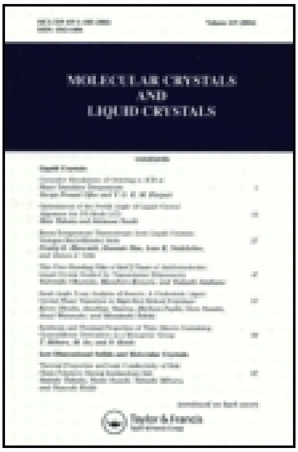

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Future of Natural Fibers, Their Coexistence and Competition with Man-Made Fibers in 21st Century

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Natural fibers are very important and very useful fibers which compete and coexist together with man-made fibers especially in area of quality, sustainability and economy of their production. In this paper we present the level of production (35–40 million tons/year) contra man made fibres and special treatment of them like enzymatic, liquid ammonia, plasma, corona, and ultra sound. Natural fibres are characterised by air permeability, hygroscopicity and capability of giving up moisture, no release of substances harmful for health, no allergic effect, biodegrability and safer behaviour in fire conditions in comparison to man-made fibers.

Natural fibers conduct heat, can be dyed well, resist mildew and have natural antibacterial properties, block UV and are easy to make them flame retardant.

Genetic modification of lignocellulosic fibrous raw materials improve their performance and giving possibilites to obtain polyhydroxy-alcanate (PHA) "in statu nascendi" in plant. For this reason, United Nations and FAO declared the year 2009 the International Year of Natural Fibres.

In the 21st century there is a growing awareness about the future of renewable, sustainable and biodegradable fibrous materials.

Keywords Lignocellulosic; man-made fibers; natural fibers; polyhydroksybutyrate (PHB); protein fibers

Introduction

Nature in its abundance offers us a lot of materials that can be called fibrous. Plants of this structure grow at every geographical latitude. Various parts of these lignocellulosic plants, like woody core, bast, leaf, cane, straw, grass and seed are sources of valuable lignocellulosic fibers suitable for use not only in textile but also in building materials as a source of biopolymers, source of human food and animal feed and also agro-fine chemicals,

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friendly cosmetics and energy [1,2]. They are totally renewable and biodegradable. The natural fibers are very important and well known for mankind since about 7000 BC. Production of these fibers generally does not damage an ecosystem; they can grow in different climatic zones and recycle the carbon dioxide (CO_2). Some of the natural fibers e.g. bast fibrous plants could be applied for cleaning soil polluted by heavy metals, thanks to their ability of extracting cadmium (Cd), lead (Pb), copper (Cu) and zinc (Zn) [3,4]. The production of these fibers is expected at the level of 35–40 million tons/year in the middle of this century. This demand should be responded by the rise of cotton production up to 26–30 million tons per year and modification as well as modernisation of other cellulosic and/or natural fibres like bast fibers. Special treatment such as enzymatic, liquid ammonia, plasma and corona, ultra sound provides new promising features and properties of fibers and fabrics [5,6]. Most of the raw materials based on lignocellulosic fibrous plants like flax, jute, hemp, kenaf, sisal, ramie, abaca, curaua, coir, cabuya, pineapple, bamboo and many others can be extracted, processed, modified and used both in textiles (woven, knitting, non woven, technical), as reinforcement of more friendly composites, in area of pulp and paper, agro-fine chemicals and also as a source of energy [1,7,8]. Generally natural fibers are characterized by important properties like air permeability, hygroscopicity and capability of giving up moisture, no release of substances harmful for health, no allergic effect (resulting from higher level of histamine in human blood), biodegrability and safer behaviour in fire conditions in comparison to man-made fibers [2,9,10].

It is also worth to put attention to the newly emerging potential of genetically modified fibrous plants (GM) because of their better performance, e.g. higher level of fiber cellulose in the yields, carbohydrates and possibility to obtain polyhydroxy-alcanate (PHA) for example polyhydroxy butyrate–natural polyester “in statu nascendi”.

GM fibrous plants can be resistant to herbicides and also environmental stress including salinity and drought. In case of bast fibrous plants production the most important are genetic modifications in area of control of lignin and pectin content.

It is being considered to apply GM to increase the biomass of bast plants as well as for higher oil content in plant (using Rubisco promotor for gene expression). The idea of novel fibrous plants containing the nano-fibers is another alternative attracting considerable scientific attention and making it possible to incorporate phosphate groups into cellulose in order to obtain modified cellulose with higher thermal resistance.

Bio-silk, fibers on base of polylactic acid and some other emerging new fibers for example those based on fibroin and chitin are also very interesting things in area of natural fibers. It should be stated that production and application of man-made fibers is also important–we can observe tremendous development of new multifunctional man-made fibers [11].

In 21st century the coexistence and competition between man-made and natural fibers is stabilized, especially in area of quality, sustainability and economy of their production. Natural fibers conduct heat, can be dyed well, resist mildew and have natural antibacterial properties, block UV and are easy to make them flame retardant. This makes them ideal for the production of comfortable healthy clothing that provide UV protection for the body, decrease of oxidative stress and muscle tension, increase of the level of alpha-globulin thus improving the well being of users [5,11].

The facts mentioned above influence the position of natural fibers and stable the level of their production thanks to the growing area of their application, not only in textiles (woven, knitting, non-woven, technical textiles), but also in more eco-friendly composites, agro-fine-chemicals used in nutrients, pharmaceuticals and cosmetics as well as reasonable blends with man-made fibers [1,5,11]. As already mentioned the 21st there is a growing

