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MULTIFUNCTIONAL COTTON KNIT FABRIC PRETREATMENT - INFLUENCE ON SEWABILITY

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Introduction

Despite a very high technical level and automation in the processes of garment manufacture, especially in the production of knitwear seams of insufficient quality are made [1-4]. Sawing damage is one of the most common sawing problems which trouble the textile and clothing industries. This causes high financial expenditures and marketing risks. The consequences of such an inferior sewing of knitwear are faults which are very often recognized too late. Therefore, it is necessary to know more about fabric sewability, especially of knitted fabric.
Damage can be attributed to fabric properties, sawing conditions and mishandling [5-10]. The selection of sewing needle, fineness of sewing thread, relative air humidity, thickness and density of knitted fabric as well as fabric pretreatment and finishing play a significant role in the technological process of sewing. Sewing needle penetration force determination and its lowering can assure less damage of knit fabric loops.
Multifunctional pretreatment of cotton knitted fabric can make surface smoother and lower the friction resulting in lower needle penetration force.
It is well known that raw cotton has genetic and added impurities. After removal of remain sculls, seeds, and dust, raw fiber is mostly cellulose, but it contains pectine, waxes, fats, organic acids, ash, vitamin B, sugars, proteins, mineral substances as well. Therefore, it is highly hydrophobic. During fabric scouring textile cleaning occurs, resulting in hydrophilic cotton. Standard procedures for cotton scouring involve alkali treatment accomplishing high cleaning effects. Unfortunately, treatment with NaOH results in partial damages to the cellulose causing a high weight loss, decreasing the strength and degree of polymerization (DP) [10-21]. The negative effect is reduced mobility of the stitches so that the loop-forming thread is not pushed but pierced, what leads to lower fabric sewability. When sewing the knitted fabric, mechanical or thermal material damages may occur, which may be caused by the position of the stitches where the threads have been looped. Damaged loops may tear during the use so that damages are clearly visible or ladders [8,9,21]. This alkali scouring is ecologically and economically unfavorable, because huge quantities of water are necessary, high energy is required for rinsing process after scouring, and NaOH polluted waste waters. Therefore, in last few years the new procedures of enzymatic scouring with pectinases have been investigated and applied.

Enzymatic scouring use pectin splitting enzymes are targeted to degrade only impurities giving an end product with fully intact cellulose including more readily treatable wastewater, because enzymes are biodegradable and non toxic, and energy is saving. Besides the removal of disturbing fiber accompanying substances the hydrophily of the cellulose fibers is increased and the accessibility of fibers for bleaching agents or for dyestuffs is improved. It also gives soft handle, good whiteness and less weight loss [17-22].

Bleach degrades yellowish pigments resulting in white cotton.

During mercerization process cotton unit cell changes from cellulose I to cellulose II resulting in more energetically favorable material. Therefore, mercerization results in higher gloss, absorbility, breaking and bending force and dimension stability of cotton.

Cationization during mercerization with cationic compound, quaternary ammonium salt 3-chloro-2-hydroxypropyl-trimethyl ammonium chloride (CHPTAC), is an alternative method for improving dyestuff and surfactant adsorption. This modification results in results in electropositive cotton which can absorb higher amounts of anionic substances [23].

UV absorber treatment results in high protection from harmful UV radiation that can cause skin damage such are sunburn, allergies, skin aging and even skin cancer especially during the summer time [24-29].

In this paper the influence of multifunctional pretreatment to cotton knitted fabric sewability was investigated. Therefore, raw cotton knitted fabric was scoured with alkali, and with pectinase. It was bleached, mercerized, cationized and treated with UV absorber. CIE whiteness and yellowness index after treatments were determined. Such fabric damage directly influence to its sewability, degree of polymerization which as determined as well. Damage of knitted fabric loops during sewing through two, three and four plies, which are closely connected with the values of sewing needle penetration force and dynamic tension of the sewing thread, were measured on new developed instrument which detects faults in samples of the knitted fabric by means of sensors [30].

Experimental

The knitted fabric used was cotton circular weft single jersey. Single jerseys have different face and back sides. Used fabric has surface mass 130 g/m^2, 56 cm (22 inch) width in tubular form, having 11 whales/cm and 12 courses/cm. It was scoured with alkali, and with pectinase, bleached, mercerized, cationized and treated with UV absorber.

