

The main objectives of the 4F CROPS Future Crops for Food, Feed, Fibre and Fuel project:

- Review of the agricultural land uses in EU27 and the prediction in short (2020) and longer terms (2030),

- Mapping of cropping possibilities
- Comparative cost analysis of the food and non-food crops
- Evaluation of the most important environmental criteria
- Record of the existing policies and the driving forces in the future crops
- Development of scenarios for promising non-food cropping alongside food cropping systems, by defining systems' boundaries and evaluating the priorities and trends, in short and long time frameworks.

Introduction

The report describes the raw materials characteristic for fibrous plants such as flax and industrial hemp.

The quality of fibre for industrial purposes depends on several factors, which are directly connected with the quality of fibrous straw. The features of the straw, which determine the classification to a certain quality grade and are influencing the quality and the yield of the derivative fibre, are: length, thickness, colour, healthiness and posture. These features are the base for the quality graduation of the flax straw described in Polish standard

PN–P–80103:1006 "Fibrous Flax Straw". The other countries, where the requirements regarding flax straw quality are enclosed in the relevant standards are: Russia, Belarus, Ukraine, and The Czech Republic.

The properties and qualities of vegetable fibres, including flax and hemp are mostly genetically determined. Hence the strongest influence of the farmer on the fibre quality can be only by selection of cultivars offering best yield parameters. Nevertheless, there are also environmental and agro-technological factors that may improve or worsen the potential offered by that cultivar. They are: selection of the preceding crop and soil, sowing date, fertilisation, post–emergence treatment, time of harvest, etc. The most important effect of the farmer on the quality of the straw (and fibre) begins when straw is swathed for dew retting. It is the responsibility of the farmer to monitor and chose the right moment (green-yellow maturity of straw <in case of flax>) to pull the straw and start the process of retting and turn the straw as well as to stop the retting (by drying and taking it out from the field) in proper time.

The most important elements of the flax and hemp agronomy practices are presented below.

It is very important to apply zink sulphate in the blend of chemical fertilizers, which guarantee the straight straw.

(Source: Elaborated by the Institute of Natural Fibres, Poznan, Poland for IENICA project, 2002)

I. THE GOOD AGRONOMY PRACTICES FOR FLAX AND HEMP

Flax for fibre production *Linum usitatissimum* L.	***Hemp for fibre and seed production*** *Cannabis sativa* L.
Crop rotation: any crop leaving the soil in good culture; minimum 6–year break before growing on the same spot. **Seed size**: length 3,0–4,9 mm, width 1,8-2,6 mm, thickness 0,5-1,0 mm. **Thousand seed weight: 4,1–5,5 g** **Seeding rates**: 110–130 kg ha^{-1} (2000-2400 seeds m^{-2}) **Sowing dates**: soil temperature: 7–9 ^oC (plants: *Caltha palustris* and *Anemone nemorosa* are in flowers) **Fertiliser status**: N: 0–20 kg/ha P_2O_5: 60 kg/ha K_2O: 80–90 kg/ha $ZnSO_4$:10-15 kg/ha **Herbicides status:** pre- emergence herbicides: *lenacil* , *linuron* post-emergence herbicides: for broadleaved weed control: *MCPA, bentazone, chlorsulfuron, thifensulfuron methyl +chlorsylfuron, chlopyralid + MCPA* for graminaceous weed control: *dichlofop-methyl, fluazyfop-P-butyl, setoxidim, haloksyfop-R, chizalofop-P-ethyl*, **Insecticides status:**	**Crop rotation:** no particular requirements, even monoculture possible. **Seed size**: length 2,0–5,0 mm, width 2,0–4,0 mm, thickness 2,3–2,8mm. Thousand seed weight: 10–26 g **Seeding rates**: -for seed production 10–15 kg/ha -for fibre production 70 kg/ha **Sowing dates**: soil temperature: 8–10 ^oC **Fertiliser status**: N: 90–120 kg/ha P_2O_5: 70–100 kg/ha K_2O: 150–180 kg/ha **Herbicides status:** Highly susceptible to most herbicides; if necessary, some *linuron*-based herbicides can be used carefully prior emergence of hemp. Generally no herbicides required (high competitiveness to weeds) graminaceous weed control: **Insecticides status:**

