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A new method for fiber length measurements – Dual-beard method

HONG-YAN WU FU-MEI WANG

REZUMAT – ABSTRACT

O nouă metodă de măsurare a lungimii fibrelor – Metoda dublu-smoc

Acest studiu prezintă o nouă metodă de măsurare a lungimii fibrelor, și anume metoda dublu-smoc, prin care se pot obține două fibrograme în același timp. Această metodologie a fost experimentată pentru a investiga fiabilitatea acestei metode. Rezultatele confirmă că metoda dublu-smoc are o bună fiabilitate, repetabilitate şi compatibilitate cu AFIS şi HVI.

Cuvinte-cheie: dublu-smoc, fibrogramă, lungimea fibrei, HVI, AFIS, imagine alb-negru

A new method for fiber length measurements – Dual-beard method

This paper presents a new method for measuring fiber length, namely Dual-beard method, which can obtain two whole fibrograms at the same time. The methodology was introduced and experiments were performed to investigate availability of Dual-beard method. The results show Dual-beard method has good trueness and repeatability and good agreement with AFIS and HVI.

Key-words: dual-beard, fibrogram, fiber length, HVI, AFIS, gray image

Length is one of the most important parameters of fibers because it has effects on yarn strength, yarn hairiness, the properties of fabrics and on the efficiency of the yarn spinning process [1–3]. There are several testing methods for fiber length measurements. The conventional method [4] is the array method which gives a weight frequency-length distribution and always serves as a benchmark to which other methods are compared [5]. This method is, however, slow and tedious and depends on operator skill for reliability and accuracy [6, 7].

Now, the two popular instruments, namely high volume instrument (HVI) and advanced fiber information system (AFIS), are fully automatic machines. HVI is the official USDA method [8]. However, it cannot obtain the entire fibrogram, because its holding length is about 4.06 mm and the start of the scan set point at 3.8 to 5.1 mm from the held point [9]. AFIS is mainly used by modern textile mills for evaluating the individual fiber properties in order to optimize their downstream processing [8]. However, there may be some questions in AFIS measurements, for example fiber break, straightening, separation, alignment and only 9–33% of fibers are counted in the measurement unit [10].

Recently, various image analyses have been used for fiber length measurement. Fischer [11] and Y. Ikiz [9] showed image processing method to measure single fiber length, respectively. This method could test single fiber length accurately, but individualizing fibers is questionable. Weilin Xu [12] introduced a new method for cotton length measurement that involved combing fibers into a test beard, cutting the beard into a number of segments of a given interval, and counting the snippets in each segment by image processing. The method seems time-consuming and tedious.

This paper presents a new fiber length measurement method, namely Dual-beard method. This new method can scan the two sides of the dual-beard from the holding line synchronously to generate two entire fibrograms. In this paper, the methodology was demonstrated and experiments were performed to examine Dual-beard method.

METHODOLOGY

Dual-beard method consisted of four parts: sampling, obtaining gray image, extracting fibrograms and calculating fiber length, as showed in figure1. Firstly, the dual-beard was produced through sampling. Secondly, the dual-beard was put on a scanner to produce a digital gray image. Thirdly, the fibrograms were extracted based on the image of the beard.

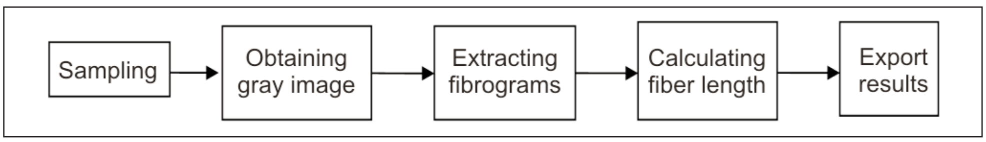

Fig. 1. The measurement flowchart of Dual-beard method

Finally, mean length by weight, coefficient of variation, modal length and quality length was calculated.

Sampling

First, 0.2 to 0.3 g sample was selected randomly from tested fibers, then opened and mixed by hands, and removed trash particles with a pair of tweezers. Second, the sample was drawn three times by a fiber draw-off device to prepare a sliver in which fibers are parallel, straight and uniform nearly. Third, the sliver was clamped randomly along the fiber longitudinal axis by a clamper, and then loose fibers on the open end of the clamper were removed. Lastly, clamp the sliver with another clamper at the holding line of the first clamper, release the first clamper and remove all loose fibers on the open end of the second one. The dual-beard with 20 mg to 40 mg and 5 cm was obtained, as shown in figure 2.

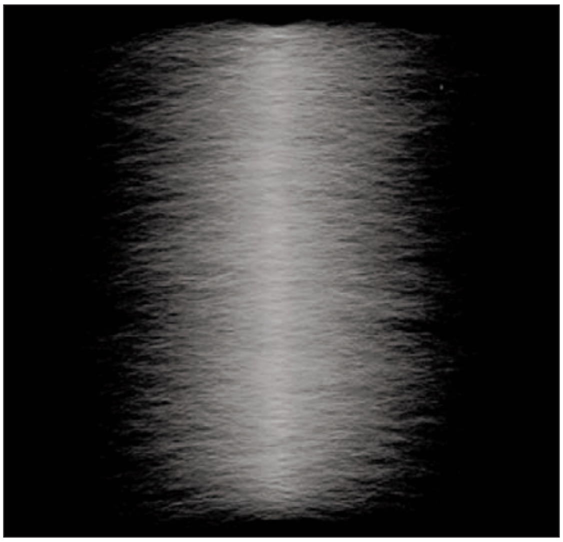

Fig. 3. Digital gray image of the dual-beard

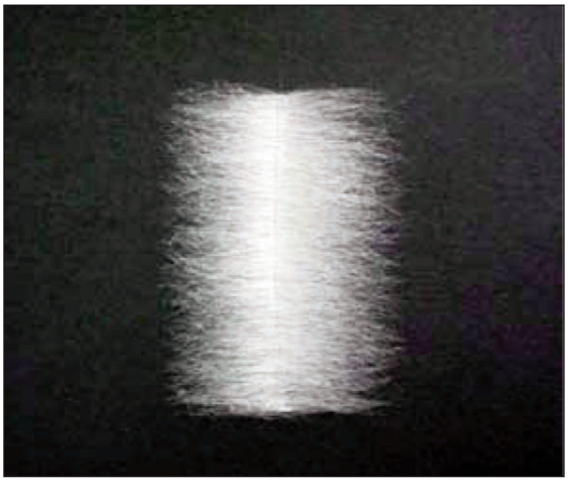

Fig. 2. Dual-beard sample

The two sides of the dual-beard are approximately symmetrical and fibers in the beards are well straightened and parallel, which allow two entire fibrograms scans apart from the holding line simultaneously.

Obtaining gray image

The dual-beard sample was scanned by a scanner to a digital gray image. A grayscale digital image is an image in which the value of each pixel is a single intensity value, that is, it contains only the luminance information without color information. Often, the grayscale intensity is stored as an 8-bit integer giving 256 (from 0 to 255) possible different shades of gray from black at the weakest intensity to white at the strongest.

The dual-beard was put on the glass tray of the scanner. The properties of the scanner were set as follows: scan type was gray scale; resolution was 1000 dpi (0.0254 mm per pixel). A beard image, with high 2257 pixels and width 2339 pixels, is shown in figure 3.

Extracting the fibrograms

As shown in figure 3, the higher gray value is, the more quantity of fibers is. Hence, the decline of gray values along the horizontal direction indicated the gradually descent of fibers quantity. The progressive accumulate gray values of every column vertical with fiber long direction was calculated by computer software. The origin of the coordinates is set at the location of the holding line where the progressive accumulate gray value is set 1. So, at the ith column, the relative quantity of fiber equaled the value that the gray values at this column divided by the gray values at the holding line, and the protruding distance to zero point equaled $i \times 0.0254$ mm. The fibrogram is the beard curve that shows the quantity of fibers at each protruding distance from the holding line, as shown in figure 4. The abscissa and ordinate values are protruding distance and relative quantity of fiber, respectively.

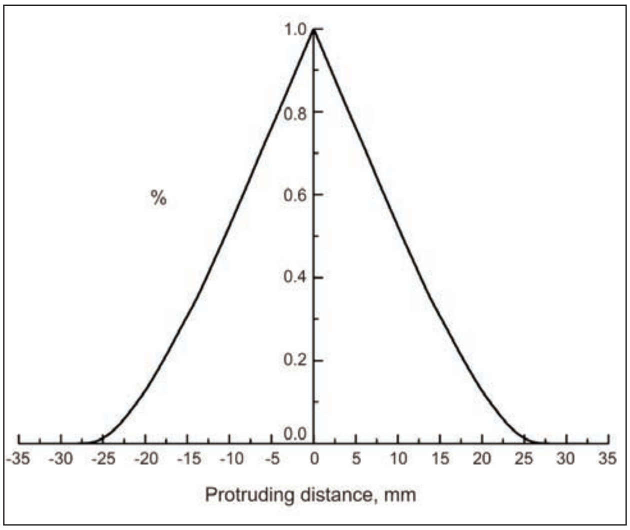

Fig. 4. The fibrograms

Calculating fiber length

To calculate fiber length, the equations [13] have been extracted directly from the fibrogram by author. According to the equations, the computer software

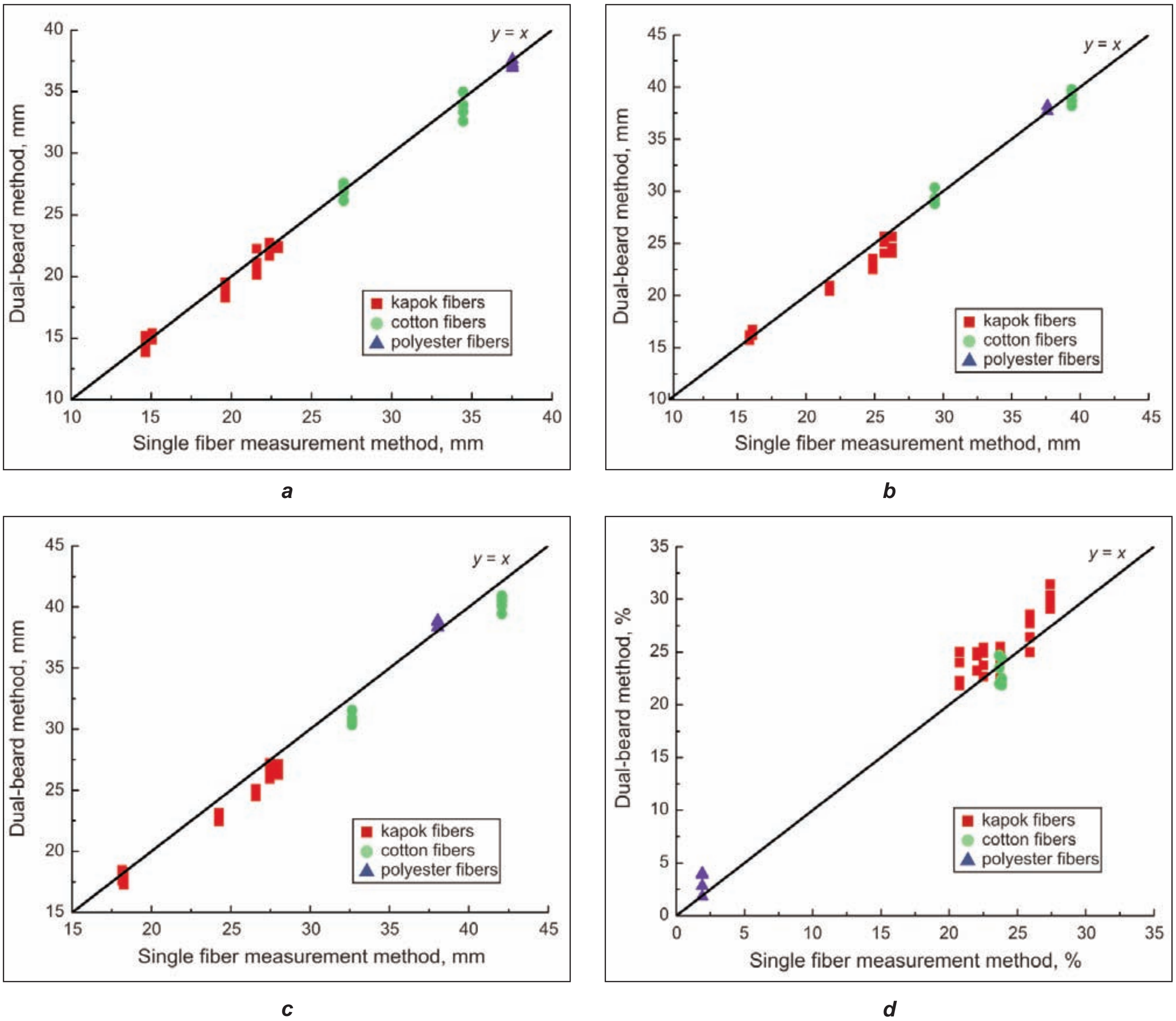

Fig. 5. The results of the two test methods:
a – mean length by weight; *b* – modal length; *c* – quality length; *d* – coefficient of variation

was developed for calculating fiber length: mean length by weight, modal length, quality length and the coefficient of variation.

EXPERIMENTAL VERIFICATION

Trueness of Dual-beard method

Sample: Six groups of kapok fibers marked as 1#~6#, two groups of cotton samples marked as 7# and 8# and one group of polyester fibers with same cut lengths marked as 9# were tested, which contained a broad range of length-distribution properties.

Methods: For every sample, four measurements were performed by Dual-beard method. The results of one measurement were the average of length indexes at the both ends of the dual-beard.

Single fiber measurement method is the most accurate method for fiber length test, so it was selected to examine trueness of Dual-beard method. The procedure of Single fiber measurement method was as follows: pick up single fiber with tweezers, drag it on velvet board to straight it and measure it with a scale reading one decimal. And then the fiber length distribution by number was obtained, which was converted to the fiber length distribution by weight based on the assumption that the fibers were uniform in cross section. Thus fiber length characteristics by weight can be calculated. For every sample, 900~1000 individual fibers were tested by Single fiber measurement method but 100 individual polyester fibers.

Results and Discussion: The results of the two methods are showed in figure 5. In figure 5 the line $y = x$ is the perfect correlation line of the two methods; an abscissa point corresponds to four ordinate points which are four measurement results of one sample by Dual-beard method.

Figure 5 shows, for mean length by weight, modal length, quality length and coefficient of variation, Dual-beard method agrees well with Single fiber measurement method. However, due to random error, data of Dual-beard method fluctuate slightly with the ideal line. In order to examine the trueness of Dual-beard method, the mean value of four measurements of every sample by Dual-beard method

Table 1

BASES OF DUAL-BEARD METHOD				
Sample	**Mean length** (mm)	**Modal length** (mm)	**Quality length** (mm)	**Coefficient of variation** (%)
1#	–0.09	0.21	–0.32	2.74
2#	0.07	0.39	–0.08	0.56
3#	–0.90	–1.04	–1.43	1.03
4#	–0.60	–1.99	–1.81	1.68
5#	–0.21	–0.72	–0.99	2.40
6#	–0.54	–1.31	–1.22	2.53
7#	–0.05	0.04	–1.80	0.04
8#	–0.75	–0.40	–1.95	–1.08
9#	–0.31	0.32	0.65	1.98
Average bias	–0.38	–0.50	–0.99	1.32
Standard deviation	0.337	0.827	0.898	1.287
T-test statistics	3.3398	1.8125	3.3182	3.0760

Table 2

VARIANCE OF THREE METHODS					
	Variance	**Mean length** (mm^2)	**Modal length** (mm^2)	**Quality length** (mm^2)	**Coefficient of variation** ($\%^2$)
Dual-beard method		0.093	0.291	0.166	1.413
AFIS		0.020	1.742	—	0.828
HVI		0.116	—	—	—

were calculated. Then the biases of Dual-beard method were calculated in table 1, which were equal to the results of Dual-beard method minus the results of Single fiber measurement method.

From table 1, it is observed that biases of Dual-beard method are small. The average biases of mean length, modal length and quality length are all less than 1 mm. In order to test significance of biases, *T*-test was applied. Under significance level $\alpha = 0.01$, it can be obtained $t_{1-a/2}(n-1) = t_{1-0.005}(8) = 3.3554$. In table 1, *T*-test statistics all are less than 3.3554, so biases of Dual-beard method are not significant. It shows that the trueness of Dual-beard method is high.

Besides, from table 1, it is observed that the average biases of mean length, modal length and quality length are negative, that shows the results of Dual-beard method are slightly shorter than Single fiber measurement method. This was due to that the straight degree of the fibers in Single fiber measurement method was slightly higher than which in Dual-beard method, because of fibers dragged on velvet board by tweezers in Single fiber measurement method.

Repeatability of Dual-beard method

Sample: The 7# cotton fiber was tested.

Methods: The sample was tested five times by Dual-beard method, HVI and AFIS, respectively.

Results and Discussion: Variance of five measurements by the three methods was calculated in table 2. *F*-test was applied to test variance of the three methods. Under significance level $\alpha = 0.05$, for mean length, it can be obtained $S_1^2/S_2^2 = 4.73$, $S_3^2/S_1^2 = 1.25$, $S_3^2/S_2^2 = 5.80$, which are all less than $F_{(1-0.025)}(4,4) = 9.60$. So, for mean length, repeatability of the three methods was in the same level. Similarly, for modal length and coefficient of variation, repeatability of Dual-beard method and AFIS was in the same level. Because AFIS and HVI do not provide quality length, variance of quality length of the three methods cannot be compared, whereas it is obvious variance of quality length by Dual-beard method is small. So repeatability of Dual-beard method is good.

Compared to other measurement methods

Besides 7# and 8# cotton samples, three groups of cotton fiber, marked as 10#, 11# and 12#, were tested by Dual-beard method, HVI and AFIS, respectively. The results of the three methods are showed in figure 6.

Figure 6 *a* shows mean length of Dual-beard method are very close to AFIS's which are slightly higher than HVI's. The square of correlation coefficient was $R^2 = 0.9901$ between Dual-beard method and AFIS, and was $R^2 = 0.9765$ between Dual-beard method and HVI. So, the mean length obtained from Dual-beard method has good agreement with AFIS's and HVI's. The small difference of the three methods may be due to random error and different measuring principles.

In figure 6 *b*, quality length, upper quartile length (UQL) and upper half mean length (UHML) are compared. Quality length is defined as the weight-weighted average length of fibers whose length exceeds the modal length; upper quartile length (UQL) is the value of length for which 75% of all the observed values are lower, and 25% higher; upper half mean length (UHML) is the average length of the longest one-half of the fibers when they are divided on a weight basis. Though, the three length indices have different meaning, they present weight average length of fibers with longer length. From figure 6 *b*, it is obvious that the quality length of Dual-beard method is same with UQL from AFIS which is slightly greater than UHML from HVI and the three methods has high consistency.

Figure 6 *c* shows modal length of Dual-beard method are so close to AFIS's. Figure 6 *d* shows coefficient of variation of Dual-beard method is agreed well with AFIS's and R^2 of the two methods is 0.8316. HVI do not provide modal length and coefficient of variation.

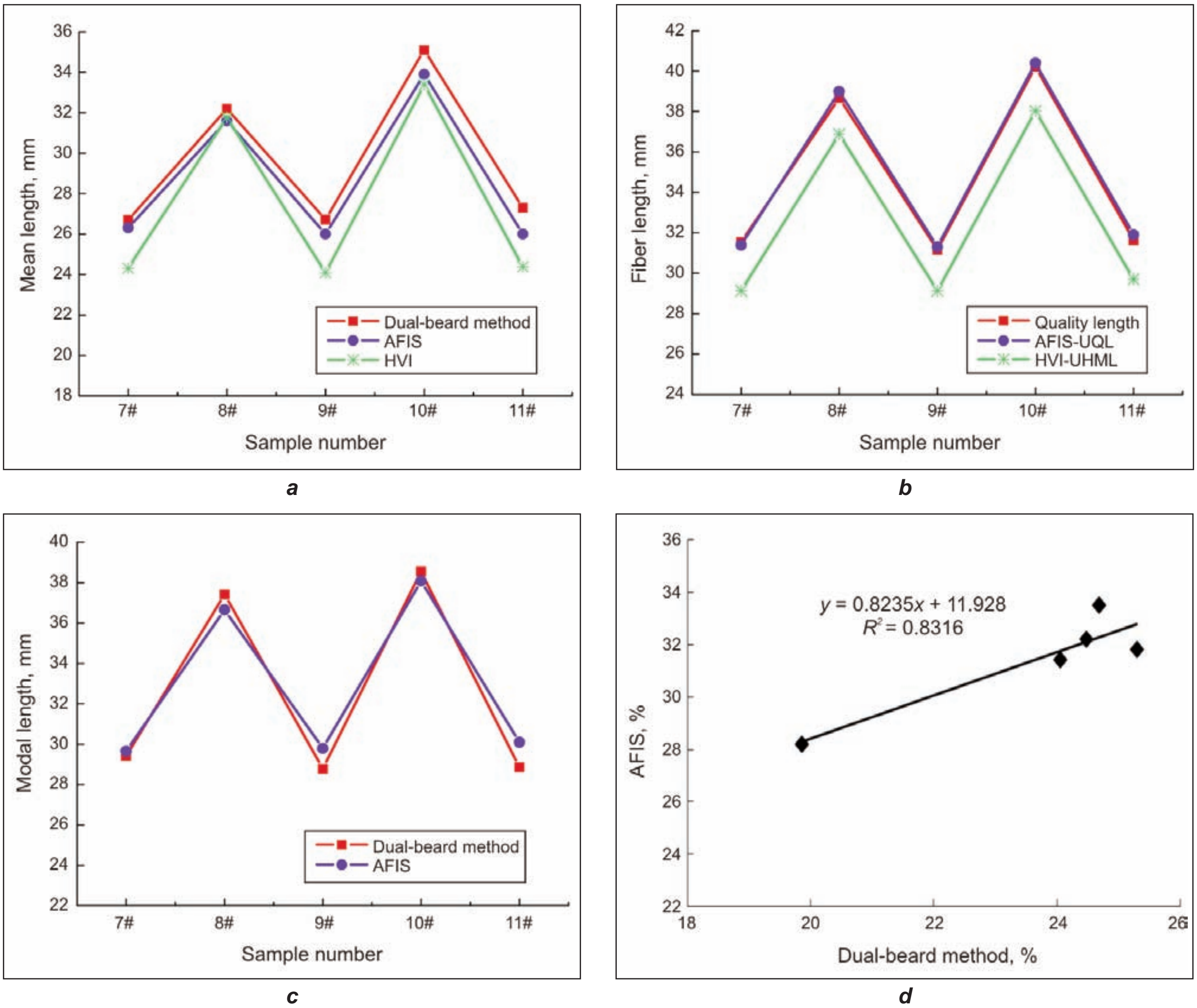

Fig. 6. Data comparisons with Dual-beard method, AFIS and HVI:
a – mean length; *b* – quality length tested by Dual-beard method, UQL tested by AFIS and UHML tested by HVI;
c – modal length; *d* – coefficient of variation

CONCLUSIONS

We present a new method for fiber length measurement, namely Dual-beard method which involved sampling, obtaining image, extracting fibrogram and calculating fiber length. This new method has two outstanding advantages: it can scan the beard from the holding line to produce the entire fibrogram and can produce two test results by one time using a dual-beard sample. A lot of experiments were performed to examine the new method. Compared to Single fiber measurement method, the biases of Dual-beard method were small and not significant, so it had high trueness. Then, repeatability of Dual-beard method was in the same level with AFIS and HVI. At last, Dual-beard method was compared to AFIS and HVI. The results showed Dual-beard method agrees well with AFIS and HVI. Therefore, it can be concluded that Dual-beard method has good accuracy, repeatability and can be applied to measure fiber length distributions.

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Effect of yarn linear density on moisture management characteristics of cotton/polypropylene double layer knitted fabrics

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REZUMAT – ABSTRACT

Efectul densității liniare asupra caracteristicilor de control al umidității tricoturilor din bumbac/polipropilenă dublu stratificate

Îmbrăcămintea ideală pentru sport, care necesită caracteristici extinse de control al umidității, poate fi dintr-un material compozit cu astfel de proprietăți. În cadrul acestui studiu au fost investigate nouă combinații de tricoturi cu straturi duble (bumbac/polipropilenă) cu densități liniare diferite, pentru a studia comportamentul controlului umidității. Materialul dublu stratificat având stratul de polipropilenă grosier pe partea interioară și cel de bumbac din fire mai subțiri la exterior a indicat o mai bună capilaritate față de celelalte combinații selectate. Pe măsură ce finețea firului de polipropilenă crește, timpul de absorbție al apei crește de asemenea. Referitor la capilaritatea transversală, stratul de polipropilenă are cea mai mică suprafață de apă răspândită și transferă imediat umezeala la următorul strat. Imediat ce umezeala intră în contact cu stratul de bumbac interior, aceasta este dispersată in toate direcțiile de la suprafața stratului de bumbac. Acesta este motivul pentru care se produce difuzia interioară și pentru care stratul interior are o suprafață mai mare de umezeală răspândită decât cel exterior. Firele de polipropilenă mai fine, împreună cu firele de bumbac mai groase, au demonstrat o perioadă mai lungă până la atingerea punctului de saturație, iar materialul din fire de polipropilenă mai groase, împreună cu fire de bumbac mai subțiri, are cea mai mare suprafață de răspândire dintre toate variantele investigate. Cel mai bun control al umidității a fost demonstrat de materialul cu stratul de interior cu fire de polipropilenă grosiere și stratul exterior de bumbac din fire mai subțiri.

