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Examination of Physical-Mechanical Parameters of Carded and Combed Yarns Produced from Biological Cotton

Abstract
Terms of 'biological and 'organic ' cotton are described. The publication presents the parameters of fibres and yarns dedicated to knitting, which are manufactured from biological cotton, in relation to conventional fibres and yarns analogically manufactured. The advantages of products made from biological cotton are emphasised, and a recommendation is proposed for baby-care and medical textile products.

Key words: *biological cotton, organic cotton, conventional cotton, ecology, classical yarns, fibre parameters, yarn parameters.*

RESEARCH AND DEVELOPMENT

Introduction

By biological cotton, we mean cotton which during all cycles of vegetation, after harvesting and in its transport was not treated with any chemical substances which have a negative influence upon the natural environment and humans. The list of prohibited chemical substances is established by Directives of the European Union.

An additional notion of 'organic' cotton is also used. The ecological aspect of such cotton is strengthened by not applying artificial manure to cotton fields and fertilising the field only with natural manure for three years before harvesting cotton. Such cotton should be harvested manually.

The 'ecology' Standard of cotton is confirmed by special verification units on the basis of agriculture documentation and auditis carried out beginning with seed selection, through vegetation stages, harvesting, storage, grinning, and preparing for sale.

In the USA where the production of ecological cotton is developed the best in the world, all chemical substances used in agriculture must be tested and admitted to application by the EPA (Environmental Protection Agency) and the FDA (Food and Drug Administration). For example, as regards some agricultural chemical substances used for cotton, any minute quantities of toxic action are allowed to be left in the raw material. It also concerns such chemical substances as, for example, Lindan, DDT, abd PCP pentachlorophenol, among others, used as protective substances against mildew, which are allowed in minute quantities according to the ÖKO-TEX criteria [1].

There are a lot of factors which clearly indicate the benefits connected with biological and organic cotton cultivation. The first is the possibility of decreeing the contamination of soil on a great scale. At present, in Africa, Asia, and Latin America the Standards of protection of the environment does not exist or are not especially rigorous. According to the World Health Organisation [2] about 20,000 dead and 3 million existing diseases per year may be connected with pesticide used in agriculture. On the other hand, the above-mentioned continents include countries of the highest share in cotton agriculture, which need great amounts of pesticides in order to achieve large crop yield. Although the cotton cultivation takes up barely 3% of the cultivable world, it absorbs up to 25% of the world's pesticide and artificial manure consumption. For example, in India about 50% of pesticides are used on 5% of cultivated land, in Turkey this is 36%, and in Egypt 50% of all pesticides are absorbed by cotton plantations [3].

An interesting factor encouraging organic cotton cultivation is the so- called 'green fashion' [3], supported by an increasing number of people, for whom ecology is the most important philosophy, and who place great importance not only on the fact of what to buy, but also on the origin of the goods bought. They are conscious that, for example, according to the international organisation WFF, the fauna and flora of the Aral Sea has been destroyed by the pillage policy of Usbek farmers cultivating cotton for a large network shops. Unfortunately, even now this is a common ecological tendency in Western Europe and the USA, but not such a large extent. All domestic producers are still not interested in organic cotton.

Denotations used

L(w) – average length for/of weight shares,
$CV_{L(w)}$ – coefficient of variation for/of weight shares
UQL (w) – 25% of fibres of a length no shorter than the one given,
SFC(w) – contents of short fibres less then 12.7 mm,
5% – content of fibres no shorter than the length given,
2.5% – contents of fibres no shorter than the length given,
Fineness – linear densities of fibres,
IFC – contents of immature fibres (maturity < 0.25),
Mat Ratio – degree of maturity,
SCN – neps from seed husks,
Neps – number of neps,
Tresh – contents of impurities of diameter greater then 500 μm,
Dust – contents of impurities of diameter less then 500 μm,
Total – total contents of impurities,
Mean Size – average quantity of impurities,
VFM – content of visible foreign matters

The level of production of biological and organic cotton is still growing, albeit very slowly. Although at present organic cotton is cultivated in 15 countries, and comprises barely 0.6% of world cotton production. Existing barriers are high cost of production, extensive knowledge of cultivation, longer working hours, and, of course, significantly lower yield efficiency. Furthermore, world industry is increasingly interested in the production of genetically modified cotton. According to Gdynia Cotton Association [4] such cotton is characterised by about 33% higher production efficiency compared with conventional cotton. Different varieties of genetically modified cotton are characterised by small absorptivity to herbicides and immunity to pests. In the season 2005/2006 the share in the world production of genetically modified cotton crops grew to 37%, and in 2006/2007 forecastes indicate even 42%.