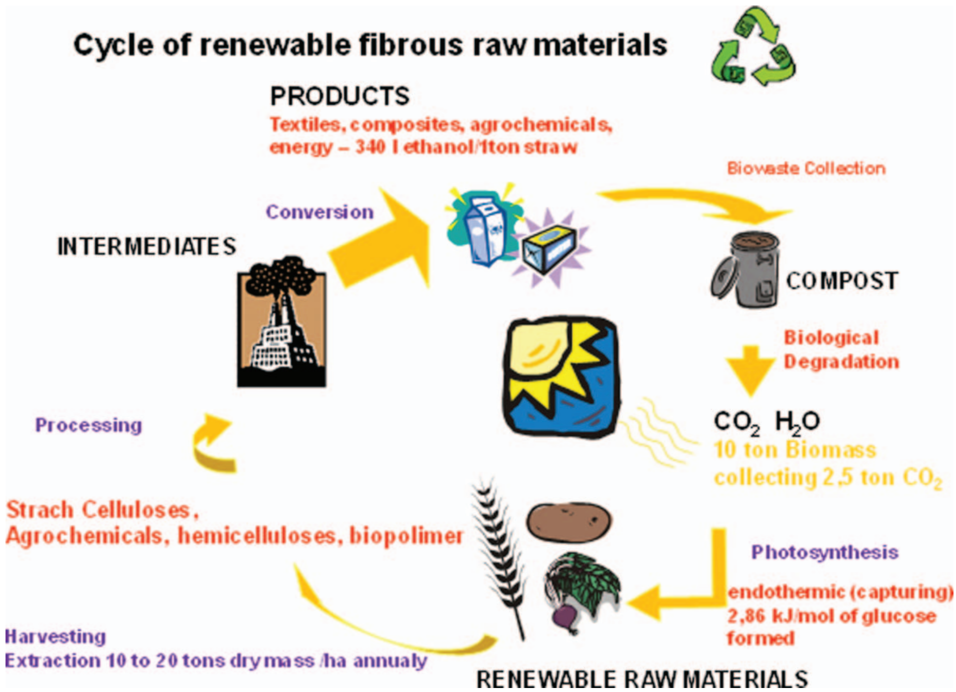


Figure 1. Cycle of renewable fibrous raw materials.

awareness in present century about the future of renewable, sustainable and biodegradable fibrous materials [12].

This paper includes the review of most important natural fibers and their future developments and prospects as well as the competition and coexistence with man-made fibers. From the data presented in this paper we can conclude that there is a stable balance between production and use of natural and man-made fibers. Natural fibers still dominate as a "cover" for human body due to their comfort providing properties and positive physiological effect [10]. Fibrous lignocellulosic and protein materials excellently fit to the Fig. 1 presented below about their production and recycling.

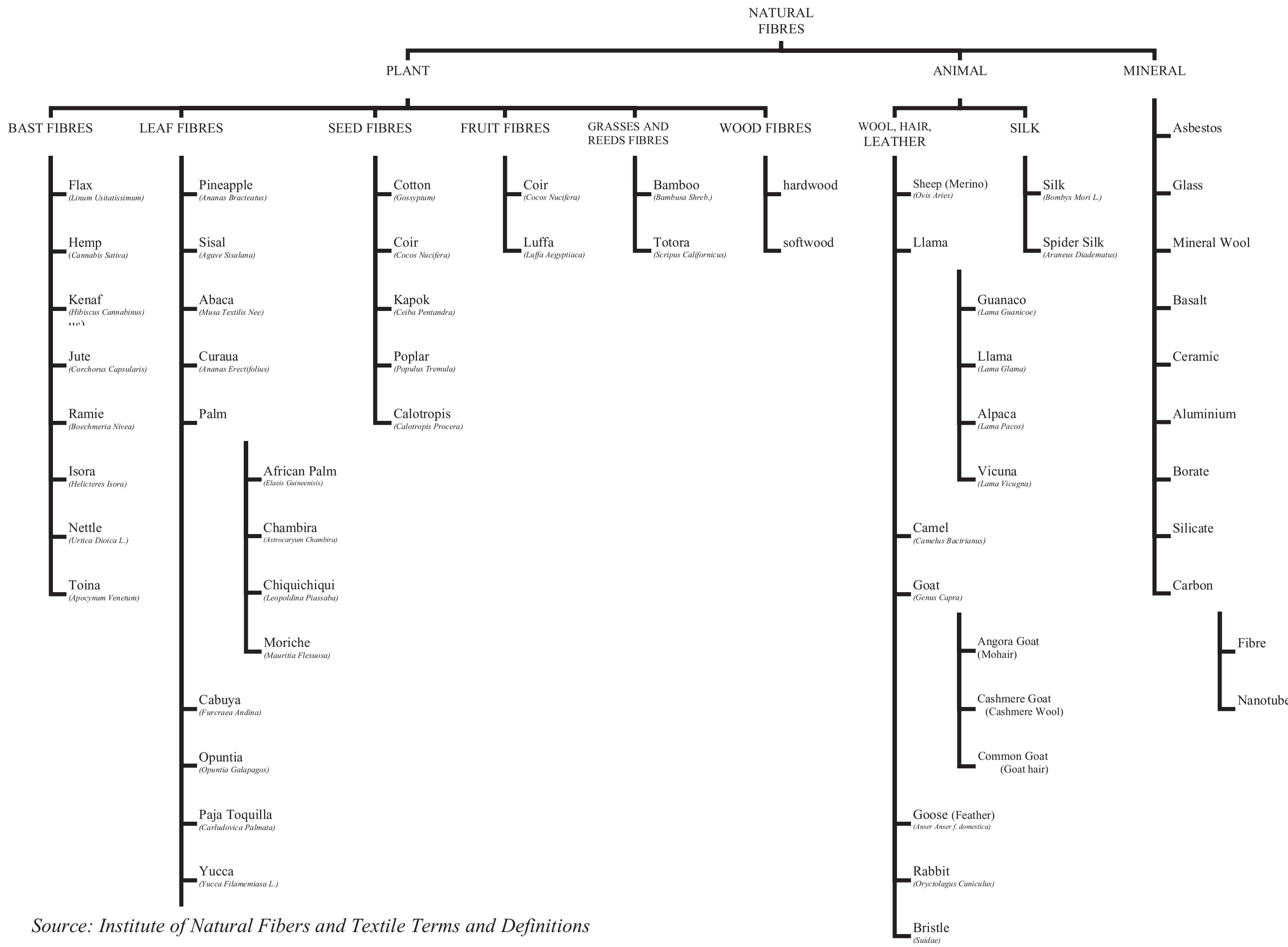
These fibrous materials can be produced around the globe without any damage of ecosystem and they also recycle carbon dioxide. They were discovered by our ancestors more than 8 000 B.C. There are two main groups of these fibers:

A. Lignocellulosic, like cotton, jute, kenaf, flax, ramie, hemp, abaca, sisal, curaua, coir, cabuya, bamboo, pineapple, nettle and many other.
B. Protein fibers such as wool, silk, alpaca, mohair, vicuna, camel, and other.

Classification of Natural Fibres

The classification of natural fibers is presented below in the Fig. 2 [13].

In above mentioned group of natural fibers we can distinguish such fibers as:



Source: Institute of Natural Fibers and Textile Terms and Definitions

Figure 2. The classification of natural fibers.

Plant Fibers

- Bast (flax, hemp, jute, kenaf, ramie etc.),
- Leaf (sisal, abaca, etc.),
- Seeds (cotton, kapok, etc.),
- Fruit (coir, African palm, luffa, etc.),
- Grass (bamboo, totora),
- Wood (hardwood and softwood),

Animal Fibers

- Animal (wool, silk, hair etc.)

