CONTRIBUTIONS TO THE PRODUCTION OF NEW TYPES OF KNITTED TEXTILE PRODUCTS WITH FUNCTIONAL BIOACTIVE AND CONDUCTIVE PROPERTIES

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ABSTRACT

Bioactive textiles produced on flat knitting machines as part of this research are designed to protect the body from germs, fungi, mites which can cause allergies and skin problems; they provide high comfort and ecological impact on the environment.
The objective of the research was to diversify the assortments of knitted fabrics by:
- using new types of bioactive yarns (lenpur, lyocell, amicor, etc.) and conductive yarns in various mixtures;
- using conductive fibres and yarns in various knitted structures ensuring protection of persons working in environments with in high risk factors;

- Scientific design of knitted structures using electronic flat knitting machines, by combining them in order develop special bioactive, ecological and biocompatible properties;
The comparative study between *lenpur fibers* and lyocell, viscose, linen, cotton and synthetic fibers, respectively, revealed the main performances of lenpur fibers, which provide a high capacity for absorbing perspiration and release of liquids, as well as body temperature self-regulation and anti-stress, with the view to prevent body odors. Moreover, lenpur yarns and knits proved high wear and care resistance correlated with excellent dyeability, thus minimizing the occurrence of streaks and unevenness in dyeing. New types of innovative knitwear for children and adults contribute to an increase of competitiveness for the knitted goods manufacturers by showing high quality of products as part of the research project.

Key words: innovative knitted structures, bioactive properties, lenpur fibers, conductive fibers and yarns

INTRODUCTION

Textile materials that provide comfort, antimicrobial, antiallergenic and anti-stress protection, shielding for persons working in environments with high risk factors are increasingly needed to protect consumers' health, prevent disease and reduce environmental impact.
A new concept was created under the name of bioactive textiles with a view to transforming the passive role of textile materials to an active role with all its influence for the industry and for consumers.
To keep up with the strategy for upgrading the textile companies, the researchers' main objective was to achieve high performance technologies with low impact on the environment and human body, promotion of the use of raw materials with superior hygienic, antibacterial, antiallergenic and protective properties of the persons working in hazardous environments;

THEORY

There are several possible ways to add additional features to textiles: new fibers, fabric structure and/or superior finish. Fabric structure plays an important role in use, but can also have physiological and ecological functions. Product design can be adequate to the intended use, which means developing research and design studies on various types of machines. The following methods were used in research:

- adding fibres and yarns with new properties into knitted structures:
  - superior antibacterial, antiallergenic, antistatic, ecological and comfort properties (lenpur, amicor, lyocell in various % and blends);
  - conductive properties (obtained from spinning of textile fibres on a metal or carbon filament core, yarns produced from 100% conductive fibres or from blends in various proportions, yarns produced from pure conductive polyaniline fibres through conductive polymer coating or metal plating).
- characterization of new types of fibres and yarns;
- production of new types of textile structures and knitted fabrics that exploit the properties of new fibres and yarns correlated with their intended use;
- testing, analysis and characterization of new types of knitted fabrics;
- evaluation of the impact on the environment and human body.

Lenpur is a novel textile fibre selected from the branches of special trees. The fibre is eco-friendly and has a soft touch. The remarkable properties of wood provide textile materials made from Lenpur with extraordinary properties. Lenpur is considered the best "vegetable fibre produced by man". Fibres retain the wood's natural properties. The properties of Lenpur fibres (US Patent no. 005599784) are owed to the specific types of timber used for its production, independent of the process used for its manufacture. The main differences in Lenpur compared to other cellulose fibres is its *softness, its absorption capacity, its ability to release dampness (as a yarn or fabric), its deodorant properties, and its adsorption characteristics (due to its morphology).* When mixed with other fibres, Lenpur creates a "mechanical synergy" with them.

Unlike other cellulose fibers - which also use wood as a raw material, but are not limited to wood - Lenpur fibre is made of 100% cellulose. This particular resource from which the fiber is produced shows that its morphology and performances are extremely varied, as it is specified in U.S. Patent.