- <u>for control of *Longitarsus parvulus* Payk. and *Aphtona euphorbiae* Schr.</u> Seed dressing: *carbofuran*, Post-emergence insecticides: *lambda- cyhalotryna* for *Trips lini* Lad. Control: Post-emergence insecticides: *lambda- cyhalotryna*	No particular pest problems in North and East Europe and Poland, depending on needs.
Plant growth regulators status: maturity regulators: *dimetipin* **Fungicides status:** <u>-for Fusarium wilt control:</u> for seed dressing: *thiram, carboxin, guazatine, metalaxyl, thiabendazol, vinclozolin* for flax spraying: *flutriafol, thiram, carbendazin, kaptafol, azoxystrobin* <u>- for *Colletotrichum lini* control:</u> for seed dressing: *carboxin, thiram* <u>- for *Rhizoctonia solani* Kűhn control:</u> for seed dressing: *carboxin, thiuram, mancozeb, talchlofos-methyl*	**Plant growth regulators status:** not used **Fungicides status:** not used
Harvest dates **Pulling**: beginning of the green- yellow maturity Collecting of dew-retted straw after reaching proper stage of retting.	**Harvest dates**: Seeds: full seed maturity in the middle part of the panicle – end of September High quality fibre: mowing in beginning of flowering stage. or left for dew retting. Collecting of dew–retted straw after reaching proper stage of retting. Decorticated straw: depending on needs. The later harvest the higher yield and the coarser fibre.

Source: Elaborated by the Institute of Natural Fibres, Poznan, Poland for IENICA project, 2002

II. THE EXPECTATIONS OF INDUSTRY REGARDING FLAX AND HEMP FIBRE QUALITY

Industry processing the fibres demands homogeneous and good quality raw material. The expectations regarding flax and hemp fibre quality features depend on the final destination of fibre:

STRAW SPECIFICATIONS (acc. Polish standard: PN–P–80096:1999)

Flax

The straw must be evened in the root part and arranged parallel in bundles of at least 2 kg (retted) or 2.5–4.0 kg (raw). Bundles should be bond with natural fibre string or flax straw. Retted straw can also be baled; raw straw – not. The thickness of the straw stems should be around 0,8mm.
The most important from the farmer point of view is the colour of the straw as it has direct effect on the quality of fibre. The light – grey, steel-grey and silver – grey colours of straw are demanded (at least for 70% of stems). For raw straw the colour must be yellow (at least 65% of stems).

Feature of straw	Retted straw	Raw straw
Technical length [cm]	at least 43 cm, but for the first class straw it has to be at least 60 cm.	at least 43 cm, but for the first class straw it has to be at least 60 cm.
Posture [%]	Straight stems at least 70%	Straight stems at least 70%
Degree of retting [%]	well–retted stems content should be at least 60% but not less than 90% for the first class straw.	not relevant
Health condition	Over 80% of stems has to be healthy	Over 80% of stems has to be healthy
Moisture content	not more that 18%	not more that 20%
Impurities content	not more 15%, of which weeds are not more than 10%	not more 20%, of which weeds are not more than 15%

Source: Polish standard: PN–P–80103:1996

Hemp

For hemp dew-retted straw steel-grey, silver-grey and light-grey, colours of straw are preferred, however also brown-grey, dark-grey and green-grey colours are acceptable for lower classes (at least for 70% of stems). For raw straw the colour must be light yellow, dark yellow and green–yellow, however also light green, light brown, light grey (at least 65% of stems) and dark green and dark–grey straw is also acceptable for lower classes.

Feature of straw	Retted straw	Raw straw
Total length [cm]	at least 80 cm, but for the higher classes straw it has to be 110-130 cm.	at least 80 cm, but for the higher classes straw it has to be 110-130 cm.
Degree of retting [%]	well retted stems content should be 90% for the first class straw for clothing textiles and 80% for second class. Under-retted stems content should not be higher than 70% for cordage.	not relevant
Health condition	Over 90% 80% and 70% of stems has to	Over 90% 80% and 70% of

	be healthy for 1st, 2nd and 3rd second class straw.	stems has to be healthy for 1st, 2nd and 3rd second class straw.
Stem thickness [mm]	4–6, 4–8 and 3–12 for 1st, 2nd and 3rd second class straw (clothing) 3–6, 3–8, 3–12 for cordage	4–6, 4–8 and 3–12
Moisture content	not more that 20%	not more that 20%
Impurities content	not more than 15%	not more than 15%

Source: Elaborated by the Institute of Natural Fibres, Poznan, Poland for IENICA project, 2002

Main directions of utilization of raw materials obtained from flax and hemp.

