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Yarns and Woven Fabrics Made from Cotton and Cottonised Flax Blends for Upholstery Applications

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Abstract

The paper presents the results of research concerning the properties of cottonised flax/cotton rotor blended yarns and fabrics for upholstery applications. A double carding technology was developed for producing rotor spun yarns of 29.5 tex, 59 tex, and 100 tex linear density from 30/70 and 50/50 cottonised flax/cotton blends. For comparison purposes, all-cotton yarns of similar linear densities were spun using standard mill procedures and practices. The 30/70 cottonised flax/cotton rotor blended yarns were woven into three variants of fabrics that were tested for tensile and tear strength in both the warp and weft directions. The woven fabrics were evaluated concerning their suitability for upholstery applications.

Key words: cottonised flax, flax/cotton blend, rotor yarns, upholstery woven fabrics.

plant *Linum usitatissimum*. The length of flax fibres in a scutched state varies from a few centimetres (tow fibres) up to 100 cm, while the linear density of technical flax fibres ranges from 1.25 tex to 2.5 tex [13, 14]. Comparing to the cotton spinning system, the traditional flax spinning system is more labour intensive, less efficient and less economical.

Technical flax fibre consists of many individual fibre cells whose physical properties are similar to those of cotton: length between 0.6 cm and 6.5 cm and mean thickness of about 0.02 mm [13]. This similarity of cotton and flax individual fibre cells (ultimate fibre) has revived interest in converting technical flax fibres into cotton-like fibres in order to process them on cotton spinning equipment. The reduction of the flax fibre length and thickness is called cottonisation and can be done by mechanical, chemical, ultrasound and enzymatic treatments. Cottonised flax can be processed in blends with cotton on cotton spinning equipment for a more diverse range of applications.

Cotton is the textile fibre most used in upholstery fabric manufacturing, with a market share of 49 percent of the total market in 1995 [15]. The fast-growing population will generate an increasing demand for textile fibres, especially for cotton, but there is no supplementary land available for cotton cultivation. The disparity between cotton demand and supply can be reduced by using chemical fibres, but the production of synthetic fibres depends on non-renewable petroleum resources. Furthermore there is a clear consumer preference for natural fibres due to their comfort and soft hand.

Taking into account the limited land areas for cotton cultivation, the increased environmental public awareness and the consumer preference for natural fibres, there is a huge opportunity for other natural cellulosic fibres, namely bast fibres, as alternatives to cotton.

In comparison to cotton, flax is also a renewable, biodegradable raw material, but it is more environmentally friendly because it requires minimal pesticide, herbicide, fertilizer, and irrigation. The flax fibre yield per acre is from 2 to 3.5 times higher than that for cotton, depending on the region and conditions [16]. Flax has outstanding health, hygienic, and comfort properties: it is hypoallergenic, antiseptic, protective against UV radiation, naturally insect repellent, highly absorbent, electrostatic free, and thermo regulating.

The objectives of this work were to develop a suitable technology for manufacturing cottonised flax/cotton blended rotor-spun yarns and evaluate the properties of yarns and woven fabrics designed for upholstery applications. Several research studies have been reported in literature on the production of OE cotton yarns with a high content of modified flax fibres [3, 8, 17]. In these studies, the first stages of experimental processing of the technology consisted in preliminary preparation of cottonised flax fibres before blending with cotton (emulsifying and seasoning), blend formation on an opening/mixing set, seasoning and manual mixing, and a second opening and mixing before blend processing on a blow room line. In order to increase the spinning stability, we developed a double carding technology that improved the individualization

Introduction

In recent years, the processing of flax and cotton blends in the short staple spinning system has gained increasing interest among researchers and textile manufacturers [1 - 9]. Traditionally cotton and flax fibres are processed on different spinning systems because of the particularities in the structure and properties of the two categories of fibres. Cotton fibres are single cells that extend from the seed coat epidermis. Their dimensions depend on the cotton species and variety. Thus the superfine Sea Island cottons (*Gossypium barbadense*) have a length of up to 5 cm and a linear density of 1 dtex, while the coarse Asiatic cottons (*Gossypium herbaceum*, *Gossypium arboreum*) have a length of about 1.5 cm and a linear density of 3 dtex [10 - 12]. Unlike cotton, flax fibres are multi-cell technical fibres obtained from the stem of the annual

of multi-cell flax fibres and the cleaning process.

