Mol. Cryst. Liq. Cryst., Vol. 484, pp. 43/[409]–50/[416], 2008

ISSN: 1542-1406 print/1563-5287 online
DOI: 10.1080/15421400801903395

Nanolignin Modified Linen Fabric as a Multifunctional Product

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Efficient protection against harmful UV radiation for human can be ensured by wearing garment made from bast fibers: linen and hemp, which also provide high use comfort thanks to high hygroscopicity, air permeability and cool touch. This paper describes application of nanolignin as a UV blocker for linen fabrics. Lignin with nano structure obtained by ultrasonic treatment was padded on linen fabrics. The linen fabrics covered by nanolignin show also antibacterial properties. Thanks to nanolignin application for finishing process of linen fabrics, it is possible to obtain multifunctional textile products with the following additional properties: UV barrier, antibacterial, antistatic properties guaranteeing positive effect on human physiology.

Keywords: antibacterial properties; finishing; nanolignin; natural fibers; UV protection

INTRODUCTION

Apparels made of natural fibers not only influence favorably some of the physiological factors of the body but also ensure safety during sunny days protecting against hazardous ultraviolet radiation. Ultraviolet rays emitted by the sun and thinner ozone layer or enlarging ozone hole create together a high risk to the humans. For this reason clothing should guarantee protection to the user against higher level of UV radiation. The protection is strictly connected with structural parameters of cloth like its density, thickness, clearance as well as color and finishing agents (e.g., Rayosan, Solartex, Ciba-Fast-P). [7] The type of fiber is also important especially in case of raw fabrics (non-dyed).

The study was done within the EU Integrated Project FLEXIFUNBAR.
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Natural fibers like hemp and flax contain in their chemical composition natural pigments and lignin, which are natural UVR absorbers and ensure good protection against UV. Lignin together with cellulose and hemicellulose is the main structural polymer in the cell walls of higher plants. Its content varies from 15 to 30%, and distribution is different in different layers of cellular wall and is correlated with the physiological function of the layer.

Lignin content in flax fibers is only between 0.6–5.0% and in hemp fibers between 3.5–5.5%.

The term "lignin" is a collective name referring to a group of highly polymerized compounds with a similar character and chemical properties, aromatic compounds containing methoxyl $-OCH_3$, carbonyl $-CO$ and hydroxyl $-OH$ groups. It is a polymer synthesized from three monomers – *p*-coumaryl, coniferyl and sinapyl alcohol [1]. They form a chain of nine carbon atoms arranged in a phenol ring with a lateral propane chain. These units have 0 to 2 methoxyl groups attached to the phenol group in ortho position (Fig. 1).

Several detailed models of lignin structure have been proposed – Freudenberg [3], Glasser and Glasser [4], however, its exact structure still remains unknown. Structure of lignin changes according to the manner in which it has been isolated.

Technical lignin is the second important component of plant biomass besides cellulose which makes it the second common organic compound found in nature. It is a by-product of the pulp and paper industry amounting for estimated 50 million tons world-wide per year. Technical lignin can be divided into two categories: sulphur bearing lignins – lignosulphonates and kraft lignin and sulphur-free lignins – organosolv lignin, alkaline and hydrolysis lignin. Usually, these compounds are burnt to produce energy due to their low quality. Additionally, they are used for production of vanillin, bonding agents,

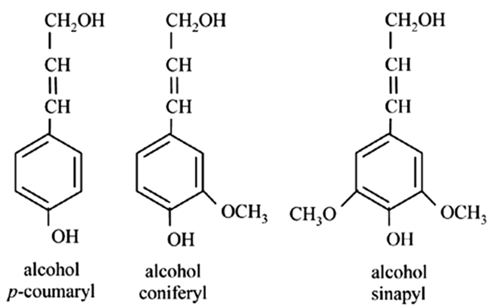

FIGURE 1 Lignin monomers: *p*-coumaryl, coniferyl and sinapyl alcohols.

tanning agents and dispersing agents and plasticizers in building industry and as fillers in rubber industry [2].

Currently, by improvement of the quality there is a trend to use the anti-oxidant, anti-microbial and anti-virus properties of these compounds that find new applications as [5]:

- cosmetics – protection against UV radiation,
- nutraceuticals,
- feed,
- biocides and bio-stabilizers – in paper industry for treatment removing slime, in polymer production as coating material and flame retardant,
- pesticides in plant cultivation,
- additive in humus forming process,
- and in production of polyolefins and epoxy resins.

There are attempts to modify technical lignin with enzymes produced by decomposition using white fungi to obtain new environmentally friendly products [6], used as an additive to synthetic polymers, glues for lignocellulosic composites, chelate compounds, an intermediate product in manufacturing lignin polymers, an additive to porous materials and a coating and dyeing agent.