1. Flax and hemp long fibres:

a) hackled fibres for yarns for wet and dry spinning

2. Flax and hemp short fibres:

a) for carded yarns,

b) for "wool-like" yarns,

c) for "cotton-like' yarns,

d) for twines,

e) flax and hemp green fibre (decorticated)

f) for non-woven.

3. Flax shives and hemp hurds (shives)/ by products

Hackled long flax fibre for yarns for wet and dry spinning

Long flax scutched fibre is usually being mechanically hackled. The hackling process leads to separation of two products: the long fibre and short fibre – the hackling noils.

Long flax hackled fibre can be used for traditional flax wet or dry spinning system. Wet spinning system, including boiling process in roving is used for finer yarns.

In dry spinning system hackled yarns of higher linear density can be obtained.

Table 1. Basic parameters of long flax scutched and hackled fibre.

Raw material	Fibre length [mm]	Fibre linear mass [tex]
Long flax scutched fibre	300-1400	4.0-6.0
Long flax hackled fibre	350-700	1.4-3.3

* source: INF research

Table 2. Basic parameters of yarns obtained from long flax hackled fibre (the examples of the yarns which are most often produced)

Parameter	Unit	Value
Wet-spun hackled yarn (Nm18)	tex	60
Specific t**enacity**	cN/tex	18
Number variability coefficient	%	3
Tenacity variability coefficient	%	12

* source: INF research

Hackled long hemp fibre used for yarns

<u>*Long hemp scutched fibre.*</u> Prior mechanical hackling the top and especially bottom ends of hemp fibre must be cut off and its length must be shortened to fit the hackling machine.

The process yields hackled fibre and to types of by-products: noils and short fibre called „ends" (cut-off ends of scutched fibre).

<u>*Long hemp scutched fibre*</u> can be used usually for dry spinning to produce dry-spun yarns with relatively high linear density. Hackled hemp fibre of high quality are wet-spun (sometimes including a roving boiling process).

Table 3. Basic parameters of scutched and hackled hemp fibre.

Raw material	Fibre length [mm]	Fibre linear mass [tex]
Long hemp scutched fibre	800-2500	8.0-12.0
Long hemp hackled fibre	350-800	3.0-5.0

* source: INF research

Table 4. Basic parameters of yarns obtained from long hemp hackled fibre (the examples of the yarns which are most often produced)

Parameter	**Unit**	**Value**
Ns 8 Yarn	tex	200
Specific **Tenacity**	cN/tex	12
Number variability coefficient	%	4
Tenacity variability coefficient	%	12

* source: INF research

Flax short fibre for spinning carded yarns

Flax short fibre: scutching and tangled noils and tow are processed by wet carding system (also including application of roving boiling and bleaching) and by dry carding system. Linear density of carded yarn varies upon the quality of fibre and used spinning system.

Table 5. Basic parameters of flax tow.

Raw material	**Fibre length [mm]**	**Fibre linear mass [tex]**
Scutching tow	80-140	3.5-5.5
Tangled tow	140-250	4.5-6.5

* source: INF research

Short hemp fibre for carded yarns.

Fibre should: show no sign of damage, be uniformed, sorted out for the class, baled and cleaned. The moisture content should not be higher than 15%.

Table 6. Basic parameters of hemp tow.

Raw material	Fibre length [mm]	Fibre linear mass [tex]
Scutching tow	250-400	8.0-10.0
Tangled tow	200-400	9.0-12.0

* source: INF research

Flax homomorphic "wool-like" fibre for blended yarn manufacture.

Main raw material for flax "wool-like" fibre is a homomorphic dew-retted flax fibre obtained from processing of straw dew-retted in the field, that was pulled out early.

A substitute of the above can be short hackling noils obtained from mechanical scutching of long dew-retted fibre.

Flax "wool-like" fibre should show the following basic quality parameters:

- average length of fibres about 60-90 mm,
- max. divisibility 2.3 tex
- max. impurities content 0.4 %
- max. length of fibres 130 mm at content of longer fibres max. 5%,
- average thickness of fibres 40-50 µm.

Table 7. Characteristic of "wool-like" flax fibre.