Aim of the research work

The aim of our research work was to develop a technology of manufacturing high-quality yarns dedicated to knitting from biological cotton imported from West Africa specially for scientific investigation, and to establish technological processing conditions. Finally, to make a comparison of the parameters obtained with those characteristic for conventional cotton.

Materials and methods of cotton invesigation

Four types of biological cotton and five of conventional cotton from West Africa (Benin) were used in our investigations. All types were laboratory tested with use of an USTER AFIS instrument in accordance with US Standards. Benin has its own cotton classification [7], and therefore African Standards and the US classification are compared in Table 1. The results of our laboratory analysis of biological cotton are listed in Table 2, whereas those of conventional cotton are in Table 3.

Table 1. *Comparison of African Standards with American classification.*

Name of the type	African Standard	American Standard
KABA/S	0+	Barely Good Middling
KABA	0	Strict Middling
BELA	1	Middling Colour. Strict Middling Leaf
BELA/C	1	Middling Light Spotted. Strict Middling Leaf
BELA/T	1	Middling Leaf. Strict Low Middling Colour
ZANA	1.1/2	Strict Low Middling Leaf Standard Spotted
ZANA/C	1.1/2	Strict Low Middling Leaf Standard Tinged
ZANA/T	B1.1/2	Strict Low Middling Leaf Low Middling Colour
KENE	2	Low Middling Leaf-Standard very Spotted
BATI	2.1/2	Strict Good Ordinary Leaf Standard Stained

Table 2. *Parameters of biological cotton fibres.*

Parameter	Unit	Types of cotton			
		Bela	Bela/C	Bela/T	Zana
L(w)	mm	24.4	24.1	24.3	24.4
$CV_{L(w)}$	%	38.0	35.0	36.4	35.0
UQL (w)	mm	30.3	29.3	29.7	29.7
SFC (w)	%	11.0	9.0	9.9	9.1
5%	mm	34.8	33.9	34.5	34.1
2,5%	mm	37.7	36.9	37.5	36.9
Fineness	mtex	145	148	146	147
IFC	%	9.3	7.8	8.3	7.9
Mat Rario	-	0.88	0.91	O.89	0.91
Neps	L/g	696	711	695	696
SCN	L/g	276	210	266	231
Trash	L/g	43	35	40	48
Dust	L/g	491	377	371	477
Total	L/g	534	412	410	525
Mean size	mm	247	226	242	250
VFM	%	1.27	0.83	0.99	1.60

Table 3. *Parameters of conventional cotton fibres.*

Parameter	Unit	1st test	2nd test	3rd test	4th test	5th test
L(w)	mm	24.8	27.0	26.0	24.4	25.2
$CV_{L(w)}$	%	34.1	34.1	34.3	34.0	33.6
UQL (w)	mm	30.3	32.8	31.7	29.5	30.4
SFC (w)	%	10.2	7.1	8.1	8.3	7.1
5%	mm	34.8	37.8	36.1	34.0	35.2
2.5%	mm	37.9	40.9	38.6	36.7	38.1
Fineness	mtex	159	157	160	152	152
IFC	%	7.7	8.8	7.9	7.6	7.5
Mat Rario	-	0.93	0.92	0.93	0.89	0.90
Neps	l/g	242	174	211	328	288
SCN	l/g	30	20	28	-	-
Trash	l/g	35	26	24	25	36
Dust	l/g	195	411	366	196	274
Total	l/g	230	437	390	221	310
Mean Size	mm	303	205	212	277	272
VFM	%	0.79	0.89	0.60	0.80	1.05

Results of cotton investigation and discussion

The parameters for conventional cotton obtained were compared with Uster Statistics 2001 Standards, and the following conclusions can be drawn:

1. The content of neps places the samples of tests 1, 2 and 3 at a level of 25% of the global production of cotton fibres, whereas tests 4 and 5 are at a level of 50%..
2. The contents of short fibres for test 1 is related to 50% of the global production. Tests 2, 3, 4 and 5 at a level of 5% of global production. It means that only 5% of the global production of cotton have such good indices concerning the contents of short fibres.
3. The content of impurities of the diameter > 500 μm, according to Uster Standards for all tests, is at a level of 5% of the global production.
4. The content of impurities of the diameter < 500 μm for tests 1, 4 and 5 places the samples at a level under 5% of the global production. It means that less than 5% of the global cotton production within the given range of fibre length has such a low number of impurities. The remaining tests were classified at a level of 25% of the global production.