Cuvinte-cheie: capilaritate transversală, controlul umidității, ţesătură dublu stratificată, fir de bumbac, fir de polipropilenă

Effect of yarn linear density on moisture management characteristics of cotton/polypropylene double layer knitted fabrics

An ideal sportswear which requires extensive moisture management characteristics can be a composite having such properties. In this investigation nine different linear density combinations of double layer knitted fabrics have been taken into consideration for the study of moisture management behavior. The effect of yarn linear density on moisture management characteristics of double layer knitted fabric was analyzed with nine different double layer cotton/polypropylene knitted fabrics. The double layer fabric having coarser polypropylene layer in the inner face of the layered fabric and finer cotton fabric in the outer layer show higher longitudinal wicking than the other selected combinations. As the polypropylene yarn fineness increases, the water absorption time increases. Regarding transverse wicking, polypropylene layer has least area of moisture spread and it immediately transfer the moisture to the next layer. As soon as moisture comes in contact with cotton inner layer it disperses in all direction on the surface of the cotton layer. That's why inner diffusion takes place and the inner layer has more area of moisture spread than outer layer. Finer polypropylene with coarser cotton yarn fabric shows longer time to reach the saturation point and coarser polypropylene with finer cotton yarn layer fabric has higher spreading area than that of all other selected specimens. Coarser polypropylene inner layer and finer cotton outer layer fabric has better moisture management characteristic than other selected fabric samples.

Key-words: transverse wicking, moisture management, double layer fabric, cotton yarn, polypropylene yarn

The properties of any fabric depend upon its constituent fibres, yarn and fabric structure and the inter-relation between them. The objective behind all garments is to satisfy the wearers in functional and aesthetic aspects and make them feel esteem and comfortable. Different raw materials and fabric structures have their own properties which results in merits and demerits and are inherent to their basics and determine the comfort behaviour of the fabric. Thermal comfort is related to the body temperature and the micro environment between the skin and the fabric layer which is in immediate contact with the skin. Whatever the heat the human body produces must be dissipated through the clothing to the external environment. This is achieved by the conduction, convection and radiation of heat from the body. During the rigourous sports activity body generates lot of heat and to keep the body cool, body perspires and cools down the heat bringing down the body temperature to normal. So the clothing must ensure a high level of moisture transmission and evaporation. But at very high levels of physical exertion, the fabric may not be able to transmit the total perspiration produced to the atmosphere immediately. A clothing first wicks and expels the moisture into outer atmosphere continuously. During this transition period some moisture might cling on. But the fabric should not feel wet to the wearer. So a sportswear must have good air, water and heat transmission and water storage properties. It is difficult to have a single textile material to have both good fluid storage and fluid dissipation properties.

For sportswear, single jersey cotton knitted fabrics are preferred as they have large pores, greater elasticity and stretchability than that of woven fabrics. But the problem arises during high level of physical exertion; the fabric becomes wet as it absorbs the perspiration and delay in transferring it to the atmosphere. This causes clamminess and the feel of discomfort to the wearer. This problem can be overcomed by producing a double layer knitted fabric in which the inner layer can transfer the moisture to the outer layer which absorbs and evaporates the moisture to the external environment. Good moisture transmission property is found with hydrophobic material of polypropylene where as good storage and evaporation properties are found in hydrophilic material of cotton. Figure 1 shows that the perspiration from the skin is being wicked in the conductive layer and its transfer to its absorptive and evaporative external layer for the dissipation into the open atmosphere.

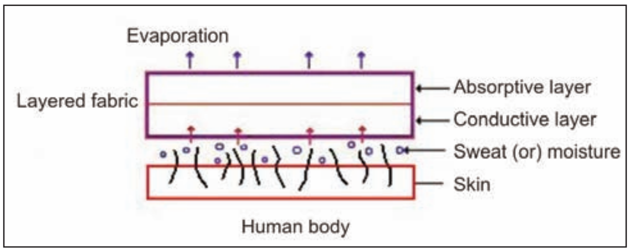

Fig. 1. Mechanism of moisture management in double layer knitted fabric

Fabrics made from natural fibres like cotton are considered comfortable for the use under normal conditions, but some of their properties like clinginess, stickiness and dampness make them unsuitable for use during strenuous physical activity as they start restricting the movement of the sportsman and also lead to post chill effect which can cause severe cold and hypothermia. Cotton fibres absorb high levels of moisture, leading to a feeling of wetness and clinginess. It has very slow transmission rate from inner fabric to outer fabric. This makes the cotton fabric not preferable for the use against the skin during vigorous physical activity as in the case of sports. Polyester and polypropylene fibres which have faster wicking rate than cotton are widely recommended for the production of active sport wears [1].

An ideal sportswear should have extensive moisture management characteristics and can be a multilayer knitted fabric formed by two or more different yarns. In a double layer knitted structure, the primary layer close to the skin should have the property of high wicking rate formed from hydrophobic fibre like polypropylene and the outer layer exposed to the atmosphere has to be a fibre having property of higher dispersion and evaporation rate usually cotton or viscose rayon. According to Adler and Walsh [2], the moisture transmission between two layers of fabrics at low moisture level is due to the vapour diffusion. Wicking in layered fabrics takes place only at a higher fabric regain level of above 100%. Water is wicked from one layer to another layer only if either the moisture content of wet layer is high or if both the layers are held together under high pressure.

Weiyuan et al [3] studied moisture transfer characteristics in knitted fabrics for different fibre combination of polypropylene and hydrophilic fibres and found that the polypropylene layer on the inner side transmits the moisture easily to the outer side of the cotton fabric and they are well suited for better sportswear. Rene M. Rossi et al [4] studied the water vapor transfer and condensation effects in multi layer textile combinations and found that the hydrophilic layers placed underneath the outer layer absorbs more moisture than the other similar hydrophobic layers.

Crow and Osczevski [1] studied the transfer wicking properties for knitted and woven fabrics and found that the amount of water wicked from one layer of the fabric to another depends on the sizes and volume of the pores. Gamze Supuren et al [5] studied the moisture related characteristics and thermal characteristics with double-face polypropylene cotton knitted fabrics and found that the inner polypropylene layer transfers the moisture quickly to the outer cotton layer. Due to the faster moisture transfer, the moisture content decreases on the polypropylene side and wetted area on the polypropylene side is also found smaller. Polypropylene-cotton fabric easily transfers the generated perspiration keeping a dry warm feeling to the wearer of the fabric.

Ramachandran and Kesavaraja [6] studied the transfer wicking characteristics with aquator and polyester eyelet knit multilayer fabrics and found that the aquator fabric transmit more amount of the perspiration from the skin to the outer layer within a short period of time. They concluded that the wicking behavior of multilayer fabrics depends on the fabric layer and its position. They found that the face-to-face contact between dry and wet fabric has higher wicking behavior than that of dry fabric in contact with the back side of the wet fabric. Zhuang et al [7] studied the transfer wicking mechanisms of knitted fabrics which are used as undergarments for outdoor activities and found that the volume of water initially present in the wet layer and the higher external pressure applied on the fabric layers will enhance the transfer wicking property of knitted fabrics. Higher amount of fluid transfer occurs when the face side of wet and dry fabric is in contact with each other.

Based on literature it is understood that cotton/polypropylene double layered fabrics are preferable for active sportswear since synthetic fibre like polypropylene has good wicking behavior and act as an inner layer to wick. At the same time, cotton being a natural fibre has a good absorbency behaviour and act as an absorbent outer layer in the double layer fabrics.

In the present study, the effect of yarn linear density on moisture management characteristics of cotton/polypropylene double layer knitted fabrics was analyzed with nine different double layer cotton/polypropylene knitted fabrics.

MATERIALS AND METHODS

In order to produce cotton/polypropylene double layer knitted fabrics, three different yarn linear densities such 120 D, 180 D and 240 D of cotton and dyed polypropylene were taken for the study. The polypropylene yarn chosen was multifilament yarn and the cotton hosiery yarn. The cotton and polypropylene yarns were knitted using interlock jacquard knitting machine to produce nine different specimens of double layer 6^{th} wale and 8^{th} course knitted structure fabric. The specifications of interlock jacquard knitting machine and the details of double layered knitted fabric are tabulated in table 1 and table 2 respectively.

Cotton/polypropylene double layer knitted fabric was subjected to bleaching with hydrogen peroxide at 2% concentration for one hour at 100 °C and dyed with hot brand reactive dye at 90 °C for one hour. Then it was washed and dried and compacted at 95 °C. Then the samples were tested for its geometrical and moisture management characteristics.

Table 1

INTERLOCK JACQUARD KNITTING MACHINE – SPECIFICATION TABLE	
Specification	**Details**
Machine type & Make	
Feeder 1, 3, 5 ...	Dial - Polypropylene
Feeder 2, 4, 6 …	Cylinder – Cotton
Diameter (inches)	30
Total no of needles	3744
No of feeders	36
Machine speed (rpm)	15

Table 2

DOUBLE LAYER KNITTED FABRICS – SPECIFICATION TABLE		
S.no	**Fabric code**	**Fabric**
1	120C / 240P	120 Denier Cotton / 240 Denier Polypropylene
2	180C / 240P	180 Denier Cotton / 240 Denier Polypropylene
3	240C / 240P	240 Denier Cotton / 240 Denier Polypropylene
4	120C / 180P	120 Denier Cotton / 180 Denier Polypropylene
5	180C / 180P	180 Denier Cotton / 180 Denier Polypropylene
6	240C / 180P	240 Denier Cotton / 180 Denier Polypropylene
7	120C / 120P	120 Denier Cotton / 20 Denier Polypropylene
8	180C / 120P	180 Denier Cotton / 120 Denier Polypropylene
9	240C / 120P	240 Denier Cotton / 120 Denier Polypropylene

Testing methods

The double layered knitted fabrics were tested to assess the moisture management characteristics such as:

– longitudinal wicking;
– water absorbency;
– transverse wicking.

Longitudinal wicking

To evaluate the longitudinal wicking characteristics of the double layered fabric, a strip of 20 cm x 2 cm test specimen was suspended vertically with its lower end (2 cm) immersed in a reservoir of distilled water. The vertical movement of the water due to capillary action was observed for every minute to evaluate the transfer rate of perspiration from the body to fabric. The wicking test was conducted with 10 samples each for wale wise and course wise directions separately [8–10].

Water absorbency by single drop test method

Each fabric sample of 10 cm diameter was mounted on an embroidery frame. The wetting characteristics of the fabrics were evaluated by measuring the time required for a piece of double layered fabric to absorb the single drop of water on polypropylene side. Ten fabric samples were tested [8–10].

Transverse wicking

Analysis of transverse wicking characteristics of the fabric is as important as longitudinal wicking because the perspiration transfer from skin depends upon its movement through the transverse direction of the fabric. Transverse wicking means the water transfer through the thickness of the fabric. For this purpose two test methods had been developed for evaluating the transverse wicking behaviour of the fabrics:

- **Area of water spread for single drop of water:** It is the ability of the fabric to transfer the water by percolation action. It helps to measure the lateral wicking area on fabrics while avoiding directional effect. A total of 10 samples were tested. Each fabric sample of 10 cm diameter was mounted on an embroidery frame. A burette is placed 6mm above the surface of the fabric. One ml of water was allowed to fall on the fabric from the burette and the area spread on the fabric was measured.
- **Saturation method***:* Similar to earlier method, ten fabric samples each measuring 20 cm diameter was mounted on embroidery frame. For every 3 seconds, one ml of water was allowed to fall on the sample from a standard height of 6 mm through a burette. The drops of water falling on the fabric were continuously absorbed by the sample. When the sample could not absorb any more water, the excess water droplets falls down through the fabric. This is called the saturation point. The time taken to reach saturation point was noted and the area of spread was also measured [8–10].

RESULTS AND DISCUSSION

Nine different cotton/polypropylene combinations of double layer knitted fabrics were produced and tested for their moisture management behaviour by analysing their water absorbency, longitudinal and transverse wicking and also by measuring their water spreading area and saturation time. Along with this their geometrical characteristics such as areal density, thickness, fabric density, fabric packing factor and fabric porosity were also studied.

Fabric geometrical characteristics

Geometrical characteristics such as areal density, thickness, fabric density, fabric packing factor and fabric porosity of cotton/polypropylene fabrics were measured and tabulated in table 3. Cotton and polypropylene layers of fabric were separated by opening the tuck stitches using scissors and the single layer fabric geometry was also studied.

From the table 3, the fabric sample 120 C / 240 P was produced with a combination of 120 denier cotton outer layer and 240 denier polypropylene inner layer. In the same manner all the nine different specimens of double layered of fabrics were produced. When the cotton yarn linear density increases from 240 D to 120 D, the areal density of the fabrics decreases, irrespective of polypropylene yarn linear density. Similarly, the increase in the linear density of polypropylene yarn from 240 D to 120 D also results in decreasing areal density of double layer fabrics. Cotton and polypropylene coarser counts of yarn (240 D / 240 D) produce higher fabric areal density. Finer count combinations of (120 D / 120 D) layer fabrics produce lower areal density. This trend was observed in all the nine specimen of fabric samples. The yarn linear density influences the fabric areal density. Polypropylene/cotton coarser yarn (240 D / 240 D) gives higher fabric thickness. Finer count combinations of 120 D / 120 D layered fabrics produce lower fabric thickness. Polypropylene yarn fabric thickness reduces when yarn linear density increases with same cotton yarn layer. Areal density and thickness of the fabric mainly depends on yarn linear density.

Fabric density is the ratio of fabric areal density and thickness expressed in grams per cubic centimeter. Coarser yarn 240 D / 240 D fabric gives high fabric density and finer yarn 120 D / 120 D fabric gives lower fabric density. When cotton yarn linear density increases from 240 D to 120 D, fabric density decreases for the same linear density of polypropylene layer in double layered fabrics. The same trend was observed in the case of fabric packing factor also. Percentage of fabric porosity [11] was calculated using the formula:

$$\text{Fabric Porosity} = \left(\frac{1 - \text{Density of the fabric (g/cm}^3)}{\text{Density of fibre (g/cm}^3)} \right) \times 100 \quad (1)$$

When the linear density of cotton/polypropylene yarns is coarser, the fabric porosity is also lower. Fabric porosity increases with decreasing packing

Table 3

DOUBLE LAYER KNITTED FABRICS – GEOMETRICAL CHARACTERISTICS TABLE					
Sample	**Areal density** (grams/m^2)	**Thickness** (mm)	**Fabric density** (grams / cm^2)	**Fabric packing factor**	**Fabric porosity** (%)
Double layer fabric					
120C / 240P	241	1.04	0.23	0.26	0.74
180C / 240P	270	1.13	0.24	0.29	0.71
240C / 240P	312	1.21	0.25	0.3	0.7
120C / 180P	211	1.03	0.21	0.18	0.81
180C / 180P	252	1.05	0.24	0.19	0.8
240C / 180P	285	1.15	0.25	0.2	0.79
120C / 120P	188	0.91	0.21	0.16	0.84
180C / 120P	223	1.03	0.22	0.17	0.83
240C / 120P	250	1.05	0.24	0.18	0.82
Single layer fabric					
120C	93	0.41	0.23	0.15	0.85
180C	120	0.43	0.28	0.16	0.84
240C	158	0.48	0.33	0.17	0.83
120P	92	0.41	0.22	0.25	0.75
180P	117	0.58	0.2	0.26	0.73
240P	142	0.61	0.23	0.28	0.72
C – Cotton layer, P – Polypropylene layer					

factor. That is, finer the yarns lower the fabric packing factor and higher will be the fabric porosity.
The two layers of cotton and polypropylene were separated by gentle removal of the tuck stitches using scissors. The individual fabric layers' geometrical properties were studied and discussed. When cotton yarn linear density increases from 240 D to 120 D areal density and thickness decreases irrespective of polypropylene layer in the double layer fabrics. Higher fabric density gives higher fabric packing factor. When the cotton yarn linear density increases fabric packing factor decreases. Higher the fabric packing factor lower will be the porosity.

Longitudinal wicking characteristics

Wicking of water on fabric is very complex mechanism. Initially, when the liquid contacts the fabric, the capillary pressure is greater than the weight of the liquid in the fabric and the liquid continues to rise. The liquid stops rising at the equilibrium height, when capillary forces are balanced by the weight of the liquid. Upon reaching the equilibrium, the force detected by the balance reading becomes constant, indicating stabilization of the wetting and wicking processes. The balance reading after separating the fabric from the liquid indicates the amount of liquid retained by the fabric [12]. In our study, the capillary rise was observed at regular interval time.
The cotton/polypropylene double layer fabrics were tested for their longitudinal wicking at various time intervals of 1, 3, 5, 10, 15 and 30 minutes for wale wise and course wise directions. It is given in the figure 2 and figure 3 respectively.

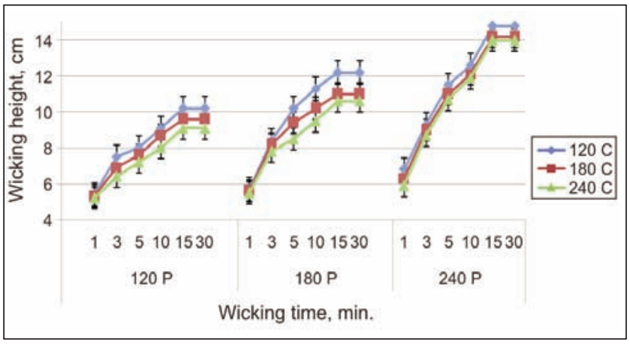

Fig. 2. Longitudinal wicking of double layer knitted fabric – walewise direction

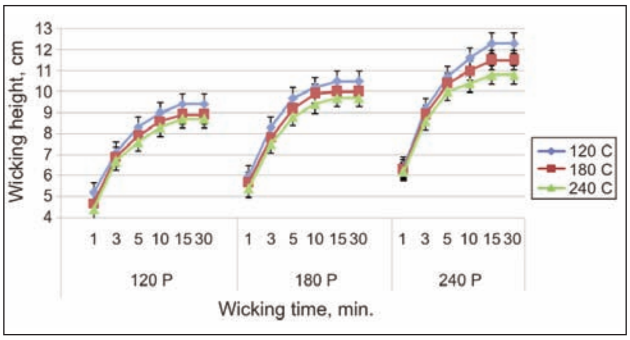

Fig. 3. Longitudinal wicking of double layer knitted fabric – coursewise direction

The fabric longitudinal wicking in wale wise direction is higher than the fabric wicking in course wise direction irrespective of all nine specimens. In general, wicking height increases with wicking time in both wale wise and course wise directions.
The rate of water rise was very fast at the beginning and slows down gradually, as observed by various researchers [13–17]. At the beginning there is no behavioural difference between the cotton and polypropylene yarns. When the polypropylene yarn linear density decreases from 120 D to 240 D, wicking rate increases, irrespective of cotton yarn fineness in the double layered fabrics. The effect of yarn fineness on wicking behaviour is significant. But at the same time, cotton yarn linear density has no significant effect on wicking behaviour of double layer fabric. Wicking is mainly influenced by polypropylene layer in the double layer fabric in both wale wise and coarse wise direction.
In the case of polypropylene inner layer, when linear density of polypropylene yarn in the fabric decreases from 120 D to 240 D, longitudinal wicking increases for the same linear density of cotton. Larger the yarn diameter, higher the wetting force, that influences the capillary rise of the water in the fabric. That's why 240 D polypropylene layer fabric has higher wicking rate than the other linear densities of polypropylene fabric. Similar trend was observed for all linear density combinations of cotton fabrics in wale wise and course wise directions.
In case of cotton outer layer, when linear density of cotton yarn increases from 240 D to 120 D, fabric wicking increases. Coarser cotton layer takes more time to transfer the water droplet. This observation contradicts the findings of Chattopadhyay and Chauhan [13]. Coarser polypropylene (240 D) layer with combination of fine count cotton (120 D) outer layer fabric shows higher wicking than other specimens. In 240 D polypropylene / 120 D cotton fabric, polypropylene has higher areal density and thickness with lower porosity (72 %), but 120 D cotton has lower areal density and lower thickness with higher porosity.
Smaller pores are completely filled first and are responsible for the liquid forward movement. As the smaller pores are completely filled, the liquid then moves to the larger pores. The sizes and shapes of fibres as well as their alignment will influence the geometric configurations and topology of the inter fibre spaces or pores, which are the channels with widely varying shape and size distribution and may or may not be interconnected [12, 14–16]. The shape of fibres in yarn assembly affects the size and geometry of the capillary spaces between fibres and consequently the wicking rates. The flow in capillary spaces may stop when geometric irregularities allow the meniscus to reach an edge and flatten [3]. The distance of liquid movement is greater in a smaller pore because of the higher capillary pressure, but the mass can be retained in larger pores but the distance of liquid advancement is limited. Therefore, fast liquid

dispersion in fibrous materials is facilitated by small, uniformly distributed and interconnected pores whereas high liquid retention can be achieved by having a large number of large pores or a high total pore volume [12].

Water absorbency by single drop test method

From figure 4, the time required to absorb single drop of water is measured for all the nine specimens of fabrics. When the polypropylene yarn linear density increases from 240 D to 120 D, the water absorption time increases irrespective of cotton layers.

When the cotton layer linear density increases from 240 D to 120 D water absorption time decreases. But, it has insignificant effect. 240 D Polypropylene / 120 D Cotton fabric clears the moisture at a faster rate.

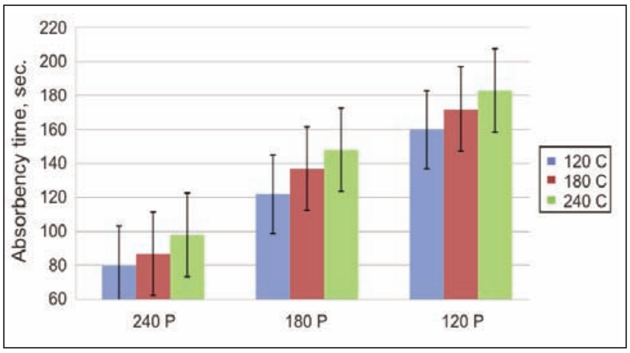

Fig. 4. Water absorbency time of double layer knitted fabric for one ml of water

Transverse wicking characteristics

Transverse wicking is as important as longitudinal wicking because the mechanism of removal of perspiration from the skin involves its movement through the fabric thickness [17, 18].

Kissa [19] developed Gillespie's equation to propose the following exponential sorption

$$\text{Area covered by the spreading liquid (A)} = K(r_{LV}/\eta)^u V^m t^n \quad (2)$$

where,

K is the capillary sorption coefficient,

η – the viscosity of the liquid,

V – the volume of the liquid,

t – the spreading time,

The values of the exponents u, m, and n are 0.33, 0.67, and 0.33 respectively.

$$r_{SV} - r_{SL} = r_{Lv} \cos\theta \quad (3)$$

$$r_{Lv} = (r_{SV} - r_{SL}) \div \cos\theta$$

$$\text{Wetting force } (Fw) = r_{Lv} P \cos\theta$$

$$Fw \quad \alpha \quad P \quad (4)$$

where, P = perimeter of the solid in m.

Wetting is prerequisite for wicking. It is directly proportional to circumference of yarn. The polypropylene and cotton layers of fabric was separated by cutting the inter-looping tuck stitches in order to study the water spreading characteristics of cotton and polypropylene independent layers. Water spreading area was calculated for single drop on fabric. Amount of water spreading area was assessed in three phases on polypropylene side, cotton side, polypropylene/cotton layered side and the mechanism of transverse wicking in double layer knitted fabrics was discussed.

Mechanism of transverse wicking in double layer knitted fabric

Figure 5 shows the mechanism of transverse wicking in double layer fabric. When water droplet placed on polypropylene layer, first it interacts with surface and immediately transported to the next layer. This is because of transverse wicking. During this period water also travels longitudinally.