Raw cotton knitted fabric was alkali scoured (standard, traditional procedure) for 2 h at 100°C in autoclave (Scholl) by pad roll using 3 % NaOH and 2 g/l of nonionic surfactant Kemonecer NI (Kemo). Afterwards, it was rinsed and neutralized until pH 7 was reached.

Enzymatic scouring of cotton knitted fabrics was performed by exhaustion method in the Linitest (Original, Hanau) using a commercial pectate lyase product BioPrep 3000L (standard strength 3000 APSU/g) from Novozymes A/S of Bagsvaerd. Fabrics were

treated in the bath containing 0.1 % (owf) BioPrep 3000L, nonionic surfactant Kemonecer NI (Kemo) 0.5 g/l and buffer (Na_2HPO_4), pH 9.2 and 65 °C, at liquor ratio 1:10. Sodium salt of EDTA (0.4 g/l) was added at the end of the treatment followed by rising the temperature to 90 °C and continuing treatment for next 15 minutes. Fabrics were washed in hot water followed by warm and cold water and air dried.
Chemical bleaching was performed for 3 h at 98°C in autoclave (Scholl) by pad roll using 20 ml/l of H_2O_2 (35 %), 4 g/l NaOH, 5 ml/l Tinoclarit CBB (Ciba), 15 ml/l of mixture Na_2SiO_3, $Na_2Si_2O_5$, 10 ml/l Invatex MD (Ciba) and 0,5 ml/l Fumexol DF (Ciba).
Cotton fabric was slack mercerized in a bath containing 24 % NaOH, 8 g/l anionic surfactant Subitol MLF (Bezema) in a liquor ratio 1:25, 2 min, at 18 °C, rinsed and neutralized until pH 7.
It was cationized during the mercerization process. Firstly was slack mercerized, and before rinsing and neutralization alkali cotton fabric was impregnated with bath containing 50 g/l 3-chloro-2-hydroxypropyl-trimetyl ammonium chloride (CHPTAC) (Fluka), in a liquor ratio 1:20, 2 min, at 18 °C. After staying at the room temperature for 24 hours in a glass with plastic cover it was rinsed until pH 7 was reached.
Treatment with 0,5% of UV absorber Tinofast CEL (Ciba) in a liquor ratio 1:10, 30 min, at 95°C, in Linitest (Original, Hanau), 10 g/l Na_2CO_3 and 10g/l Na_2SO_4 was performed for better UV protection.
Fabric labels and treatments are given in Table 1.

Table 1: Fabric labels and treatments

Label	**Treatment**
R	raw, untreated
S	alkali scouring
ES	enzymatic scouring
B	alkali scouring, bleaching
EB	enzymatic scouring, bleaching
BM	alkali scouring, bleaching, mercerization
EBM	enzymatic scouring, bleaching, mercerization
BMC	alkali scouring, bleaching, cationization during mercerization
EBMC	enzymatic scouring, bleaching, cationization during mercerization
BMCUV	UV absorber treatment after cationization of alkali scoured samples
EBMCUV	UV absorber treatment after cationization of enzymatic scoured samples

Fabric mass per unit area was determined according to ISO 3801:1977 *Textiles - Woven fabrics - Determination of mass per unit length and mass per unit area***.**
Number of whales and courses per 10 cm was determined according to ISO 4921:2000 *Knitting - Basic concepts – Vocabulary.*
Degree of polymerization, DP was measured according to DIN 54 270 *Bestimmung der Grenzviskositat von Cellulosen* based on limit viscosity of celluloses, Cuen-procedure.