5. The contents of visible foreign matters in tests 2 and 5 places them at a level of 25% of the global production, whereas the remaining tests are at a level of about 5% of the global production of fibrous mass.

On the basis of the tests carried out, we can state that the cotton batches tested were characterised by high quality due to low contents of impurities, a proper degree of maturity (Micronaire within the range of 3.9 and 4.0) and low contents of short fibres. The linear density of fibres was within the range of 1.52 – 1.6 dtex, and the fineness factor of the fibre 155 – 165.

The physical – mechanical parameters of biological cotton fibres were also tested and compared with Uster Statistics 2001 Standards with the following results:
1. The samples tested had a great number of neps. The contents of neps places the tests at a level between 75% and 95% of the global cotton fibre production.
2. Cottons of all types were characterised by very small contents of short fibres. Only 5% of the global production of cotton achieve such good quality regarding their parameters.

Lots of the biological cotton imported from Benin were characterised by a classified length of fibres within the range of 1 1/8”.

It should be emphasised that the fibres tested were characterised by high quality. The only concern was the number of neps, but the results of around 700 neps per gram of fibre mass are not far from the level represented by 95% of global cotton production. According to Uster statistics a technological process properly carried out should decrease the number of neps in the card sliver by 2 - 3 times, and even 7 - 9 times during the combing process in relation to the content of neps in raw material. In the technological process, therefore, having in mind the quality of the final product (yarn), attention should be paid to those stages of the spinning process which are decisive in removing neps from the fibre stream.

As regards conventional cotton of the same types and same origin, which was a reference for comparison, the content of short fibres in biological cotton is slightly higher. Fibres of a length shorter than 12,7 mm make up only 9 - 11% of all the mass of fibres, which is a good initial value for the process of thinning the fibre stream in the drawing apparatus of a spinning machine. The degree of maturity of biological cotton is at a proper level (Micronaire for all samples was 3.7). Therefore, the cotton tested was classified as thin cotton. Also, the indicator of fibre fineness for all samples was very similar and amounted to 16.3÷16.8. The fibre thinness is/was within the required boundaries of 10 ÷ 25. Only after exceeding this value, a tendency of knotting, i.e. the formation of neps appears.

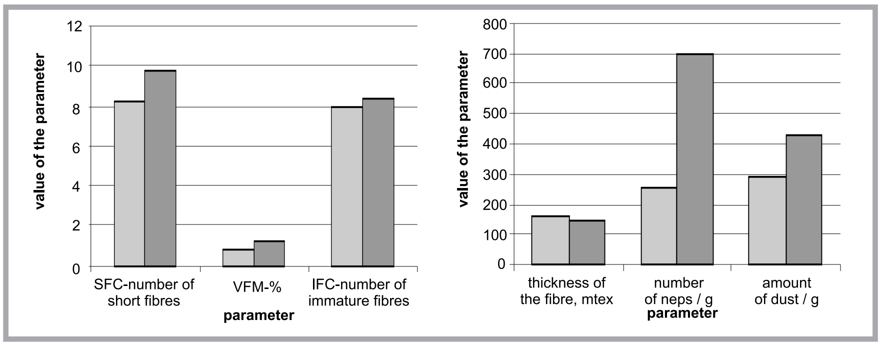

Figure 1. *Comparison of parameters of conventional “A” (■) and biological “O” (■) cotton fibres.*

Comparison of the quality parameters of biological and conventional cottons are presented in Figure 1.

Summarising the results obtained with the use of USTER AFIS apparatus and taking into account the parameters examined, we can state that biological cotton imported from Benin is good raw material for processing using the cotton spinning system. During processing, special attention should be given to those processes in which the neps are removed, that is carding and combing. In this investigation, the process of carding was performed with the use of a one-cylinder carding machine.

Materials and methods of yarn investigation

The aim of this investigation stage was to manufacture yarns from biological cotton, test their parameters and compare them with those of conventional cotton.

The following yarn assortments were chosen for examination:
Yarn 15 tex 100% cotton O.combed 18. Tricot par. G-33\Ac,
Yarn 15 tex 100% cotton O.combed 18. Tricot par T\Ac,
Yarn 20 tex 100% cotton O.combed 18. Tricot par G-33\Ac,
Yarn 20 tex 100% cotton O.carded Tricot par G-33\Ac

Notations:

O – biological cotton
C 18 – degree of combing
Tr.p – knitting yarn (dedicated to knitted fabrics, paraffin)
G-33\Ac – yarn produced with the use of a G33 type Rieter spinning frame and transferred on an Autoconer winder.
T\Ac – yarn produced with the use of a 2110 B Textima spinning frame and transferred on an Autoconer winder.