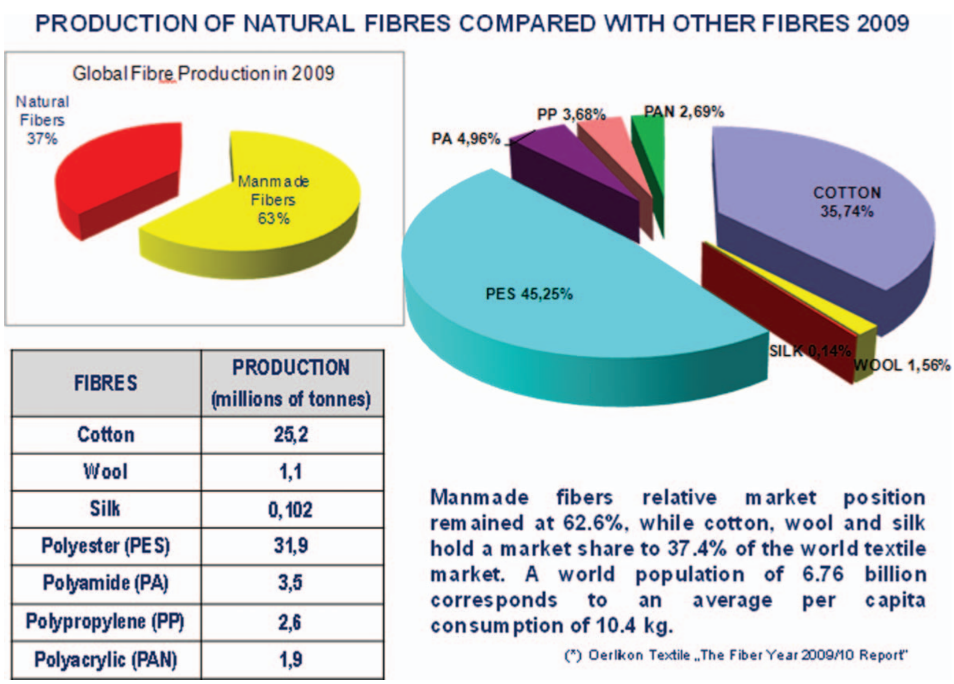
Natural and Man-Made Mineral Fibers

- Asbestos, glass, basalt, etc. [13]

Statistical Data Regarding Fibers in the World

Production of natural fibers in 2009/2010 in comparison to man-made fibers is presented in Fig. 3 [14,15].

Cotton is the major player in the world market of natural fibers. Cotton was recognized for the first time by Herodotus in 445 B.C.–he announced that in India there are "growing tree which fruit of them consist a wood exciding in beauty and goodness that of sheep". Indians were making their clothes of this "free wool". Cotton was also recognized by



FIBRES	PRODUCTION (millions of tonnes)
Cotton	25,2
Wool	1,1
Silk	0,102
Polyester (PES)	31,9
Polyamide (PA)	3,5
Polypropylene (PP)	2,6
Polyacrylic (PAN)	1,9

Figure 3. Production of natural fibers in 2009/2010 in comparison to man-made fibers.

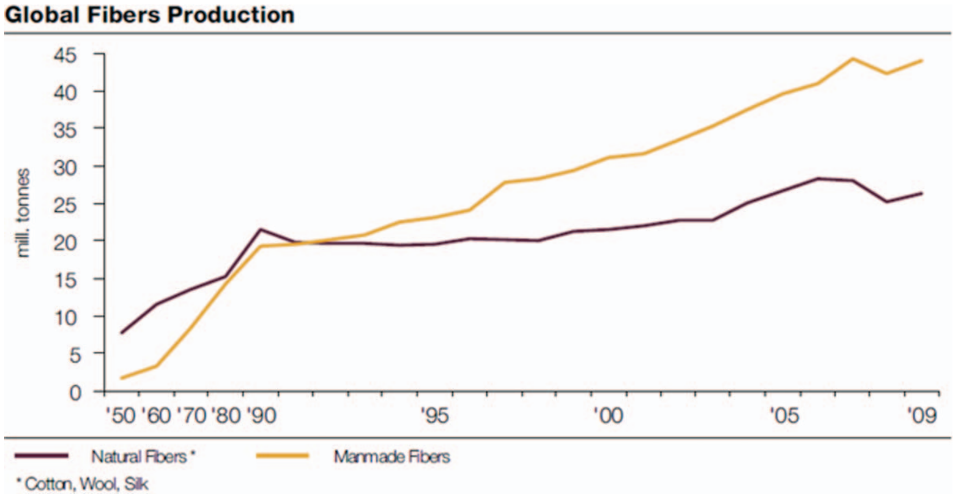


Figure 4. Global natural fibers production in 2009/2010 in comparison to man-made fibers.

Alexander the Great after invasion of India. In America cotton was known by Peruvian Indians as a Pima cotton. In Europe carrier of American cotton began at the end of 18th century, replacing the flax and hemp as dominant fibers at that time [15].

Global fiber production from 1950, 1960, 1970, and 1980 up to 2009 is presented in Fig. 4.

Now man-made fibers relative market position remained at 62.6%, while cotton, wool and silk hold a market share to 37.4% of the world textile market. A world population of 6.76 billion corresponds to an average per capita consumption of 10.4 kg [15].

Figure 5 presents the world fiber supply [15].

The global supply of man-made fibers and major natural fibers has increased from 52.6 million tons in 2000 to 70.5 million tons last year (2009). This corresponds to an

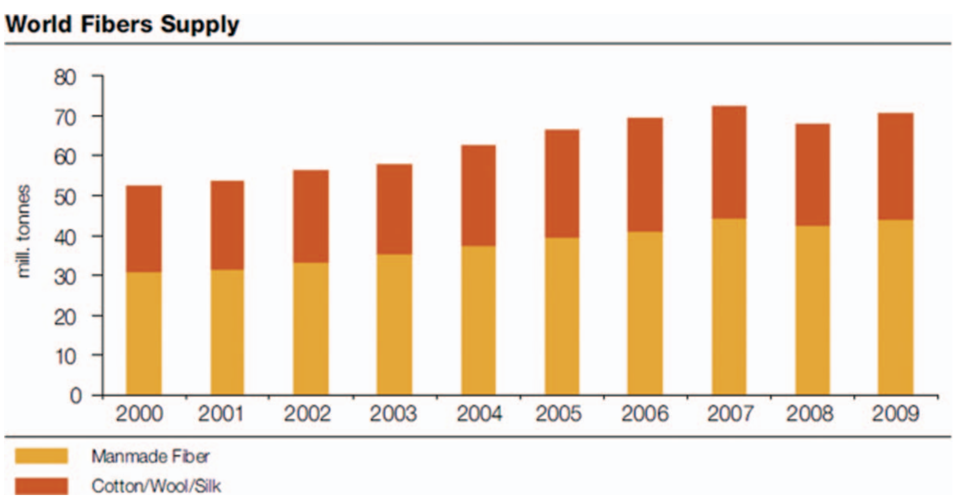


Figure 5. World fibers supply in 2000–2009.