As gravitational force is higher than wetting force, it comes to the next layer quickly without spreading much on first layer. So, it has minimum spreading area. As soon as droplet comes to cotton inner layer it travels in both transverse and longitudinal directions. Here, wetting force is higher than gravitational force. It will take time to travel in transverse direction. In the mean time, due to wetting force, water moves in longitudinal direction. Slowly it reaches the outer cotton layer. That's why cotton inner layer has more spreading area than outer layer. This is the reason why cotton layer always act as absorbent layer and polypropylene act as a transfer layer in double layer fabrics.

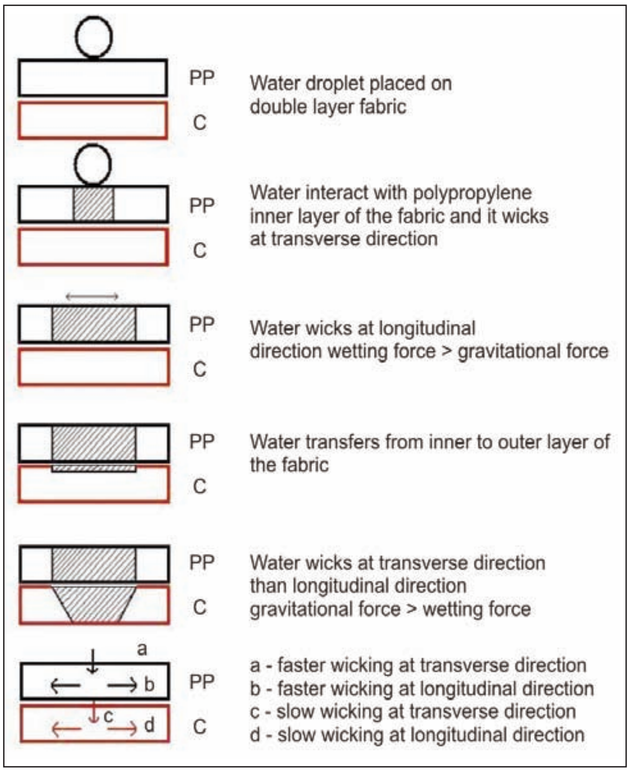

Fig. 5. Transfer wicking mechanism in double layer knitted fabric

From figure 6, double layer fabrics' water spreading area was measured as per the method described by Sampath et al [8–10]. Polypropylene layer has quicker

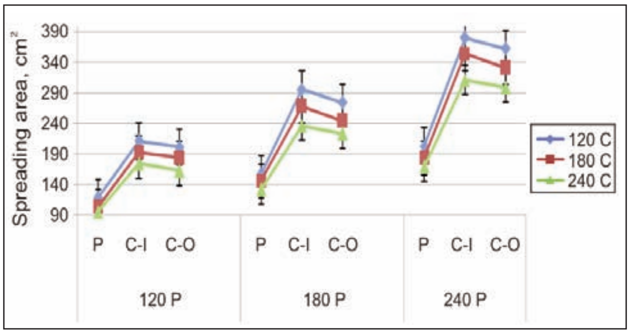

Fig. 6. Water spreading area of double layer knitted fabric

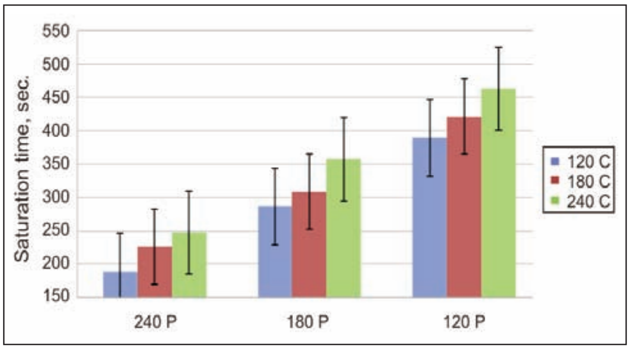

Fig. 7. Saturation time of double layer knitted fabric

wetting time so water spreading area of polypropylene is very low. Also the water spreading area of cotton inner layer is higher than the cotton outer layer. This was observed in all the nine specimens of double layered fabrics.

Water spreading area in coarser polypropylene yarn fabric is higher than finer yarn fabrics. But cotton fineness has insignificant effect with respect to water spreading area. Coarser polypropylene yarn with finer cotton fabric has higher area of water spreading among the selected specimens.

Saturation point and area spread

From figure 7, Water was allowed to drop on the fabric from a height of 10 mm at the rate of 1 ml/min flow rate. The water droplet percolation time was noted at the bottom side of the fabric. It was noted as saturation point, in seconds. Finer polypropylene (120 D) with coarser cotton fabric shows more time to reach saturation point among the specimens.

When polypropylene layer yarn linear density increases from coarser to finer, water saturation point time increases irrespective of cotton layer yarn linear density. 240 D Polypropylene with 120 D cotton fabric has quicker saturation time which is more preferable for active sports since this combination help to evaporate the moisture faster.

Water spreading area

From figure 8, coarser polypropylene with finer cotton layered fabric has higher spreading area than that of all other selected combinations. Polypropylene coarser yarn (240 D) has higher yarn diameter, wicks well due to higher wetting force. When linear density of polypropylene increases (yarn become finer) wetting force reduces and spreading area decreases irrespective of second absorbent layer yarn linear density.

However, coarser cotton yarn fabric has lower spreading area than finer cotton yarn fabrics irrespective of count of polypropylene. So, both the polypropylene and cotton layers behave independently as far as transverse wicking is concerned. cotton layer has insignificant effect. The polypropylene yarn requires larger yarn diameter, to transfer amount of water and cotton yarn requires finer diameter to absorb it.

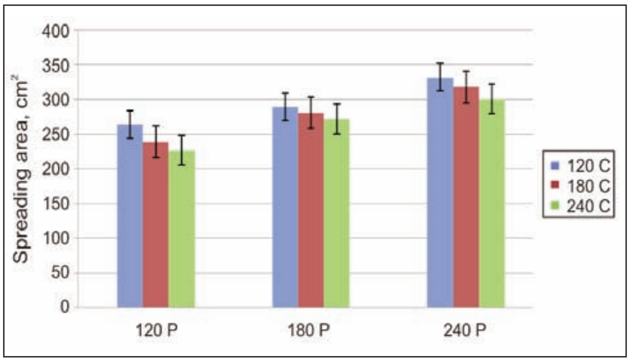

Fig. 8. Water spreading area of double layer knitted fabric at the rate of 1 ml/min

CONCLUSIONS

In this present study, the effect of yarn linear density on moisture management characteristics of double layered cotton/polypropylene knitted fabrics was studied; the combination of cotton/polypropylene double layered knitted fabrics was analyzed with nine different specimens by varying the linear densities of cotton and polypropylene yarns.

Finer cotton outer layer with coarser polypropylene inner layer fabric shows higher longitudinal wicking than other selected specimens. When the polypropylene yarn fineness increases, the water absorption time increases. At the same time, it decreases for the cotton layers.

Coarser polypropylene yarn with finer cotton yarn double layer fabric has better water absorbency.

As far as transverse wicking is concerned, polypropylene layer shows least area of spread and it quickly transfers the water to the next layer. Finer polypropylene with coarser cotton layered fabric shows longer time to reach the saturation point and coarser polypropylene with finer cotton layered fabric has higher spreading area than that of all other selected specimens.

The 120 D cotton / 240 D polypropylene double layered fabric has good moisture management characteristics than that of selected specimens. Selection of right yarn linear density is important for improving moisture management characteristics of double layer knitted fabrics.

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Medical efficiency of antibacterial wound dressings

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REZUMAT – ABSTRACT

Eficiența medicală a pansamentelor cu proprietăți antibacteriene

Textilele medicale reprezintă un domeniu important de utilizare, cu un excelent potențial de piață. Aplicațiile non-invazive precum pansamentele sunt în prezent elaborate încorporând medicamente și alte substanțe cu caracteristici de vindecare, care le îmbunătățește eficiența. Lucrarea prezintă un pansament cu suport textil (tricot din bumbac) cu o nouă emulsie cu propolis, ceară de albine și chitosan. Sunt evaluate caracteristicile de confort (higroscopicitate, permeabilitate la aer și permeabilitate la vapori).

Pentru a verifica eficiența medicală a noului tip de pansament, s-a studiat comportarea antibacteriană a emulsiei, folosind medii de cultură solide și lichide. S-au realizat tăieturi pe animale de laborator (șobolani Wistar), iar tăieturile au fost acoperite cu pansamente simple și pansamente cu emulsie. S-au făcut apoi comparații în ce privește procesul de vindecare, evidenţiindu-se accelerarea acestuia în cazul folosirii emulsiei.

Cuvinte-cheie: tricoturi medicale, propolis, ceară de albine, comportare antibacteriană, proces de vindecare

Medical efficiency of antibacterial wound dressings

Medical textiles are an important field of applications, with excellent market potential. Non-invasive applications such as wound dressings are currently developed with embedded drugs and healing substances in order to maximize their efficiency. The paper presents a wound dressing with textile support (cotton knitted fabric) with a newly developed emulsion based on propolis, beeswax and chitosan. The comfort properties of the product were evaluated (hygroscopicity, air permeability and vapour permeability).

In order to show the medical efficiency of this new wound dressing, the emulsion was studied to determine its antibacterial behaviour using solid and liquid culture mediums. The emulsion was also evaluated to determine its healing potential. A number of laboratory Wistar rats were cut and the wounds were covered with simple dressing and dressing with the emulsion. The healing process was then compared and shown to be accelerated in the case of the emulsion's use.

Key-words: medical knitted fabrics, propolis, beeswax, antibacterial behaviour, healing process

Medical textiles have shown an excellent potential for development for both implantable and non-implantable applications. There is a constant trend of developing special new materials, with specific properties, new fabrics with controlled structures and new materials with added healing substances. Apart from developing new materials and raw materials, there is a strong return to natural healing substances, as their power for patient treatment is now increasingly used. Propolis and honey based products are increasingly used for treating different types of diseases and open wounds. Several studies [1–7] have shown the efficiency of propolis in improving the tissue granulation during wound healing. The propolis is used in hydro soluble dressings directly or in embedded delivery systems. All references to such systems indicate that they are applied on the skin as wound dressing, without textile support.

In Romania, the use of propolis is widely spread, mostly for homeopathic medicine and treatments with natural ingredients. There are no national companies offering wound dressings with embedded delivery systems containing propolis.

In this direction, the paper presents a new type of wound dressing made of cotton fibres and impregnated with a new type of emulsion containing beeswax, used for its non-adhesive properties, chitosan polymer for embedding the propolis extract with healing characteristics and glycerol as humectants. A non-ionic surfactant was used in order to stabilize the emulsion.

Cotton materials have different medical and healthcare applications, due to their advantages such as biodegradability, softness, affinity to skin and sweat absorption [3–5]. Bacterial contamination leading to infection is a common problem in hospitals. Therefore it is mandatory to reduce the transmission of microorganisms by developing medical textile fabrics with antibacterial properties [6–7].

The propolis, known as the bees 'glue', is a substance used to sheath the beehive openings, in order to avoid air currents, and as antibacterial compound; it is used to prevent decaying of foreign insects killed inside the beehive [8, 9]. Qualitative and quantitative chemical composition of propolis varies according to the geographic area where the beehives are placed. Up to now, over 180 components were identified, including flavanoids, phenolic acids and their esters, phenolic aldehides, chetones, etc. [10]. In traditional medicine propolis is known for its antibacterial, anti-inflammatory, antioxidant and allergenic characteristics [11, 12]. The commercial propolis ethanolic solutions are often used in treating minor lacerations, angina or skin infection. Further positive aspects of propolis refer to non-toxicity and lack of secondary effects although there were reported isolated cases of allergies to propolis, caused by certain allergens in the plants [13, 14].

Chitosan β-(1-4) linked 2-amino-2-deoxy-D-glucose, a polysaccharide obtained from the alkaline deacetilation of chitin attracts special interest due to its antibacterial and immuno-enhancing characteristics, non-toxicity and bio-degradability [14] and can be used to inhibit fibroplasias in wound treatment and enhances tissue regeneration, thus making it usable in the field of medical textiles [15].

Glycerol, widely used as humectant due to hygroscopicity, is known to protect against irritants and to accelerate recovery of irritated skin and is widely used in pharmaceutical formulations and cosmetics for its' good emollient properties. It is usually regarded as a nontoxic and non-irritant material [15].

The paper presents the development of this type of wound dressing and evaluates its medical efficiency – the antibacterial behaviour and the healing process. A lot of studies show the antibacterial activity, but discussing about the healing properties of wound dressings is also of utmost importance.

MATERIALS AND METHODS

Production of wound dressing

Chitosan (molecular weight 100.000 – 300.000 and a degree of deacetylation value of 85% was obtained from Fluka Chemie GmbH – Switzerland. 1% chitosan solution was obtained by solving of chitosan in 1% acetic acid solution (in order to insure the complete solving of chitosan). The solution was stirred 24 h at room temperature, filtered in order to remove the impurities.

The non ionic surfactant Tween 80 was supplied by Merck – Germany and the anhydrous glycerol by SC Comecom SRL Bucureşti, while the beeswax and propolis were procured from a private apiary located in the North-East region of Romania. The ethylic alcohol was acquired from Chemical Company SA, Romania.

The propolis ethanol extract (EEP) of 30% (w/v) concentration was prepared by solving raw propolis in ethylic alcohol at 25°C, in a dark environment, for 96 h.

Knitted fabrics were used as textile support. The choice is justified by the lower compactness specific to such fabrics caused by their geometry. Initial experimental studies showed that a much higher amount of substance can be embedded in knitted fabrics than in woven fabrics.

The textile support was made of 100% cotton single jersey fabrics, produced on a circular knitting machine Mesdan Lab Knitter, gauge 10E. The yarn count was Nm 60/1. Three fabric variants were produced with different stitch density. The fabric samples were cleaned and bleached. The structural parameters of the finished fabrics are presented in table 1.

The emulsion is obtained by mixing under stirring at 80°C the components according with the concentration from table 2.

Table 1

STRUCTURAL PARAMETERS OF THE FINISHED FABRICS			
Do (wales/5 cm)	**Dv** (rows/5 cm)	**Stitch length** (mm)	**M/m^2** (g)
50	58	4.25	105

Table 2

THE EMULSION'S COMPOSITION		
Compound	**Concentration**	
Beeswax	20	g/l
Glycerol	80	ml/l
Tween 80	25	ml/l
Chitosan 1% (m/v)	250	ml/l
EEP 30% (m/v)	90	ml/l

The fabrics were impregnated with the emulsion at 40°C, using a Benz padding machine. After padding, the samples were dried at 50°C. Figure 1 presents the emulsion coating of the cotton fibres, using SEM. The samples were prepared by cutting them to 5×5 mm dimension. No additional coating was required.

The weight percentage of emulsion retained by the fabric after drying (*W*) was determined with the formula (1):

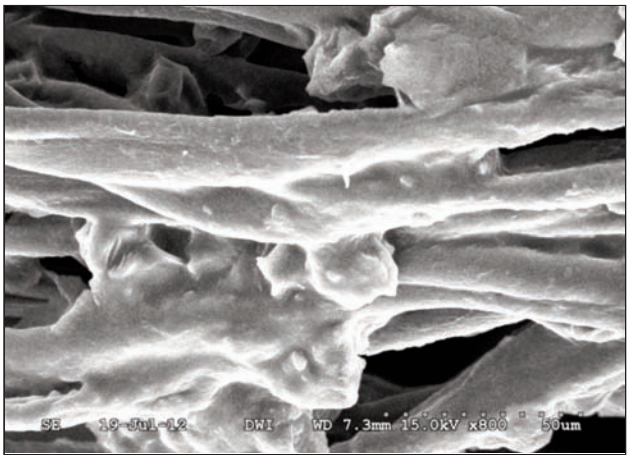

Fig. 1. SEM aspect of emulsions coating the cotton fabric

$$W = 100 \times \frac{(w_1 - w_0)}{w_0} \quad (1)$$

where: w_0 = the weight of the fabric before impregnation and w_1 = the weight of the fabric after impregnation, dried at 50 °C and conditioned for 24 h at 65 %Rh. The solution's *p*H-was adjusted using NaOH 10% to 5. The amount of emulsion retained by the knitted fabric was determined to be 34%.

Comfort characterization of wound dressing

The impregnated fabric was tested to determine its comfort characteristics: hygroscopicity, air permeability and vapour permeability. Air permeability was determined on a METEFEM (Hungary) apparatus, according to SR EN ISO 9237 using 10 mm water column pressure difference for the cotton fabric and the emulsion impregnated fabric. Vapour permeability was measured with Permetest (Sensora, Czech Republic), using a method similar to ISO 11092. The samples were conditioned for 48 h at two sets of conditions: φ_1= 20% humidity and θ_1= 20 °C temperature, respectively φ_1= 65% humidity and θ_2= 20 °C temperature.

Antibacterial testing of the emulsion

The emulsion was tested for different gram-positive and gram-negative bacteria: *Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Streptococcus pyogenes*. The tests were carried out using the difusimetric method [16]. The following materials were used:

- Mueller-Hinton agar growth culture (respectively Mueller – Hinton agar with blood for *S.pyogenes*).
- Bacterial quality control strains (ATCC) for the 4 types of selected bacteria.
- 0.5 McFarland ethanol and bacterial suspension dosymetry for standardization.

The tests contained the following working stages

- A bacterial suspension was produced for each ATCC strain out of the cultures in the exponential stage. The dilution factor used was 10^8 UFC/ml (0.5 McFarland standard).
- The bacterial suspension was inoculated uniformly on the culture medium using a sterile wool swab.
- 10 µl of the propolis emulsion was applied directly on the culture medium or first on sterile filter paper discs and then on the mediums.
- The plates were incubated at 37°C, for 24 hours.

After the incubation was completed, the plates were examined for the presence of inhibition areas in the culture mediums caused by the propolis emulsion.

For control, another antibacterial test for *S.aureus* was carried out using Mueller-Hinton bullion with successive dilutions (1/2, 1/4, 1/8, 1/16, 1/32, 1/64) and 1 ml amount of emulsion for each test tube. A suspension with 5×10^5 UFC/ml density was taken from the *S.aureus* ATCC culture in exponential phase by diluting it to 1/200 in Mueller Hinton bullion. 1 ml of standardized bacterial suspension was put in each test tube. A *S.aureus* strain was inoculated in a test tube without the emulsion in order to monitor the growth. The tubes were incubated at 37°C, for 24–48 hours. After incubation was completed, the test tubes were examined to determine the highest propolis dilution completely inhibiting bacteria growth. In the tubes without evident growth the viable bacteria were quantified by transferring them to solid culture mediums and determining the decrease in viable bacteria.

Healing process protocol

In order to observe if the wound dressing with the propolis emulsion has healing properties, a protocol was developed based on existing references [17, 18, 19]. Four incisions were made on the back of 50 Wistar rats. Half of the cuts were covered with normal wound dressing and the other half with wound dressings with the propolis emulsion (fig. 2). The progress of wound healing was controlled by measuring the closure of the cuts daily.

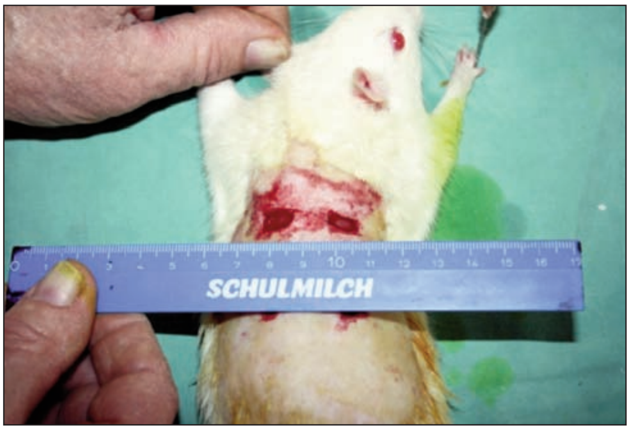

Fig. 2. Aspect of the four cuts after incision

RESULTS AND DISCUSSIONS

Comfort properties

Comfort characteristics of the treated fabric are almost similar to the untreated cotton material keeping the general comfort sensation of the 100 % cotton fabrics. The treatment however had a significant influence only on the hygroscopicity due to the glycerol concentration in the emulsion, confirmed by the results in figure 1. The emulsion coating the fibres has a certain influence on the air permeability explained by the chitosan film blocking the free space between the fibres. A more detailed view on the emulsion aspect covering the fibres is shown in figure 3.

The relative vapour permeability is highly influenced by the relative air humidity. As seen in figure 3, C, for the samples (treated or untreated) conditioned at 20% RH the RVP is lower than the samples conditioned at 65% RH. The small difference between the treated and untreated fabrics is due to the presence of glycerol.

Antibacterial characteristics

The tests carried out on solid culture mediums shown that the emulsion inhibited only the *S.aureus* ATCC

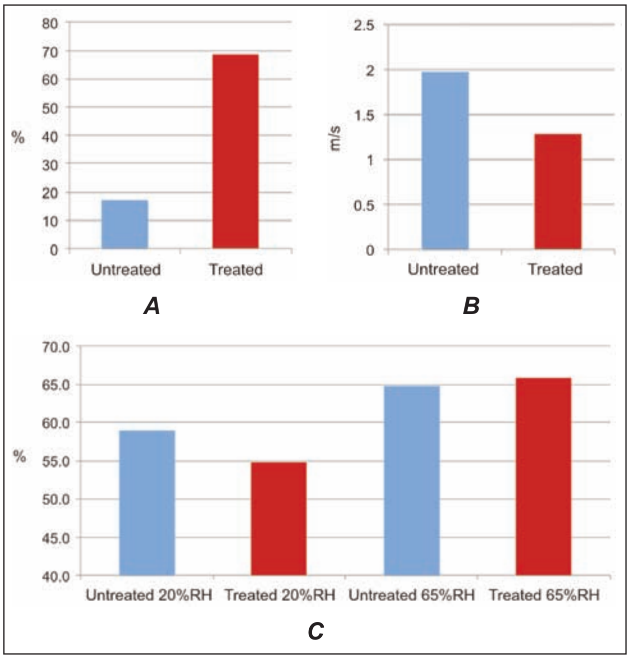

Fig. 3. Comfort measurements:
A – hygroscopicity, *B* – air permeability,
C – vapour permeability

strains (fig. 4 and 5). No effect was recorded for *E.coli* (fig. 6), *P.aeruginosa* (fig. 7) and *S.pyogenes* (fig. 8). In the case of the liquid culture medium for *S.aureus* (fig. 9), the emulsion caused bacteria growth inhibition for dilutions up to 1/64 and eliminated all bacteria for dilutions up to 1/32.

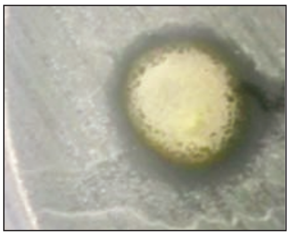

Fig. 4. *S.aureus*

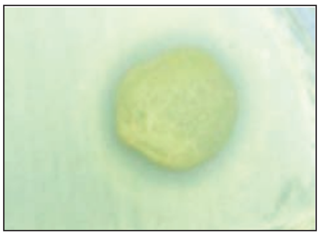

Fig. 5. *S.aureus*

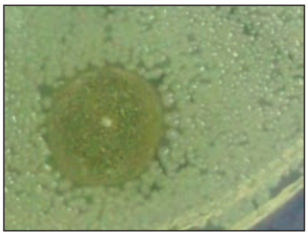

Fig. 6. *E.coli*

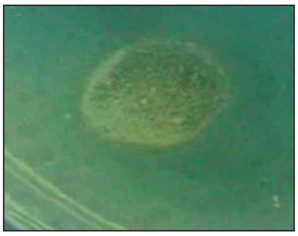

Fig. 7. *P.aeruginosa*

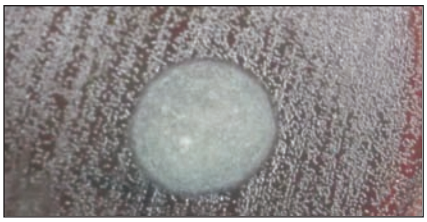

Fig. 8. *S.pyogenes*

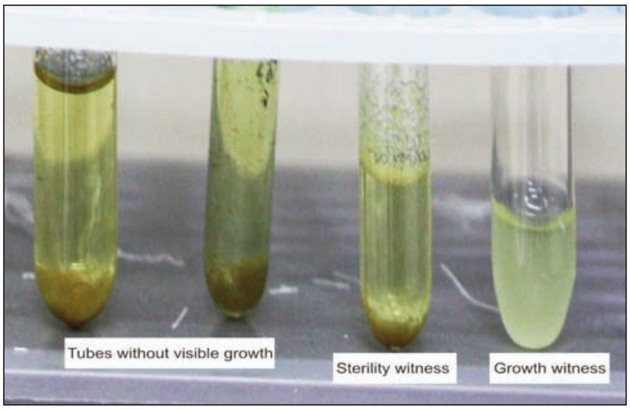

Fig. 9. Antibacterial tests in liquid medium

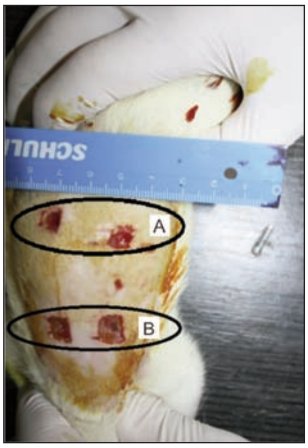

Fig. 10. Aspect of the healed cuts after 3 days

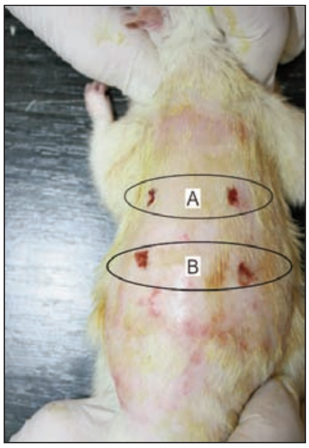

Fig. 11. Aspect of the healed cuts after 11 days

Wound healing process

All rats presented differences in the size of wound closure between the cuts covered by normal dressing and the cuts covered by the dressing with the propolis emulsion. The differences were obvious from the beginning. After three days (fig. 10) the cephalic cuts (zone B) that were treated with the emulsion impregnated dressing, already presented macroscopic modifications of the wounds, while this was not the case for the other two cuts (zone A). After 11 days, as illustrated in figure 11, the cuts treated with the emulsion were almost healed – the cuts were completely closed and the re-epithelialisation process was more advanced.