The assortments above were produced on machines installed at Zawiercie S.A. Spinning Mill, Poland. The yarns manufactured were analysed at the company’s laboratory; and the following parameters were tested:
- linear density,
- twist,
- tenacity,
- elongation at break,
- mass irregularity,
- yarn faults (thin places, thick places, neps), and
- hairiness.

All laboratory tests were performed according to the Polish Standard (PN) or its ISO equivalent The following apparatuses and measuring instruments were used:
- a reel and Uster Autosorter – to measure linear density,
- a mechanical twist tester – to measure twist,
- an automatic tensile testing device - Uster Tensorapid 3 – to measure tenacity and elongation at break,
- Uster Tester 3 apparatus – to measure the irregularity of linear density, number of faults (thin places, thick places, neps) and for the hairiness indicator.

At the very beginning two assortments of 15 tex combed yarn were analysed. Differentiation of the assortments were obtained with the use of two spinning frames (Rieter G33 and Textima 2110B).

The yarn parameters obtained of yarns produced from biological cotton were compared with those manufactured from conventional cotton.. The results are included in Tables 4 and 5.

Results of yarn investigation and discussion

The results obtained by laboratory analysis of 15-tex yarn fully confirmed the usability of biological cotton for the combed cotton yarn spinning system. The linear densities of the intermediate products were within the assumed boundaries and their irregularity was lower than the maximum level accepted. Neps were removed in a proper way both in the carding and in the combing process. The irregularity of the sliver after the final drawing frame reached a level of 50% according to Uster Statistics 2001.

Comparison of the yarns was performed based on Uster statistics for both the spinning frames used in the test spinnings. The following conclusions can be drawn from the analysis:

For yarn produced with use the of a G33 Rieter ring spinning frame:

- The irregularity (CV%) of the linear density, according to Uster, of both yarns reached a level of below 5%. That is why the yarn produced is/was of high quality (taking CV into consideration).
- Yarn produced from biological cotton is characterised by higher tenacity (at the level of 50 ÷ 75% according to Uster Statistics 2001) and a lower number of thin places (at the level of 5%) in comparison to yarns produced from conventional cotton,
- Slightly worse quality parameters of yarns were obtained from biological cotton, taking into account the irregularity of tenacity, which was/is at a level of 50 ÷ 75%, and the number of neps at a level of 25 ÷ 50%.

For yarn produced with the use of a Textima type 2110B ring spinning frame:

- The irregularity (CV%) of the linear density, according to Uster, of yarn from biological cotton reached a level of below 5%. That is why the yarn produced is/was of high quality (taking CV into consideration). This is a better result than for yarn produced from conventional cotton, which was at a level of 5÷25%,
- Yarn from biological cotton is characterised by higher tenacity and a lower number of thin places in comparison to yarn produced from conventional cotton,
- Slightly worse quality parameters of yarns were obtained from biological cotton, taking into account the irregularity of tenacity, which was at a level of 50÷95%, and the number of neps was at a level of 25÷50%.

Table 4. Comparison of quality parameters of 15 tex yarns produced from biological cotton and conventional cotton with the use of a Rieter G33 ring spinning frame - yarn winded.

Parameter	DTT quality Standards	Biological cotton "O"	Level according to Uster Statistics 2001	Conventional cotton "A"	Level according to Uster Statistics 2001
Tt, tex	15±3% /14.6-15.4	14.8	-	15.0	-
V_{tex}, %	Max. 3.0/2.8	1.7	25÷50%	1.1	5÷25%
Tenacity W_w, cN/tex	min. 11.0/13.0	17.0	50÷75%	15.2	95%
V_{Ww}, %	Max. 12.5/10.5	9.0	50÷75%	7.5	5÷25%
Elongation, %	---	4.7	95%	4.8	95%
CV % Uster	max. --/13.8	12.2	<5%	12.5	<5%
Thin places (-50 %)	max. --/10	0	5%	2	5÷25%
Thick places (+50%)	max. --/50	22	5%	18	5%
Neps (+200%)	max. --/200	131	25÷50%	68	5÷25%
Hairiness H indicator	---	5.3	50÷75%	5.0	25%
Twist, twist/m	max. 940	879	-	872	-
α_m	max. 115	106.9	-	106.8	-

Table 5. Comparison of quality parameters of 15 tex yarns produced from biological cotton and conventional cotton with the use of a Textima 2110B ring spinning frame - yarn winded.

