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An event-related potential study on the aesthetics of colour matching on silk fabric

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ABSTRACT – REZUMAT

An event-related potential study on the aesthetics of colour matching on silk fabric

In this work, cognitive behaviour and electroencephalography (EEG) of 16 subjects applied colour matching and contrast colour matching to silk fabrics had been measured. The results showed that, the exogenous components P1 (100 ms) and P2 (200 ms) were mainly produced in the frontal, temporal, apical, and occipital regions, while the endogenous component P3 (300 ms) was mainly produced in the front-top area, the front-central area, the central-top area, and the top-pillow area. Regarding P1, the information transmission speed was faster than contrasting colours with matching process. Regarding P2, external and internal factors and their interactions significantly affected amplitude, whereas only interactions affected latency, and the interaction was stronger with colour matching. Regarding P3, colour matching type, involved brain area, and interactions had no significant effect on amplitude and latency. The information processing of same colour system in brain has shorter information processing time and faster information transmission. That indicated the EEG technology could provide objective visual cognitive aesthetic rules for silk fabric colour matching, and provide reference value for fabric manufacturers to timely understand consumers' preference for fabric colour categories.

Keywords: *silk fabric, colour matching, EEG technology, visual cognition, aesthetic law*

Un studiu potențial legat de evenimente privind estetica asortării culorilor pe țesătura din mătase

În această lucrare, au fost analizate comportamentul cognitiv și electroencefalografia (EEG) a 16 subiecți care au aplicat asortarea culorilor și contrastul culorilor pe țesăturile din mătase. Rezultatele au arătat că, componentele exogene P1 (100 ms) și P2 (200 ms) au fost produse în principal în regiunile frontale, temporale, apicale și occipitale, în timp ce componenta endogenă P3 (300 ms) a fost produsă în principal în zona frontală superioară, zona centrală frontală, zona centrală-superioară și zona superioară. În ceea ce privește P1, viteza de transmitere a informațiilor a fost mai ridicată decât contrastul culorilor în procesul de asortare. În ceea ce privește P2, factorii externi și interni și interacțiunile acestora au influențat semnificativ amplitudinea, în timp ce doar interacțiunile au influențat latența, iar interacțiunea a fost mai puternică la asortarea culorilor. În ceea ce privește P3, tipul de asortare a culorilor, zona creierului implicată și interacțiunile nu au avut o influență semnificativă asupra amplitudinii și latenței. Procesarea informațiilor din același sistem de culori din creier are un timp de procesare a informațiilor mai scurt și o transmisie mai rapidă a informațiilor. Acest lucru a indicat că tehnologia EEG ar putea oferi reguli estetice cognitive vizuale obiective pentru asortarea culorii țesăturilor din mătase și valoare de referință pentru producătorii de țesături, pentru a înțelege în timp util preferința consumatorilor pentru categoriile de culori.

Cuvinte-cheie: *țesătură din mătase, asortarea culorilor, tehnologia EEG, cunoaștere vizuală, lege estetică*

INTRODUCTION

The eyes are considered the windows to the human mind. Upon opening one's eyes, the brain instantly registers visible colours and uses cognition to judge the colour matching which people prefer.

Unsurprisingly, the colour matching of fabrics is an indispensable element of the visual perception of clothing. Accordingly, apparel fabric designers and fabric production companies strive to meet the aesthetic requirements of the public in terms of colour matching. Silk fabric is a primary representative apparel fabric, and the consumer demand for this fabric increases each year. Therefore, a study of visual cognition during the colour matching of silk fabrics could provide a reference for the visual cognition of other fabrics.

Colour matching is a physiological phenomenon produced by the sense of vision, which relies on a balance in the retinal perception of colour. Colour matching can be classified as same colour matching or contrast colour matching, according to the involved hues. Same colour matching refers to the matching of different brightness or purity levels of the same colour [1], such as sky blue and light blue, or rose red and pink. Generally, people find hues within the same colour system to be aesthetically pleasing. Contrast colour matching involves colours that are opposites in the hue circle (i.e., contrast colours). The pairing of these colours can yield strong contrasts. This concept also includes contrasts in brightness, warmness/coolness, and area [2], among other properties. Appropriate colour matching can give silk fabrics different artistic styles.

To date, studies of the colour matching of silk fabrics have mainly relied on subjective cognition evaluation methods. Traditional evaluations of subjective cognition are usually based on subjective descriptions and questionnaire surveys. However, these methods cannot accurately record or objectively evaluate the cognition required for colour matching. Currently, evaluations of subjective cognitive are combined mainly with the psychological software E-prime. This universal software package for the development of psychological experiments is equipped with multiple multifunctional expansion packages that can be used with many technical devices at the frontier of psychology research. For example, a new combination of event-related potential (ERP), functional magnetic resonance imaging and eye movement, as a software for stimulus presentation and data collection, have being used in the field of textile evaluation [3, 4].