Raw material	**Parameters**		**Blend**	**Yarn [tex]**
	Linear mass [tex]	Length [mm]		
Mechanically cottonised "wool-like" fibre for blended yarn with wool	0.61-0.98	90	L30/W40/An30	64x2
			L30/W30/Arg30	40x2
	1.5-2.5	94	L30/W40/30PAN	42x2
			L30/Wis30/PAN40	
			L15/85PAN	32x2

* source: INF research

Hemp "wool-like" fibre for the production of blended yarns

Hemp "wool-like" fibre should show the following basic quality parameters:

- average length of fibres 100-250 mm,
- average linear density 6.0-8.0 tex.

Table 8. Characteristic of hemp "wool-like" fibre .

Raw material	Hemp grown for fibre		Hemp grown for fibre and seed	
	Linear mass of fibres [tex]	Length [mm]	Linear mass of fibres [tex]	Length [mm]
Mechanically cottonised hemp "wool-like" fibre	2.12-2.78	58.8-69.4	3.47-4.46	53.6-62.5

* source: INF research

Flax "cotton-like" fibre for blended yarn.

Flax noils of quality class 170-120 tex (Ns10-14) obtained from mechanical hackling of scutched fibre are the best raw material for production of flax "cotton-like" fibre. Also so called homomorphic fibre obtained from dew-retted flax straw and scutching waste fibre meeting certain technological parameters can be used for production of flax "cotton-like" fibre as well. All kinds of fibre for this purpose should be mechanically or mechanically-chemically treated to meet the requirements relevant for the technological conditions of blended yarns manufacture.

Uniformity and quality of fibre (regarding length, thickness of fibre and impurities content) are crucial for production of flax "cottonised fibre".

Table 9. Laboratory tests of "cotton-like" flax fibre.

Length class interval fibre share [mm]					Color	Impurities [%]	Fibre Tenacity [daN]
0-20	21-40	41-60	> 60	Mean			
21.1	69.2	9.7	-	30.7	Steel-gray	0.2	9.0

* source: INF research

Table 10. Parameters of "wool-like" cottonised flax fibre for the production of blended yarns.

Raw material	Linear mass [tex]	Length [mm]
Mechanically cottonised "cotton-like" fibre	0.7-2.0	18-35
	1.2-2.0	18-35
	1.11-1.98	13.4-31.8

* source: INF research

Flax cottonised "cotton-like" fibre can be spun in blend together with 30-70 % of flax or viscose or polyester yarns at linear density 30, 40, 50, 60 and 80 tex.

Table 11. Quality parameters of cotton-flax yarns with 54% of linen cottonised fibre

Nominal linear mass of yarn [tex]	Laboratory parameters				
	Real linear mass of yarn [tex]	Coefficient of variation of Linear mass [%]	Tenacity [CN/tex]	Coefficient of tenacity variability. [%]	Twist factor
40	41.8-42.6	3.1-5.2	8.5-9.2	10.0-15.1	171-186
50	50.5-52.6	3.3-5.2	7.4-8.8	12.3-15.6	149-164
60	59.8-61.3	2.9-4.5	7.5-9.5	9.8-17.2	159-184
80	81.4	2.8	9.6	12.4	176
100	102.0	5.3	10.1	10.9	143

* source: INF research

Hemp fibre "cotton-like" for the production of blended yarns (on cotton system spinning)

Hemp fibre of diversified kinds, such as hemp noils, hemp tow or homomorphic hemp fibre could be a raw material for the production of cottonised hemp fibre.

The most appropriate raw material for the production of cottonised hemp fibre is hemp from the cultivation for fibre. Hemp grown for seed or for both purposes (fibre and seed), is not suitable for production of cottonised fibre. Hemp grown specifically for the fibre is sowing at much higher densities and harvested much earlier (in flowering phase), resulting in much finer fibre than that obtained from hemp grown for seed or for fibre and seed.

It prevents obtaining excessive amounts of thick straw and lignin. Lignin in hemp fibre decreases the spinning abilities, fibre with high amount of lignin is usually less divisible, more rigid and coarse. Hemp for fibre and seed is usually cultivated for economic reasons. The long scutched hemp fibre is hackled. The hackling process provides long hackled fibre as well as short by-product fibres (noils).

The long hackled fibre is processed into hackled yarn by dry-spun system while hemp noils blended with short flax fibre are the raw material for the carded yarn.

The hemp cottonised fibre is obtained on the following machines:

- tearing – cleaning machine
- cottonising– cleaning machine arranged in a production line.