Parameter	DTT quality Standards	Biological cotton "O"	Level according to Uster Statistics 2001	Conventional cotton "A"	Level according to Uster Statistics 2001
Tt, tex	15±3% /14.6-15.4	14.7	-	15.0	-
V_{tex}, %	max. 3.0/2.8	2.6	75%	2.3	50÷75%
Tenacity W_w, cN/tex	min. 11.0/13.0	16.0	75÷95%	14.1	>95%
V_{Ww},%	max. 12.5/10.5	10.1	75÷95%	8.9	50÷75%
Elongation, %	---	4.7	95%	4.9	75÷95%
CV % Uster	max. --/15.5	12.8	<5%	13.3	5÷25%
Thin places (-50 %)	max. --/30	1	5%	3	25%
Thick places (+50%)	max. --/130	40	5÷25%	35	5÷25%
Neps (+200%)	max. --/200	126	25÷50%	88	25%
Hairiness H indicator	---	5.9	75%	5.8	75%
Twist, twist/m	max. 940	863	-	861	-
α_m	max. 115	104.7	-	105.3	-

A comparison of quality parameters of yarns produced from biological and conventional cotton is presented in Figures 2, 3 and 4 .

We have indicated that yarns produced by a Rieter spinning frame achieve better parameters. Therefore, in the next stage, only the carded and combed 20 tex yarns produced with the use of the Rieter spinning frame were analysed. The examination cycle and the measuring methodology were the same as those applied in the previous stage of tests.

The results of laboratory analysis obtained for for both carded and combed yarns with a linear density of 20 tex also confirmed the usability of biological cotton for spinning.

The linear density of the slivers and roving produced did not exceed the boundaries described by technological regulations. In no case did the factors of irregularity for intermediate products of the spinning process exceed the maximum values accepted. Neps were generally removed in a proper way, but better results were obtained by applying combing. In a few cases a lower ability of neps removing than the assumed values for carding was observed.

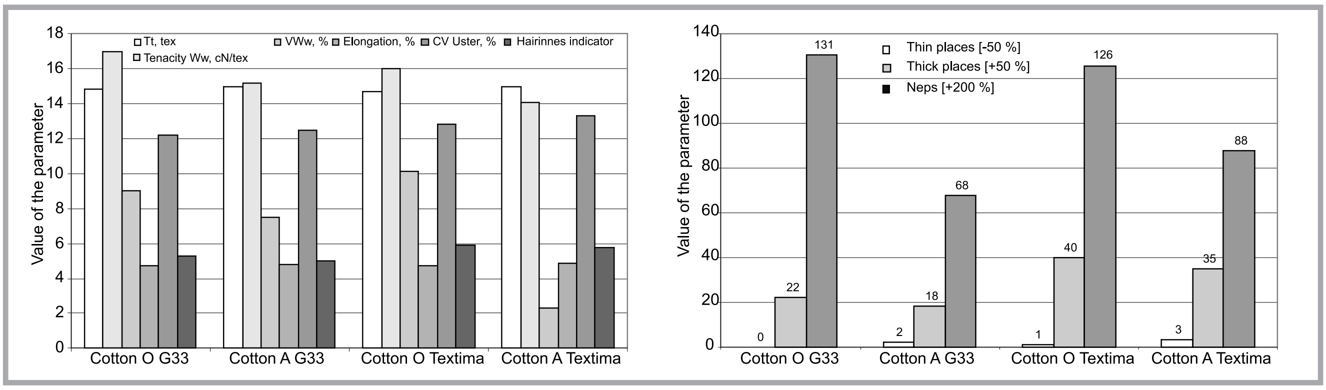

Figure 2. *Comparison of parameters of combed yarn of 15 tex produced from biological and conventional cotton.*