In this research 30/70 and 50/50 cottonised flax/cotton rotor blended yarns of 29.5, 59 and 100 tex linear density were obtained using the cotton spinning system. All-cotton yarns of similar linear densities were spun for comparison purposes. The 30% cottonised flax/70% cotton rotor blended yarns were woven into fabrics for upholstery applications. The tensile and tear properties of three variants of upholstery fabrics were evaluated.

Materials and methods

Characteristics of the raw materials used in the blends for the manufacturing of rotor spun yarns are presented in **Table 1**. Cottonised flax fibres were obtained by the enzymatic process. Even if the thickness of multi-cell flax fibres have been reduced by cottonisation, they are still about two times coarser than cotton fibres. The length of cottonised flax fibres is close to that of cotton fibres, but the short fibre content is more than two times higher when compared to cotton. The tenacity of cottonised flax fibres is lower by about 15% than that of cotton fibres.

Table 1. Characteristics of raw materials.

Characteristics	Unit	Cotton	Cottonised flax
Linear density	tex	0.185	0.382
Fibre tenacity	cN/tex	19	16
Fibre length	mm	28	27
Short fibre content	%	17	37
Fibre impurities	%	1.2	1.96

A quantity of 380 kg of cottonised flax fibres was subjected to oil-water emulsion application before blending with the aim of softening and protecting rigid flax fibres and of reducing dust emissions during mechanical processing. After 24 hours of storing at room temperature, the cottonised flax fibres were manually blended with cotton (Russian cotton) using “sandwich” (horizontal) layers. Two blends of 30/70 and 50/50 cottonised flax/cotton ratios were prepared. The blend fibres were subjected to opening, cleaning and blending in an Ingolstadt blow room (Germany). The scutcher lap was fed to an Unirea 4C card (Romania). Using a traditional system of sliver preparation that consists of two draw frame passages after carding, the number

of end breaks during spinning was high enough to make spinning inefficient on an industrial scale. Because of the high bending rigidity of flax fibres, the short fibres expelled with the trash were not sucked into the waste box and obturated the aperture of the trash extraction tube. Thus trash particles were sucked back into the spinning process, deposited in the rotor groove, and generated a break in the yarn. In order to increase spinning stability, the spinning system was modified using the double carding process. After the first passage of the fibre material on the card, the card slivers were wound into a sliver lap on a Textima sliver lap machine (Germany). Three sliver laps were simultaneously fed side-by-side at the second card passage in order to continue the individualization of multi-cell flax fibres and the cleaning process. Two draw frame passages, Ingolstadt (Germany) and Unirea LB (Romania), were used for doubling, drafting and evening-up of the slivers. Characteristics of the semi-finished products and the waste ratio at each processing stage are presented in **Table 2**.

Second passage drawn slivers were spun into 29.5, 59 and 100 tex yarns on a BD-200 RN rotor spinning machine (Czech Republic) with a metric twist multiplier of 150. The rotor spinning machine settings were as follows: 29000 r.p.m. rotor speed and 8000 r.p.m. opening roller speed, with OK 40 opening roller wire. All-cotton yarns of similar linear densities were spun for comparison purposes.

Yarn properties were measured under standard conditions (temperature, 20 ± 2 °C; humidity, 65 ± 2 %). The breaking strength and elongation were determined on a TINIUS OLSEN H5 K-T tensile yarn tester (UK) according to the EN ISO 2062 standard. Twist measurements were made on a Mesdan twist tester (Italy) according to the EN ISO 2061 standard. Uster CV and imperfections were tested on Uster Tester-II

apparatus (Switzerland) at a speed of 25 m/min.

Rotor yarns from the 30/70 cottonised flax/cotton blend were woven into fabrics on a Dornier rapier weaving machine (Germany). The preparation of warp and weft yarns for weaving was done on the following machinery: an IMATEX winding machine (Romania), an IMATEX doubling machine (Romania), a SAURER ALLMA double twisting machine (Switzerland), an ELITEX warping machine (Czech Republic), and a BENNINGER ZELL sizing machine (Switzerland). Drawing-in was performed manually. Three variants of woven fabrics for upholstery applications were obtained. The fabric variants differ from each other in the weave (plain, weft rib, and 3/1 twill), fabric density, weight, width, fineness and type (single, folded) of warp and weft yarns. Weaving was done on a semi-industrial scale at the IASITEX S.A. weaving mill (Romania), where the same variants of upholstery fabrics are currently produced from 100% cotton blends. The main shaft rotational speed of the weaving machine was adjusted for each fabric variant between 320 r.p.m. and 400 r.p.m.

Greige fabrics with single warp yarns were subjected to a finishing process which consisted in desizing, double washing, drying, dyeing, double washing, drying and sanforization. In the case of woven fabric with folded warp yarns, in the sequence of finishing operations the desizing was replaced by soaping.