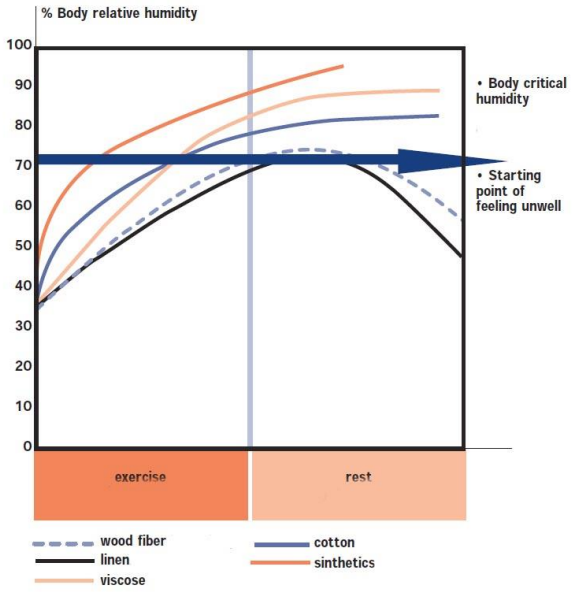

Figure 1: Capacity to absorb perspiration and release of liquids

The main performances of Lenpur that are already observed in the past are a surface-like cashmere, high capacity to absorb perspiration and release of liquids, and a self-regulation capacity, thus avoiding the occurrence of odors, as seen in Fig. no 1. It is also characterized by a very good resistance to washing and by an excellent ability to retain its shape. Lenpur fibers can be used in the pure state or blended with any type of fiber. Laboratory tests have shown the following: capacity for absorption of this fibre derived from wood is by 35% higher than that of cotton, while this is almost double than that of viscose. Ideal knitted fabrics have the ability to control body heat. Microscopic studies revealed the following: Lenpur fibre has a grooved section with irregular diameter caused by convolutions, Lyocell fibres have a section which is almost cylindrical, the Modal section is two-lobed, the Viscose section is grooved an fairly regular in diameter and the Lenpur section is very grooved with irregular diameters caused by the "convolutions".

METHODS AND FINDINGS

Characterization of Lenpur yarns

As shown in Table 1 the following considerations were made on physical-mechanical and appearance properties of Lenpur Ne20 yarns:
- uniformity of fineness is at an appropriate level, of 1.85 to 3.75%, thus providing a good uniformity of knitted fabrics, including plain knitted fabrics;
- tensile strength and coefficient of variation (CV) show adequate values, as a result good processability on automatic flat knitting machines and high productivity;
- elongation at break shows high values ranging from 7.45-7.99%, which allows the production of a wide variety of knitted structures;
- twist and coefficient of twist variation show very good values providing the knitted fabrics with very good appearance uniformity, good processability on machines.

Table 1: Physical-mechanical and appearance properties of Lenpur Ne20 yarns

No.	Properties	UM	Sample			Standard
			Lenpur yarn – light green	Lenpur yarn - orange	Lenpur yarn - black	
1	Length density	Tex (Nm)	29.0 (34.2)	27.6 (36.2)	29.6 (33.8)	SR EN ISO 2060:97
		Cv%	3.75	3.0	1.85	
2	Tensile strength	N	2.78	2.55	2.72	SR EN ISO 2062:2010
		Cv%	6.81	8.62	7.85	
3	Elongation at break	%	7.99	7.45	7.77	
		Cv%	7.62	5.9	7.83	
4	Twist direction		Z	Z	Z	ISO 2/1973

5	Twist	t/m	626.8	628.8	623.1	SR EN ISO 2061: 2011
		Cv%	5.27	5.25	7.5	
6	Apparent diameter	µm	252.6	217.3	253.2	SR 13152:93

Data presented in Table 2 with reference to colour fastness of Lenpur Ne20 yarns show:

- colour fastness values are very good, providing very good wear and care behavior correlated with excellent dyeability, thus minimizing the occurrence of streaks and unevenness in dyeing;
- cold and hot washing resistance is better than that of conventional cellulose man-made fibers. Excellent dyeability for the dye minimizes the occurrence of streaks. Lenpur fibers have also excellent dyeability.

Table 2: Colour fastness properties of Lenpur NE20 yarns

No.	**Properties**			**Sample**			**Standard**
				Lenpur yarn - orange	Lenpur yarn – light green	Lenpur yarn - black	
1	Colour fastness to washing	Color change		4 - 5	4 - 5	4 – 5	SR EN ISO 105-C 06: 2011
		Colour bleeding	Diacetate	5	5	4 – 5	
			Cotton	5	5	4 – 5	
			PA	5	5	4 – 5	
			PES	5	5	4 – 5	
			Acryl	5	5	4 – 5	
			Wool	5	5	4 – 5	
2	Colour fastness to acid perspiration	Colour change		5	4 - 5	4 – 5	SR EN ISO 105-E 04: 2012
		Colour bleeding	Diacetate	5	5	4 – 5	
			Cotton	5	5	4 – 5	
			PA	5	5	4 – 5	
			PES	5	5	4 – 5	
			Acryl	5	5	4 – 5	
			Wool	5	5	4 – 5	
3	Colour fastness to dry rubbing			5	5	4 – 5	SR EN ISO 105-X12: 2003
4	Colour fastness to wet rubbing			5	4 - 5	4 – 5	
5	Color fastness to water	Colour change		5	5	4 – 5	SR EN ISO 105-E 01: 2011
		Colour bleeding	Diacetate	5	5	4 – 5	
			Cotton	5	5	4 – 5	
			PA	5	5	4 – 5	
			PES	5	5	4 – 5	
			Acryl	5	5	4 – 5	
			Wool	5	5	4 – 5	

Characterization of knitted fabrics made from Lenpur yarns

Table 3: Physical-mechanical properties of knitted fabrics made from Lenpur yarns