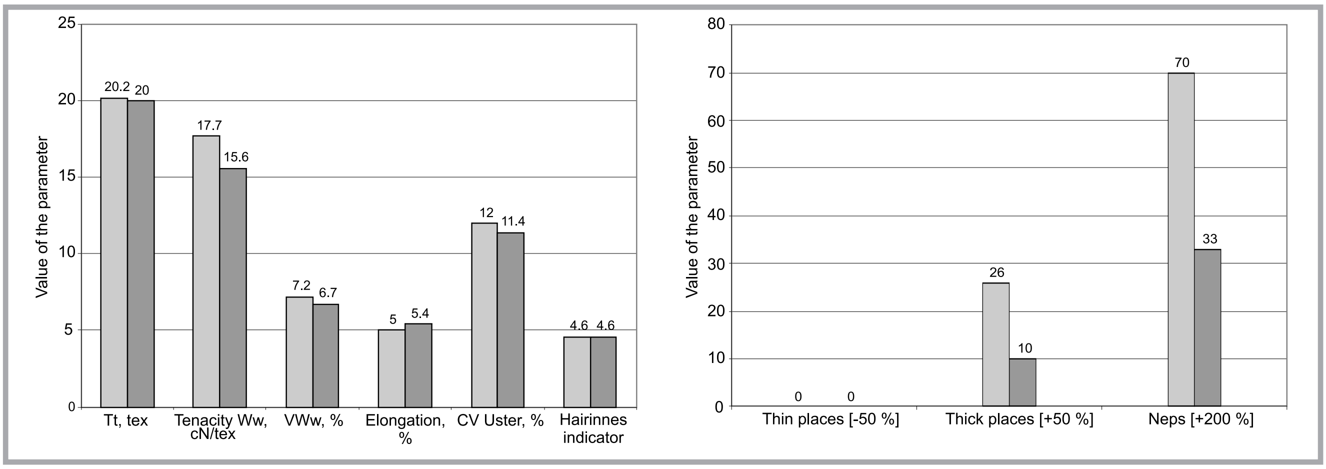

Figure 3. *Comparison of parameters of combed yarns of 20 tex produced from biological (□) and conventional (■) cotton by using a Rieter G33 spinning frame.*

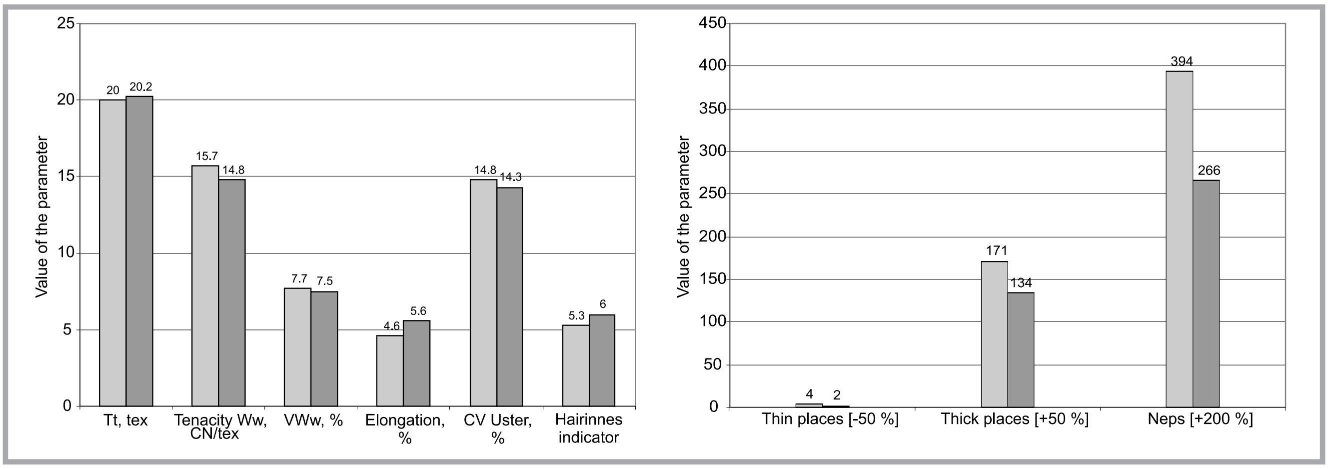

Figure 4. *Comparison of parameters of carded yarns of 20 tex produced from biological (□) and conventional (■) cotton by using a Rieter G33 spinning frame.*

Conclusions

Summarising the observations and analyses of the yarn tests carried out, it can be stated with assuredness that the tests with biological cotton were successful**.** Biological cotton as a new raw material in the Polish market is good for spinning using the classical cotton spinning system with the use of a ring spinning frame, both for carded and combed yarns**.** In order to find a niche for clothes from biological cotton, which can be offered to Polish customers, widely understood promotion is needed and a great effort should be made to familiarise people with pro-ecological textile products which are environmentally and human friendly. Biological cotton, in particluar, should be used for the production of baby linen, personal hygiene products and clothing used in hospitals.

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