In recent years, the development of neurophysiology had led researchers to combine concepts from that field with computer technology for applications in the fields of textiles and clothing. For example, Yoko et al. selected two skirts as stimulating materials in a contrast colour study, which demonstrated that the alpha wave probability of the skirt with higher colour brightness was obviously higher than that of with lower colour brightness [5]. A combination of these data with an evaluation of the sensations of tightness and comfort revealed a change in the α wave intensity that corresponded to the pressure exerted by a belt on the abdomen [6]. Chen et al. had used four-colour combinations of blue, white, red and yellow, with black as the visual stimuli, determined that N75, P100 and N145 could be used to detect the effects of stimulating materials on human optic nerve production [7–9].

In this study, cognitive behavioural and electroencephalography (EEG) techniques were combined to evaluate cognition during colour matching. Silk fabrics and contrast colour systems were used as stimuli, and ERP signals were collected from the cerebral cortices of 16 female subjects during the process of aesthetic evaluation process [10, 11]. The obvious visual components registered by different brain regions were associated with external (colour matching) and internal (brain) factors during three stages: early perception (P1 component), combination of physical and biological components (P2 component), and decision (P3 component). The influence of processing in different areas of the brain on amplitude and latency were explored through an analysis of differences in the generated wave frequencies, as well as the distributions and energy distributions of waves of different frequencies in each brain region in response to colour and contrast colour matching.

MATERIALS AND METHODS

Test subjects

Sixteen female subjects between 18 and 25 years old were selected, stochastic.

Experimental materials and instruments

For this experiment, plain satin silk fabric with a weight of 52 g/m^2 was used. The selected materials were scanned to generate a standard image (resolution). The same colour matching analysis included two shades each within the red (rose red and pink) and blue systems (sky blue and light blue). One group: rose red × pink; sky blue × light blue; and the other group: red × blue and red × green.

The prepared sample was scanned at a resolution of 600 dpi to generate a test image measuring 20 cm^2. Each group was matched with nine images for a total of 36. The following equipment was used for the analyses: a computer with E-prime 2.0 (Professional) behavioural software; an EEG amplification and data detection system (Compumedics, Australia); a SynAmp2 amplifier; a 64-lead Quik-Cap electrode cap; Curry 7.0; and Scan4.5 EEG signal acquisition and analysis software.

Experimental paradigm and experimental process

Prior to the experiment, the subject was informed about the experiment and precautionary measures. The subject was required to pay attention to the contents of the visual presentation and react quickly [10]. No influencing visual stimuli were provided in the idle state. Therefore, the combination of the same colour system and contrast colour system was the main component of the ERP analysis.

At the beginning of the experiment, the subjects were exposed to visual stimuli intended to elicit brain waves. The experimental paradigm is shown in figure 1. In each experiment, E-prime 2.0 software was used to display the same colour matching and contrast colour matching images on the screen in a random order [11]. The subjects were required to assign aesthetic scores rapidly (presentation time: 500 ms) to ensure that the evaluation was completed. Each subject was instructed to press the Z button with their left hand if they deemed the presented image to be US, and to press the M button with their right hand if the image was not aesthetically pleasing.

Each image evaluation was followed by an idle period of 100 ms to prevent the visual impact of the previous image. A red "+" flashed on the screen to indicate that the next presentation time would occur in 50 ms, thus prompting the subject attention [12–14].

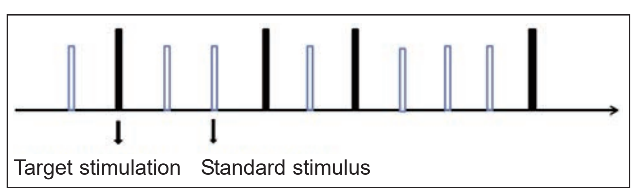


Fig. 1. Paradigm of random image presentation

Data collection

During the experiments, the sampling frequency and mode were 1000 Hz and DC, respectively, and the ears were used as the reference electrode sites. The electrode distribution is shown in figure 2. Raw data were pre-processed using the Curry 7.0 EEG analysis software, which performed artefact removal and correction, EEG segmentation, and baseline correction. The start time of each stimulus was set as zero, and the stimulus was selected according to the time interval set by the experimental paradigm. 800 ms after the start as the analysis data, this is suitable for the 100–200 ms and 200–300 ms and 300–600 ms latency of the exogenous and endogenous components. The time for baseline correction is usually equal to 1/10 – 1/5 length of the whole analysis [15]. Therefore, a point of 200 ms before the start of the stimulation was selected for the superimposed average baseline correction data.