However, introduction of lignin in industrial scale requires further, intensive interdisciplinary research in chemistry and microbiology and on improving cost-effectiveness of processing.

A new way of improvement of UV barrier properties of textiles is application of lignin in finishing process.

MATERIALS AND METHODS

A study on the possibility of using lignin as a UV blocker for fabrics was conducted at the Institute of Natural Fibres in Poland. A typical linen fabric, usually applied for shirt production, was used for the study. Mass per square meter of the fabric was 150 g/m^2 and densities of warp and weft were 210 and 192 threads per dm, respectively. Additionally, the linen fabric after PLASMA pretreatment was used for the best process conditions applied for covering by lignin. Pretreatment process was conducted in the conditions of secondary plasma, with kHz-generator and power: 2000 Watt. Time of plasma treatment was 5 minutes with gas mixture containing oxygen – 2000 sccm (standard cubic centimeters per minute). Figure 2 shows the scheme of the plasma process.

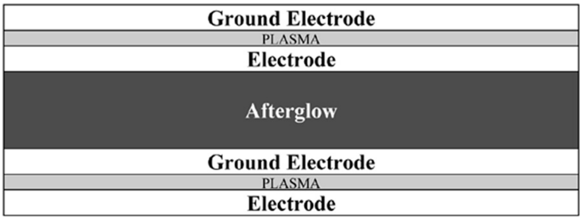

FIGURE 2 The scheme of plasma treatment process.

The study on UV barrier properties was conducted also on hemp fabric as well as flax nonwoven covered by lignin. Nano structure lignin – obtained from kraft lignin by ultrasonic treatment was used for covering the linen fabric. Distribution of particle-size is shown on Figure 3.

The size of the nanolignin particles was determined with the use of Transmission Electron Microscopy JEM 1200EX II, Joel.

The experiments of covering the linen fabric by nanolignin were conducted using a padding method. Operation of padding was repeated ten times. The bath temperature was 18°C. After padding the fabric was dried at 40°C. Silicone emulsion with different level of concentration (5%, 25% and 50%) was applied for better fixation of the nanolignin particles on linen fabric.

Determination of the Ultraviolet Protection Factor of a dry linen fabric covered by nanolignin was done according to European Standard EN 13758-1:2001 for sun protection clothing with the use

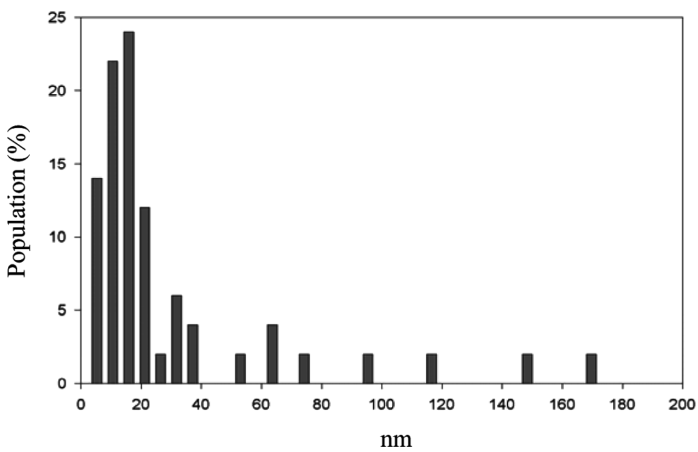

FIGURE 3 Distribution of particle-size of nanolignin.

TABLE 1 UPF Classification System [7]

UVR protection category	UPF range
Good protection	15 to 24
Very good protection	25 to 39
Excellent protection	40 to 50, above 50

of Cary 50 Solascreen apparatus (Table 1) after each time of padding operation. The most efficient way of covering linen fabric with nanolignin was evaluated during the study.

Antibacterial properties of linen fabric covered by nanolignin were determined by screening tests according to AATCC 147-1998. Surface resistance of linen fabric covered by nanolignin was conducted according to standard PN-92/E-05203. The tests were done in the following conditions: relative air humidity – 50%, temperature – 20°C.

RESULTS OF THE STUDY ON NANOLIGNIN INFLUENCE ON UV PROTECTION

Treatment of linen fabric with a solution of nano structure lignin improves the fabric UV barrier properties. Increase of nanolignin amount on linen fabric resulted in higher level of Ultraviolet Protection Factor. The highest UPF was obtained after 8 passages and reached the level of 25 (Fig. 4).

Application of silicone emulsion, to better fix the nanolignin particles on linen fabric, improves the fabric UV protection factor more effectively. The most efficient level of silicone emulsion concentration is 25 g/l and the best UPF result is 45 (Fig. 5).