CONCLUSIONS

Propolis extract can be used successfully in formulation applicable on textile support to obtain comfortable wound dressing products. Textile materials have a significant influence regarding the emulsion redemption and certain types of materials are to be used accordingly to the treatment requirements. The comfort properties of the emulsion impregnated cotton fabric show that the emulsion has a strong influence on hygroscopicity and air permeability and does not affect the vapour permeability. The presence of the emulsion increases significantly the hygroscopicity and decreases to a certain point the air permeability. The vapour permeability depends on the relative humidity, but the emulsion does not have a strong influence.

The antimicrobial activity was tested using solid and liquid culture mediums and was proven to be successful for *S. aureus* bacteria.

For the study of the healing capacity of the emulsion, incisions were made on laboratory Wistar rats and the wounds were cover by normal dressings and dressings with the propolis emulsion. The results show that the healing process is clearly improved when the dressings with the propolis emulsion are used.

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Materials used for temporary abdominal closure following decompression laparotomy in the abdominal compartment syndrome

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REZUMAT – ABSTRACT

Materiale folosite pentru închiderea temporară a abdomenului după laparotomia de decompresie în sindromul de compartiment abdominal

Sindromul de compartiment abdominal (SCA) poate să apară la pacienţii grav bolnavi în urma traumatismelor, infecțiilor intra-abdominale și după intervenții chirurgicale majore. Tratamentul este laparotomia de decompresie, urmată de o metodă de închidere temporară a abdomenului. Alegerea materialului pentru închiderea temporară are foarte mare importanță în ceea ce privește apariția fistulelor, a reușitei de a închide abdomenul și a mortalității. Am comparat două metode de închidere temporară a abdomenului, Bogota bag și plasarea unei proteze compozite la 9 pacienți care au fost diagnosticați cu SCA în clinica noastră. Proteza compozită este alcătuită din două straturi, unul extern polipropilenic și unul intern, colagenic, absorbabil. Bogota bag a fost folosită în 4 cazuri și sistemul cu proteză compozită în 5 cazuri. Mortalitatea globală a fost de patru cazuri din nouă. S-au diagnosticat trei fistule intestinale, două pentru Bogota bag, amândouă ducând la deces. Închiderea abdomenului a fost posibilă în trei cazuri, două dintre ele după folosirea protezei compozite. Deși lotul studiat este mic, proteza compozită pare a fi alegerea mai bună pentru închiderea temporară a abdomenului după laparotomia de decompresie din SCA.

Cuvinte-cheie: sindrom de compartiment abdominal, proteză compozită, abdomen deschis

Materials used for temporary abdominal closure following decompression laparotomy in the abdominal compartment syndrome

Abdominal compartment syndrome (ACS) can appear in critically ill patients following trauma, intra-abdominal infections and after major surgery. The treatment is decompressive laparotomy followed by a temporary abdominal wall closure (TAC) technique. The choice of material for the TAC is highly influential in regards to fistula formation, delayed closure rates and mortality. Materials and method: We compared two TAC techniques, Bogota bag and composite mesh, for 9 patients that developed ACS in our department. The composite mesh contains a polypropylene outer layer and an absorbable collagen film on the visceral surface. We used the Bogota bag system for 4 cases and the composite mesh system in 5 cases. Overall mortality was high with four deaths out of nine patients. Three intestinal fistulas developed, two for the Bogota bag, both of them resulting in death. Delayed primary closure was obtained in three cases, two for the composite mesh. Although the sample size is small we feel that the composite mesh was a better choice of TAC after decompressive laparotomy for ACS.

Key-words: abdominal compartment syndrome, composite mesh, open abdomen

INTRODUCTION

The abdominal cavity is surrounded by rigid structures such as the pelvis, spine and the costal arches, and by flexible tissues, the abdominal wall and the diaphragm. Intra-abdominal pressure (IAP) follows hydrostatic laws where the degree of the flexibility of the abdominal wall and the specific gravity of its contents would determine the pressure at a given point in a given position. The movements of the diaphragm and the rib cage, the resting tone and contractions of the abdominal wall musculature, obesity and the variations in its content in certain physiological or pathological conditions cause modifications of IAP. The IAP is the pressure concealed within the abdominal cavity, it varies with respiration and is normally below 10 mmHg [1]. It should always be measured at end-expiration in the complete supine position. Elevated IAP is now commonly identified in the critically ill and acknowledged as a cause of significant morbidity and mortality [2–4]. It causes significant impairment of cardiovascular [5], pulmonary [6], renal [7], gastrointestinal [8], and hepatic [5] functions. The IAP that may induce malperfusion in one organ system can have little effect on another demonstrating each organ's unique vulnerability.

IAP is highly variable in normal individuals and depends on body mass index [2] and position [9, 10]. The mean IAP is around 6.5 mm Hg with a range from subatmospheric up to 16 mm Hg. Consensus definitions from the World Society of the Abdominal Compartment Syndrome (WSACS) define intra-abdominal hypertension (IAH) as the sustained or repeated pathological elevation in IAP ≥ 12 mm Hg. It is further subdivided into four grades (I to IV) as evidenced in table 1. ACS is defined as a sustained IAP > 20 mm Hg that is associated with new organ dysfunction/

Table 1

CONSENSUS DEFINITIONS OF THE WSACS	
Open abdomen	**Non-closure of fascia and skin**
Normal intra-abdominal pressure (IAP)	5–7 mm Hg in critically ill adults
Intra-abdominal Hypertension (IAH)	Sustained or repeated pathological elevation of IAP ≥ 12 mm Hg
IAH grade 1	12–15 mm Hg
IAH grade 2	16–20 mm Hg
IAH grade 3	21–25 mm Hg
IAH grade 4	> 25 mm Hg
Abdominal Compartment Syndrome (ACS)	Sustained IAP > 20 mm Hg that is associated with new organ dysfunction/failure
Primary ACS	Associated with injury or disease in the abdomino-pelvic region
Secondary ACS	Without the presence of intra-abdominal injury
Recurrent ACS	Condition in which ACS develops after previous surgical or medical treatment of primary or secondary ACS

failure. The WSACS further define primary and secondary IAH or ACS if the event occurs in the setting of injuries in the abdominopelvic region. Recurrent IAH or ACS is defined as the condition in which the entities redevelop following previous medical or surgical treatment [11].

The causes of ACS are primarily related to the accumulation of intra-abdominal blood, ascites and visceral edema to the degree that abdominal wall compliance is overcomed. The incidence of ACS depends largely on the population examined. Approximately 1% of all patients admitted following trauma in the intensive care unit (ICU) develop ACS [12]. However, up to 36% of patients requiring damage control surgery will develop ACS [13]. ACS can develop in settings other than trauma. The WSACS lists several risk factors other than trauma such as: abdominal surgery, intra-abdominal infections, peritonitis.

The treatment of ACS according to the consensus conference of the WSACS is decompressive laparotomy. It results in an immediate decrease in IAP and an improvement in organ function [14]. However, decompressive laparotomy is associated with multiple complications and overall reported patient mortality is high (approximately 50%) [15].

Decompression laparotomy leads to an direct outcome, the open abdomen. The management of the open abdomen was introduced in the English literature by Ogilvie in 1940 [16]. Since then it has been a subject of debate. Its indication has varied from a last resort option in abdominal catastrophes to a preferred initial treatment strategy in damage control surgery for both trauma and non-trauma patients. The management of the open abdomen requires temporary abdominal closure (TAC) techniques. A summary of TAC options is listed in table 2. The outcome of these patients is highly dependent on the materials used during these techniques. [17].

Although the benefits of measuring the IAP and the simplicity of the methods are obvious, less than a third of centers, worldwide, routinely measure the IAP when risk factors are present. Various indirect IAP measurement techniques, as bladder, gastric or rectal, have proved to be reliable, simple and easy to apply. The intra-bladder techniques are the gold standard for indirect IAP measurement [18].

MATERIALS AND METHOD

We retrospectively evaluated 9 cases of open abdomen management following decompression laparotomy for ACS. The cases were admitted to our department in the period May 2013 to February 2015. IAP was measured using an indirect bladder technique. The Harrahill method was used. The method uses the patient's own urine as a transducing medium. The Foley catheter is clamped just above the urine collection bag. The tubing is then held at a position of 30 to 40 cm above the symphysis pubis and the clamp is released. The IAP is indicated by the height (cm) of the urine column from the pubic bone. The meniscus should show respiratory variations. This method can be used only in cases with sufficient urine output. In oliguric patients, 50 ml of saline can be injected as priming.

ACS was defined as an IAP of 20 mm Hg or above, and a newly aquired organ dysfunction. Organ failure was defined as a Sequential Organ Failure Assessment (SOFA) (table 3) organ subscore ≥ 3 [19].

The methods chosen for TAC were Bogota bag and mesh placement. Bogota bag (figure 1) placement consisted of a large sterile saline infusion bag or a collection bag (plastic), cut open and sutured to the edges of the rectus sheath. One drain was placed above the bag and a self adhesive foil was placed over the wound and skin edges for better control of fluid and barrier functions. The mesh technique consisted of a composite mesh (figure 2) sutured to the rectus sheath edges that was reduced in size (by middle folding) as swelling subsided in the postoperative period. The composite mesh has two different surfaces, one that overlies the viscera, an absorbable

Table 2

DESCRIPTION OF SURGICAL TECHNIQUES FOR TEMPORARY ABDOMINAL CLOSURE	
Technique	**Description**
VAC (vacuum-assisted) closure	A sutureless system. A perforated barrier plastic sheet covers the viscera and a polyurethane sponge or damp surgical towels are placed between the fascial edges. The wound is covered by an airtight seal. This is pierced by a suction drain that is connected to a suction pump and fluid collection system. The negative pressure keeps a tension on the abdominal wall and collects exudates. Commercial systems are available with a pre-packed dressing system with a special drainage tube that can be connected to a dedicated specialized pump
Witmann patch	Two opposite Velcro sheets are sutured to the fascial edges. The Velcro sheets overlap in the middle allowing gradual re-approximation of the abdominal wall. This can be done without the need for general anesthesia
Dynamic retention sutures	The viscera are covered with a barrier sheet. Horizontal sutures are placed through a large diameter silastic catheter 4 cm from each fascial edge and through the entire abdominal wall in an extraperitoneal plane. These sutures maintain tension and can be gradually tightened allowing re-approximation of the abdominal wall
Bogota bag	A sterile irrigation bag is sutured between the skin or the fascial edges protecting the abdominal content and preventing retraction of the fascial edges
Mesh/sheet	A biological, absorbable or non-absorbable mesh or sheet is sutured between fascial edges
Loose packing	First method used as TAC. The abdominal cavity is loosely packed and the fascial defect is covered by standard wound dressing only
Skin only	The skin is closed over the fascial defect with towel clips or a running suture
Zipper	A mesh or sheet with a sterilized zipper is sutured between the fascial edges

Table 3

SEQUENTIAL ORGAN FAILURE ASSESMENT (SOFA) SCORE				
SOFA score	**1**	**2**	**3**	**4**
Respiration				
PaO_2/FIO_2 (mmHg)	< 400	< 300	< 220	< 100
SaO_2/FIO_2	221–301	142–220	67–141	< 67
Coagulation				
Platelets x $10^3/mm^3$	< 150	< 100	< 50	< 20
Liver				
Bilirubin (mg/dl)	1.2–1.9	2.0–5.9	6.0–11.9	> 12.0
Cardiovascular				
Hypotension	MAP < 70			
CNS				
Glasgow Coma Scale	13–14	10–12	6–9	<6
Renal				
Creatinine (mg/dl) or urine output (ml/d)	1.2–1.9	2.0–3.4	3.5–4.9 or < 500	> 5.0 or < 200

collagen film, and an outer polypropylene layer. The decision to use one method over the other was not randomized. The choice was based on surgeon preference and availability of the composite mesh of sufficient size.

Morbidity and mortality were analyzed for the two methods. Important outcomes of open abdomen management, as delayed primary closure and intestinal fistula rates, were also described and compared for each method.

RESULTS AND DISCUSSION

Nine patients were treated for ACS in the study period. The population consisted of seven female and two male patients. Mean age of the study population was 63 years. Seven out of the 9 patients had a BMI over 35 kg/m^2. The Bogota bag technique was used in 4 cases and the mesh technique in 5 cases.

ACS was diagnosed following severe acute pancreatitis in three cases, one with Bogota bag and two with mesh, following abdominal surgery in four

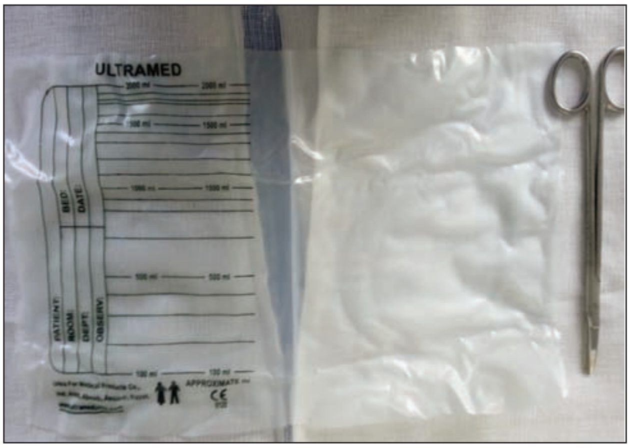

Fig. 1. Bogota bag

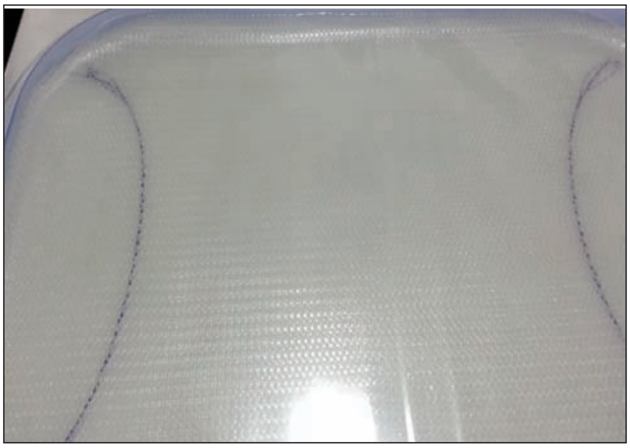

Fig. 2. Composite mesh

cases, 2 cases with each TAC technique, following the non-operative management of a blunt abdominal trauma in one case, using the Bogota bag, and following sigmoid colon volvulus, treated with mesh covering in one case. The two postoperative cases treated with the mesh technique were colorectal cancer surgeries (one sigmoid colon and one splenic flexure tumor) that presented as large bowel obstructions. The postoperative cases treated with the Bogota bag were two cases of peritonitis, one with a perforated ulcer with generalized purulent peritonitis and the other with a perforated sigmoid colon diverticulitis. One case presented after blunt abdominal trauma with a grade II liver injury that was managed nonoperatively. Sigmoid volvulus was identified in one case and was managed endoscopically, later developing ACS.

All cases of ACS were diagnosed in the first week after the onset of the initial pathology. Postoperative ACS developed earliest in the first 2 days in three case and in the 3 day in one case. Severe acute pancreatitis developed after the longest time period in our series, after day four. The SOFA scoring system was used for the diagnosis of organ dysfunctions. Renal failure was identified in six cases and respiratory failure in the remaining three.

Mortality occurred due to multiple system and organ failure in four cases, two cases for each TAC method. Two patients from the Bogota bag group and one from the mesh group developed small bowel fistula. Delayed closure was possible in three cases, two from the mesh group. The remaining two patients, one from each group, were grafted with full thickness skin and were discharged with a large parietal defect and scheduled for reoperation 3–6 months later. Both cases were successfully operated with a component separation approach.

A summary of the results is presented in table 4 for a better understanding of our series.

CONCLUSIONS

The management of the open abdomen has evolved over the last three decades. Simple packing was first reported in 1979 [20]. In the 1980s non-absorbable meshes were used but these led to a high rate of intestinal fistulas [21]. Then, absorbable meshes began to be used. In 1990 Witmann et al. [22] described their technique in which it was possible to insert two sheets of mesh without the need for further surgery. In 1995 Brock [23] described a sutureless technique, which included the insertion of a perforated polyethylene sheet, damp towels and drains with an airtight

Table 4

RESULTS

Bogota bag					Composite mesh				
No	Cause of ACS	Organ Dysfunction	Day of Onset	Outcome	No	Cause of ACS	Organ Dysfunction	Day of Onset	Outcome
1	Blunt trauma	Respiratory	3	Skin Graft	1	Sigmoid volvulus	Renal	1	DC
2	PO	Renal	2	DC	2	PO	Renal	2	Death
3	SAP	Renal	5	Fistula; Death	3	SAP	Renal	4	DC
4	PO	Respiratory	2	Fistula; Death	4	SAP	Respiratory	6	Death
					5	PO	Renal	3	Fistula; Skin graft

seal covering the wound. In 2002 the surgical towels were substituted with a polyurethane sponge and attached to a special drain to a dedicated pump for liquid aspiration [24]. What is very much clear from the above is that the discussion surrounding the field of open abdomen management is one that deeply concerns the materials used. The main outcomes when discussing open abdomen management are mortality, the ability or inability to eventually close the parietal defect and bowel fistula formation. Recent improvements in any of these regards is very much based on the understanding and exploration of the materials used for temporary abdominal closure. There is a lack of high quality data in the literature concerning these matters. Most reports have limited study populations and there is a lack of randomized control trials. There are numerous problems in conducting these, as there are limiting factors involved. Informed consent is difficult to obtain from critically ill patients and several ethical issues are raised [17]. The ideal features of the perfect TAC material are listed in table 5.

Table 5

Ideal features of the TAC material
Contain abdominal contents
Protect from external contamination and injury
Preserve the integrity of the abdominal wall and support final closure
Prevent adherence of the viscera to the abdominal wall and closure material
Prevent intra-abdominal hypertension
Minimize loss of abdominal domain
Be easily and rapidly performed
Provide easy re-entry
Prevent fluid loss
Facilitate nursing care
Be inexpensive and cost effective
Allow patient transport

Our results show a superiority of the composite mesh in terms of fistula formation (one versus two in the Bogota bag group) and abdominal closure (two versus one in the Bogota bag group). The specially prepared collagen internal, visceral layer minimizes adhesions between the mesh and the viscera and leads to a lower fistula formation rate. The ability to shorten the distance between the fascial edges as swelling subsides by folding the middle part of the mesh leads to a better rate of closure within the same hospital admittance period. Mortality was high for both methods although a clear delineation between mortality due to initial pathology and mortality influenced by TAC method is very hard to achieve.

One of the biggest problems with ACS and TAC methods is that the IAP is still measured in very few centers. Any paper that helps raise awareness over this issues is welcomed. IAP measurement is cheap, easy to learn and teach and, as demonstrated, extremely useful.

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Investigating the effect of the marker assortment size distribution and fabric width on the fabric use efficiency

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REZUMAT – ABSTRACT

Investigarea efectului încadrării din punct de vedere al dimensiunii tiparelor, lățimii țesăturii și distribuției pe mărimi asupra eficienței utilizării țesăturii

Folosirea imputurilor sistemelor de producție într-un mod efficient este unul dintre cei mai importanți factori pentru creșterea competitivității companiilor. Creșterea eficienței utilizării țesăturii reprezintă unul dintre indicatorii cei mai importanți pentru scăderea costului produsului. Factorii care afectează eficiența folosirii țesăturii sunt plasarea tiparelor de îmbrăcăminte pe încadrare, lățimea materialului și dimensiunile mărimilor încadrărilor. Au fost analizate 24 lățimi de material, obținute din 4 tipuri de mărimi de distribuții și au fost pregătite 96 de încadrări. Prin analizarea tipurilor de încadrare pregătite s-a obținut raportul folosirii materialului și au fost investigate efectele lățimii materialului și a distribuției mărimilor asupra eficienței folosirii materialului textil.

Cuvinte-cheie: eficiență, eficiența folosirii materialului, încadrare, lățimea materialului, distribuția mărimilor

Investigating the effect of the marker assortment, size distribution and fabric width on the fabric use efficiency

Using the inputs of the production system efficiently is one of the most important factors to increase the competitiveness of the companies. Increasing efficiency of the fabric usage which is one of the most sufficient inputs of the ready-made garment production, decreasing the product cost. Factors which affect the fabric usage efficiency are placement of the garment patterns to the marker plan, fabric width and size distribution of marker assortment. In this study, effect of the size distribution of marker assortment and the fabric width on the fabric usage efficiency was investigated. For the application processes, 24 different fabrics width were obtained for (from) 4 different size distributions and totally 96 marker plans were prepared. By analyzing the prepared marker plans, fabric usage ratios were obtained and the effect of the fabric width and the assortment distribution on the fabric usage efficiency was investigated.

Key-words: efficiency, fabric usage efficiency, marker plan, fabric width, assortment distribution

INTRODUCTION

Material is an important factor for the production of the quality products and efficiency by combining with human and machine. Cost of the raw materials is very important for the companies. For some companies the cost of the raw materials represents 60% of the product cost [1].

Increasing the efficiency of the fabric usage which is one of the most important inputs of the ready-made garment production decreases the product cost. Prediction, planning and control of the waste are very important for the ready-made garment companies, as they want to obtain maximal profit with minimal input. Therefore, production cost of the companies decrease and their competitiveness increase [2].

Cost of the fabric and auxiliaries are about 50–60 % of the total cost [3]. Cost of the materials are about 30–65% of the total ready-made garments cost. According to Lectra Company, 27% of the total fabric is discarded during the garment production. 17.4% of the fabric waste is obtained due to the unevenness of the cutting arrangement plan [4].

According to this information, the reason of the 64.4% of the total fabric waste is spaces between patterns which performed on marker plan.

When the work plan of the cutting department considered, the first work is calculation of the assortment values of the marker plan. By making this calculation, plies of the fabric, number of the sizes and their arrangements are determined. After preparation of the marker plan, fabric grading and cutting processes are performed (figure 1).

The marker making is: the graphic which is laid out on the top of the spread out fabric, and which shows the optimum cutting of the fabric [5].

The most important step during the preparation of the marker plan is the arrangement of the garment patterns efficiently. By performing these arrangement first bigger patterns than smaller patterns by fitting the small gaps should be placed. Despite obeying this principle, assortment size distribution and unsuitable fabric width, may affect the fabric use efficiency negatively. Especially by decreasing the assortment size distribution, nesting possibility of the patterns decreases and rate of waste increases, also waste rate of the patterns which consisting of bigger pieces increases if the fabric width is unsuitable.

Studies reported that multi size marker plans are more efficient, there is a relation between fabric width and fabric quantity per product and marker efficiency.

