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# Preparation of Enzymatically Modified Flax Fiber for Producing of Rotor-Spun Yarn for Apparel

## Abstract

*At the Institute of Natural Fibres, Poznań, we developed a new method for cottonising short bast fibres with the use of enzymes in the cottonising process. The final product of this cottonising process is a fibre with a mean length of 60 to 80 mm, characterised by irregular staple length, so about 20% of the fibres are longer than average. However, the open-end cotton system of spinning requires the use of cotton-type flax in respect of its mean fibre length (of the order of 30 to 40 mm, evened-up staple length). That is why a research project was undertaken in 2004 aimed at further improving the enzymatic modification of technical flax fibres (flax hackling noil) and producing modified cottonised flax. This paper is a presentation of the results of the research work in 2004.*

**Key words:** flax hackling noil; bio-cottonizing; bio-modified flax fibers; enzymatic preparation.

## ■ Introduction

Attempts to process the flax fibre by technologies other than the conventional flax-processing technology were undertaken in parallel with the first endeavours to reduce the flax fibre bundle to a more elementary form. The process by which the technical flax fibre was 'elementarised' to a fibre whose mean staple length was similar to that of cotton was described as 'cottonising' and the product of the cottonising process as 'cottonin'. Intensive research to improve the cottonising process, together with attempts to process the cottonin by the cotton system, were carried out in the first half of the 20<sup>th</sup> century in Germany, Russia, Italy, and Poland [13]. The work was continued in many countries with the dual aim of improving the quality of cottonin and adapting it for selected spinning systems [3,4]. At present, two types of cottonin, differing in staple length and linear density, are standard: cotton-type cottonin, 0.9-1.8 tex and 20-45 mm; and wool-type cottonin, 1.2-3.5 tex and 50-122 mm.

A number of technological processes were developed in many countries, including Poland, for manufacturing flax-containing yarn on existing textile machinery. In Poland, a technology was developed and implemented in industry for manufacturing a blend yarn containing 30% flax by the worsted system [1]. Currently, the worsted system is being employed for the manufacture of 42-64 tex yarns from blends containing 30% flax cottonin, 40% wool, and 30% manmade fibres, such as polyester, PAN, or viscose. In Poland again, a technology is successfully being employed by which 50-100 tex knitting

yarns with a 30% content of flax fibre are being manufactured on the Suessen spinning machine, Parafil 2000 [4].

The greatest use of flax cottonin, however, is in the production of cotton blend yarns manufactured by conventional cotton and rotor-spinning systems. For many years the Polish textile industry has been using the BD spinning machines for manufacturing 40-64 tex yarns from blends of 50% flax cottonin+50% cotton [2]. The above overview of the present situation in the production of blend yarn containing flax cottonin shows that the greatest use of this fibre is in the cotton system for which it was originally developed in the early twentieth century. In the remaining spinning systems, the proportion of flax cottonin in commercially manufactured blend yarns does not exceed 30%. However, there is continuous improvement of the cottonising process, and new properties are imparted to the flax cottonin, extending the area of its application.

During the last five years, a new method of cottonising technical bast fibres has been developed at the Institute of Natural Fibres, Poznan, and implemented in Polish industry. The new method is based on the use of an enzymatic preparation to facilitate de-gumming of the fibre bundles and their easier separation into smaller bundles of loosely-bound ultimates (elementary fibres) [6-11]. That is why this modified flax fibre is suitable for use as the outer wrap of a friction-spun core yarn, in a proportion ranging from 70% to 100% [12]. The mean length of the modified fibres is about 60 mm, and the proportion of fibres with a length

above average is about 20%. Naturally, the modified fibre in this form could not be used for open-end spinning.

This research work was initiated in order to improve the process of enzymatic modification of short flax fibres, as well as the mechanical processes by which their staple length is made more uniform. Since, upon modification, the flax fibre is characterized by flexibility, softness and greater proneness to mechanical separation, especially in carding, it is expected that the modified flax fibre, if properly evened up, can be used in increasing proportions for the production of cotton/flax yarns. At present, the main manufacturer of such yarns in Poland is the company Zamatex. Cotton/flax yarns of linear density 64÷100 tex are manufactured by rotor spinning from blends containing 40÷50% flax. Since the Zamatex company was inclined to increase its production of this group of yarns by adding to it yarns with 50% and over of cottonised flax, a joint project with the Institute of Natural Fibres was started in the middle of 2004 to develop and implement a process of manufacturing rotor-spun cotton/flax yarns with a high proportion of enzyme-modified flax. The objectives of the research project were as follows:

- to determine the optimum process parameters for enzymatic modification of flax hackling noil using the Polish enzymatic preparation Pektopol PT;
- to find an optimum method of producing modified cotton-type cottonised flax; and
- to explore the possibility of using cottonised flax in proportions of 50% and over for the production of medium-fine yarns by the open-end cotton system.