Table 12. Parameters of hemp “cotton-like” fibre.

Raw material	**Cultivation for fibre, early harvest**		**Cultivation for fibre and seed**	
	Linear mass [tex]	**Length [mm]**	**Linear mass [tex]**	**Length [mm]**
mechanical cottonised „cotton-like”fibre	1.76-2.15	28.42	3.1-3.25	34
chemical cottonised „cotton-like” fibre	1.5-1.76	32-43	2.66-3.74	37.4

* source: INF research

The procedures to obtain more delicate hemp fibre:

- it is advisable to cultivate dioecious hemp versus monoecious
- dioecious hemp cultivation combined with earlier harvesting

Table 13. Sampling of hemp straw from the plantation in different growth phases (aim-to evaluate the % fibre content).

	Monoecious hemp									Dioecious hemp								
No	Harvest	Straw length [mm]		Thickness [mm]	Fibre content [%]			Nm –metric number of fibre [tex]		Harvest	Straw length [mm]		Thickness [mm]	Fibre content [%]			Nm –metric number of fibre [tex]	
	Growth phase	techn.	total		long	short	total	long	short	Growth phase	techn.	total		long	short	total	long	short
1	12.VI Phase of quick growth	68.0	85.0	3.2	6.1	7.7	13.8	170	1000	12.VI Phase of quick growth	44.0	59.0	2.8	2.7	1.6	4.3	140	1000
2	4.VII Flower buds forming (Inflorescence emergence)	140.0	160.0	5.1	13.2	8.1	21.3	200	2000	4.VII Phase of quick growth	130.0	150.0	6.5	9.3	3.8	13.1	170	1000
3	5.VIII Flowering	200.0	240.0	6.7	14.6	8.0	22.6	200	2000	5.VIII Flower buds forming (Inflorescence emergence)	220.0	260.0	7.2	9.6	7.4	17.0	170	2000
4	4.IX Early maturity of seed	210.0	250.0	7.5	19.7	12.1	31.8	200	3000	4.IX Flowering	250.0	290.0	8.8	9.7	8.1	17.8	200	2000
5	1.X Full maturity of seed	210.0	250.0	7.5	22.2	13.6	35.8	280	3000	1.X Coacere ripeness	250.0	290.0	9.2	10.8	5.0	15.8	200	2000

Source: The INF trials

Such method of hemp fibre production is seldom applied, due to lower yields of obtained fibre. In the common practice the monoecious varieties are sown and harvested later aiming at gaining high biomass production.

Green fibre (decorticated)

The raw material for the production of decorticated fibre is the straw, obtained from the following plantations:

- for seed and fibre production,
- linseed (oilseed), where the straw contains low quality fibre,

Plantations of fibre flax – where fibre is not appropriate for the spinning processing:

- plantations with high level of flax infestation by weeds,
- plantations for seed production,
- high level of flax lodging,
- plants strongly infected by diseases,
- plantations with short and under-retted straw.

Quality parameters of fibre, especially its length over 15 mm, as well as the chemical content predisposes such fibre as a good raw material to production of long-fibre cellulosic mass, applied for the production of high quality papers as well as the filler in composite materials.

Table 14. Parameters of decorticated fibre

Parameters of fibre	After decortication	After cleaning
Average impurities in fibre	20-25%	4-5%
Average length of decorticated fibre	58.9 mm	48.5 mm
Average **tenacity** of fibre	33.4 cN/tex	22.5 cN/tex

* source: INF research

The green hemp fibre - obtained from not-retted straw, decorticated for twines applied in agriculture.

The fibre production is based on the decortication of monoecious hemp derived from plantation cultivated for fibre .

Stems that are 4.5 – 6 mm in diameter, without tops and with moisture content between 15-18% are used for twines. The optimal results for twine production were obtained when moisture content hemp stems was 17%.

Table 15. The parameters of fibres applied for twines and nonwovens

Parameters	**Value**
Flax fibre-tow	
Length	100-400 mm
Impurities	5-40%
Divisibility	5-20 tex
Tenacity	5-9 cN/tex
Decorticated hemp fibre	
Length	100-500 mm
Impurities	4-25%
Divisibility	10-30 tex
Tenacity	10-35 cN/tex

* source: INF research

Short flax fibre is mixed with short hemp fibre for the production of twines and nonwoven in the proportion:

- short flax fibre 60-80 %
- short hemp fibre 20-40%

Flax and hemp fibre, applied for nonwovens production:

Fibres applied for the production of nonwovens are obtained mainly during decortication process of green hemp straw, sometimes of the linseed straw.