Table 1. Consumption of natural fibers 2000–2009

Year	Cotton	Wool	Silk	TOTAL	± in%
2009	25,191	1,099	102	26,392	4.5%
2008	23,973	1,187	100	25,260	−10.1%
2007	26,773	1,221	98	28,092	−0.6%
2006	26,937	1,233	98	28,268	5.8%
2005	25,404	1,218	97	26,719	6.7%
2004	23,735	1,216	98	25,094	10.4%
2003	21,359	1,232	97	22,688	−0.4%
2002	21,422	1,272	92	22,786	3.7%
2001	20,563	1,317	88	21,968	2.2%
2000	20,067	1,343	86	21,496	1.1%

[15]

average annual growth rate of 3.3%. During that period, the share of man-made fibers managed to increase from 59% to 63% [15].

Consumption of natural fibers (cotton, wool, silk) versus man-made is presented in Table 1, while global fiber consumption in Table 2 [15].

Structures of Fibers

Natural fibers can be also created by Nature in 3D shape; below, on Fig. 6 there are 3D fibers presented, taken from Cuban palm, luffa cillindrica and opuntia fibers reinforcing plant, which grows like a tree on Galápagos Islands.

The wall structures are presented in Fig. 7 [16].

Wall structure of a fiber seen in transverse (bottom) and three-dimensional view (top). Secondary Wall (1–3, three different layers with differentially oriented cellulose microfibrils), dead lumen (4), primary wall (5) and middle lamella (6) [16].

Table 2. Global Fiber Consumption 2000–2009

Year	Cotton	Wool	Synthetics	Cellulosics	TOTAL
2000	38%	3%	54%	5%	52,643
2001	38%	2%	54%	5%	53,563
2002	38%	2%	55%	5%	56,303
2003	37%	2%	56%	5%	57,979
2004	38%	2%	55%	5%	62,582
2005	38%	2%	55%	5%	66,469
2006	39%	2%	54%	5%	69,374
2007	37%	2%	56%	5%	72,517
2008	35%	2%	57%	5%	67,690
2009	36%	2%	57%	5%	70,526

Unit: 000 tones * Since 2002 with Tencel® included [15].

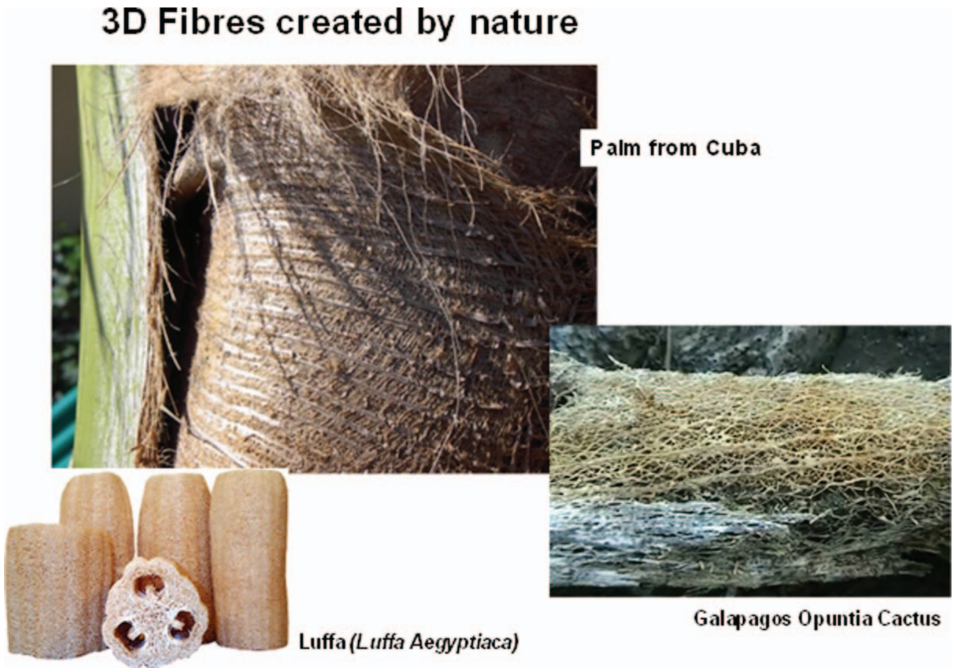


Figure 6. 3D fibers created by Nature.

In Table 3 there are presented diameters of elementary fibers of most common natural fibers. From this table one can see that the ones with the lowest diameter are:: spider silk (2–8 μm, and curaua (7–10 μm), while cotton 11–21 μm.

Chemical Composition of Fibers

Generally natural fibers are miniature composites, formed from a "reinforcement" of cellulose embedded in a "matrix" of lignin and other polysaccharides e.g. chemicellulose. The content of chosen natural fibers is presented in Table 4 [5].

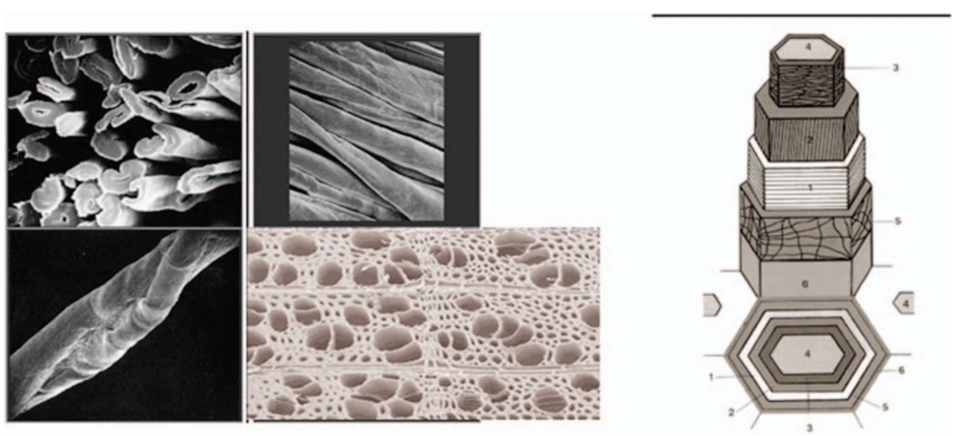


Figure 7. The wall structure of some natural fibers [17].