Table 1

INFORMATION ABOUT THE COMPANIES							
Companies		**A**	**B**	**C**	**D**	**E**	**F**
Annual Production Quantity (thousand pieces)		3.300	2.000	700	300	250	4.000
Production Type and Ratio	**Domestic Market**	30%	90%	5%	10%	-	-
	International Market	70%	10%	95%	90%	100%	100%
Number of the Employees		850	300	200	54	50	1000
CAD System		Gerber	Assyst	Assyst	Konsan	Lectra	Gerber
Length of the Spreading Table (m)		40	20	20	17	20	40

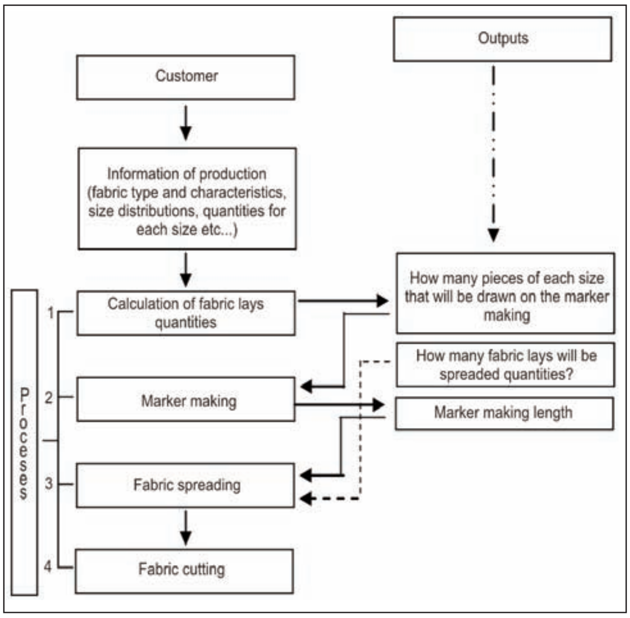

Fig. 1. Operations of the Fabric-Cutting Department

Using of CAD system for the preparation of the marker plan makes savings in terms of fabric costs [6–10]. In different studies effect of the fabric width unevenness on the fabric waste and cost were investigated [7, 11–13].

Proper length of the fabric quantity on fabric batches decreased the waste of the fabric and size changing of the garments is effective on the fabric use quantity [14, 15].

MATERIAL AND METHOD

In this study, standard man pants were chosen as material (figure 2).

For this study, negotiated with the 6 pants manufacturers and information of the companies are given in table 1. Patterns and size tables of the standard man pants were obtained from the companies and selected pants patterns were graded according to size table. Also used assortments and fabric widths of the companies were determined. Experimental design was organized according to the assortments and fabric widths. Worked fabric widths of the 6 companies are given in table 2. Used size distributions of the assortments are given in table 3.

Table 2

FABRIC WIDTHS USED BY THE COMPANIES						
Companies	**A**	**B**	**C**	**D**	**E**	**F**
Fabric width (cm)	140 – 145	148 – 150	147 – 150	148 – 150	147 – 150	148 – 150

Table 3

ASSORTMENT PLANS						
Size Assortments	**28/32**	**30/32**	**32/32**	**34/32**	**36/32**	**Total**
Assortment 1	1	1	3	2	1	8
Assortment 2	1	2	2	2	1	8
Assortment 3	1	2	3	3	1	10
Assortment 4	1	1	2	1	1	6

Fig. 2. Appearance of the selected product

By analyzing the data from table 2 it can be noticed that fabric widths of the companies are changing between 140 and 150 cm, but maximum fabric width determined as 163 cm which is manufactured by 3.90 m looms, so in this study fabric width was obtained between 140 and 163 cm and 4 different marker plans were prepared for each fabric width. Totally 96 marker plans were prepared by using 24 fabric widths and 4 different assortment plans (figure 3). Obtaining the highest fabric usage efficiency was targeted during the preparation of the marker plans. Lectra CAD system was used for the preparation of the marker plans.

For the calculation of the fabric usage efficiency from the marker plans, the ratio of the total pattern area to marker area is based on [8]:

% Fabric Usage Efficiency =

= Total Pattern Area / Marker Area

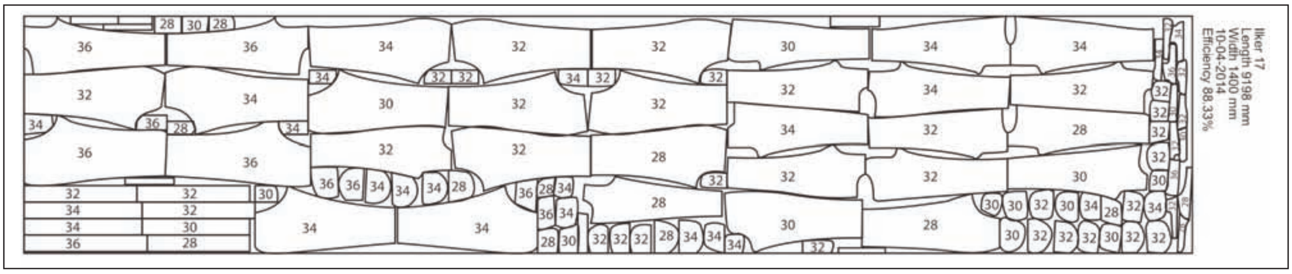

Fig. 3. One of the Prepared Marker Plan (Fabric width: 140 cm, Fabric Usage Efficiency 88.33%)

RESULTS

After the preparation of the marker plans, the results are given in figure 4 as assortment distribution.

Correlation graphics between fabric width and fabric usage efficiency of assortments 1, 2, 3 and 4 were given in figure 4. Correlation values were obtained –0,939444093 for the assortment 1, –0,932282606 for the assortment 2, –0,880511914 for the assortment 3 and –0,962173175 for the assortment 4. As seen from the figure 4 fabric usage efficiency decreased by increasing the fabric width. Negative correlation values confirm this statement.

In this study, 96 marker plans were prepared considering 24 different fabric widths and 4 different assortments (size distributions). Figure 5 shows the assortments which have the highest fabric usage efficiency for each fabric width. According to these results; the assortment 1 has the highest fabric usage efficiency for 140 cm width, the assortment 3 has the highest fabric usage efficiency for 163 cm width. It shows that size distribution of assortment affects the fabric usage efficiency. Also it can be seen from figure 5, assortment 1, 2, 3 and 4 have the highest fabric usage efficiency on 9, 6, 7 and 2 fabric widths respectively. According to these results, higher number of sizes in an assortment affects the fabric usage efficiency positively.

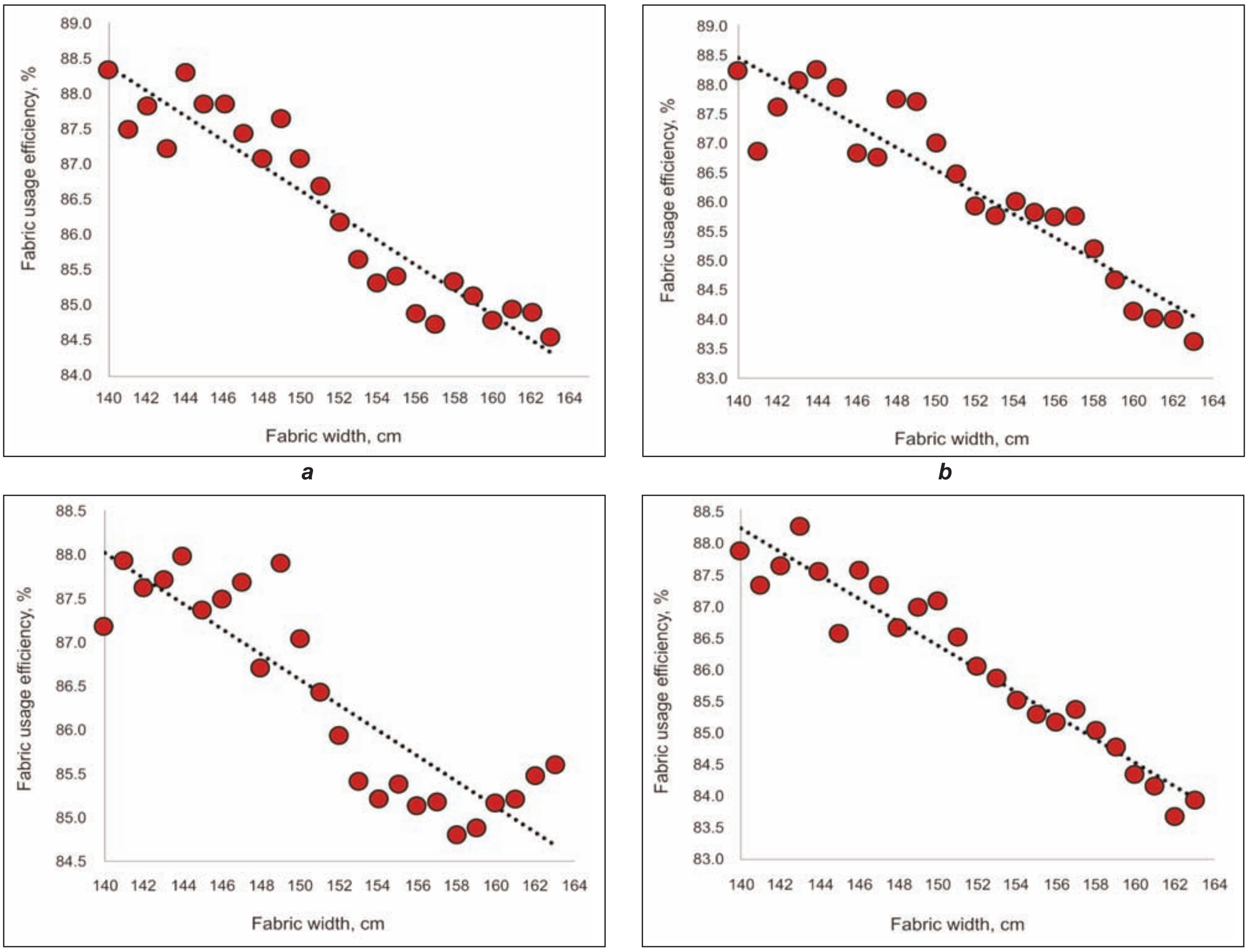

Fig. 4. Values of the fabric width and fabric usage efficiency of the assortment 1 (*a*), the assortment 2 (*b*), the assortment 3 (*c*) and the assortment 4 (*d*)

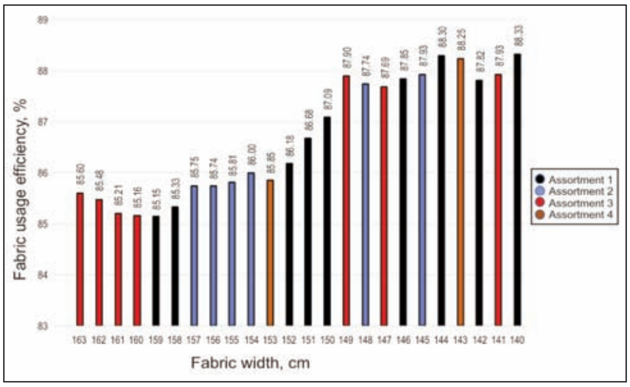

Fig. 5. Fabric usage efficiency values of four assortments for different fabric widths

CONCLUSIONS

The aim of this study was to investigate the effect of the assortment distribution and fabric width on the fabric usage efficiency. For this purpose, 96 different marker plans were prepared from different fabric widths and different size distributions afterwards the results were evaluated.

As a result of the study, fabric usage efficiency values were decreased by increasing the fabric width for all assortment distributions and it can be seen from the figure 4 that there is a linear relation between fabric usage efficiencies and fabric widths. Also according to these results it can be said that size distribution of the assortment affects the fabric usage efficiency. Therefore ready-made garment manufacturers should consider the size distributions during the calculation of the fabric consumption. By performing this principle, clothing manufacturers can reach to highest fabric usage efficiency values and they can produce the garments effectively by decreasing the fabric waste.

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A new image analysis based device and a new method to determine fabric drape and bending stiffness

GULSUM GOKCE PLATTURK MUSA KILIC

REZUMAT – ABSTRACT

Nou dispozitiv de măsurare pe baza analizei de imagine și o nouă metodă de determinare a drapajului și a rigidității la încovoiere

În ultimii ani, tehnicile asistate de calculator au fost utilizate pe scară largă în detrimentul celor tradiționale, pentru a economisi timp, bani și muncă. În această lucrare sunt descrise elaborarea unui nou dispozitiv și a unei metode bazate pe analiza imaginii, cu scopul măsurării proprietăților de drapaj și rigiditate ale țesăturilor. Scopul prezentului studiu a fost de a măsura coeficientul drapajului (%) și rigidității la încovoiere (mg.cm) dintr-o probă unică de material, prin metoda de analiză a imaginii. În acest scop, au fost măsurati coeficienții drapajului a 42 de materiale țesute diferite, produse din 100% fire pieptănate de lână, atât metoda tradițională cât și prin metoda dezvoltată recent de analiză a imaginii. Rezultatele analizei ANOVA au arătat că nu există nicio diferență semnificativă din punct de vedere statistic între cele două metode. Suplimentar, au fost descriși doi parametri noi, bazați pe măsurătorile de analiză a imaginilor, pentru a determina rigiditatea la încovoiere a materialelor textile plane: „Distanţa Centru-Margine“ și „Unghi de drapaj“. Conform modelelor de regresie, rigiditate la încovoiere a fost explicată peste 91% prin utilizarea de „Distanța centru-Margine“ sau a „Unghiului de drapaj“.

Cuvinte-cheie: drapajul materialului, rigiditatea țesăturii, rigiditate la încovoiere, metoda de analiză a imaginii

A new image analysis based device and a new method to determine fabric drape and bending stiffness

In recent years, computer aided techniques have been widely used instead of traditional ones in order to save time, money and labor. In this paper, a new device and method based on image analysis were developed for the purpose of measuring drape and stiffness properties of the fabrics. The aim of the present study was to measure drape coefficient (%) and flexural rigidity (mg.cm) from single fabric sample with image analysis method. In the scope of the study, drape coefficients of 42 different woven suiting fabrics, produced from 100% wool worsted yarns, were measured by both traditional and newly developed image analysis method. The ANOVA analysis results showed that there were no statistically significant difference between two methods. Furthermore, two new parameters, based on image analysis measurements, were described to determine the fabric flexural rigidity: "Center-Edge Distance" and "Drape Angle". According to the regression models, flexural rigidity was explained over 91% by the use of "Center-Edge Distance" or "Drape Angle".

Key-words: fabric drape, fabric stiffness, flexural rigidity, image analysis method

INTRODUCTION

Fabric drape can be described as the degree of change in shape with its own weight (ISO 9073-9, BS 5058). Drape, in other words, is a measure of fabric aesthetic appearance in use. Moreover, bending can be expressed as the deviation of a rectangular shaped fabric sample from the horizontal direction with its own weight (ISO 9073-7, ASTM D1388-14).

In recent years, drape and bending properties of fabrics have become important since comfort perception was increased. Drape and bending properties of fabrics influence material selection, comfort properties, fabric design and appearance. Because of the consumers watch out comfort properties, drape and bending measurements have been played a crucial role for the studies. Pierce [1] carried out the first research on fabric drape and measured the fabric bending to determine the two dimensional drape value by developing the Cantilever device in 1930. Besides, the effect of bending and shear properties on fabric drape was emphasized by Chu *et al.* [2, 3]. They developed "Fabric Research Laboratories" to measure three-dimensional drape and described a parameter named "Fabric Drape Coefficient (F %)" (eq. 1). They stated that drapability depends on three basic fabric parameters that are Young's modulus (E), the cross-sectional moment of inertia (I), and the weight (W). Where the function f can involve interactions in this parameters between the warp and filling systems.

$$\text{Drape Coefficient } (F\ \%) = f\,(E\,I\,/\,W) \qquad (1)$$

In 1960s, Cusick [4, 5] adopted a similar approach and developed "Cusick Drape Tester" to measure the drape of the fabric. In this method, fabric drape is determined by drawing the shadow on a paper screen. Drape tester which was developed by Cusick in 1965 has been still in use with its original state.

Recently, new devices, which are using the same principle with Cusick drape tester, have also been developed. Novel devices are generally equipped with a CCD camera mounted on top of the fabric and image analysis techniques have been used for the simulation of draped fabric behavior [6–12]. Jeong

[13] calculated the drape with using image analysis method, based on the number of pixels of the projected area of the draped fabrics. For this purpose, a camera was mounted the on the Cusick drape tester. At the end of the study, a new parameter, called "Drape Distance Ratio (DDR)", was proposed alternative to the drape coefficient. Behera and Mishra [14] used image analysis method to simulate the aesthetic properties of fabrics. In this research, computer vision system was developed to measure and integrate the most important aesthetic features of an apparel fabric such as pilling, drape, texture and wrinkle for the purpose of developing an index called "Fabric Appearance Index (FAI)". Behera and Pattanayak [15] also investigated the measurement of drape of apparel fabric by using digital image processing. For this purpose "Drapemeter", based on image analysis technique, was designed and developed. In the study, bending rigidity, tensile, shear and compressional properties of fabrics were also measured by KES system. Ngoc and Anh [16] used V-stitcher 3D in order to simulate 3D skirt modeling. The drape profile was expressed on x–y coordinate system. Draped fabric image was divided into 32 equal angles. x axis was represented the node position from 1 to 33 angles (0–2π radian) and y axis was represented the fold displacement with respect to the number of nodes. In the study, skirts were worn over a model stand for examining 3D fabric drape and images were captured from front, side and back. The difference between skirt drape as worn over model stand and as 3D simulated in software V-Stitcher was analyzed. The correlation between two methods were also investigated and it was concluded that the new method can be used to estimate drapability of garment in CAD system.

In parallel to the development of image analysis techniques, researchers also started to investigate dynamic drape behavior of the fabrics. Shyr *et al.* [17] integrated Cusick drape tester principle with the image analysis technique to measure the static and dynamic drape of fabrics. Wang and Cheng [18] developed the 'Four in One' automatic measuring system to measure dynamic drape properties of fabrics. The changes in the dynamic drape of fabric, when people walk at different speeds, was simulated with this device. Automatic measuring system for dynamic drape (AMSDD) mainly consisted of CCD camera, adjustable seven steps of forward speed, three kinds of dynamic state to simulate the walking behavior of forward, reciprocating and swinging motion, curved reflective glass, drape image reflection panel, halogen light and circular templates of 24, 30, 36 cm diameters. Matsudaira *et al.* [19] investigated the changes in dynamic drapability of polyester fabrics in point of weave density, yarn twist and yarn count. Fabrics mechanical parameters measured by KES system and fabrics dynamic drape parameters were defined by using dynamic drape tester. Thilagavathi and Natarajan [20] developed a method for measurement of fabric three-dimensional drape by using modified drape meter. Modified drape meter was basically consists of top disc, supporting disc, stand, supporting plate, mirror and light. Draped images of fabrics were projected for warp and weft directions and projected area was calculated.

Studies on fabric drape and bending properties showed that high correlations exist between drape coefficient and bending rigidity. Therefore, many studies were focused on to explain the degree of correlation between the fabric drape and bending rigidity. Hu and Chan [21] investigated the effect of fabric mechanical properties on fabric drape. In the study, Cusick drape tester and Fast system were used to measure drape coefficient and bending rigidity. The results showed that statistically significant correlation coefficients were existed between drape and bending properties of fabrics (R = 0.8859). Süle [22] examined bending and drape properties of woven fabrics. In the study, the effects of weft density, weft yarn count and warp tension on bending and drape properties were analyzed. The bending rigidities of fabrics were measured by using Shirley stiffness tester and also drape coefficient of fabrics were measured by using Cusick drape tester. At the end of the study, high correlation coefficients (0.86–0.96) were found between fabric bending and drape properties. Sun [23] developed a new tester to measure the stiffness of the fabric. A new tester basically consisted of rectangular block, millimeter scales mounted on the rectangular block and a weight to hold the specimen. The principle of measurement was the same as the Cantilever method and difference was warp and weft bending rigidity could be measured at the same time by measuring drape angle. Drape angle was calculated by x and y coordinates of the hanging the warp and weft strips. Warp and weft strips were 2.5 cm wide and 5 cm long but the length and width of the samples could be changed with the material type.

In recent years, researchers have also dealt to measure the fabric drape and bending properties by using different approaches such as particle-based models, lattice models, finite element techniques, co-rotational grid-based models, artificial neural network (ANN) and 3D simulations.

The aim of this study is to develop a new device and method, based on image analysis technique, in order to measure fabric drape coefficient (%) and flexural rigidity (mg.cm) from single fabric sample. It is expected to save time, money and labor when compared to conventional methods.

MATERIALS AND METHOD

In the study, 42 types of woven suiting fabrics, produced from 100% wool worsted yarns, were used as material.

Within the context of the study, drape and bending properties of the fabrics were measured by both conventional and newly developed methods. In the first part of the study, drape coefficient (%) values were measured by Cusick drape tester in accordance with the ISO 9073-9 standard and flexural rigidity (mg.cm) values were measured by Shirley stiffness tester according to the ASTM D1388 standard. In the second part of the study, drape coefficient (%) and flexural rigidity (mg.cm) values of the fabrics were calculated from the draped image of the fabric samples, captured by the newly developed device, using image analysis method.

Newly developed device based on image analysis method

In the study, a new device, based on Cusick drape tester and image analysis methods, was developed to measure drape coefficient (%) and flexural rigidity (mg.cm) using single fabric sample (figure 1).

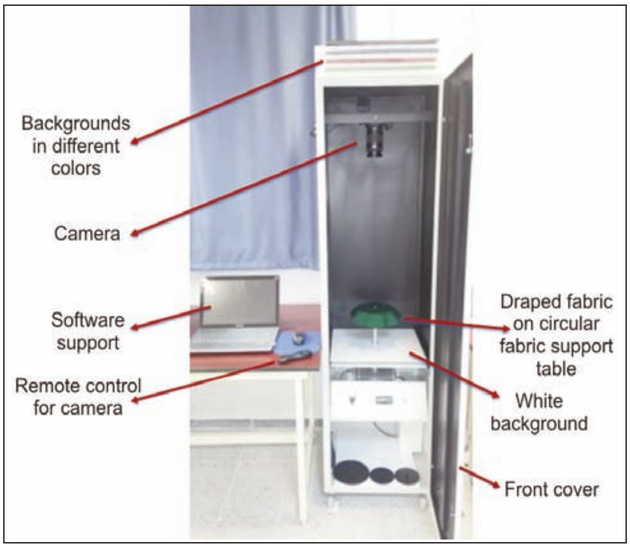

Fig. 1. Newly developed device based on image analysis method

New device basically consisted of a digital camera system and a circular fabric support table where fabric sample was placed on. The images were captured by a high resolution digital SLR camera equipped with 18 megapixels CMOS image sensor and 18–55 mm lens. A wireless remote control was also attached to the camera to allow capturing images when the front cover of the device was closed. Diameter of the fabric support table was 18 cm in accordance with the conventional Cusick drape tester. Distance between the camera and the support table was set to 80 cm. In addition, backgrounds in different colors (black, white, red, green and yellow) were produced to capture images more suitable to process using image analysis methods.

Capturing and processing the image of draped fabric

The first step of the method was capturing the image of draped fabric (figure 2a) placed on the circular support table using SLR digital camera. After the captured image was sent to the computer, it was converted into the gray scale image (figure 2b) and binary image (figure 2c) by the help of the codes written in Matlab package programme.

The determination of the drape coefficient (%) by using image analysis method

In new method, drape coefficient (%) was calculated by using the area of draped fabric's binary image depending on the basics of Cusick method. For the calculation, a pixel area in square centimeter was needed to determine the area of draped fabric image. For this purpose, fabric support table with 18 cm diameter was chosen as reference. After the real color image was captured by using camera, the image of support table was converted into gray scale and binary modes respectively (figure 3).

Pixel counting process was applied to the binary image of support table and 1,275,664 pixels were counted by the help of the codes written in Matlab package programme. After this operation, area of one pixel was calculated as 0.0001994796 cm^2 by using the total area of support table.

After the pixels of draped fabric's binary image had been counted, drape coefficient (%) was calculated according to the eq. 2 below:

$$DC_{IA}\,(\%) = \frac{A_{DF} - A_{ST}}{A_{FS} - A_{ST}} \cdot 100 \qquad (2)$$

where DC_{IA} represents the drape coefficient value (%) was calculated by image analysis method, A_{DF} represents the area of draped fabric (A_{DF} = Number of black pixels × 0.0001994796 cm^2), A_{ST} represents the area of support table ($A_{ST} = \pi \cdot 9^2 = 254.469$ cm^2), and A_{FS} represents the area of fabric sample ($A_{FS} = \pi \cdot 15^2 = 706.858$ cm^2).

The determination of the flexural rigidity (mg.cm) using image analysis method

In the study, two new parameters, obtained by image analysis methods, were suggested to calculate flexural rigidity: "Center-Edge Distance, X_{CE}" and "Drape Angle, DA_α".