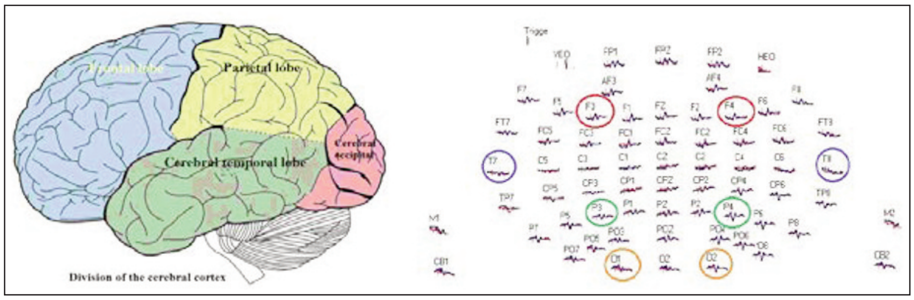


Fig. 2. Brain region (left) and electrode distribution (right) images

Analysis of exogenous component data

The data were compared using a two-factor repeated measures analysis of variance and mean analysis. If the results of the analysis of variance (ANOVA) violated the spherical hypothesis (i.e., Mauchly spherical test, $P<0.05$), then the Huynh–Feldt degrees of freedom were used for correction [16].

RESULTS AND DISCUSSIONS

The ERP waveform and topographic image analysed revealed that the P1 and P2 components were produced in the frontal and temporal regions, while significant P3 components were produced in the top and occipital and temporal regions. P1 and P2 were corresponding to exogenous components. P1 was generated during the sensing stage, while P2 was generated from a combination of physical and biological components, and P3 components were endogenous and be generated during the decision-making stage. The frontal, temporal, apical, and occipital regions were mainly include the component of F3, F4, T7, T8, P3, P4, O1, O2, CP1, CPz, CP2, PO3, POz and PO4, from which could lead to difference of the waveform very significantly with the baseline. In this case, the typical electrode points F3, F4, T7, T8, P3, P4, O1 and O2 in these areas were selected for the EEG waveform analysis. Among these, blue colour worked as the same colour waveform, and red colour as the contrast colour waveform.

P1 was mainly observed in the bilateral occipital region and generally initiated at 60–90 ms after the start of stimulation, with a peak between 100 and 130 ms [17, 18]. P2, which observed in the central region of the forehead, was a significant positive component with an incubation period of approximately 200 ms and it could lead to the strongest visual stimulation response in the back of the scalp. The enlarged ERP brain waveform with electrode point was shown in figure 3 according to the magnitude of the amplitude. According to the waveform diagram, the P1 and P2

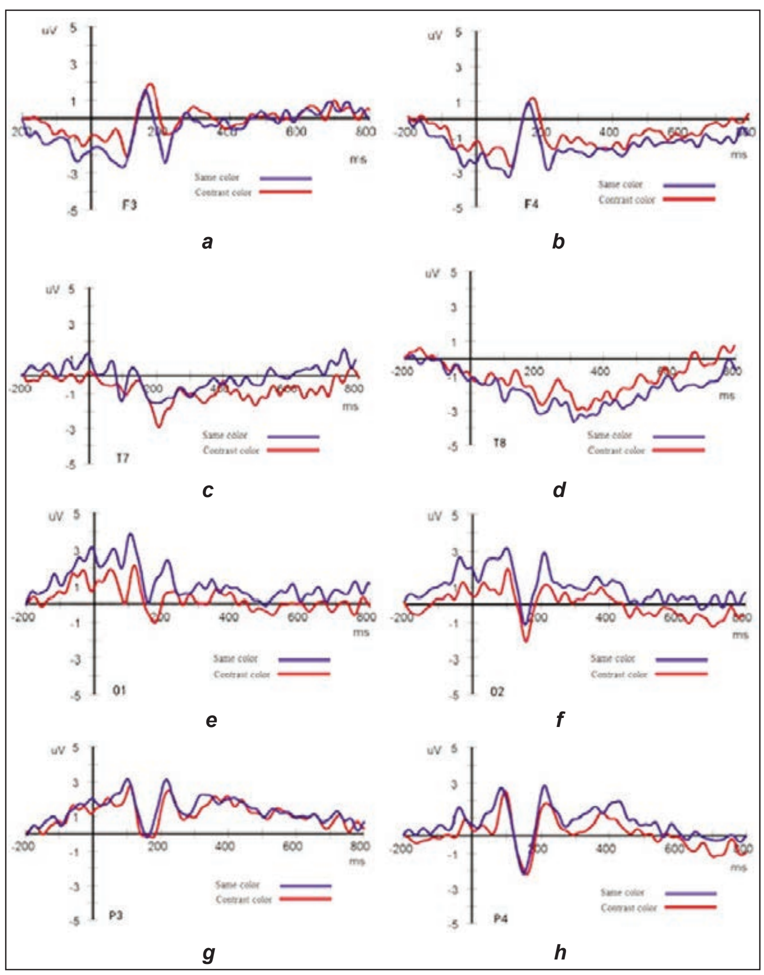


Fig. 3. The images of EEG waveforms: *a* – electrode point F3; *b* – electrode point F4; *c* – electrode point T7; *d* – electrode point T8; *e* – electrode point O1; *f* – electrode point O2; *g* – electrode point P3; *h* – electrode point P4