Table 3. Diameter of the elementary fibers

Natural Fiber	Diameter [μm]
Spider Silk *(Araneus Diadematus)*	2–8
Totora *(Scirpus Californicus)*	6–16
Poplar *(Populus Tremula)*	6–22
Chambira *(Astrocaryum Chambira)*	8–16
Curaua *(Ananas Erectifolius)*	7–10
Coir *(Cocos Nucifera)*	10–16
Isora *(Helicteres Isora)*	10–17
Paja Toquilla *(Carludovica Palmata)*	10–20
Cotton *(Gossypium Hirsutum)*	11–21*
Silk *(Bombyx Mori L)*	10–25
Abaca *(Musa Textilis Nee)*	10–30
Pita *(Agave Americana)*	12–18
Palmyra *(Borassus Flabelliformis)*	12–25
Lama *(Lama Glama)*	12–50
Kenaf *(Hibiscus Cannabinus)*	13–20
African Palm	14–28
Flax *(Linum Usitatissimum)*	15–22
Sisal *(Agave Sisalana)*	15–30
Jute *(Corchorus Capsularis)*	15–35
Alpaca *(Lama Pacos)*	15–45
Hemp *(Cannabis Sativa)*	17–24
Sheep's Wool *(Ovis Aries)*	20–30
Calotropis *(Calotropis Procera)*	20–40
Opuntia *(Opuntia Galapagos)*	20–45
Luffa *(Luffa Aegyptiaca)*	20–50
Cabuya *(Furcraea Andina)*	23–35
Pineapple Fiber *(Ananas Bracteatus)*	25–34

*CNR-ISMAC, Biella, Italy [17].

Future Fibres in 21st and 22nd Century

Future fibers in 21st and 22nd century are: spider fibers, nanocellulosic fibers, carbon hollow nanotubes, and "Buckypapers" for novel aeronautical multifunctional composite structures as well as hollow fibers on base of polylactic acid, fibroin, flexible basalt fibers etc., see Fig. 8 [17,18].

Efforts are undertaken also to obtain the biosilk. Now there are two ways of research aiming to obtain the biosilk; the ideas of obtaining biosilk are presented below on Figs 9 and 10.

The other two ways of obtaining biosilk mentioned above are those presented in Fig. 10.

Canadian/American scientists have attempted to obtain spider silk from goat milk by introducing spider genes coding protein synthesis into goat DNA [20].

European way of biosilk production deal with GM potatoes.

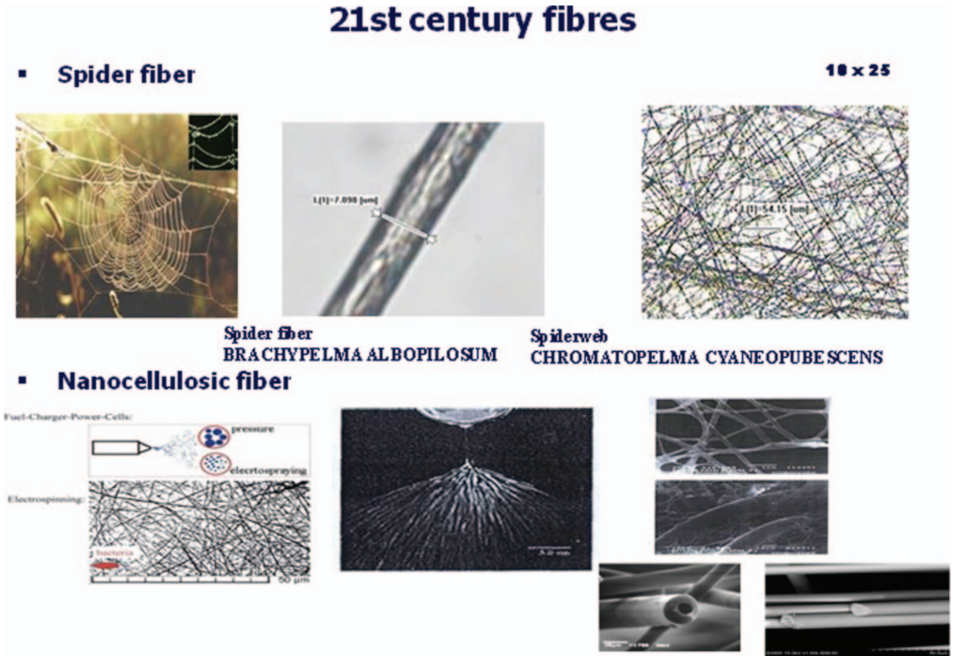


Figure 8. 21st Century fibers.

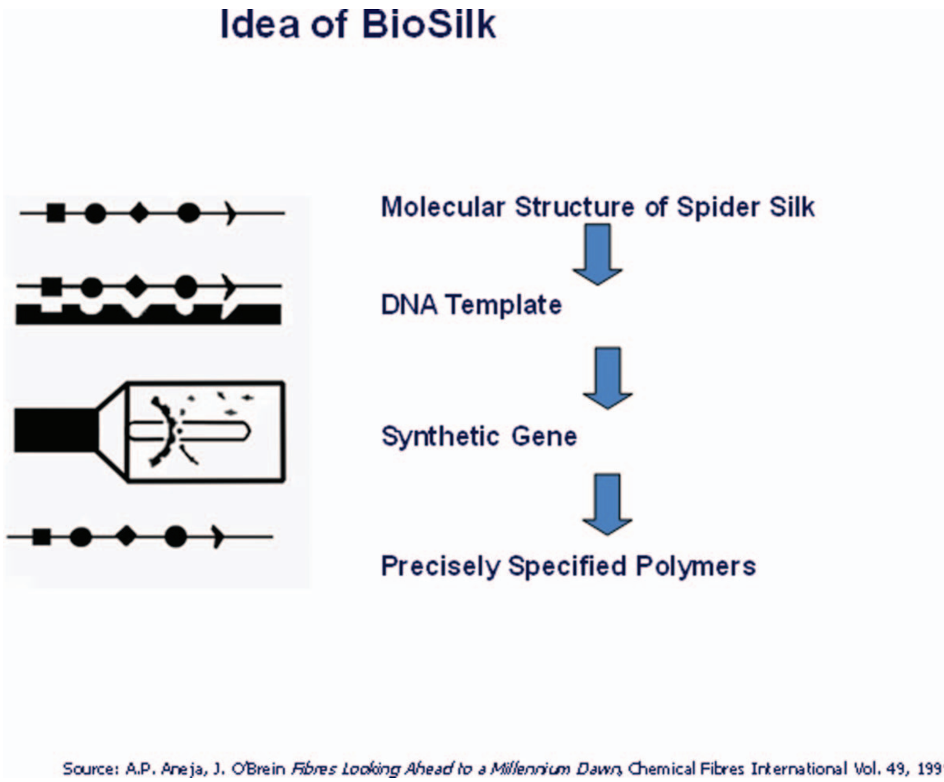


Figure 9. The idea of biosilk.