Remission spectrophotometer SF 600 PLUS CT (Datacolor) was used for measuring CIE whiteness and Yellowing Index according to DIN 6167 *Description of yellowing of practically white or practically colourless materials*.
UV-A and UV-B transmissions were measured on transmission spectrophotometer Cary 50 Solarscreen (Varian) according to AATCC Test Method 183-2000 *Transmittance or Blocking of Erythemally Weighted Ultraviolet Radiation through Fabrics*. On the base of these values Ultraviolet protection factor (UPF) was calculated according to:

$$\mathrm{UPF} = \frac{\sum_{280}^{400} E(\lambda)\cdot S(\lambda)\cdot \Delta\lambda}{\sum_{280}^{400} E(\lambda)\cdot S(\lambda)\cdot \tau(\lambda)\cdot \Delta\lambda} \qquad (1)$$

Where:
$E(\lambda)$ = relative erythemal spectral effectiveness
$S(\lambda)$ = solar spectral irradiation [W m^{-2} nm^{-1}]
$\tau(\lambda)$ = average spectral transmittance through specimen
$\Delta\lambda$ = measured wavelength interval [nm]
Ultraviolet protection factor, UPF values indicate the ability of fabrics to protect the skin against sun burning. It indicates how much longer a person can stay in the sun with the fabric covering the skin as compared with the uncovered skin to obtain same erythemal response.
Penetration force of the sewing needle is mostly based on friction occurring between sewing work piece and sewing needle, and the highest penetration force of the sewing needle occurs at the moment when the sewing needle penetrates the sewing material which should be taken into consideration especially with knitted fabrics [12-19]. It depends on various factors such are type and amount of layers of the sewing material, needle size, shape of needle point, stitch speed of the sewing machine, treatment of the sewing material and several others. Needle stitch force was measured on new developed measuring instrument (Faculty of Textile Technology, University of Zagreb) which detects faults in knitted fabrics by means of sensors (Figure 1), using Pfaff 1053 sawing machine, type of needle Nm 80 SES (Schmetz) with working speed of 4000 stitch/min through two, three and four fabric layers.

Figure 1 - Instrument for needle stitch force measurement

Under the influence of the sewing needle force occurring during the penetration of the work piece, the elastic tape bends downward in the middle. The software program enables the presentation of the results obtained in form of tables as well as the graphic presentation of results.

Results and Discussion

In this work cotton knitted fabric were pretreated and treated for multifunctional properties. The influence of pretreatments to fabric sewability was investigated. Degree of polymerization and fabric mass per unit area, whiteness and yellowness were determined as well.

It is well known that fabrics treated in wet conditions, like scouring and bleaching, undergo some structural changes. Therefore, knit fabric parameters, such are mass per unit area and number of whales and courses per 10 cm were measured. Results are collected in Table 2.

Table 2: Number of whales (Dv) and courses (Dh) per 10 cm, Mass per unit area (m) and Degree of polymerization (DP) of knitted cotton fabrics after multifunctional pretreatment

Label	**Dv [No/10 cm]**	**Dh [No/10 cm]**	**m [g/m²]**	**DP**
R	110	140	123	2880
S	130	153	154	2430
ES	125	150	150	2720
B	130	154	154	1800
EB	135	155	154	2100
BM	145	190	188	2150
EBM	145	200	218	2320
BMC	145	205	234	1920
EBMC	150	210	231	2180
BMCUV	155	215	225	1690
EBMCUV	160	220	228	1930

It was shown that in every wet treatment cotton swells what leads to shrinkage of fabric. Shrinkage of knitted fabric in wet condition is affected by stresses accumulated during the production so that relaxation in wet conditions is inevitable. Even though during the cotton scouring process impurities like pectin, waxes etc. remove from cotton, shrinkage of knitted fabric results in fabric mass per unit area increment.
Degree of polymerization is an indirect measure of fiber damage. It is evident from Table 2 that pectinase scoured knit fabrics have higher degree of polymerization than traditionally scoured ones. Pectinase scoured knit fabrics are less damaged than conventionally scoured, what is well confirmed from sewability results (Figure 2-4).
Spectral characteristics of cotton knitted fabrics were measured using remission spectrophotometer Datacolor SF 600 PLUS CT. CIE whiteness (CIE-WH) and yellowness index (YI) were calculated automatically. Results are collected in Table 3.