Such fibres are strong,durable and resilient. This is necessary to get appropriate resistance of nonwovens to elongation, while the **resiliency** enables the recovery to the original size.

The flax and hemp tow of the worse quality is suitable and applied for the production of the disinfection mats on the base of natural fibres. (Tab. 15).

The application of flax fibres in production of non–woven is connected with the adaptation to non–linen spinning systems, namely with the need of the following operations: cleaning, dividing, and shortening of fibres. The application of the appropriate blends of fibres enables their processing into non–woven with the application of traditional non–woven lines.

The production of non-woven exclusively of short flax fibres requires the application of special carding machine. It is possible to utilise green decorticated, even not clean fibre or the short fibre wastes for the production of geo–textiles e.g. grass carpets and non–woven applied in the building and furniture industries, for insulation purposes.

Flax and hemp fibres for the production of composites

The detailed requirements regarding the features of fibres for the composite production are: high cleanness and homogeneity. In some cases the fibre has to be modified and treated: by plasma/corona physical treatment or by using chemical treatment (e.g. for changing high hydrophylic to hydrophobic properties by coupling the maleic anhydrite)

The quality requirements focus mainly on very low impurity content that should be below 0,2 %. The fibres from 1 mm up to more than 10 cm of length can be used. In some cases the special forming of fibres is required, which is conducted by the pulltrusion method. However, this field of fibres application is still in the stage of research in several R&D centres and object of know-how and patents protecting the method. The Institute of Natural Fibres has got relevant know–how in this area as well.

In some cases the chemical modification should be involved, but this it is also the subject of know-how and licences. (Source: Report elaborated by the Institute of Natural Fibres, Poznan, Poland for IENICA project, 2002)

Flax and hemp fibres for the production of pulp and paper

The requirements for flax and hemp fibre in pulp and paper industry are limited to the length – maximum 50 mm and purity – maximum 5%.(Source: Report? elaborated by the Institute of Natural Fibres, Poznan, Poland for IENICA project, 2002)

The directions of utilization of flax and hemp shives.

The waste material (shives) coming from the extraction of flax and hemp fibre could be applied as: bedding material for animals. The shives obtained from the processing are contaminated by dust and silica.

- The utilization as a bedding material requires removal of short fibre and dust, because fibre impurities cause conglomerates of shives,

- For mushrooms cultivation after grinding

- The building materials (according to applied technology the shives should be submitted to grinding.

Table 16. The parameters of hemp shives for the "building boards"

Parameters	**Value**
Humidity [%]	10-13
Weight density [kg/m^3]	90-100
Water retention [%]	360
Volume of particles [mm]	5-35
Fibre content [%]	< 0.1

- Source: Lhoist, Belgium

For particle boards production generally urea formaldehyde, resin, isocianate as well as lime and Portland cement are used (Lhoist).

- <u>for solid fuel</u>

The utilization of flax and hemp shives for solid fuel e.g. in the briquettes production requires cleaning process to remove short fibres and silica. The silica causes quicker wearing-off the working parts of the briquetting machine adapted to briquetting of flax and hemp shives, while the short fibres decrease the stability of the briquettes especially during transportation.

Table 17. The energetic value of the shives

Raw material	**Value**
Flax shives	18.3 MJ/kg
Hemp shives	18.8 MJ/kg

* source: INF research

- <u>fillers in composite materials,</u>

The requirements: grinding of shives. The lignocellulosic raw materials are submitted to the breaking process according to the kind of final application in composite materials (fractions from 0.2 to 2 mm). Generally the requested humidity of shives is below 10% to maintain the proper technology conditions and to avoid biodeterioration.

Summing up

Healthy apparels, bedlinen, upholstery, non-woven, geotextiles, cellulose, composites, agro-fine chemicals, shives for animal bedding, can be produced from bast fibrous plants – flax and hemp, kenaf.

These fibrous resources are unique sources of fibre for North and East Europe. They are fully sustainable and easy to recycle. The challenges and obstacles are: the high competition of man-made fibres and often inadequate stage in technology development in scope of extracting and processing. The economic competition and high cost of investment in new technologies are the reason of the limitation in the development and growth.