Table 4. Chemical composition of some natural fibers

Fiber	Cellulose	Lignin	Pectin
Abaca	60-80	6-14	13
Bamboo	26-43	21-31	-
Cabuya	80	17	-
Coir	36-43	41-45	3-4
Cotton	83-99	6	5
Curaua	70-80	13	-
Flax	64-84	0,6-5	19
Hemp	67-78	3.5-5.5	17
Henequen	60-78	8-13	4-28
Isora	75	23	-
Jute	51-78	10-15	37
Kenaf	44-57	15-19	-
Nettle	53-82	0.5	0.9-4.8
Pineapple	*80*	*13*	-
Pita	*80*	*17*	-
Ramie	67-99	0.5-1	22
Sisal	60-80	6-14	13

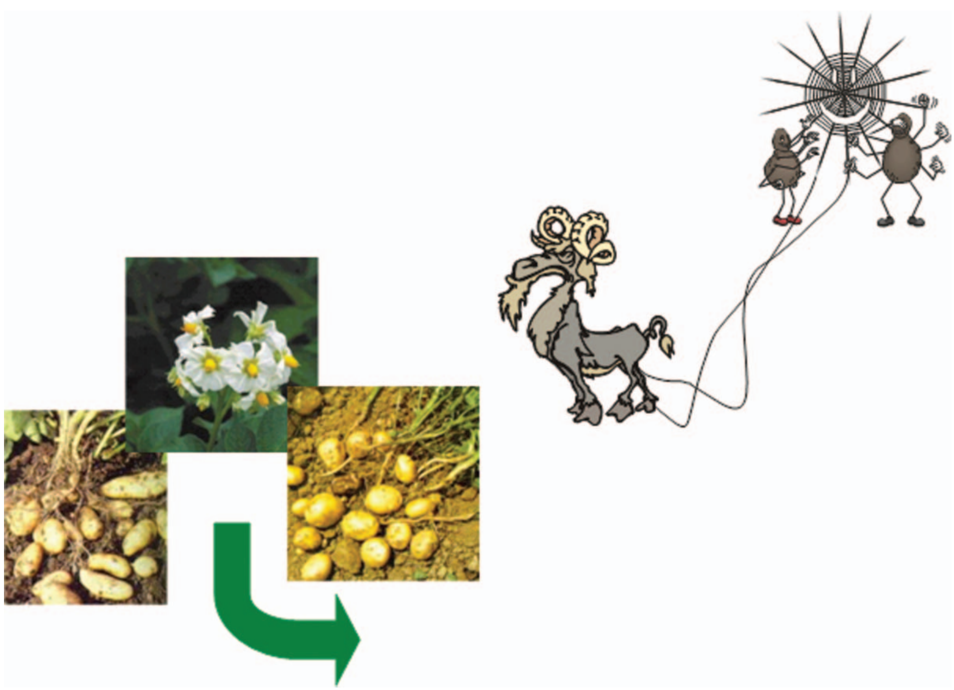


Figure 10. The idea to obtain spider silk from goat milk and potatoes.

Table 5. Antifungal activity after 2 weeks of test with *Chaetomium globosum (1)*

	Flax non-woven			
	Degree of mildew growth on the samples			
Biocide	Outer side	Inner side (in contact with agar)	Degree of mildew growth in the agar medium	Inhibiton zone around the samples (mm)
Reference sample (with methanol)	50-very intense growth	50-very intense growth	50-very intense growth	—
Thyme extract 10% (methanol solution)	00-no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—
Bios extract 12% (water solution)	00-no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—

Table 6. Antifungal activity after 2 weeks of test with *Chaetomium globosum (2)*

	Linen-cotton blended fabric			
	Degree of mildew growth on the samples			
Biocide	Outer side	Inner side (in contact with agar)	Degree of mildew growth in the agar medium	Inhibiton zone around the samples (mm)
Reference sample (with metanol)	50-very intense growth	50-very intense growth	50-very intense growth	—
Thyme extract 10% (methanol solution)	50-very intense growth	50-very intense growth	50-very intense growth	—
Bios extract 12% (water solution)	00-no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—

Table 7. Antifungal activity after 2 weeks of test with *Aspergillus niger (1)*

	Flax non-woven			
	Degree of mildew growth on the samples			
Biocide	Outer side	Inner side (in contact with agar)	Degree of mildew growth in the agar medium	Inhibiton zone around the samples (mm)
Reference sample (with methanol)	50-very intense growth	50-very intense growth	50-very intense growth	—
Thyme extract 10% (methanol solution)	00-no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—
Bios extract 12% (water solution)	00-no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—

For improving the productivity (yield) and quality of natural fibers the genetic modification (GM) of fibrous plants was developed as well. For example, GM transgenic cotton is resistant to bollworm larva (*Helicoverpa armigera*). In case of other fibrous plants like flax, hemp, kenaf, jute etc. genetic modification can be done to create PHA "*in statu nascendi*" (poly hydroxy alcanate) e.g. poly hydroxy butyric acid (PHB) and to increase the biomass and amount of oil from the seeds and leaves.

In case of bast plants efforts are going to decrease lignin content to make the fiber more delicate and avoid the stiffness and to breed drought resistant flax and make degumming of them easier.

- Commercialization of plant derived PHA requires the creation of transgenic crop plants that produce high yields, have normal phenotypes and which transgenes are stable over several generations [21]
- Production of PHA in an agronomic scale could allow synthesis of biodegradable plastics in the million tone scale, while bacteria or yeast produce material in the thousands tone scale
- PHA when synthesized in plants to a level of 20–30% dry mass weight, could be produced at the cost of US$ 0.20–0.50/kg and thus become competitive with the petroleum based plastics [22]

Arabidopsis Thaliana was the first choice for transgenic studies; the maximum obtained amount of PHB in the leaves was 14% dry weight [23].

Natural fibrous lignocellulosic materials in the future will be used also in following areas:

- in polymer industry, as e.g. natural fibers reinforcing fibers in composites [5],
- in pulp and paper industry (which should be also driven towards the sustainable development and annual lignocellulosic plants resources) [5],
- for remediation of the lands polluted by heavy metals from industries, e.g. mining, foundry etc. [2,18,24].