Tensile properties of the finished fabrics were measured on a C&B Tessile tensile tester (Italy) according to the SR EN ISO 13934-1: 2002 standard using the strip method. The tearing strength of trouser-shaped test specimens was determined according to the SR EN ISO 13937-2: 2001 standard test method. The dimensional stability test was carried out in accordance with SR EN ISO 5077: 2009 standard specifications.

Table 2. Characteristics of semi-finished products and the waste ratio at the processing stages.

Blend type	Semi-finished product Characteristic	Lap	Card sliver (1 st passage)	Sliver lap	Card sliver (2 nd passage)	Draw frame sliver passage	
						1 st	2 nd
30/70 cottonised flax/cotton	Linear density, ktex	304	5.5	112	5.2	5.1	5
	Count irregularity, %	2.07	6.1	0.74	0.61	0.49	0.42
	Waste ratio, %	4.3	8.6	0	6.2	0	0
50/50 cottonised flax/cotton	Linear density, ktex	297	5.3	102	5.1	5	5
	Count irregularity, %	2.63	6.22	1.04	0.67	0.66	0.5
	Waste ratio, %	4.6	9.1	0	6.2	0	0

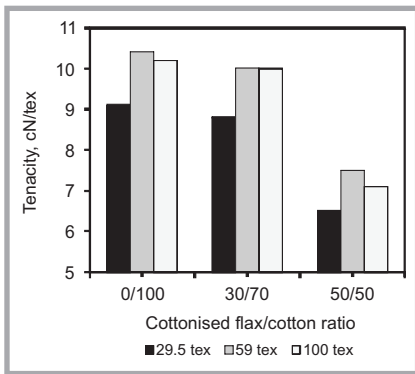


Figure 1. Tenacity of yarns.

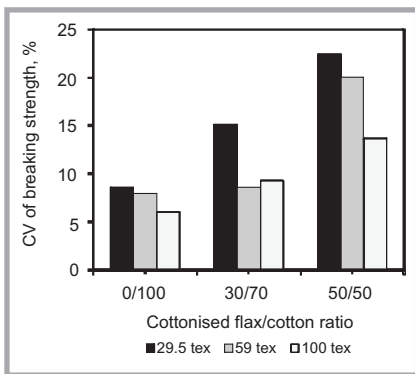


Figure 2. Breaking strength irregularity of yarns.

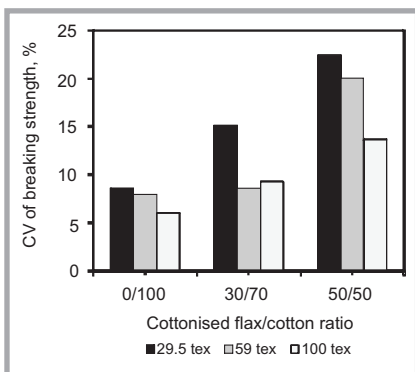


Figure 3. Breaking elongation of yarns.

Results and discussions

Rotor blended yarns of 29.5, 59, and 100 tex linear density were obtained from cottonised flax/cotton blends of 0/100, 30/70 and 50/50 ratios. In order to maintain the number of yarn breakages at an acceptable level, the twist of cottonised flax/cotton blended yarns was adjusted by 20 to 30% higher than that of all-cotton yarns. An increase in yarn twist causes a decrease in rotor spinning machine productivity.

The total waste ratio on the entire production line of cottonised flax/cotton yarns totalled about 20%, almost two

times higher in comparison to cotton processing (10.5%). An explanation can be found in the presence of short fibres with a higher percent of cottonised flax than cotton and in the second passage of the fibrous material on the card. The waste could be used either within the same manufacturing process that generated it or could be sold to other industries.

As can be seen in *Figure 1*, the tenacity of yarns decreases with increasing cottonised flax content. When the cottonised flax content increases from 0 to 50% the tenacity of yarns decreases by 2 - 30%. This behaviour can be explained by differences in the fineness and tenacity of cotton and cottonised flax fibres. In comparison to cotton, cottonised flax fibres are weaker and coarser. The lower number of fibres in the cross-section of cottonised flax/cotton blended yarns than in that of corresponding all-cotton yarns affects yarn tenacity. Also the presence of a higher short fibre content in cottonised flax than in cotton causes a reduction in the blended yarn strength.

The breaking strength irregularity of cottonised flax/cotton blended yarns is higher than that of all-cotton yarns (*Figure 2*). As the cottonised flax content in the blend increases, the breaking strength irregularity of yarns increases. As yarns become finer, the CV of the breaking strength has a tendency to increase.