## Methods employed

The optimum process parameters for the modification of flax hackling noil was determined in two stages on both laboratory and commercial scales, using the method of successive approximations. The experiments with evening up the length of the modified flax fibre were carried out under industrial conditions on a Rieter-Elitex cottonising machine, type RCZ 120-3.03.

The evaluation of the individual variants of enzymatic modification was based on analysis of the change in linear density of the fibres, as well as photomicrographs

of the surface and cross-sections of the fibres viewed under a JSM-5200 LV scanning microscope (JEOL).

The evaluation of the yarns was based on laboratory tests of their physical and mechanical properties.

The optimal variant of the modified flax fibre was tested in blends with cotton, and the trial spinning was carried out at Zamatex on a BD 200.

## Materials

On both laboratory and commercial scales, the focus of the trial modification was the short hackling noil fibre 1.72 tex/82 mm. For the enzymatic modification, the Polish biological preparation Pektopol PT was used; this is produced in the process of biosynthesis with the use of the *Aspergillus niger* strain. This preparation incorporates a complex of pectinolytic enzymes as well as cellulase, hemicellulase, protease and other enzymes that hydrolyse polysaccharides and proteins. The manufacturer of the preparation is Pektowin Co. Ltd, Jasło, Poland [5].

## Experiments

### Determining the optimum parameters of enzymatic modification

The laboratory experiments were carried out using 10 g samples. The bath ratio

**Table 1.** The parameters and processes of flax hackling noil modification – laboratory scale; \* % of weight of fibres.

Item	Process	Parameters	Variant							
			1	2	3	4	5	6	7	8
1	Soaking in enzymatic bath	concentration of preparation*	0.40	0.45	0.50	0.55	0.60	0.65	0.70	0.75
		temperature of bath	55							
		pH	4.5							
		soaking time	60							
2	Scouring	detergents	2.5							
		time	30							
3	Rinsing/softening	temperature	40							
		time	20							

**Table 2.** Sequence of processes in variants of manufacturing of modified cotton-type cottonized fiber.

Item	Process	Variant I M1 + RCZ	Variant II M2 + RCZ	Variant III RCZ + M1
1	Cottonizing on RCZ 120-3.03	-	-	X
2	Enzymatic modification – continuous process	X	-	X
3	Enzymatic modification – discontinuous process	-	X	-
4	Cottonizing on RCZ 120-3.03	X	X	-

was 1:30. In the experiments only one parameter was varied, i.e. the amount of the enzymatic preparation. The variants of trial modification are described in Table 1.

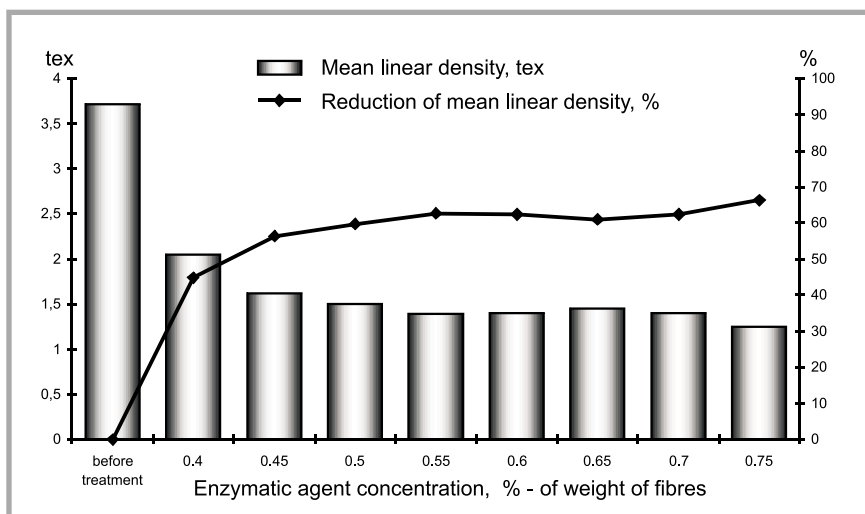
The optimum laboratory variant was tested in a commercial-scale modification of 100 kg of cottonised flax and 200 kg of flax hackling noil. Two trial enzymatic treatments, each with a different time of exposure to enzymes, were carried out for each lot, as follows:

1. Trial M1: soaking time 60 minutes, continuous process;
2. Trial M2: time of exposure 16 hours, discontinuous process. Padding the fibre with enzymatic preparation was expected to take place during the so-called 'seasoning'.