Bio-products from fibrous and oil plants e.g. from seeds agro-fine chemicals are also very important as a nutrition, medical products and others—e.g. polyunsaturated fatty acids: alpha-linolenic acid (ALA), stearidonic acid (SDA) (omega -3 family) and linoleic (LA) as well as gamma-linolenic (GLA) (omega 6 family), lignans—phytoestrogens, plant mucilage–soluble fiber, cyclolinopeptides, natural waxes, essential oils, vitamins, minerals, others "fine chemicals" such as squalene [1,18].

Disadvantages of Natural Lignocellulosic Fibers

Among DISADVANTAGES of natural lignocellulosic fibers some are connected with a problem of extracting of these fibers from the stalks. This can be done by the process of degumming; there are several methods of degumming which are presented on Fig. 11.

Nowadays at industrial scale only dew retting and in some cases water retting are being practised. The retting is connected with a great risk of over-retting and creating tremendous amount of sewage (about 30 m^3 waste water from 1 tone of straw of bast fibrous plants) as well as gives no guaranty of the same quality and homogeneity of fibers. Improvement of the fiber can be also done by enzymatic and US treatment. Unfortunately, these two processes are usually not implemented at the industrial scale in scope of bast fibrous plants [27].

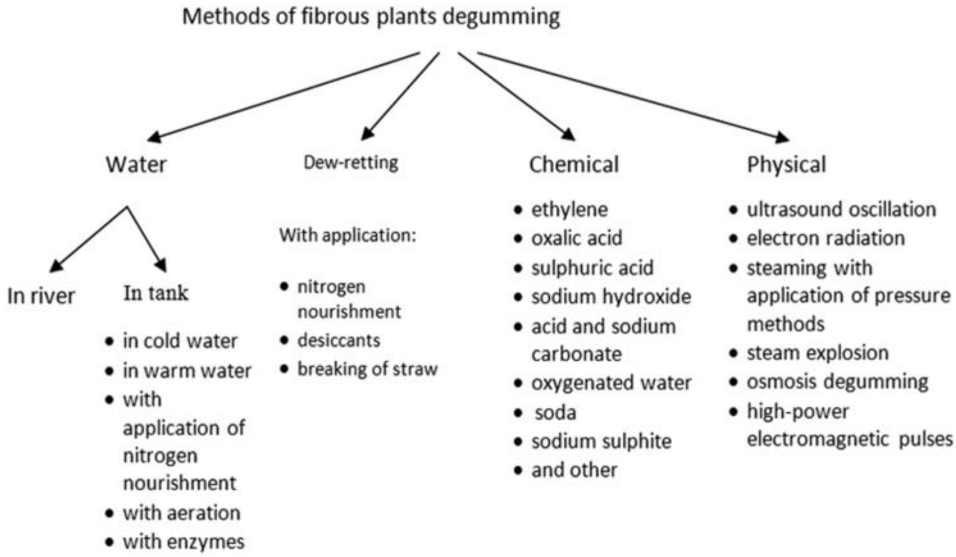


Figure 11. The methods of degumming bast fibrous plants.

The osmotic degumming, which is currently just in state of development in Institute of Natural Fibres and Medicinal Plants. INF&MP has conducted the registration of the European Patent PCT/PL2006/000085: "Device for processing fibrous raw materials and the method of fibrous plants processing" (submission date 23rd November 2006). This is the method of bast fibrous plants processing which uses osmosis phenomena; the fibers obtained as the result of osmotic degumming are more delicate, white and fine and can be used for producing better textile products (yarn, fabric or non-woven). At present, osmotic degumming method can be used for evaluation of new breeding lines and new cultivars [25,26,28,29].

Another disadvantage of natural fibers versus man-made is their susceptibility to biodeterioration and decomposition; fungi and bacteria decompose lignocellulosic substances, also the main component: cellulose, and lower strength properties. Antimicrobial finishing of natural textile products allows obtaining wider area of their application (medical materials, lining for shoes, packaging products, non-wovens for insulation [24,30,31].

Antifungal and antibacterial properties of lignocellulosic natural fibers can be improved by using natural extract from Citrus paradise and Thyme essential oil [32].

In the studies *flax non-woven* and *linen-cotton blended fabric* were protected against mildew growth with biocides based on *Extracts of plant origin.*

Test methods:

- *Test of antifungal activity* – acc. to the Standard EN 14119:2003 Protected flax non-woven and linen-cotton blended fabric were exposed to the fungi action *Aspergillus niger* and *Chaetomium globosum.* Antifungal activity of the finishing agent was studied.
- *Test of resistance to odour and mildew growth* – acc. to the GME Standards 60276 and 60287

- *Materials:*
  - Needled flax (100%) non-woven
    - × Surface mass - 883 g/m2
    - × Thickness - 4,39 mm
  - Linen-cotton (55/45%) blended fabric
    - × Surface mass - 360 g/m2
    - × Thickness - 0,622 mm

Application method: the samples were treated by padding method
Amount applied: 5 ml/g
Concentration:

Extract of Thymus vulgaris(Thyme) – 10%
Extract of Citrus paradisi (Bios) – 12%

Results are presented in Tables 5–8.
Remarks:

- Bios extract used for protecting flax non-woven and linen-cotton blended fabric show antifungal activity:
  - *0 degree of mildew growth* (no visible growth evaluated microscopically)
  - *no change of odour*
- Thyme extract used *only* for protecting flax non-woven show antifungal activity:
  - *0 degree of mildew growth* (no visible growth evaluated microscopically)
  - *no change of odour*

In this case no mildew growth, no loss of breaking force, no bacteria growth and distinctly inhibition zone of growth both Gram positive and Gram negative bacteria are observed [31–33].

Antifungal properties of lignocellulosic non-woven can be obtained also by applying copper-boron ammonium compound (Cupramina B). In this case no mildew growth, no loss of breaking force as well as no odour are observed–sees Table 8 and 9 [32].

Natural, mainly cellulosic fibers, are flammable, except wool (which is difficult to be ignited), but the heat release rate is lower and they never drip in comparison to man-made fibers [34].

Advantages of lignocellulosic natural fibers are as follows:

- ability to block UV radiation and antibacterial activity (due to the lignin content in a nano-structure),

In the study [35,36] Kraft nanolignin was applied for linen fabric coating.

Optimal parameters of the padding process were—number of passages – 8, silicone concentration – 25g/l, concentration of nanolignin solution—below 1 g/l.