Figure 3 shows the influence of the cottonised flax content on the yarn elongation at break corresponding to three different yarn linear densities. With an increase in the cottonised flax content, elongation at break of the blended yarns decreases. This expected variation is due to the extremely low elongation of flax fibres of only about 2% [11]. As yarns become finer, their elongation at break decreases as a result of the reduction in the number of fibres in the yarn cross-section.

Observations concerning the mass irregularity of the yarns measured by the CV Uster and the number of imperfections per 1000 m of yarn show a better quality of cotton yarns (*Figures 4, 5, 6 and 7*). The cotton yarns are more even than the blended yarns because cotton fibres are finer and less variable in fineness than cottonised flax ones. Obviously for a given yarn count, the finer the fibres, the higher the number of fibres in the yarn cross-section will be, and as

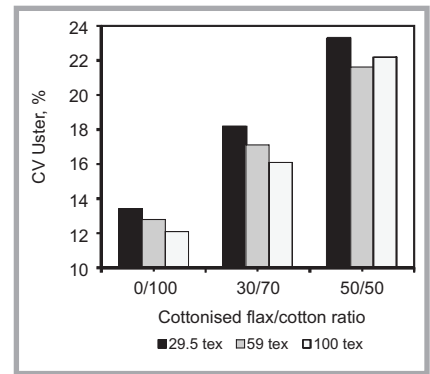


Figure 4. Uster irregularity of yarns.

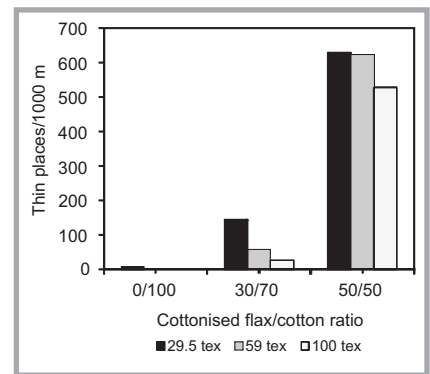


Figure 5. Thin places/1000 m of yarns.

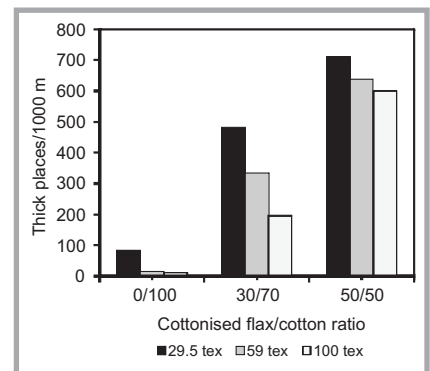


Figure 6. Thick places/1000 m of yarns.

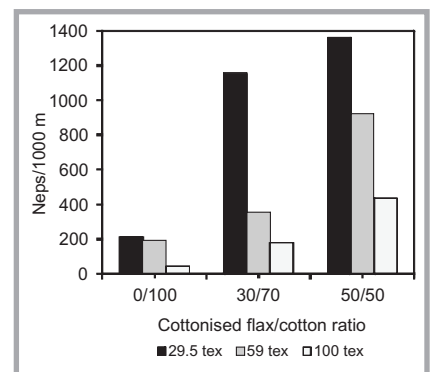


Figure 7. Neps/1000 m of yarns.

a result the lower the CV Uster % will be. Furthermore the presence of a higher short fibre content in cottonised flax

causes not only weaker yarns, increases in processing wastes and less efficient spinning, but also uneven yarns. An increase in cottonised flax content in the blend worsens the yarn unevenness and increases the number of imperfections per 1000 m of yarn, especially in the case of 50/50 cottonised flax/cotton blend. Also as yarns become finer and the number of fibres in the yarn cross-section decreases, the mass irregularity of yarns and the number of imperfections increase.

Rotor yarns from the 30/70 cottonised flax/cotton blend were woven into three variants of fabrics in a weaving mill where the same variants of upholstery fabrics are currently produced from 100% cotton blends.

Physico-mechanical properties of 30/70 cottonised flax/cotton upholstery fabrics are presented in **Table 3**.

The minimum requirements for 100% cotton upholstery fabrics with similar structure characteristics in terms of breaking strength and tear resistance are as follows:

- breaking strength in warp direction: 60 daN;
- breaking strength in weft direction: 50 daN;
- tear resistance in warp direction: 25 N;
- tear resistance in weft direction: 25 N.