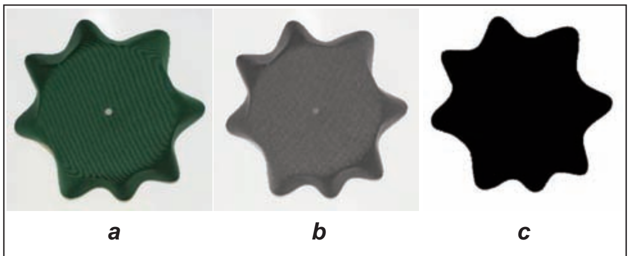

Fig. 2. Capturing and processing the image of draped fabric: *a* – Real color image; *b* – Gray scale image; *c* – Binary image

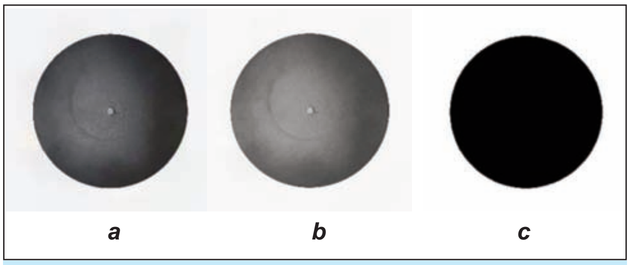

Fig. 3. Capturing and processing the image of fabric support table: *a* – Real color image; *b* – Gray scale image; *c* – Binary image

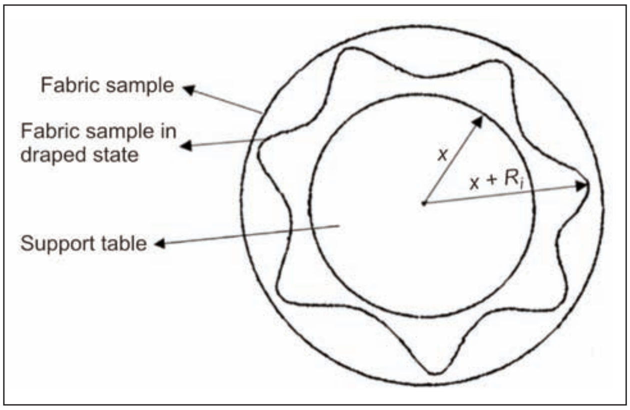

Fig. 4. Center-edge distance

Center-edge distance ($X_{CE} = X + R_i$) could be described as the distance from the center to the edge of draped fabric (figure 4). Here, X represents the radius of the support table and R_i represents the distance from the edge of the support table to the edge of the draped fabric image.

Center-edge distance was suggested as an input variable to the regression model for estimating the flexural rigidity. In order to characterize a fabric flexural rigidity, it would be necessary to measure an infinite number of center-edge distances theoretically.

In the first part of the calculation, support table was used as reference material for calibration and distance of a pixel was determined. By the help of image analysis method, pixels in X distance was counted as 148 and the length of one pixel was calculated as 0.0608 cm.

In the second part of the calculation, center-edge distances of a draped fabric image were measured with 10-degree angles and 36 center-edge (X_{CE}) distances were measured for one fabric image (figure 5). Mean center-edge distance ($\overline{X}_{CE}$) for one fabric image was calculated by eq. 3:

$$\overline{X}_{CE} = \frac{1}{n}\sum_{i=1}^{n=36}(X + R_i) \qquad (3)$$

In the study, 10 $\overline{X}_{CE}$ values from one fabric sample was obtained considering front and back faces of the fabric.

Second parameter suggested for estimating flexural rigidity was “Drape Angle, DA_α” which is derived from the center-edge distance (figure 6).

Drape angle was calculated according to the eqs. 4–7:

$$\sin\alpha = \frac{R_i}{R'} \qquad (4)$$

$$\sin\alpha = \frac{\overline{X}_{CE} - X}{(X + R') - X} \qquad (5)$$

$$\alpha = \arcsin\left(\frac{\overline{X}_{CE} - X}{(X + R') - X}\right), \text{ radian} \qquad (6)$$

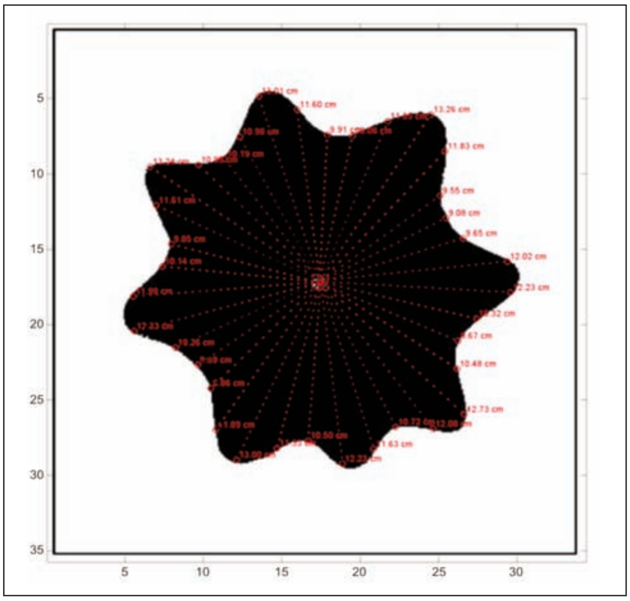

Fig. 5. The measurement of the center-edge distances by using Matlab programme

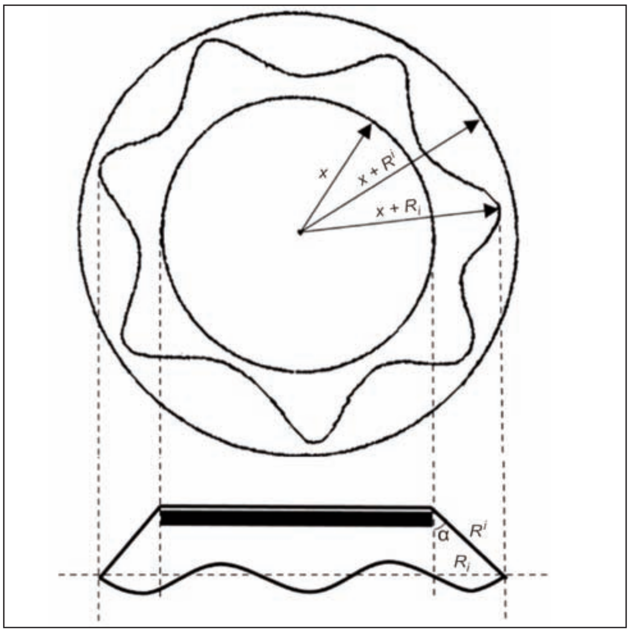

Fig. 6. Drape angle, DA_α

$$DA_\alpha = \arcsin\left(\frac{\overline{X}_{CE} - X}{(X + R') - X}\right)\cdot\frac{180}{\pi}, \text{ degree} \qquad (7)$$

Here, $\overline{X}_{CE}$ represents the mean center-edge distance (cm), X represents the radius of the support table (9 cm) and $X + R'$ represents the radius of the fabric sample in undraped state (12 cm, 15 cm or 18 cm).

RESULTS AND DISCUSSION

In the study, a new method and a new device based on image analysis were developed to measure drape coefficient (%) and flexural rigidity (mg.cm) of fabrics. The first step of the study was the measurement of the drape coefficient (%) by using image analysis method, alternatively to the conventional cut and weight methods. At the second step of the study,

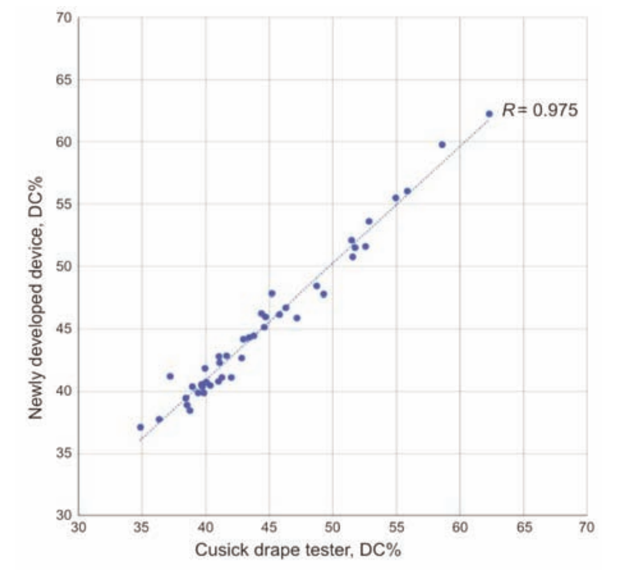

Fig. 7. Relationship between the drape coefficients (%) obtained by Cusick drape tester and newly developed device

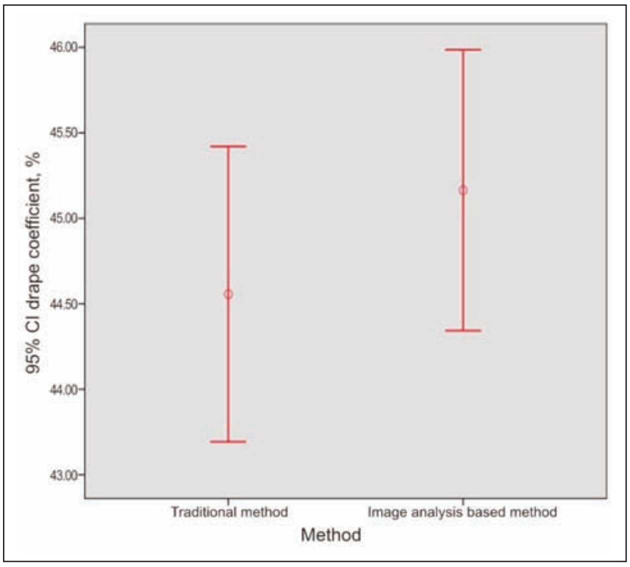

Fig. 8. 95% confidence interval graphs for the drape coefficients obtained by two methods

flexural rigidities of fabrics were estimated by newly described parameters named "Center-Edge Distance, X_{CE}" and "Drape Angle, DA_{α}".

The comparison of the drape coefficients obtained by conventional and new developed methods

In order to validate the new method, the drape coefficient values measured by newly developed method, based on image analysis, were compared with the values obtained by the conventional Cusick drape tester. Firstly, a correlation analysis was carried out and fairly high correlation coefficient (R = 0.975) was obtained at 95% confidence level (figure 7).

Two methods were also compared using ANOVA and the result (p = 0.654) showed that differences between the two methods were not statistically significant at α = 0.05 (table 1). 95% confidence interval graphs given in figure 8 also supported the ANOVA result.

The estimation of the flexural rigidity by using the new developed method

Firstly, flexural rigidities of the fabrics were measured by conventional Cantilever test method in accordance with ASTM D1388. Since center-edge distance is known as a parameter influenced by drape and stiffness properties of a fabric [16, 25], mean center-edge distance value ($\overline{X}_{CE}$) was used as independent variable of the regression model to estimate the flexural rigidity. The relationship between center-edge distance ($\overline{X}_{CE}$) and flexural rigidity is given in figure 9. Correlation coefficient between center-edge distance ($\overline{X}_{CE}$) and flexural rigidity was found as R = 0.855 and statistical analysis showed that relationship between center-edge distance ($\overline{X}_{CE}$) and flexural rigidity is important at α = 0.05 level. From this point of view, center-edge distance was used to estimate flexural rigidity of a fabric (G_0). Eq. 8 shows the simple linear regression model where $\overline{X}_{CE}$ was taken as independent variable.

$$G_0 = -6722 + 606\,\overline{X}_{CE} \qquad (8)$$

Regression determination coefficient was calculated as R^2 = 0.732 for this model. It means that model can only explain the dependent variable by the ratio of 73.2%. This value was found relatively low compared to other studies estimating flexural rigidity from different fabric parameters [9, 21, 22, 26–29]. For this reason, fabric unit weight (W) parameter, which is measured easily in laboratory conditions, was entered to the model as second independent variable.

Table 1

THE VARIANCE ANALYSIS TABLE OF DRAPE COEFFICIENT (%) VALUES OBTAINED BY CUSICK DRAPE TESTER AND NEWLY DEVELOPED DEVICE

Source	Sum of Squares	df	Mean Square	F	Sig. (p)
Corrected Model	7.802	1	7.802	0.203	0.654
Intercept	169 111.440	1	169 111.440	4 392.870	0.000
Method	7.802	1	7.802	0.203	**0.654**
Error	3 156.738	82	38.497		
Total	172 275.980	84			
Corrected Total	3 164.540	83			

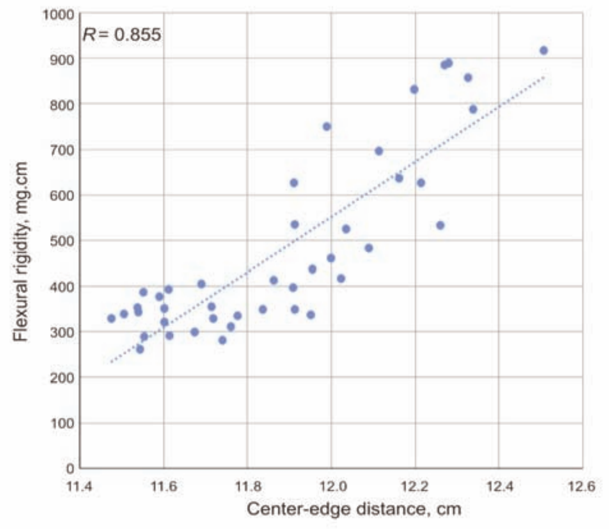

Fig. 9. Relationship between center-edge distance (cm) and flexural rigidity (mg.cm)

Adjusted *R* square value was found as 0.911 in the second regression model. Table 2 shows the coefficients of multiple linear regression analysis.
Eq. 9 derived from table 2 is given above. Now, this regression model can explain the dependent variable by the ratio of 91.1% using only center-edge distance and fabric unit weight parameters. When compared to the R^2 values of other studies varies between from 0.79 to 0.99, this result can be thought as satisfactory to estimate the flexural rigidity.

$$G_0 = -5055 + 408\,\overline{X}_{CE} + 4\,W \tag{9}$$

From the same point of view, drape angle (DA_α) parameter is also used as input variable to estimate the flexural rigidity (eqs. 10 and 11).

$$G_0 = -1113 + 55\,DA_\alpha \tag{10}$$

$$G_0 = -1277 + 37\,DA_\alpha + 4\,W \tag{11}$$

Since DA_α is derived from $\overline{X}_{CE}$ parameter, explanation rates (regression determination coefficients) of the models are found similar to the models indicated in eqs. 8 and 9. Nevertheless, only the coefficients of the eqs. 10 and 11 are differently from the others. Eq. 11 shows the multiple linear regression model to estimate flexural rigidity (G_0) using DA_α and *W* parameters as independent variables. This model represented the adjusted R^2 = 0.911 value similar to that in eq. 9.

CONCLUSIONS

Drape and stiffness properties of fabrics have been measured by both conventional and modern methods since 1960s. In recent years, computer aided techniques especially image analysis methods have been widely used instead of conventional ones. Many studies with different approaches dealt with the measurement of drape coefficient by the help of image analysis methods [7–10, 15]. Moreover, many studies dealt with determination of stiffness properties by the help of the methods such as image analysis, artificial neural networks, fuzzy logic etc. [21–23, 27, 28].
In this study, a new method and a new device were developed to determine drape and stiffness properties of fabrics from only one fabric sample using image analysis method. It was also aimed to save time, money and labor. Study consisted of two stages: calculation of drape coefficient (%) and estimation of flexural rigidity (mg.cm).
Drape coefficient (%) was calculated by using binary image of draped fabric depending on the basics of Cusick method. The results showed that relationships between newly developed method and conventional method is highly correlated (*R* = 0.975). Moreover, the ANOVA results showed that there is no difference between two methods at α = 0.05 level.
Flexural rigidity (mg.cm) was estimated separately by the help of the parameters namely “Center-Edge Distance” and “Drape Angle” which are produced from draped fabric image using image analysis methods. Regression determination coefficient (R^2 = = 0.732) of each model was found relatively low and fabric unit weight as another independent variable was put in the models.
After the contribution of fabric unit weight, adjusted regression determination coefficients of the models to estimate the flexural rigidity were found fairly high (R^2 = 0.911).
In conclusion, this study suggested a device and a method based on image analysis technique to determine drape and stiffness properties of the fabrics using just one sample. Drape coefficient measurement were concluded as successful in comparison with Cusick method. In addition, fairly high *R* square values were also obtained to estimate flexural rigidity. Further studies can focus on improving the *R* square values by using larger experimental designs in order to suggest general regression models.

Table 2

RESULTS OF MULTIPLE LINEAR REGRESSION ANALYSIS

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	Constant	–5055.108	431.414		–11.718	0.000
	Center-Edge Distance ($\overline{X}_{CE}$)	407.758	39.381	0.576	10.354	0.000
	Fabric Unit Weight (*W*)	4.014	0.436	0.511	9.198	0.000

Dependent Variable: Fabric Flexural Rigidity (G_0)

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Filtration properties of composite fabrics combined by electrospun poly lactic acid nanofiber with non-woven fabrics

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REZUMAT – ABSTRACT

Proprietățile de filtrare ale materialelor compozite din nețesute cu nanofibră electrofilată de acid polilactic

Nanofibrele de acid polilactic au fost filate în materiale nețesute consolidate prin filare chimică și, respectiv, prin metoda de electrofilare în materiale nețesute prin filare din topitură cu jet de aer. Au fost testate proprietățile de filtrare ale materialului compozit, produs din nanofibră electrofilată și material nețesut. S-a constatat că eficiența filtrării a nețesutului consolidat prin filare chimică a crescut de la aproape zero la 41,7 % după ce a fost combinat o membrană de nanofibră de 2 mm și 23,1 % cu o membrană de 1 mm. Eficiența filtrării materialului nețesut obținut prin filare din topitură ci jet de aer a fost îmbunătățită, de la 80 % la 99 % sau mai mult. Rezultatele obținute au arătat că eficiența filtrării materialului compozit crește foarte mult prin adăugarea unor straturi de nanofibră materialului nețesut, în detrimentul rezistenței filtrării.

Cuvinte-cheie: acid polilactic, nanofibră, material neţesut, filtrarea aerului

Filtration properties of composite fabrics combined by electrospun poly lactic acid nanofiber with non-woven fabrics

PLA nanofibers were spun onto the spunlace and melt-blown non-woven fabrics respectively by electrospinning method. Filtration properties of the composite material combined by electrospun nanofiber and nonwoven fabrics were tested. It figured out that the filtration efficiency of spunlace nonwoven was increased from near zero to 41.7% after compounding with 2 mm thickness of nanofiber membrane, and to 23.1% with 1 mm. And the filtration efficiency of combined melt-blown nonwoven fabrics is improved to 99% or above from 80%. The results revealed that the filtration efficiency of the composite fabrics was increased sharply when nanofiber layers were added to the nonwoven fabrics at the expense of filtration resistance.

Key-words: polylactic acid, nanofiber, non-woven fabric, air filtration

Electrospun method is used widely to produce nano scale fibers and filaments in a range of polymers and its composites [1–2]. These nanofibrous membranes possess many novel properties and have great potential applications in many fields, including as electromechanical actuators, as opto-electronic devices, as selective adsorbents for oil spill cleanup, as gas sensors, and as filters for gas or liquid filtration and separation [3–5]. In particular, when used as filters, the nano-membranes have several unique advantages, i.e. high porosity, good flexibility, large surface area per unit volume, and interconnected open pore structure. These characteristics make them attractive for filtration applications [6–9]. The disadvantage of nanofibrous membrane was the low tearing strength. By combining with nonwoven fabrics, its tearing strength can be improved notably. In this paper, PLA membrane combined nanofibrous membrane with spunlace and melt-blown non-woven fabrics respectively were prepared and the gas filtration properties were tested.

MATERIALS AND EXPERIMENTS

PLA (Mw ~70,000) was purchased from Shenzhen Bright China Industrial Co., Ltd. (Shenzhen, China). Dichloromethane (DCM) and N, N-dimethylformamide (DMF) were purchased from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). All other chemicals and reagents were of analytical quality and used without further purification. Deionized water was used during all experiments.

PLA were dissolved in a mixture of DCM/DMF (70/30, v/v) to prepare the electrospinning solution at a concentration of 10 wt%. The mixtures were electromagnetic stirred for 12 h with digital temperature magnetic mixer (85-II, Jintan Instrument Co., Ltd., China) at room temperature to obtain the homogeneous codissolved spinning solutions. The solutions were carefully placed into a 20 ml syringe with a metallic needle attached which has an internal diameter of 0.7 mm. The electric field was fixed at 16 kV / 17 cm supplied by a high-voltage dc power (DW-P303-1ACD8, DONGWEN High Voltage Power Supply, Tianjin, China). The feeding rate was controlled at 0.5 ml/h by

Table 1

FILTRATION OF PLA NANOFIBER / NONWOVEN COMPOSITE MEMBRANES								
Sample	Thickness of nano-membrane							
	PLA/Spunlace				PLA/Melt-blown			
	2 mm		1 mm		2 mm		1 mm	
	Resistance pa	Efficiency %	Resistance pa	Efficiency %	Resistance pa	Efficiency %	Resistance pa	Efficiency %
1	2.5	48.1	1.5	27.2	170	99.2	203	99.97
2	2.1	37.3	1.1	14.6	145.8	99.96	112	97.64
3	2.2	29.3	1.3	22	210.8	99.99	154.3	99.86
4	2.4	47.6	1.4	25.2	160.2	99.93	130	98.34
5	2.8	46.3	1.5	26.6	210.8	99.95	144.3	99.76
Ave.	2.4	41.72	1.36	23.12	179.52	99.806	148.72	99.114
nonwoven	-	-	-	-	9.7	79.7	9.7	79.7

a microinfusion pump (WZ-50C6, Zhejiang Smith Medical Instrument Co., Ltd., China). Spunlace non-woven fabrics and melt-blown non-woven fabrics were used to collect the electrospinning filaments respectively.

Filtration test was conducted using charge neutralized polydisperse aerosol particles (NaCl with 0.3–0.5 μm) at 5.3 cm per second flow rate using a TSI 8130 Automated Filter Tester, which employed a forward light scattering photometer to measure the flux of light scattering from particles.

The surface morphology of PLA nanofibers were taken by a scanning electron microscope (JEOL, Model No: JSM-6335F) with a magnification of 5,000X.

The thickness of non-woven fabrics and the composite fabrics were measured by DUALSCOPE MPO (Fischer Instrumentation Ltd., Germany).

All experiments were conducted at room temperature and a relative humidity of 65 %.

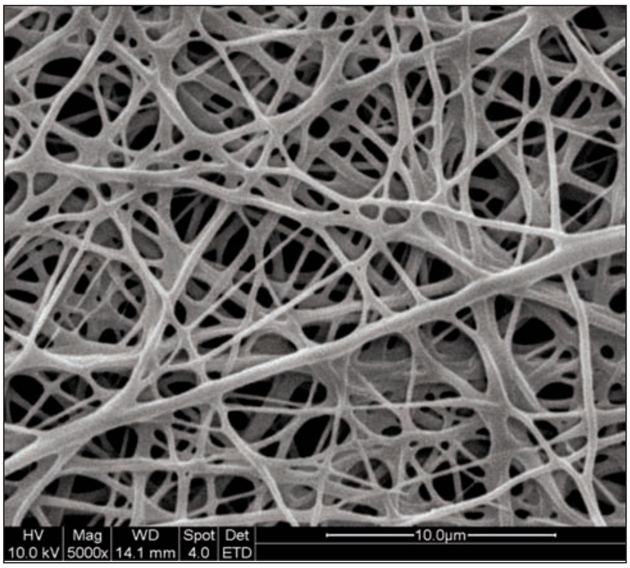

Fig. 1. PLA nanofiber membrane

RESULTS AND DISCUSSION

The morphology of PLA nanofibers was showed in figure 1, which demonstrates that nanoporous membrane was formed with irregular holes. Test results of resistance and efficiency of gas filtration are listed in table 1. As known the nanofiber membrane almost can't stand any filtration force due to its low tearing strength. And generally, filtration efficiency of PLA spunlace nonwoven fabric is almost zero. But, as it may be seen from table 1, the filtration is greatly improved after it combined with nanofibrous membrane. With 1 mm thickness of nanofibrous membrane, filtration efficiency of the composite fabric reaches to 23.1%, while with 2 mm, 41.7%. But the resistance also goes up with the thickness of nanofibrous membrane from 1.4 to 2.1. The filtration efficiency of PLA melt-blown nonwoven membrance is about 80%. After combined with nanofibrous membrane, it increases to 99.6% and 99.1% at the expense of resistance of 165.2 and 143.7 at 2 mm and 1 mm nanomembrane respectively.