The remaining parameters of the enzymatic bath, scouring, and rinsing were as in Table 1.

### Determining the optimum method for manufacturing modified cotton-type cottonised fibre

In selecting the method for manufacturing the modified cotton-type cottonised fibre, the modifying treatment was applied before or after the mechanical cottonising process, which was carried out on a Rieter-Elitex cottonising machine, type RCZ 120-3.03. The variants of the trial manufacturing process are presented in Table 2.



**Figure 1.** Effect of enzymatic agent concentration on linear density of modified flax hackling noil.

### Assessing the suitability of the modified cottonised flax for producing yarns

Three variants of cottonised flax were additionally evaluated in the course of trial spinning by the medium-fine cotton rotor-spinning system. The trials were made for blends of cotton + cottonised flax in proportion 50/50. At this stage of the experiments, the blends were planned to be processed into 64 tex yarns. Trial spinning of the blends, each in an amount of 50 kg, was carried out on a processing line for manufacturing medium-fine yarns by the rotor-spinning cotton

system, including the following steps: blending, picking, carding, drawing, and spinning on a BD 200. The results of the steps were evaluated, and laboratory tests were made of the essential properties of the yarns.

### Results and discussion

In the course of enzymatic modification of the flax hackling noil, significant changes occurred in the fineness and structure of the fibres. The effect of enzyme concentration of the modifying bath expressed as

a proportion of the enzymatic preparation to weight of the fibre mass is presented in Figure 1.

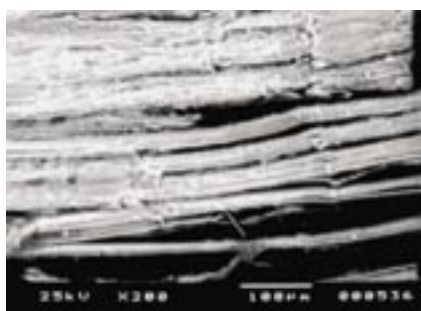
The test results showed that if the concentration of Pektopol PT ranged from 0.5% to 0.6% (variants 3,4,5), the linear density of the flax hackling noil was reduced on average by 60%. For further trial processing, on the commercial scale, a concentration of 0.5% was selected.

The resultant changes in the structure of the fibres can be seen in the photomicrographs of the fibre cross-sections before and after the enzymatic treatment (Figures 2-5).

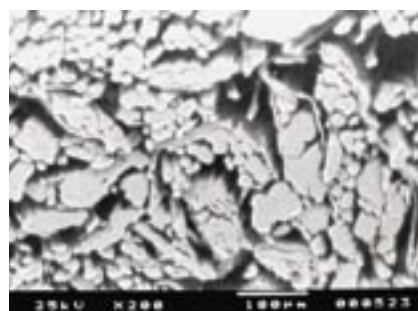
The flax fibres before biological modification, shown in Figure 2, have a rough surface with lignin permeated by pectinous glue, which cements the individual fibres into bundles. The same fibres after biological modification, shown in Figure 4, have a smooth surface and are well separated from one another. In the cross-section of a fibre representing the flax hackling noil before modification, large aggregates of the elementary fibres (ultimates) are visible in close inter-adherence (Figure 3). After modification, however, smaller aggregates and elementary fibres are visible (Figure 5).

The properties of the cotton-type cottonised flax after each processing step in three variants are presented in Table 3.