The linen fabrics enriched with nanolignin were examined in respect of the ability of blocking the ultraviolet radiation (Fig. 12). The antibacterial (Table 10) properties of the products were evaluated.

- good electrostatic properties,
- good air permeability,
- positive influence on human body and physiology, which influences the comfort/ health
- their biodegradability, eco-response and positive social impact especially in rural areas of the globe [5,10,37,38,39].

Table 8. Antifungal activity after 2 weeks of test with *Aspergillus niger (2)*

	Linen-cotton blended fabric			
	Degree of mildew growth on the samples			
Biocide	Outer side	Inner side (in contact with agar)	Degree of mildew growth in the agar medium	Inhibiton zone around the samples (mm)
Reference sample (with methanol)	50-very intense growth	50-very intense growth	50-very intense growth	—
Thyme extract 10% (methanol solution)	50- very intense growth	50-very intense growth	40-considerable growth	—
Bios extract 12% (water solution)	00- no visible growth evaluated microscopically	10-growth not visible with naked eye	40-considerable growth	—

Table 9. Resistance to odour and mildew growth

Biocide	Flax non-woven	Linen-cotton blended fabric
Reference sample (with methanol)	6,8–Clearly noticeable, but not objectionable Presence of mildew	7,8–Noticeable, Presence of mildew
Thyme extract 10% (methanol solution)	9,8–Odourless No presence of mildew	8,2–Noticeable Presence of mildew
Bios extract 12% (water solution)	10–Odourless No presence of mildew	10–Odourless No presence of mildew
Modified Cupramine B	10–Odourless No presence of mildew	—

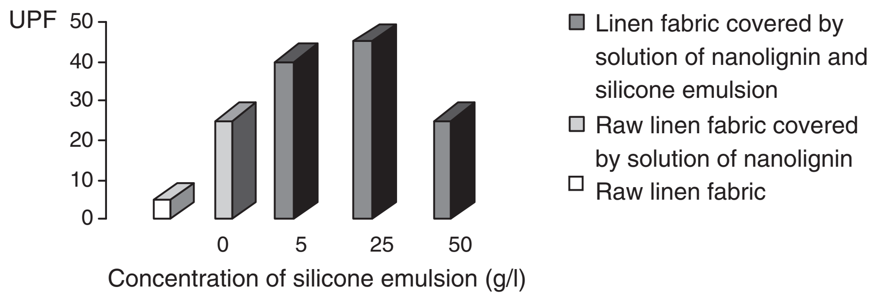


Figure 12. Effect of linen fabric covered with nanolignin and silicone emulsion (after 8 passages) on UPF.

Apparels and bedding textiles made of natural fibers are very comfortable; which is the reason that great majotity of underwear and bedding textiles in the market is made of them. Natural fibers, except wool, never cause allergy, which is very often induced by man-made fibers.

Table 10. Antibacterial properties of UV blocking of linen fabric covered by nanolignin

Type of bacteria	Antibacterial activity Screening tests acc. to AATCC 147–1998	
Corynebacterium xerosis	—	Bactericidal activity
Bacillus licheniformis	—	
Micrococcus flavus	—	
Staphyloccocus haemolyticus	—	
Staphyloccocus aureus	—	
Klebsiella pneumoniae	—	
Escherichia coli	—	
Pseudomonas aeruginosa	—	

The level of Alfa-globulin is higher in our body when we sleep on e.g. linen bed cloth and anti-oxidant stress is the lowest in case of application of natural fibers [9,10].

All natural fibers are biodegradable and after using it is very easy to recycle them and decompose. From the other side, these natural fibers are usually produced in rural areas by often poor farmers and producing them improves the economical situation of these areas [2,40].

New Trends in Natural Cellulosic Fibers Finishing Processes

- enzymatic finishing, including bio-scouring,
- corona treatment,
- plasma treatment,
- nano–TiO_2, nano Ag treatment,
- liquid ammonia treatment,
- using natural dyestuffs,
- ultrasound (US) treatment,
- fire retardancy (FR) treatment,
- bio-deterioration protection.

[6,28,29,41]

Enzymatic finishing provides better homogeneity and fineness of fibers e.g. such as flax, hemp, kenaf; in some cases gives opportunity to obtain these fibers with properties similar to cotton, called "cottonized fibers", which can be processed in more efficient way on "cotton system" and these fibers can be used wider in blends with cotton and man-made fibers [28,29,42,43].

Corona treatment—provides considerable improvement of hygrophylicity (creation of channels easing water penetration and oxidation of waxes and fats).

Plasma treatment contributes to the improvement of bleaching, printing, and dyeing processes of natural fibers [17].

Nano—TiO_2 treatment—enables better stain removal, self-cleaning, and provides bacteriostatic and UV barrier properties.

Liquid ammonia treatment–increases the crease resistance, provides better touch and minimization of shrinkage in washing process, and induces intracrystalline swelling of cellulose what causes conversion of cellulose I into cellulose III [6].

Dyeing natural fibers and derived materials with natural dyestuff–is the important goal to obtain entire environmentally friendly "green products". There are several natural dyestuffs explored and developed to be successfully applied for dyeing natural fibers [35,44].

Ultrasound (US) treatment is accelerating: the degumming process of fibrous plants, washing of wool and other protein fibers.

Fire retardancy (FR) treatment of natural fibers: delay ignition time, reduces heat release, surface spread of flame as well as mass loss rate, and fire propagation, resulting in better protection of human life. There are generally two types of flame retardancy: and durable and non-durable for washing [44–46].

Bio-deterioration protection against bacteria and mildew fungi is very important for the use of natural fibers as insulation materials, non-woven and reinforcing of composites and more details are provided above [31,37].

Conclusion

New trends towards sustainable development turn the positive attention to the natural, renewable, biodegradable raw materials. Development in science and technology contribute to enlarging their utilization not only in textile but also in transportation, building and composite industries.

Natural fibers with their long service of mankind now in 21st century are most welcome in many area of their application.

The disadvantages of natural fibers regarding their production and processing, especially connected with economical viability and low homogeneity should be minimalized.

Following a period of dynamic development for man-made fiber and a drastically lowered trend of production of natural fibers in the last decade, a more stable coexistence between them may now be observed.

The ecological alarm over atmospheric and water pollution dictates the conditions of future coexistence. In the opinion of textile authorities, "the present ecological legislation is a pale shadow of what will be needed in the future to come to grasp with the ecological problems which the world is facing". Treatment of effluents, disposal of waste and packing material will require enormous capital outlays. The competitive edge in the future will be determined to a great extend by the ability to solve the ecological problems. This is what may be termed as the greatest challenge for textiles industries in this new millennium.

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