Table 1 indicates that filtration efficiencies both of spunlace and melt-blown nonwoven fabrics are improved when combined with nano-membrane. It may be explained that the diameter of the nanofiber is much lower than filter particles and much more pores are formed by nanofibers, which is called a nano-effect. On the other side, for the fineness of the nanofibers, size of pores formed by the nanofibers was much smaller. There is has a negative correlation between the sizes of pores and filtration resistance. An optimized effect of filtration efficiency and resistance is important.

CONCLUSIONS

Nanofibrous membrane of PLA produced by electrospinning was combined with spunlace and melt-blown nonwoven fabrics respectively. The gas filtration efficiency and resistance were tested and analyzed. It demonstrated that with nanofibrous membrane, the air filtration efficiency of the composite nonwoven fabrics can be improved critically at the expense of filtration resistance. With nonwoven fabrics, the strength of composite membrane can be highly improved, which will widen the application of nanofibers. Also a novel filed will be explored about the comprehensive effect of nano-conventional filtration mechanism.

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Environmental and socioeconomic sustainability through textile recycling

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REZUMAT – ABSTRACT

Sustenabilitatea de mediu și socioeconomică prin reciclarea textilelor

Lucrarea analizează procesul de realizare a sustenabilității mediului prin reciclarea deșeurilor textile. Lucrarea este concepută sub forma unui articol de tip review dar și articol editorial, prin prezentarea unor cercetări relevante pentru dezvoltarea durabilă și reciclarea deșeurilor textile, subliniază implicațiile economice, sociale și de mediu și propune acțiuni pentru viitor. Reciclarea deșeurilor textile poate servi ca un mijloc de a oferi soluții la probleme financiare, sociale și de mediu, cum ar fi: costul ridicat de eliminare a deșeurilor, diminuarea resurselor naturale, crearea de locuri de muncă, deschizând oportunități pentru IMM-uri. Beneficiile și problemele aferente acestui proces sunt, de asemenea, evidențiate. Concluzia care se desprinde este că reciclarea deșeurilor aduce beneficii care acoperă toate cele trei aspecte care definesc durabilitatea: economice, sociale și de mediu, în special în rezolvarea numeroaselor probleme ecologice și stimularea de noi sectoare ale economiei. Există însă și aspecte negative. Pentru a cuantifica potențialele beneficii ecologice, efectele economice și sociale ale procesului de reciclare a deșeurilor textile, lucrarea propune un model cadru care echilibrează costurile asociate rețelei inverse, pentru obținerea și operarea cu deșeurile textile și efectele asupra creșterii ocupării forței de muncă, precum și câștigurile obținute prin revinderea produselor care mai pot fi purtate. Principala limită a modelului prezentat provine de la faptul că se bazează pe premisa existenței unei infrastructuri de colectare și o piață pentru produsele reciclate. Dar, în România colectarea deșeurilor textile, mai ales cea post-consum rămâne o problemă nerezolvată. În concluzii, lucrarea prezintă câteva propuneri, a căror soluționare reprezintă teme viitoare de cercetare.

Cuvinte-cheie: dezvoltare sustenabilă, reciclare, modelare SCM, deşeuri textile

Environmental and socioeconomic sustainability through textile recycling

This paper examines the process of achieving environmental sustainability through recycling of textile wastes. It is organized as a review and editorial article, relating relevant research regarding sustainable development and recycling of textile waste, and outlining economic, environmental and social implications and suggested future actions. The recycling of textile waste can serve as a mean of providing solutions to financial, environmental and social problems such as high cost of waste disposal, and diminution of natural resources, create workplaces, opening opportunities for SMEs. The benefits and problems of this exercise are also highlighted. The conclusion drawn is that the recycling of waste brings benefits to all three aspects that define sustainability: economic, social and environmental, especially in solving the numerous ecological problems and boosting new economy sectors, but there are also negative aspects too. To quantify the potential ecological benefits, the economic and social effects of textile waste recycling, the paper proposes a framework model which makes tradeoff between costs of reverse network for textile waste establishing and operating, and its effects on the employment increase, and resold wearable textiles earnings. The main limit of the presented model is the fact that it is based on the premise that there is already a collecting infrastructure and a market for the recycled products. But, in Romania the textile waste collecting, especially the post-consumer one still remains an unsolved problem. In the conclusions, the paper presents several proposals whose solutions represent future research directions.

Key-words: sustainable development, recycling, closed loop SCM modelling, textiles waste

INTRODUCTION

In the recent years sustainable development has become a widespread constituent part of economic and environmental policy not only in developed country but also in many developing countries. Today's most burning environmental problems arise from ever increasing worldwide production and consumption and the associated material flow [1]. The supply of goods is always correlated to the use of natural resources, including raw materials (renewable and non-renewable), energy, water and land. The processes of accelerated population growth and urbanization translate into a greater volume of waste generated [2].

The literature review revealed a large gap in terms of Life Cycle Assessments (LCAs) conducted over the end-of-life of textiles. Some LCAs studies, deal with the assessment of the environmental impacts of clothing [3, 4, 5] or other type of textile products like carpets [6] or furniture [7] but little highlights was placed on potential benefits from recycling. The economists and environmentalist's studies on technical [8, 9] and economic [10] requirements for sustainability revealed the need for increasing waste prevention and recycling.

TEXTILE RECYCLING

Textile industry represents an important part of the manufacturing industry and plays a significant role in the economy and social welfare of many regions across the world [11]. Textile industry is not only one of the most important consumer goods industries but it also has an essential impact on the environment. Because it is a diverse and heterogeneous industry, which covers an important number of activities from the transformation of fibres to yarns and fabrics to the production of a wide variety of products such as hi-tech synthetic yarns, wool, bed-linen, industrial filters, geo-textiles, clothing, it generates various significant adverse environmental and social impact across it global lifecycle.

Textile waste is not a large waste stream by weight or volume, but has a significant environmental impact connected to the production of textiles. The clothing and textile industry accounts for an estimated 5 to 10% of all environmental impacts throughout the EU, so improving the environmental performance of the industry is vital [10]. Estimates of the global warming potential of textile productions are 16.9 kg CO_2-equivalents per kg of 50% cotton and 50% polyester or 25 kg CO_2-equivalents per kg of textiles and the general carbon dioxide saving of textile recycling are 1–1.5 kg of CO_2-eq. per kg textiles [12]. Therefore compared to most other wastes the global warming potential from production of textiles can be considered rather high per unit weight.

Directive 2008/98/EC defines recycling as a recovery operation by which waste materials are reprocessed into products, materials or substances. Similar textile recycling refers to the processing of fibres back to make new products. However in this paper recycling is defined as a method of reprocessing used clothing, fibrous material and clothing scraps from the manufacturing process. A fairly large amount of textiles is recycled into wipers or used as filling material but the actual processing of recovered textile into new products is still relatively minor [13]. Textile reuse as second-hand clothes is also sometimes considered as a form of textile recycling while there is no reprocessing. The reusing or recycling of textile waste is not only an important means of solving several environmental problems, but also a means of socioeconomic and environmental sustainability. Re-using slows the consumption process and the need for costly and energy consumptive new products manufacturing process [14].

SOURCES OF TEXTILE WASTE

The use and application of textiles is widespread. Apart from the clothing, there are other numerous applications where textile fabrics can be found e.g. in furniture, homewares, transportation, medical field etc. Textile waste originates from two main streams: industries/institutions and population. Industrial textile waste is generated from commercial and industrial textile applications including commercial waste from properties such as carpets, drawer, curtains, hospital refuse or other industrial applications. Collection and chemical contamination issues make this category as the least likely to be recycled so an important share of these goods is send to landfill or incineration. However, there is research currently being undertaken by a number of industries to utilize this resource [15].

According to the Council for Textile Recycling, textile recycling material can be classified as pre – or post consumer waste. Pre-consumer waste is arising during the manufacture of a product and post-consumer waste is “any type of garment or household article made from manufactured textiles that the owner no longer needs and decides to discard”. During the processing of textile products, large quantities of pre-consumer fibrous waste can be generated in the form of fiber and yarn, off-cuts, selvages, sheerings and rejected materials. During their production, 50% of the fibers are wasted [16].

Post-consumer textile waste consists of any type of garments or household article, made of some manufactured textile that the owner no longer needs and decides to throw away. The characteristics of fast fashion have driven the consumption of new clothes to increase by 60% in the past decade [17]. Several researchers who studied reasons for clothing disposal revealed that most respondents kept items as long as they were wearable and said that they stopped wearing cheap clothing for three main reasons: lower quality, new fashion trend or clothes were bought for one specific occasion [18]. The main stream of fast fashion literature indicated following key variables that are related with the consumer behavior: renewal cycle, price, quality and supply to which we add sustainability concerns. The big fast fashion stores like H&M, Gap, Zara, C&A, and United Colours of Benetton etc. have made clothing so affordable that it has led to an overconsumption of unsustainable clothing. Another recent study from the UK exposed that the respondents discarded clothing mainly due to the condition of clothing, new trends in fashion, lack of space, loss of emotional attachment and changes in body shape. As a result, textile waste is directly influenced by the state of the economy and has become the fastest growing sector of household waste [20].

Textile recycling process

In the following paragraphs are presented the possible advantages and issues that might come up during the entire recycling process, also illustrated in figure 1. In the first stage the discarded textiles are collected and processed, where they are sorted, cleaned and made ready for recycling or manufacturing new products.

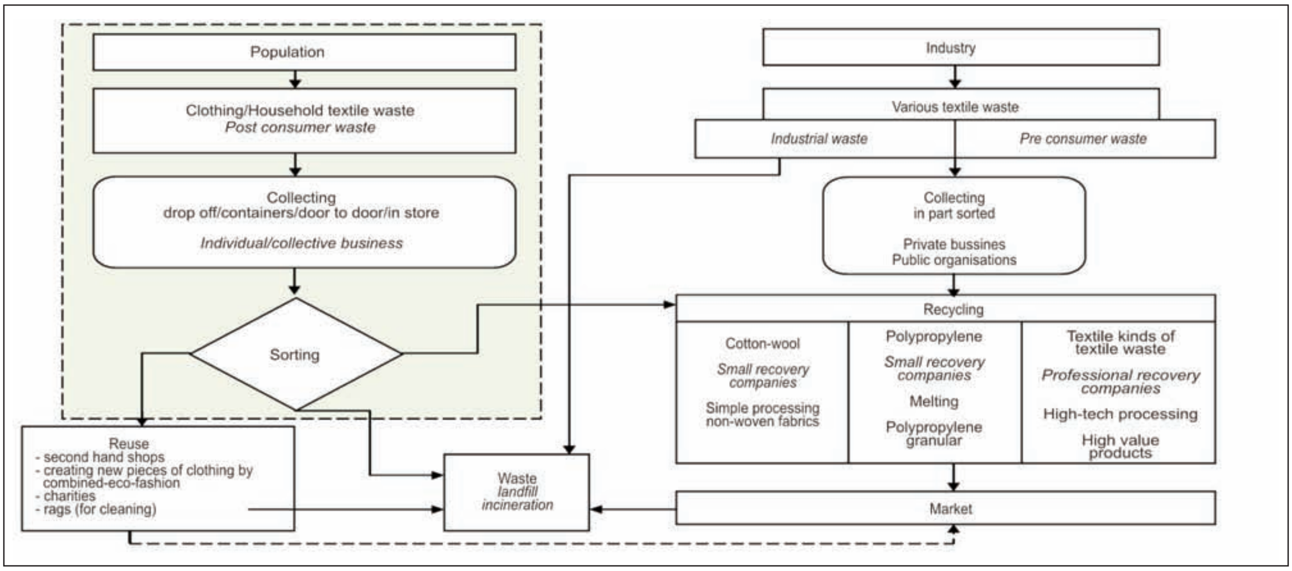

Fig. 1. Textile Recycling Process

The environmental aspects of the waste stage of clothing or other household article depend on the method of disposal. Clothing is disposed of in two ways: through separate collection or, more typically, with the domestic waste and end up in municipal landfills or are burnt.

Separate collection leads to reuse, like second-hand usage or recycling as cloth, yarn, or even as fiber. A study of the disposal of clothing among 40-year-old women in Norway shows that all the women in the study disposed clothing they had never used and about 18 % of them declared garments that had never been used or only used once or twice [21].

A number of different systems have been implemented to collect material for recycling from the general waste stream. These systems tend to lie along the spectrum of trade-off between public convenience and government simplicity and expense. The main categories of textile collection are through drop-off centres, curbside collection, door to door collections and, newest, in store collection. Big brands that have initiated their own take-back programs in recent years include H&M ("Don't Let Fashion Go to Waste"), The North Face ("Clothes the Loop"), Puma ("Bring Me Back"). All of these collect clothes from any company at their stores, and contract with I:CO (short for I:Collect), a global Swiss-based firm that collects, sorts and recycles them. For example, only in 2013 H&M has collected 3 047 tones of garments. That's the equivalent of about 15 million t-shirts [22]. Drop-off centres require the waste producer to carry the material to a central location, either an installed or mobile collection station or the reprocessing plant itself. They are the easiest type of collection to establish, but suffer from low and irregular throughput. The door to door collection method of garments is a successful method and is being prevalent in poor land from a long time.

The recycling or usage of textile waste for new product manufacturing is connected to certain requirements for the waste. When considering textile recycling we must identify what the material consists of. Various wastes are classified into detailed groupings according to their materials, colors, and average piece size. The contents of textile waste are very complex including products manufactured from a unique type of fiber or from a combination of several fibers. Cărpuș & all provide a comprehensive classification of the categories of textile waste by origin, fiber composition, size, color [23]. The textile's composition will affect its durability, method of recycling and, of course the costs too. Complex mixtures of fibers make separation more difficult and more costly, and this has implications for the profitability of textile recycling. Generally, textile waste recycling has low profit margins with an average profit rate lower than 0.01 USD per kg waste recycling, so that many recyclable textile wastes were treated as municipal solid waste [24]. However, this situation is changing with entry into the market of several professional recovery enterprises utilizing advanced technologies to produce high valued-added products. Conversion of this type of textile waste into useful materials, serves a dual function: elimination of waste, and introduction of new products such as recycled fibers, recycled clothes, toys, carpets and filling material, especially from cotton fiber. All collected textiles are sorted and graded by experienced workers, who are able to recognize the large variety of fiber types resulting from the introduction of synthetics and blended fiber fabrics that make the process more costly, and this has implications for the profitability of textile recycling. There is a trend of moving these facilities from developed countries to developing countries either for charity or sold at a cheaper price.

The second stage involves the manufacturing of new products from the raw material obtained by the processing of the old products. Recycling technologies, existing for textile too, are divided into primary, secondary, tertiary, and quaternary approaches. Primary approaches involve recycling a product into its original form. Secondary recycling involves processing a used product into a new type of product that has a different level of physical and/or chemical properties. Some companies are developing ways to reuse shredded materials within their own manufacturing and production processes. For example, H&M has launched a clothing line composed of 20 percent post-consumer denim fibers [25]. Tertiary recycling involves processes, such as pyrolysis and hydrolysis, which convert the waste into basic chemicals or fuels. Quaternary recycling refers to waste-to energy conversion through incineration. Studies have indicated that many forms of fibers recovered from various waste streams are suitable for concrete reinforcement. There are two major ways of recycling pre-consumer textile materials; mechanically, where fibres are pulled apart and reworked into yarn, and chemically where fibres are repolymerized into a chemical and spun. For many recycling processes such as nylon depolymerization and polymer resin recovery, it is required or mandatory to sort the feedstock according to the type of face fibers. The most fiber types can been identified true a simple melt point indicator or, more effective with infrared and Raman spectroscopy [26]. Knitted or woven woollens and similar materials are "pulled" into a fibrous state for reuse by the textile industry in low-grade applications, such as car insulation or seat stuffing. The textiles are shredded and mix together with other selected fibres, depending on the intended end use of the recycled yarn. The blended mixture is carded to clean and mix the fibres and spun ready for weaving or knitting. The fibres can also be compressed for mattress production. Textiles sent to the flocking industry are shredded to make filling material for car insulation, roofing felts, loudspeaker cones, panel linings and furniture padding.

Regarding the industrial waste, especially carpet recycling, in the last years a broad based research agenda has been carried out at the Georgia Institute of Technology in collaboration with the industry [27]. These studies include depolymerization, melt processing, material component separation, composite material and reinforcement for concrete and soil. There is a relativy new trend towards the use of textile waste in the construction building field, such as roofing material and brick from textile waste sludge [28]. Finally, the process ends with the purchasing of recycled goods by the consumers at the top of reverse supply chain (production plants) and completes the recycling loop.

The non recyclable products or those that are collected together in municipal waste ends up in landfills or are incinerate. Public concerns exist for the incineration of polymer waste. The main negative environmental impact of the incineration is the emission of greenhouse gases. A positive effect of burning waste is the production of energy. However, with advanced technologies and proper management, waste-to-energy conversion can be a viable alternative to landfill. Textile waste in landfill contributes to the formation of leach ate as it decomposes, which has the potential to contaminate groundwater. Another product of decomposition in landfill is methane gas, which is a major cause of greenhouse gases, significantly contributing to global warming (compared with carbon dioxide, it has a high global warming potential of 25 for a time period of 100 years) [29]. The decomposition of organic fibers and yarn such as wool produces large amounts of ammonia as well as methane. Cellulose-based synthetics decay at a faster rate than chemical-based synthetics. Synthetic chemical fibers can prolong the adverse effects of both leachate and gas production due to the length of time it takes for them to decay [30].

MODELING FRAMEWORK FOR THE TEXTILES WASTE RECYCLING EFFECTS ESTIMATION

The life cycle of a product can be either a closed loop or an open loop. Closed loop products move from raw materials to design and production to packaging and distribution to use and maintenance, and are then recycled with materials and components being captured and entering back into the system. In an open loop system, products are incinerated or disposed of at the end of their useful life. In order to quantify potential ecological and social benefits and economical effects of textiles waste recycling this paper proposes the LP optimization model of the closed loop supply chain network, shown in figure 2. Model is based on the assumption of an existing forward supply chain, operating on a market with known supply and demand, and reverse network that should be established. Hence, the purpose here is to analyze modelling approach that could be used to establish three level reverse logistics network for textile waste, composed of a set of collection points, sorting points and recycling facilities, while respecting its impact on the land use reduction, employment increase, and resold wearable textiles income, versus reverse network for textiles waste establishing and operating.

Most of the literature about reverse logistics network design considers various facility location models based on the MILP, and in many cases forward and reverse networks are modelled separately. Consequently, this leads to significant problem reduction, which is the case with this paper. However, there are only few researches related to problems in textiles recycling networks [31]. A remarkable chapter about carpet recycling explores the issues of reverse logistics for recycling within the carpet industry, including an economic analysis of the success of carpet recycling [32]. Unlike carpet, which is usually

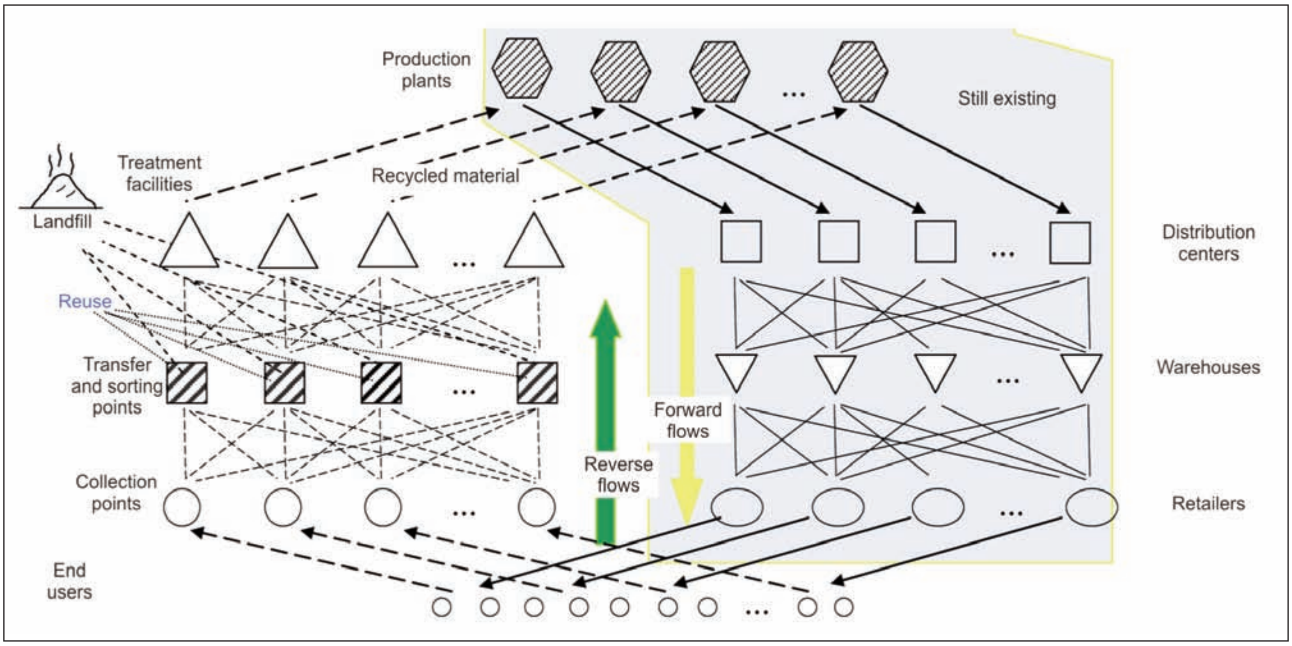

Fig. 2. Textiles closed loop supply chain network

transported to collection facilities by contractors, collection of post-consumer apparel may necessitate pick-ups of small volumes from a high number of locations, like apparel drop-off locations or curbside pick-ups. The transportation cost of this type of collection is significant higher compared to full truck loading. To minimize total transportation and fixed costs, a collector has to identify the optimal number and location of local and regional collection facilities. In its main idea, facility location model proposed here is similar to the formulation of two-stage capacitated facility location problem (TSCFLP) described in Klose and Drexl [33] but because of multilevel problem nature, different network structure and different objectives, mentioned approach has modified. In the proposed model formulation following notation has been used [34]:

- i – end user/owner of textile products (aggregated in larger units like buildings, schools etc.);
- k – collection point (drop – off location) which receives textile waste products from users;
- l – sorting facility which receives textile waste from collection points;
- j – recycling facility which receives sorted textiles waste from sorting facilities;
- C_{kl}, C_{lj}, C_{lJ+1}, C_{lJ+2}, C_{js} – costs of transporting textiles waste from collection point k to sorting facility l, respective from sorting facility l to recycling facility j, from sorting facility l to second hand shop, from sorting facility l to the landfill site, from recycling facility j to production plant s;
- X_{ik}, X_{kl}, X_{lj}, X_{lJ+1}, X_{lJ+2}, X_{js} – fraction of textile waste from user i collected at collection point k respective from collection point k transported to sorting facility l, from sorting facility l transported to recycling facility j ,from sorting facility l transported to second hand shop, from sorting facility l transported to the landfill site and from recycling facility j to production plant s;
- G_k, G_l, G_j, G_s – capacities of collection k, sorting l, recycling j, and production facility, resp.;
- f_k, f_l, f_j – costs of opening collection, sorting and recycling facilities at locations k, l, j respectively (including financial equivalent of land use);
- Y_k, Y_l, Y_j – binary variables, equals 1 when collection, sorting or recycling sites are opened, otherwise equals 0;
- α – fraction of wearable textile waste that can be resold and directly reuse $0 \leq \alpha \leq 1$;
- β – fraction of sorted textile waste that will be land filled $0 \leq \beta \leq 1$;
- λ – earnings from resoling unit quantity of textile waste that can be directly reused;
- ρ – financial equivalent of employment increase per unit quantity of recycled textiles.

Proposed multilevel MIP model of reverse logistics network for textile waste, composed of a set of collection points, sorting and recycling facilities, which respects sustainability criterions is presented below.