Table 3 shows that the breaking strength in the warp direction of all three fabric variants exceeds the minimum limit required by the customer. In the case of the breaking strength in the weft direction, only fabric variants V_1 and V_2 meet customer requirements.

The results displayed in **Table 3** indicate that fabric variants V_2 and V_3 do not have the tear resistance required. As a consequence, the only fabric variant that fulfils the requirements in respect of breaking strength and tear resistance in both the warp and weft directions is variant V_1 .

For upholstery fabrics dimensional stability is a characteristic of great importance because the fabrics must not sag or shrink after a person rises from the furniture item or after cleaning (in the case of removable furniture coverings). Shrinkage values of the only fabric variant suitable for upholstery application (V_1) were 2.7% in the warp direction and 3% in the weft direction, respectively, below

Table 3. Physico-mechanical properties of 30/70 cottonised flax/cotton upholstery fabrics.

Characteristic	Fabric variant		
	V_1	V_2	V_3
Fabric width, cm	137.5	144.7	155
Yarn linear density, tex	warp	59	29.5
	weft	100	
Density, threads/10 cm	warp	252	394
	weft	104	170
Fabric weight, g/m ²	318.1	282.5	165.8
Weave	Plain	Weft rib	3/1 Twill
Breaking strength, daN	warp	83.1	65.9
	weft	67	22.9
Elongation, %	warp	9.8	10.1
	weft	11	6.5
Tear resistance, N	warp	23.7	12.2
	weft	38	7.5

the accepted limit of 5% for upholstery fabrics.

Conclusions

Taking into consideration that flax has several advantages over cotton (it is environmentally friendly, produces higher yields per hectare, and can grow in cold as well as in hot temperate climates, including Romania, where cotton cannot be cultivated), short staple length (cottonised) flax fibres can constitute an alternative to cotton ones. In order to process cottonised flax/cotton blends using the rotor spinning system, a double carding technology was developed. Rotor spun yarns of 29.5, 59 and 100 tex linear density were obtained from 0/100, 30/70 and 50/50 cottonised flax/cotton blends. Rotor yarns from the 30/70 cottonised flax/cotton blend were woven into three variants of upholstery fabrics with different structure characteristics.

Based on the results of this research, the following conclusions can be drawn:

1. In comparison to 100% cotton yarns, cottonised flax/cotton blended yarns have lower strength, higher CV of breaking strength, lower elongation at break, higher mass irregularity and a higher number of imperfections per 1000 m of yarn. This behaviour is due to differences between the two categories of fibres in respect of fibre fineness, short fibre content and fibre structure. Cottonised flax fibres are coarser than cotton ones, and thus the number of fibres in the cross-section of blended yarns is lower than in the case of all-cotton yarns. The presence of a higher short fibre content in cottonised flax causes not only weaker

yarns, increases in processing wastes and less efficient spinning, but also uneven yarns.

2. An increase in cottonised flax fibre content causes the worsening of all yarn characteristics. Also as yarns become finer, their properties deteriorate because the number of fibres in the yarn cross-section decreases.
3. In the spinning of cottonised flax/cotton blended yarns, higher twists and lower rotor speeds were used in order to maintain the number of yarn breakages at an acceptable level. As a result, the productivity of the rotor spinning machine diminished.
4. The only fabric variant that meets the requirements for upholstery applications in respect of breaking strength, tear resistance and dimensional stability in both the warp and weft directions is the fabric variant characterized by plain weave and folded yarns in both directions.



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**On 30 July 2015, we bid farewell and gave thanks
and recognition to**



ZBIGNIEW ROSKWITALSKI

who passed away on 25 July 2015.

He was the Director and Executive Vice President
of the Gdynia Cotton Association,
co-initiator and former President
of the International Forum for Cotton Promotion,
Member of the Board of Directors
of the European Federation of the Cotton
and Allied Textiles Industries (EUROCOTON),
Rapporteur of the Task Force on Commercial
Standardization of Instrument Testing of Cotton
(ICAC),
Member of the Council
of Polish Chamber of Commerce

He was holding the post of the GCA Director and Vice President for 27 years. All that time, he was actively participating in the works of and maintaining contacts with many cotton organisations all over the world. The world of cotton became his passion when he had began his career with us. All who met him, knew that he was a man of action, personally engaged in professional matters, promotion of cotton and its best image, supporter of progress and development in the whole chain of cotton industry. He was not afraid of challenges, problems and complicated situation of cotton in our times, always trying to get some solution. Until his last moments, he was supporting the Association with his knowledge and experience, although serious illness made it hard to him.

We lost a professional, but most of all, our sincere friend.