The finest fibres were obtained in variant II, both after discontinuous modification (Trial M2, with 16 hrs exposure) and after cottonising (M2+RCZ). After each of these treatments, the flax noil in this Variant undergoes a reduction in diameter and a significant shortening. In addition, the linear density of the fibres here was reduced by 54% and the length by 66% compared to the input material. Evidence of the high capability of separation of these fibres after modification is the high proportion of fibres which were less than 20 mm long (47.8%) and the low proportion of fibres over 50 mm long (15.4%). The longest fibres were obtained in variant I, where the processing consisted of a continuous modifying treatment (Trial M1) followed by cottonising (M1+RCZ). Here, the fibre linear density was reduced by 46% and the length by 51%. the proportion of fibres below 20 mm and higher of fibres above 50 mm was lower than in variant II. Applying the enzymatic modification after cottonising, i.e. to



**Figure 3.** Cross-sections of the flax fibers before biological modification.



**Figure 2.** The surface of the flax fibers before biological modification.



**Figure 4.** The surface of the flax fibers after biological modification.



**Figure 5.** Cross-sections of the flax fibers after biological modification.

**Table 3.** Fineness and length of the fibers in noil and cottonized flax before modification, after modification, after cottonizing, and after both treatments.

Parameter	Unit	Before modification	Variant I		Variant II		Variant III	
			M1	M1+RCZ	M2	M2+RCZ	RCZ	RCZ+M1
Linear density	tex	1.71	1.28	0.93	1.1	0.78	1.42	1.28
Mean length	mm	82.0	56.5	40.2	53.6	27.8	28.0	23.2
Proportion of fibers up to 20 mm long	%	5.0	7.5	33.0	16.0	47.8	39.8	47
Proportion of fibers more than 50 mm long	%	64.7	59.5	40.5	54.0	15.4	12.8	4.0

**Table 4.** The physical and mechanical properties of the 64 tex yarns produced from blends of cotton with modified flax.

Parameter	Unit	Proportions: cotton/cottonized flax 50/50		
		Cottonized flax produced according to Variant		
		I	II	III
Mean linear density	tex	61.4	64.0	64.3
Variation of linear density	%	3.8	1.2	1.5
Mean tenacity	cN/tex	8.0	7.2	6.8
Variation of tenacity	%	12.7	20.3	15.7
Twist	T.P.M.	749	610	733

cottonised flax (variant III), results in a reduction of the fibre diameter of about 25% and a reduction of the percentage of fibres longer than 50 mm to 4%.

Taking into account the mean fibre length of variant III and its high proportion (47%) of fibres below 20 mm, it is possible to conclude that fibres of the most uniform staple length were obtained in this variant (Figure 6).

The final evaluation of the produced variants of cottonised flax was made while they were being processed into yarn on the processing line for the manufacturing of cotton and blend yarns by the medium-fine rotor-spinning system. For the cotton/flax blends, the operations of blending, picking and carding were free of any technological disturbances. However, disturbances did occur in the drawing operation, especially when processing blends with flax cottonised according to variants II and III, which contained 47% of fibres below 20 mm. Three draw-

box variants of sliver were trial-spun into yarns with a linear density of 64 tex. The results of laboratory tests of the yarns are presented in Table 4.

When comparing the yarns made from blends of cotton with cottonised flax, an effect of increasing short flax (to 20 mm) can be seen. The increased proportion of short flax is followed by a decreased irregularity of the linear density and strength of the yarn (variants II and III).

In the expected continuation of this research work, the objective will be to further increase the proportion of flax in the cotton/flax blends.

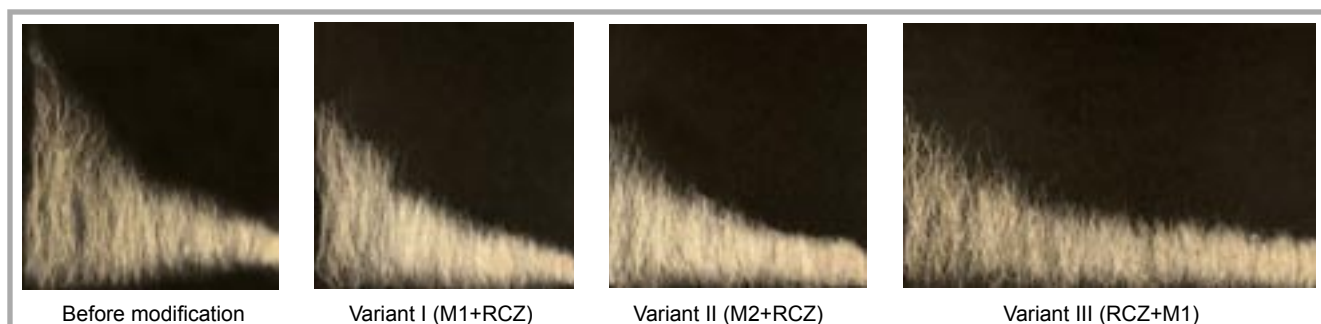
## Conclusions

1. The preparation of the modified cottonised flax fibre suitable for blending with cotton is based on two processing steps, namely the enzymatic modification of flax hackling noil and cottonising the modified flax fibre.