No.	**Properties**	**UM**	**Sample**				
			L.1	**L.2**	**L.3**	**L.4**	**L.5**
1	Mass	g/m^2	183	382	338	548	447
2	Density	Do/10cm	65	69	58	18.5	79
		Dv/10cm	87	92	102.5	24.5	106
3	Bursting strength	(kgf)	No burst	No burst	No burst	No burst	No burst
4	Abrasion	no. of	>10000	>10000	>10000	>10000	>10000

	resistance	cycles					
5	Pilling	note	4 – 5	4 – 5	4 – 5	4 – 5	4 – 5
6	Hygroscopicity	(%)	10,8	11,2	10,8	10,8	10,8

Correlation between physical-mechanical properties of knitted fabrics produced shows:
- uniform appearance of knitted fabrics;
- very good abrasion resistance (> 10,000 cycles) which is due to both the properties of yarns (high tensile strength) and the corresponding settings of knitting machines as well as the design of structural parameters appropriate for the field of application;
- very good pilling (grade 4 – 5);
- superior hygroscopicity as compared to knitted fabrics made from other cellulose yarns

Development of conductive knitted products

As there is a need to develop knits that offer protection to persons who work in hazardous environments, highly complex research activities are under way in order to correlate the comfort and protection characteristics by combining knitted structures with new raw materials.
Considering that we have previously approached especially the comfort characteristics of yarns and knits, we shall in these chapters refer to technical aspects of the protective characteristics of persons who work in hazardous environments. The study and the research work were conducted by introduction in the knitted structure of new conductive fibres and yarns.
Conductive yarns can be obtained from conductive fibres, conductive filaments, classical yarns coated with conductive polymers, metal-plated yarns, conductive yarns obtained from 100% conductive fibres or from a mix of various ratios, yarns coated with conductive powders such as carbon, metal powders. These can be used in applications as anti-static products, heating elements, signal transfer, electromagnetic shields. Highly conductive yarns can offer static control in a large variety of industrial fields: conveyor belts, woven filters. Conductive yarns can generally be sewn, knitted or woven: metal coated yarns; carbon core yarns; conductive polymer yarns; metal yarns (mono-filament and multifilament).

Figure 2: Conductive yarns

Use of conductive fibres and yarns in knitting products made on flat knitting machine

Conductive fibres and yarns are instruments to be developed on those markets where uncontrolled static discharge may pose quality, health and security problems. As many textile producers are looking for new opportunities with a higher added value for their clients, besides the mass production, the products developed to control electrostatic discharge are a current theme.
Current ESD clothing articles do not fully solve the problem of accidental electrostatic discharges. In order to develop an ESD clothing product with better characteristics the development of a two-layer structure was proposed in the current project: an external and an internal layer. The two layers differ in terms of electrostatic behaviour and allow for solving problems that cannot be solved by the use of one single layer.
The external layer is the surface of the material being in direct contact with the human operator work environment and the internal layer is the surface being in contact with the operator. In these conditions the

two layer approach permits the demarcation of the accidental discharge path from the controlled discharge path of the material electrical charges.

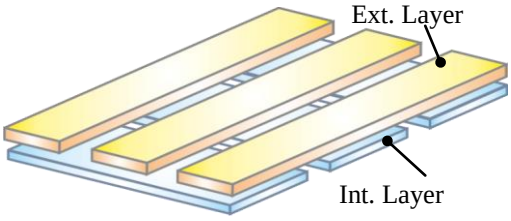

Figure 3: The equivalent structure for knitted textiles

The external layer needs to have a higher surface resistivity so that it does not allow for a path with high circulation of static energy. This is accomplished by using insulating/dissipative materials. Moreover, the structure of the external layer is composite, the constituent yarns having conductive core. The conductive part of the external layer has no contact with the environment. The internal layer was introduced to provide a larger drainage surface for the electrical charges than the surface ensured by the conductive part of the external layer. This layer can be made of composite yarns with conductive core, but also of composite yarn with conductive core that has no contact with the environment.

The external layer is predominantly dissipative and it provides protection to short circuit and the limitation of the electrostatic energy that can be dissipated to the work environment and the internal layer is predominantly conductive, providing controlled drainage of cumulated electrostatic charges.

An additional requirement for the internal layer is to provide comfort to the user.

An important activity is to determine the yarn/fibre type/structure on the basis of ESD/EMC tests and investigations in order to ensure higher ESD properties to the two-layer knitted structure.

CONCLUSIONS

The development of new types of bioactive and conductive products on automatic flat knitting machine is expected to lead to a more efficient using of the machines in the textile companies. Better antibacterial, antiallergenic, antistatic, protective, conductive, ecologic and comfort properties lead to higher quality products due to: prevention of skin diseases and allergies; improvement of comfort characteristics (rapid drying, reduced weight, thermal insulation capacity, higher elasticity, good hygroscopicity, soft touch, pleasant adherence to the body, freshness and coolness); protection of persons who work in hazardous environments; easy care, good wear resistance; low environmental impact.

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