Table 3: CIE whiteness (CIE-WH), Yellowness index (YI) and Mean UPF of knitted cotton fabrics after multifunctional pretreatment

Label	CIE-WH	YI	Mean UPF
R	9,88	24,25	17,01
S	37,71	15,20	15,72
ES	17,51	21,80	15,83
B	66,87	5,58	7,38
EB	67,66	5,19	7,01
BM	51,38	10,88	18,41
EBM	51,48	10,76	18,24
BMC	47,32	12,24	20,15
EBMC	48,15	11,81	22,14
BMCUV	55,32	9,53	25,69
EBMCUV	57,62	9,34	31,99

Textile cleaning of genetic and added impurities during scouring leads to cotton whitening (Table 3). Pectinase scouring degrades only pectine. Therefore, CIE whiteness of pectinase scoured cotton is a little bit lower than CIE whiteness of alkali scoured one. Bleaching in peroxide baths removes pigments resulting in white cotton. Mercerization and cationization leeds to small lost of fabric whiteness and small yellowing occurs. After treatment with UV reactive apsorber on the base of oxalanilide fabric whiteness increased a little bit due to its chemical constitution. Analogue to whiteness increment, yellowing index decreases.
The protection against UV radiation with cotton knitted fabrics is expressed by ultraviolet protection factor (UPF) values measured on transmission spectrophotometer Varian Cary 50 Solarscreen according to the AATCC Test Method 183-2000. Results of Mean UPF are presented in Table 3 as well. Pectine and waxes in raw cotton absorb small quantities of UV radiation; therefore raw fabric has small sun screening properties but for UV protection it is still non-rateable. Removal of these impurities and pigments during scouring and chemical bleaching results with lower UV protection even though fabric shrinks. In mercerization fabric highly shrunk (mass increment ≈ 90

%), what have resulted in weaker transmission of UV-R through a more tightly knitted fabric. Therefore, UV protection of mercerized cotton is good. Cationization during mercerization results in good UV protection while treatment with UV absorber leads to very good UV protection.

It is to point out that these fabrics have multifunctional properties. As light fabric its application is specially for summer clothing. Therefore it was necessary to determine fabric sewability. For good fabric sewability properties it is necessary to minimize the forces during the penetration and withdrawal of the needle. The highest sewing needle penetration force occurs at the moment when the needle eyelet penetrates the material. The sewing needle eyelet, having a greater diameter, passes through the material at a greater distance of the yarn and fibers respectively, leading to a greater friction and increased resistance force of the material against the sewing needle and to increased penetration force respectively. When the sewing needle leaves the fabric, friction decreases because the needle passes through the previously formed opening. The consequence is a great reduction of the absolute value of the penetration section. Therefore, the needle stitch force was measured through two, three and four fabric layers. Results are presented on Figure 2.

Needle stitch force on the beginning of sewing process is the highest one and decreasing in time. According to results on Figure 2 the needle stitch forces through two, three and four fabric layers it was shown that alkali scoured cotton knit fabrics are very high as result of cotton damage in harsh scouring conditions with negative consequence on damages in peroxide bleaching process. Therefore, the friction between sewing needle and knitted fabric is respectively higher. On the other hand, needle stitch forces of enzymatically scoured fabrics are significantly lower than of alkali scoured ones. For better fabric sewability properties it is necessary to minimize the forces during the penetration and withdrawal of the needle. It is usually done with applying softeners in chemical finishing of knitted fabrics.