- The best results regarding the fineness and reduction of length of the flax fibre previously subjected to enzymatic modification are obtained if the modification is carried out in a continuous treatment at a 0.5% concentration of Pektopol PT in the enzymatic solution.
- The sequence of the operations is significant for evening up the staple length of the flax fibres to make them more like cotton. The best result was recorded with the enzymatic modification of cottonised flax as in variant III, RCZ+M1.
- The experiments with processing cotton in blends with modified cottonised flax in 50% proportions showed that further shortening and evening-up of the fibres occurred in the succeeding mechanical operations. Despite having the highest proportion of fibres above 50 mm, the modified fibres from variant I gave positive results regarding their suitability for processing in blend with flax in 50% proportions.
- Increasing the amount of fibres below 20 mm in modified flax (variants II and III) results in the decreased irregularity of linear density of the yarn and its reduced strength.
- We will continue research work to develop a cottonised flax fibre which might closely replicate the parameters of cotton, together with a rotor-spinning process that would enable the production of blend yarns with a high proportion of flax.

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**Figure 6.** Distribution of fiber length of the flax noil and of the three variants of cottonized flax.

## References

1. Cierpucha, W; Rynduch, W; Mańkowski, J: *Wool-Based Blends with Flax Processed by the Worsted System. Fibres & Textiles in Eastern Europe*, vol. 4 No 3-4, 1996, Łódź, Poland. (1996).
2. Cierpucha, W; Mańkowski, J; et al: *Ekologiczne dzianiny i tkaniny na bazie przędz mieszkankowych bawełnopodobnych z udziałem lnu i konopi (Ecological Knitted and Woven Fabrics Based on Blend Cotton-Type Yarns Made with Flax and Hemp). Proceedings of 3rd Conference 'Knitt Tech', 8 April 2000. (2000).*
3. Czekalski, J; Jackowski, T; Krucińska, I: *Analysis of the Manufacturing Process of Fine Blended Yarns, Made with a Content of Flax Fibre. Manchester. 16-19 April 2000 (2000).*
4. Kozłowski, R.; Manyś, S.: *New Outlook on Flax-Fibre Properties in Textiles. Natural Fibres*, vol. XXXVIII, 1994, Poznan, Poland (1994)
5. *Prospectus of the PEKTOPOL preparation. Manufacturer PEKTOWIN Sp. z o.o., Jasło, Poland.*
6. Sedelnik N.: *Linen Core Yarns Produced by the Friction Spinning System on Machine Dref 3. Fibres & Textiles*, vol. 7, No 3 (26), 1999, 22-25. (1999).
7. Sedelnik, N.: *Method of Cottonising of Bast Fibres (Sposób kotonizacji włókien łykowych). Patent NR 182572. 10 04.2002. Patent protection since 17 December 1995 (2002).*
8. Sedelnik N., Wrzosek H.: *Flax Fibre Structure following Enzymatic Cottonising Treatment Natural Fibres* vol. XLII, 1998, pp.39-51. ISSN 1230-4476 (1998).
9. Sedelnik N : *Biotechnology to Assist Cottonising of Flax Fibre. The 1st Nordic Conference on Flax and Hemp Processing 'Nord Flax I'. Fibre, Textile and Clothing Science Tampere University of Technology. ISBN 952-15-0019-0. Tampere, Finland. 10-12 August 1998. (1998).*
10. Sedelnik, N.: *Effect of Biological Modification of Technical Flax Fibres. Fibres & Textiles*, vol. 7, No3 (26), 1999, 19-21. ISSN 1230-3666 (1999).
11. Sedelnik, N. : *Improving Bast Fibres by Enzymatic Treatment. The Textile Institute 80th World Conference. Manchester 2000. 16-19 April 2000. (2000).*
12. Sedelnik, N.: *Linen and Hemp Core Yarn Produced by the Friction Spinning System on Mashine Dref. The International Conference "Flax and Allied Fibre Plants for Human Welfare". Cairo, Egypt 8-11 December 2003. (2003).*
13. Żyliński, T.: *Nauka o włóknie (Fibre Science). Wydawnictwo Przemysłu Lekkiego i Spożywczego. Warszawa. (1958).*

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