Minimize:

$$\sum_k \sum_l C_{kl}X_{kl} + \sum_l \sum_j C_{lj}X_{lj} + \sum_l \left(C_{lj+1}X_{lj+1} + C_{lj+2}X_{lj+2}\right) +$$

$$+ \sum_j \sum_s C_{js}X_{js} + \sum_k f_k Y_k + \sum_l f_l Y_l + \sum_j f_j Y_j - \qquad (1)$$

$$- \lambda \sum_l X_{lJ+1} - \rho\left(\sum_k \sum_l X_{kl} + \sum_l \sum_j X_{lj}\right) \text{ s.t.}$$

$$\sum_k X_{ik} = q_i \quad \forall i \qquad (2)$$

$$\sum_i X_{ik} - \sum_l X_{kl} = 0 \quad \forall k,$$

$$\sum_k X_{kl} - (1-\alpha-\beta)\sum_j X_{lj} - X_{lJ+1} - X_{lJ+2} = 0 \quad \forall l \qquad (3)$$

$$\sum_l X_{lj} - \sum_s X_{js} = 0 \quad \forall j$$

$$X_{ik} \le Y_k G_k \quad \forall i,k, \qquad X_{kl} \le Y_l G_l \quad \forall k,l, \qquad X_{lj} \le Y_j G_j \quad \forall l,j \qquad (4)$$

$$\sum_i X_{ik} \le G_k \quad \forall k, \qquad \sum_k X_{kl} \le G_l \quad \forall l, \qquad \sum_l X_{lj} \le G_j \quad \forall j, \qquad \sum_j X_{js} \le G_s \quad \forall s \qquad (5)$$

$$Y_k \in (0,1),\ Y_l \in (0,1),\ Y_j \in (0,1),\quad X_{ik}, X_{kl}, X_{lj}, X_{lJ+1}, X_{lJ+2}, X_{js} \ge 0, \qquad (6)$$

The objective function (1) minimizes the sum of reverse network for textiles recycling costs, and its effects on the virgin materials consumption, land use reduction, employment increase, and earnings from wearable textiles. Note that because objective function should be minimized, positive effects of network establishing are included as negative values that are subtracted from costs. All the supply of textile waste available at the users site is defined by constraint set (2). Equalities set (3), represent flow conservation constraints. Constraints sets (4) prohibit units from being routed through collection, sorting and recycling sites unless the site is opened. Constraint set (5) limit the quantities sent to the collection, sorting, recycling and production sites up to the capacity of those sites. Constraint sets (6) enforce the domain of decision variables.

STAGE OF TEXTILE WASTE RECYCLING IN ROMANIA

There are numerous economic, social, technological, environmental and institutional barriers to the implementation of textile recycling in Romania. The main textile waste sources in Romania are similar with the other European countries: industry and population.

In the last period, due to expansion of the garment sector and decline of the fibers and woven production, in Romania, the main part of all pre-consumer waste consists of textile material cuttings. These are cuttings of a different size with dyeing defects, stained, knitted fabric cuts up to 2 kg of weight, fine knitted fabric waste, woven fabric borders, weighted cuttings of woven fabrics (0.1–2 m length), cutouts from garment sewing industry. According to Eurostat in Romania were generated around 363,315 million tons of waste, of which 99.4% are non-hazardous and 0.6% hazardous waste. From these, 18,774 tones are textile waste. Much of these, 76.43% are generated by industry of textile manufacturing, wearing apparel, leather and related products [35]. Across Europe, an estimated 15 to 20% of potential existing tonnage is really collected. Germany and the UK on the one hand and Poland and Romania on the other hand are a few exceptions. Germany and the UK have an ecological tradition and collect roughly 70% of its potential while Poland and Romania are importers of textiles from Western countries. However, no specific evidence has been found regarding the amount of the imports of unsorted used clothes. It is not clear how much of these are resold, in second-hand shops, or are ending in the landfill. The number of second hand shops or the tonnage of textile they processed is also unknown. Without greater transparency in the industry, it is difficult to determine the size of this segment.

Unfortunately, while sustainability requires a long term outlook, both private and public sector leaders are focused on short-term results. Therefore the main method of waste disposal in Romania is landfill. The EU waste directive from 2008 (2008/98/EC) presents a structure for preferred treatment of waste, where landfill (or other means of disposal) is the least preferable option and waste prevention is the most preferable option [36]. The energy content of the waste materials may be recovered, at least in part, by burning the waste materials. Incineration of waste is not a wide spread practice in the country. The Resolution no. 870/2013 regarding the approval of National Waste Management Strategy 2014–2020, requires that the waste which does not comply with recycling standards, but has a corresponding calorific value, textiles being included in this category, can and should be subject to recovery or thermal treatment with energy recovery installations appropriately equipped. Even if the number of incinerators rapidly soared from 7 (2010) at 73 (2014), their number is still very low. Moreover, incineration needs to be done carefully, because without effective filtering, it can result in pollution through emissions, potentially significant risks to human health and the environment.

A further problem is the lack of recycling technologies in Romania. Regarding the green technologies, a roadmap for 2010–2013 was developed in order to implement the Environmental Technologies Action Plan (ETAP Romania). Romania was granted transition periods to achieve conformity with the EU directives for municipal waste sites by 2017. On 2 July 2014, the EC adopted a legislative proposal to review recycling and other waste-related targets in the EU Waste Framework Directive 2008/98/EC, the Landfill Directive 1999//31/EC and the Packaging and Packaging Waste Directive 94/62/EC [37], textile wastes are not treated separately, they are included by "other waste". The main elements of the proposal include: recycling and preparing for re-use of municipal waste to be increased to 70 per cent by 2030, recycling and preparing for re-use of packaging waste to be increased to 80 per cent by 2030, with material-specific targets set to gradually increase between 2020 and 2030 (to reach 90 per cent for paper by 2025 and 60 per cent for plastics, 80 per cent for wood, 90 per cent of ferrous metal, aluminium and glass by the end of 2030) and phasing out landfilling by 2025 for recyclable waste. According to

Eurostat, Romania recycled only one per cent of municipal waste in 2012, a result which placed the country at the bottom of the member state ranking. Today, local experts believe that Romania manages to recycle around five-six per cent of the household waste generated, a slightly higher figure due to the waste collected by homeless people, something not monitored at EU level. Still, the figures are very low and urgent measures need to be done to put Romania on the "green map".

CONCLUSIONS

There are benefits to all three aspects that define sustainability: **economic (**recycling programs cost less than waste disposal programs), **social** (creating new jobs, new opportunities for small/family business, and build communities around environmental issue) and **environmental** (preserves natural resources, saves energy, prevent the destruction of natural habitats). There are also negative aspects too. One of the problems is that the used textile imported (especially second hand clothes) by poor or developing countries can lead to an economic decline in that sector.

The most important barriers to recycling are lack of infrastructure, equipment and technology, lack of material to recycle and lack of consumer awareness. The amount of textiles for recycling in a region is too small for an efficient recycling. Therefore recycling must be done either abroad or partly with imported textiles.

Governments, as well as businesses and individual consumers, each play an important role in making the recycling process a success. Government intervention may mean that new value-added recycling technologies enter the market, and therefore the average system will change. If recycling technologies improved, then recycling could be as or even more worthwhile than reuse, particularly if the systems become closed loop. Recycling of textiles presents several promising technologies and ideas for recycling systems. It is useful to settle on the far-off prospects of material use for an environmentally sustainable economy. The motivation for waste and pollution prevention through recycling can only be fully appreciated when related to long-run goal of material conservation.

The current inadequated situation regarding waste management in Romania is a challenge for change. This can be brought under control by focused efforts and by a participation of all interested factors in the Integrated Waste Management Plan, which was approved in 2004 and completed in 2007. Effects of textile recycling on sustainable development is modelled as MIP model with the objective of analyzing trade off between costs of reverse network for textiles waste and its effects on the virgin materials consumption, land use reduction, employment increase, and earnings from wearable textiles. Model application and adjusting is left for the future research.

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Hedonic value of clothing products

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REZUMAT – ABSTRACT

Valoarea hedonică a produselor vestimentare

Achiziționarea produselor vestimentare este asociată de obicei cu o serie de motivații de ordin emoțional, hedonice, în completarea celor de ordin practic, utilitariste. Astfel, comportamentul de cumpărare și consum asociat produselor vestimentare va reprezenta un amalgam complex rezultat al acestor tipologii diferite de motive și motivații de consum. Scopul cercetării din cadrul acestui articol este de a identifica factorii care determină indivizii să se angajeze în utilizarea hedonică a articolelor vestimentare, având în vedere importanța relativă a caracteristicilor intrinseci ale acestora în asociere cu factorii individuali și sociali care influențează comportamentele de cumpărare și consum/utilizare. Rezultatele cercetării au relevat, în premieră pentru piața din România, corelația existentă între variabile precum: percepția față de importanța calității materialelor din care sunt confecționate hainele purtate, percepția referitoare la aspectul estetic al vestimentației, referitoare la prețul ridicat al acesteia etc, și consumul motivat de către imaginea de sine, modă sau imaginea celorlalți consumatori față de produsele vestimentare.

Cuvinte-cheie: consum hedonic, consum utilitarist, proces decizional de cumpărare, satisfacție în consum, motivații de consum

Hedonic value of clothing products

Purchasing clothing products is usually associated with a range of emotional type motivations, hedonic ones, in addition to the practical, utilitarian ones. The buying and consuming process will represent a complex amalgam result of these different types of reasons and motivations for consumption. The purpose of the research within this paper is to identify the factors that determine individuals to engage in hedonic use of clothing products, given the relative importance of their intrinsic characteristics in combination with individual and social factors that influence purchase and consumption/use behaviors. The research results have revealed for the first time at the level of Romanian market the correlation between variables such as: perception regarding the quality of materials used for clothes, perception referring to aesthetic aspect of clothes, perception regarding the high price of clothes etc., and the consumption motivated by self-image, fashion or other consumers' image regarding apparel products.

Key-words: hedonic consumption, utilitarian consumption, decisional buying process, consumption satisfaction, consumption motivations

In the recent years, more and more specialists have studied the issue related with the typology of consumption motivations in terms of hedonic or utilitarian values that may underlie consumer's behavior. The hedonic consumption is not necessarily an economic one, but the expression of previous experiences lying beyond the actual acquisition of the goods. [1–9] Therefore, it is not limited to luxury consumption such as clothes produced by the great fashion house designers, that require large expenditures, but it may be associated with a "thrifty behavior" in relation with the financial effort.

The hedonic value is given, in fact by the individual's capacity to produce hedonic responses, like the perceived freedom, fulfillment, fantasy, escape etc. [2]

For products based on hedonic consumption motivations, the general impression is that consumers justify their consumption before they actually consume the products itself. There are studies which have shown that very often consumers will justify their purchase decisions for these products both before and after purchase and consumption. [4]

Usually, hedonic products type are associated with needs related with fantasies, entertainment, fun, pleasure, being opposed to utilitarian ones which are addressing to pragmatic, rational needs.

Therefore, in fact, the hedonic products are desired but not necessarily required. Thus, consumers may have difficulties to find justification for purchasing decisions, the differences between utilitarian and hedonic products being associated with juxtapositions like (vices and virtues, luxury and necessity). [12]

Hedonic values are non-instrumental, experiential, having a strong emotional substrate and are often bound with non-tangible attributes of products or services. The hedonic dimension of the consumption experience is derived from the uniqueness of the product or the service, its symbolism and emotional arousal and images that they evoke. [8]

The hedonic products are products whose consumption is characterized by an affective and sensorial experience through which the consumer satisfies his aesthetic or sensual pleasure, a fantasy or has fun. By contrast utilitarian products are represented by those goods whose consumption is determined by cognitive motives, is instrumental and oriented towards concrete goals and succeed to accomplish a functional or practical task. [17]

In the case of clothing, they present a complex, and to a certain extent unique situation. Various categories of consumers will associate the consumption of clothing products with utilitarian type consumption, at least when we talk about the clothing worn on daily basis. At the same time it may speak of a hedonic consumption associated to clothing products especially when buying fashion products or that highlights through their peculiarities a certain social status or membership to a particular social group. The marketing communications techniques utilized by the clothing products manufacturers will bring their contribution in terms of boosting the hedonic type consumption through the positioning that they can give for clothing products in relation to consumer perception. [16]

Hedonic consumption associated with clothing products involves the necessity of identifying variables able to clarify the purchasing decision making mechanism, consumption motives emergence and the development of the consumer's satisfaction, approach that characterizes also the present paper.

RESEARCH METHODOLOGY

In order to identify the factors that determine the hedonic type consumption of clothing products, the authors have implemented a survey type research carried in urban area.

As research objectives it can be outlined: determine the respondent's perception regarding consumption motivations of other consumers, determine the respondent's perception regarding the importance of materials' quality used for their own worn clothing products, determine the respondent's perception regarding the aesthetic aspect of worn clothing products, determine the respondent's perception regarding the brand of usual worn clothing products, characterize the significance of consumer motivations associated with respondents' self-image, determining the importance of consumer motivations associated with fashion, determining the importance of consumer motivations associated with the image that other consumers have regarding clothing products (the extent that they appreciate expensive clothes).

Among the hypothesis considered, we can remember: the consumption motivation related with self-image is correlated with variables regarding perceptions referring to friend's clothes, the quality of materials, the aesthetic aspect, brand importance and clothing products high price, the consumption motivation related with fashion is correlated with perception regarding aesthetic aspect, brand importance and high price, the consumption motivation related with other consumers image on clothes is correlated with perception referring to friend's clothes and clothing products high price.

The research was conducted among adult population in the urban area from Bacău, Brașov, Bucharest and Iași, and has a final validated sample of 246 respondents. The sample was determined using the simple random sampling method.

RESULTS AND DISCUSSIONS

For analyzing the data resulted from the research it has been utilized the IBM SPSS version 20.0 statistical analysis software package. The analysis aimed to highlight correlations that can be made between the two sets of variables: independent – referring to the factors that are influencing hedonic consumption and dependent – variables that are actual measuring this type of consumption. Also, the analysis tested the hypothesis stated within the research methodology.

To analyze the correlations enlisted, we used the multiple linear regression method. Using this multivariate analysis method it has been created multiple regression models. Thus it has been analyzed three sets of equations corresponding for the hedonic determinants consumption patterns.

In the figure below there are presented the correlations for the hedonic determinants consumption patterns in a synthetic manner:

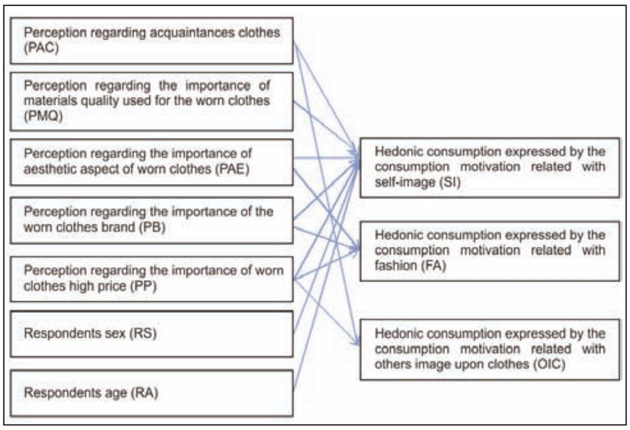

Fig. 1. The graphic model of hedonic consumption determinants – sets of equations conjugation

In the first stage it was analyzed the first set of equations corresponding to the correlations between self-image (*SI*) as an dependent variable and perceptions in relation with the following independent variables, able to determine specific behaviors for the hedonic consumption:

– Acquaintances' clothing (*PAC*)
– The importance of materials quality in case of worn clothing (*PMQ*)
– Aesthetic aspect importance of worn clothes (*PAE*)
– The importance of worn clothes brand (*PB*)
– The importance of the worn clothes high price (*PP*)
– Sex of respondents (*RS*)
– Age of the respondents (*RA*).

Tabelul 1

REGRESSION EQUATIONS DETERMINED WITH THE INTRODUCTION OF EACH INDEPENDENT VARIABLE BASED ON THE VALUES OF THE MULTIPLE DETERMINATION COEFFICIENT FOR THE FIRST SET OF EQUATIONS				
Regression equation	R (multiple correlation coefficient)	R^2 (multiple determination coefficient)	Adjusted R^2	Modification R^2
[1] $SI = \beta_0 + \beta_1 \times PAC + \varepsilon$	0.578	0.334	0.320	0.334
[2] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \varepsilon$	0.665	0.442	0.431	0.108
[3] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \varepsilon$	0.694	0.482	0.471	0.039
[4] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \beta_4 \times PB + \varepsilon$	0.705	0.497	0.487	0.015
[5] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \beta_4 \times PB + \beta_5 \times PP + \varepsilon$	0.841	0.707	0.701	0.210
[6] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \beta_4 \times PB + \beta_5 \times PP + \beta_6 \times RS + \varepsilon$	0.636	0.404	0.392	–0.303
[7] $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \beta_4 \times PB + \beta_5 \times PP + \beta_6 \times RS + \beta_7 \times RA + \varepsilon$	0.623	0.388	0.375	–0.016

The analytical model of multiple linear regression equation corresponding to the first set of variables takes the form: $SI = f(PAC, PMQ, PAE, PB, PP, RS, RA) + \varepsilon$ or, in a linear-additive form, $SI = \beta_0 + \beta_1 \times PAC + \beta_2 \times PMQ + \beta_3 \times PAE + \beta_4 \times PB + \beta_5 \times PP + \beta_6 \times RS + \beta_7 \times RA + \varepsilon$

It has been performed a multi criteria measurement of the variables taken into consideration for the multiple linear regression model, and for this reason, the actual creation of the model assumed the step by step inclusion of independent variables, one by one, taking into account their ability to explain the dependent variable variation. The results of the regression equations are presented in table 1.

In this case, we can say that 70.7% of the dependent variable variation – the Hedonic consumption expressed by the consumption motivation related with self-image (*SI*) – is determined by the variation of causal variables, namely: perception regarding acquaintances clothes (*PAC*), perception regarding the importance of materials quality used for the worn clothes (*PMQ*), perception regarding the importance of aesthetic aspect of worn clothes (*PAE*), perception regarding the importance of the worn clothes brand (*PB*) and perception regarding the importance of worn clothes high price (*PP*). The remaining of 29,3% variation of the dependent variable is due the variation of the residual variable ε.

Estimation of the parameters of the regression model was made using the least squares method, and the resulting regression equation is:

$$IS = x_0 + x_1 \times PVC + x_2 \times PC + x_3 \times PAE + x_4 \times PB + x_5 \times PP + \varepsilon$$

$$IS = 6{,}071 + 0{,}475x_1 + 0{,}262x_2 + 0{,}115x_3 + 0{,}206x_4 + 0{,}543x_5 + \varepsilon$$

It can be seen that all causal variables positively influence the dependent variable (all variables have the + sign), so hedonic consumption expressed by the consumption motivation related with self-image (*SI*) is positively influenced by perception regarding acquaintances clothes (*PAC*) (+0,475 for x_1), perception regarding the importance of materials quality used for the worn clothes (*PM*Q) (+0,262 for x_2), perception regarding the importance of aesthetic aspect of worn clothes (*PAE*) (+0,115 for x_3), perception regarding the importance of the worn clothes brand (*PB*) (+0,206 for x_4) and perception regarding the importance of worn clothes high price (*PP*) (+0,543 for x_5).

Besides the sense in which the dependent variable is influenced, the regression coefficients indicate also the intensity of their influence on it. Comparing the values of regression coefficients it becomes clear that the greatest influence is exerted by the variable perception regarding the importance of worn clothes high price (the coefficient with the highest value of 0,543). This demonstrates the fact that a change with one unit of the perception regarding worn clothes high price importance will change the hedonic consumption expressed by the consumption motivation related with the self-image by 0,543 units.

The second equation set intended to identify whether there is a correlation between consumption motivation related with fashion (FA) as the dependent variable and the following independents variables: perception regarding the importance of aesthetic aspect of worn clothes (*PAE*), perception regarding the importance of the worn clothes brand (*PB*) and the perception regarding the importance of worn clothes high price (*PP*).

The analytical model of multiple linear regression equation corresponding to the second set of variables is: $FA = f(PAE, PB, PP) + \varepsilon$ or $FA = \beta_0 + \beta_1 \times PAE + \beta_2 \times PB + \beta_3 \times PP + \varepsilon$.

In this case (table 2) it has been determined that 67,7% from the dependent variable variation, hedonic consumption expressed by the consumption motivation related with fashion (*FA*) is determined by the variation of causal variables, namely: perception regarding the importance of aesthetic aspect of worn clothes (*PAE*), perception regarding the importance of the worn clothes brand (*PB*) and the perception regarding the importance of worn clothes high price (*PP*).

Thus all causal variables positively influence the dependent variable (all the variables have the "+"

Tabelul 2

REGRESSION EQUATIONS DETERMINED WITH THE INTRODUCTION OF EACH INDEPENDENT VARIABLE BASED ON THE VALUES OF THE MULTIPLE DETERMINATION COEFFICIENT FOR THE SECOND SET OF EQUATIONS				
Regression equation	*R* (multiple correlation coefficient)	R^2 (multiple determination coefficient)	Adjusted R^2	Modification R^2
[1] $SI = \beta_0 + \beta_1 \times PAE + \varepsilon$	0,624	0,389	0,381	0,389
[2] $SI = \beta_0 + \beta_1 \times PAE + \beta_2 \times PB + \varepsilon$	0,675	0,456	0,449	0,066
[3] $SI = \beta_0 + \beta_1 \times PAE + \beta_2 \times PB + \beta_3 \times PP + \varepsilon$	0,823	0,677	0,673	0,222

Tabelul 3

REGRESSION EQUATIONS DETERMINED WITH THE INTRODUCTION OF EACH INDEPENDENT VARIABLE BASED ON THE VALUES OF THE MULTIPLE DETERMINATION COEFFICIENT FOR THE THIRD SET OF EQUATIONS				
Regression equation	*R* (multiple correlation coefficient)	R^2 (multiple determination coefficient)	Adjusted R^2	Modification R^2
[1] $IC = \beta_0 + \beta_1 \times PAC + \varepsilon$	0,507	0,257	0,251	0,257
[2] $IC = \beta_0 + \beta_1 \times PAC + \beta_2 \times PP + \varepsilon$	0,719	0,517	0,513	0,260

sign), resulting that hedonic consumption expressed by the consumption motivation related with fashion (*FA*) is positively influenced by the perception regarding the importance of aesthetic aspect of worn clothes (*PAE*) (+0,855 for x_1), namely perception regarding the importance of the worn clothes brand (*PB*) (+0,241 for x_2) and the perception regarding the importance of worn clothes high price (*PP*) (+1,459 for x_3). Comparing the regression coefficient values, it becomes clear that the greatest influence is exerted by the same variable as in the first equations set – the perception regarding the importance of worn clothes high price (the coefficient with highest value in this case being 1,459). This means that a change of one unit regarding level of perception will cause a change of the hedonic consumption based on consumption motivation related with fashion by 1,459 units.

For the third equations set we wanted to identify a correlation between consumption motivation based on others image upon clothes (*IC*) (others appreciate expensive clothes) seen as a dependent variable and perception regarding acquaintances clothes (*PAC*) and perception regarding the importance of worn clothes high price (*PP*).

In other words, the factors which are influencing hedonic consumption as the listed effects (independent variables called also cause variables) could determine the increase of hedonic consumption.

The analytical model of multiple linear regression equation corresponding to the third set of variables is: IC=f(PAC, PP) + ε or IC= β_0+β_1*PAC+ β_2*PP + ε.

After calculations we can say that 51,7% of the variation in the dependent variable named hedonic consumption expressed by the consumption motivation related with others image upon clothes (*IC*) is determined by the variation of causal variables, namely: perception regarding acquaintances clothes (*PAC*) and perception regarding the importance of worn clothes high price (*PP*) (table 3).

Also, like for the previous sets of equations if we compare the regression coefficients values we can observe that the greatest influence is exerted by the variable "perception regarding the importance of worn clothes high price (*PP*)" (having the coefficient with the highest value – 4,554). This means that a change of one unit of the level of perception regarding the importance of worn clothes high price (*PP*) will cause a change of the hedonic consumption based on consumption motivation related with others image upon clothes (*OIC*) by 4,554 units.

Data analysis revealed that all variables taken under discussion influences the hedonic type consumption highlighted by the variables considered. Also it is revealed that the variable referring to the perception regarding the importance of worn clothes high price represents the variable with the greatest influence on hedonic consumption.

CONCLUSIONS

Determinants of hedonic consumption for clothing products are complex variables representative both for the emotional dimension of the consumption motivations and in the same time, for quantitative aspects having a practical nature – the quality of materials, level of prices.

The three sets of equations analyzed revealed the great importance of the perception regarding the importance of worn clothes high price has in relation to all three dependent variables corresponding to the hedonic consumption (consumer motivation related to self-image, fashion and other consumers image regarding clothing products).

This result shows that the high price level represents for the interviewed Romanian consumers an important determinant of hedonic consumption. It seems that expensive clothing products will augment the consumer's satisfaction based on hedonic values. Also from the analyzed data it can be observed that, from the three sets, the variable referring to the perception regarding the importance of worn clothes high price has the greatest influence upon the hedonic consumption based on consumption motivation related with others image upon clothes. This gives us a clue related to the fact that the consumers' satisfaction will be higher in terms of hedonic values if the clothing products are not only at a high price but in the same time appreciated by other consumers with the same values scale – searching for the hedonic values determined by high prices.

The present research was an exploratory demarche, having its own limitations. Yet, the results are showing that in the field of clothing products, the consumption motivations and behaviors are strongly influenced by hedonic values and not necessarily only in the field of fashion clothing products.

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