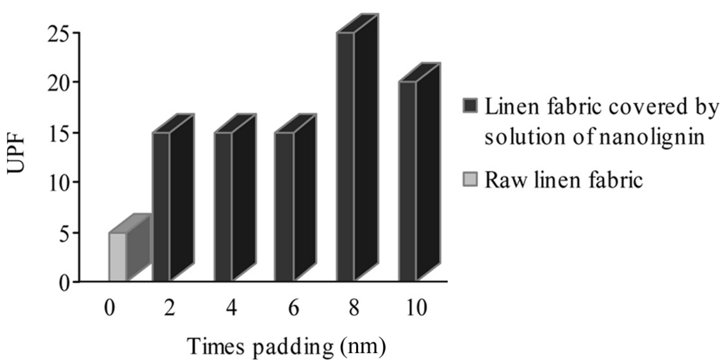

FIGURE 4 Effect of nanolignin coating on the UPF of linen fabric.

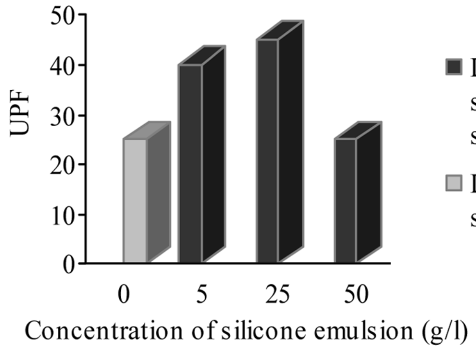

FIGURE 5 Effect of nanolignin and silicone emulsion coating (8 passages) on the UPF of linen fabric.

However, plasma pretreatment of linen fabrics combined with nanolignin coating does not improve level of UPF. Textiles coated by nanolignin have excellent UV protection – see Figure 6 and good washing resistance. Their air permeability remains the same. Nanolignin coating does not increase fabric stiffness.

Applying lignin as a UV barrier seems to be a very good solution for UV problem. Lignin is a natural polymer and its application to textiles does not decrease the hygienic properties of clothing, which is particularly important in summer. Using lignin application instead of chemical UV absorbers, it is possible to reduce the amount of chemicals applied in the finishing processes of textiles, resulting in improved environmental protection. Coating textiles by nanolignin causes not only improvement of the barrier properties of textiles against UV radiation but also enhances their biological activity

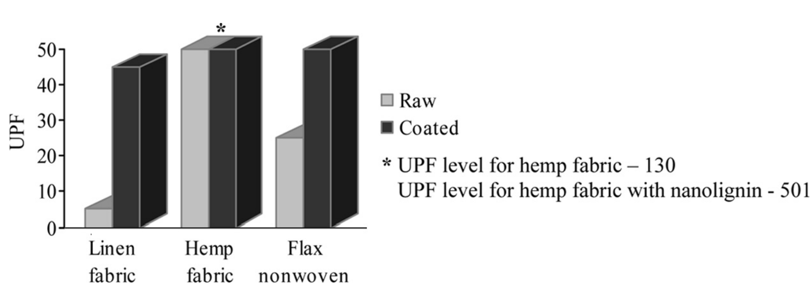

FIGURE 6 Effect of textiles covered by nanolignin and silicone emulsion (25 g/l) after 8 passages on UPF.

TABLE 2 Antibacterial Properties of Linen Fabric Covered by Nanolignin

Type of bacteria	Antibacterial activity	
Corynebacterium xerosis	–	Bactericidal activity
Bacillus licheniformis	–	
Micrococcus flavus	–	
Staphyloccocus haemolyticus	–	
Staphyloccocus aureus	–	
Klebsiella pneumoniae	–	
Escherichia coli	–	
Pseudomonas aeruginosa	–	

against selected micro-organisms. Antibacterial properties of linen fabric covered by nanolignin is shown in Table 2.

The tests conducted proved, that linen fabrics covered by nanolignin have bactericidal activity for eight bacteria cultures, which are most often found in human environment. It is well known, that textiles made from lignocellulosic raw materials show very low ability to collect electrostatic charges on their surface. Covering the textiles by nanolignin does not worsen such properties. The conducted tests proved that surface resistance of linen fabric covered by nanolignin is below $2 \times 10^{10}\,\Omega$. Based on the results, linen fabric with nanolignin can be classified as an antistatic material. Thanks to nanolignin application for finishing process of lignocellulosic textiles, it is possible to obtain a multifunctional product with the following properties: UV barrier, antibacterial, antistatic and guaranteeing positive effect on human physiology.

CONCLUSIONS

1. Treatment of the tested textiles with a solution of lignin in nano structure significantly improves the UV barrier properties of the fabric. The best results were obtained for eight passages and with application of silicone emulsion for better fixation.
2. The application of nanolignin as a natural polymer for textile treatment does not worsen their physical and bio-physical properties.
3. Application of nanolignin with silicone emulsion for lignocellulosic fabrics gives a multifunctional product with the following properties:
   - Excellent UV protection
   - Bactericidal activity
   - Maintaining antistatic properties

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