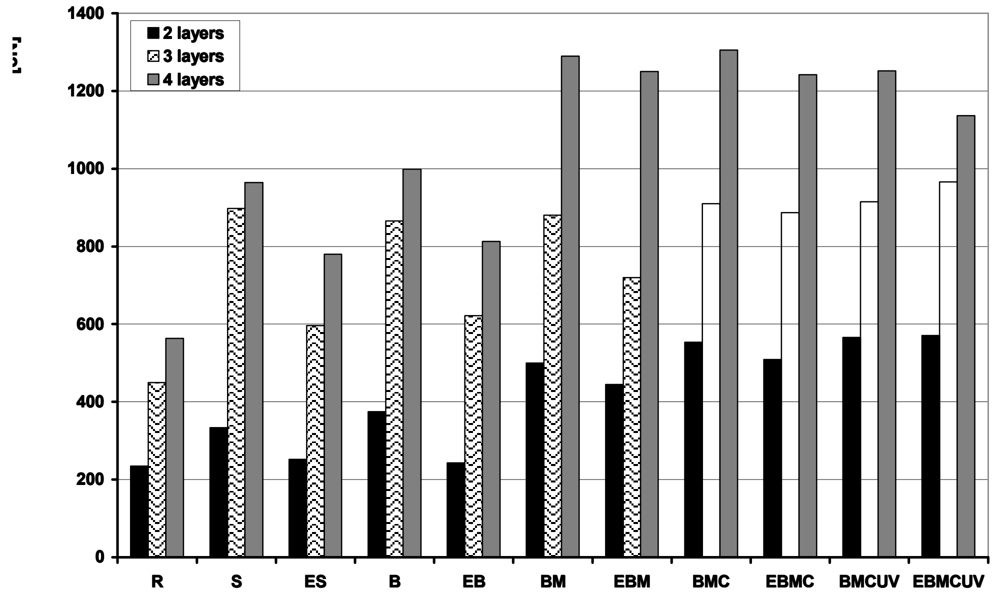

Figure 2. Needle stitch force (F) through two, three and four fabric layers

In this work cotton knitted fabrics were not softened, but pretreated for multifunctional properties only. It was shown that even though mercerization results in needle stitch force increment, cationization and treatment with UV absorber do not change it significantly. It is very important to take into account the influence on better sewability of fabric pretreatment, such is enzymatic scouring on prebleached, bleached, mercerized and cationized fabrics.

Comparing the needle stitch force results for two, three and four fabric layers, it is evident that increment of fabric layers number results in needle stitch force increment as well.

Conclusion

Alkali and enzymatic scouring, bleaching, cationazation during mercerization and UV treatment result in cotton knitted fabric multifunctionality.

During the cotton knit fabric wet treatments shrinkage occurs, resulting in fabric mass per unit area increment.

Textile cleaning of genetic and added impurities during scouring and bleaching process leads to higher whiteness of cotton fabrics, while after mercerization, cationization and UV absorber treatment do not change significantly.

Pectinase treated fabrics have better mechanical properties than alkali scoured ones. They are less damaged according to degree of polymerization and sewability of knitted cotton fabric, regardless of how many layers were sewn. Increment of fabric layers number results in needle stitch force increment as well.

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Izvod

MULTIFUNKCIJSKA PREDOBRADA PAMUČNOG PLETIVA – UTICAJ NA PROŠIVLJIVOST

Naučni rad

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Oštećenja pletiva, koja mogu nastati prilikom šivenja, još uvek su veliki problem tekstilne i odevne industrije. Ta oštećenja na pletivu zavise od njegove strukture i svojstava, kao i načina šivenja i rukovanja pri izradi odeće. Osim relativne vlažnosti, brzine šivenja, finoće igle i konca, razlog za pojavu oštećenja na pamučnom pletivu može se naći i u postupci predobrade. Smanjenjem probodnih sila šivaće igle može se sprečiti oštećenje očica pletiva. Zato je neophodno poznavati predobradu i prošivljivost pletiva.

U ovom radu ispitivan je uticaj multifunkcionalne predobrade na prošivljivost pamučnog pletiva. U tu svrhu pletivo je iskuvano alkalijama i pektinazama, beljeno, mercerizirano, katjonizirano i obrađeno UV apsorberom. Iskuvavanjem se uklanjaju voskovi, masnoće i druge primese pamuka, a beljenjem se uklanjaju pigmenti koji sirovom pamuku daju neuglednu žućkastu boju. Mercerizacijom se postiže povećan sjaj, poboljšana apsorptivnost, povećana otpornost na habanje i savijanje, povećana prekidna sila, te stabilnost dimenzija. Katjonizacijom se dobija modifikovani pamučni materijal sa pozitivnim električnim nabojem čime se povećava adsorptivnost anjonskih jedinjenja. Oplemenjivanjem pletiva UV apsorberom postiže se zaštita od nepovoljnog i štetnog ultraljubičastog zračenja. Budući da oštećenje pamuka direktno utiče na prošivljivost, pletivu je ispitan stepen polimerizacije. Prošivljivost pletiva određen je na novom aparatu za merenje probodnih sila PFAFF-1053 kroz dva, tri i četiri sloja pletiva.

Ključne reči: Pamučno pletivo, multifunkcionalna obrada, bioiskuvavanje, prošivljivost, probodna sila igle