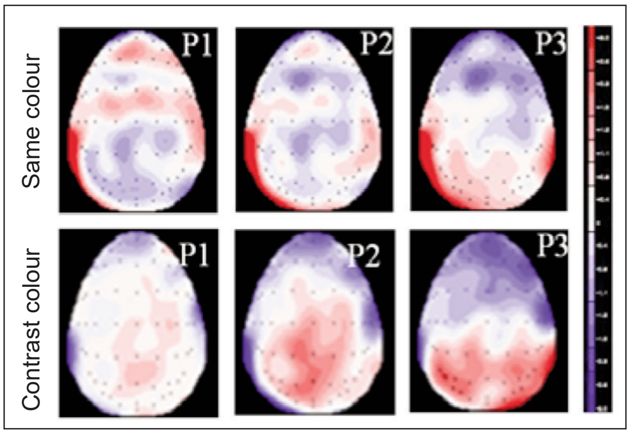


Fig. 4. Brain topographic images of the three components

components induced by the contrast colour matching were larger than the contrast colour matching, and the top region and the pillow were in the top region. The district is the opposite. P3 had a relatively large amplitude and wide span and induced by rare, task-related stimuli (i.e. target stimuli). Generally, the incubation period of P3 was approximately at 300 ms [19–21], and usually distributed in the central-top region near the midline. The P3 component was selected according to the magnitude of the amplitude. An example ERP brainwave waveform was shown in figure 4, which indicated that the amplitude of the EEG was greater than the contrast colour, while the amplitude of the contrast colour in the frontal region was greater than the same colour. The amplitude of the contrasting colour in the central top region and the occipital region was larger than the contrast colour.

The EEG signal was input into Scan 4.5 software and converted into an EEG topographic image. The P1 component induced by the same colour system was more prominent in the temporal and frontal regions, while the P2 component amplitude was greater than the P1 component amplitude. The component P3 was mainly distributed in the top and occipital zones, where the amplitude was larger. The induction of the P1 component by the contrast colour system yielded small and insignificant amplitude. The P2 component was mainly distributed in the top and occipital zones. The P3 component was mainly distributed in the top and occipital zones, and the amplitude was significantly greater than the amplitude of the exogenous component.

Analysis of P1 component data

The main effects and interactions of external factors (colour matching) and internal factors (brain processing) on the amplitude and latency of each component were explored experimentally. Two external factors levels, colour matching and contrast colour matching were used, while four internal factor levels, frontal area processing, squatting area processing, top area processing, and occipital area processing were used. The results of amplitude and latency variance analyses were shown in tables 1 and 2. The difference in amplitude was not significant, and the main effect of

Table 1

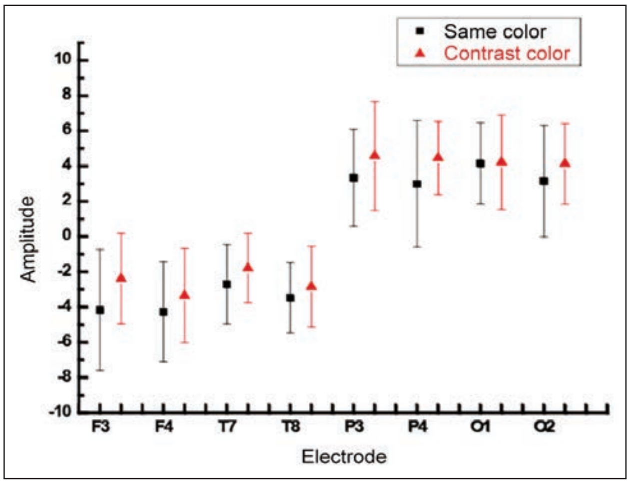
RESULTS OF A P1 AMPLITUDE VARIANCE ANALYSIS

Source	Type III square sum	df	Mean square	F	Sig.
Colour matching	6.065	1.000	6.065	0.540	0.474
Error (colour matching)	168.579	15.000	11.239	-	-
Brain processing	1359.695	1.494	910.268	140.817	0.000
Error (brain processing)	144.836	22.406	6.464	-	-
Colour matching *Brain processing	22.549	1.856	12.147	4.764	0.019
Brain processing (Colour matching *Brain processing)	70.996	27.845	2.550	-	-

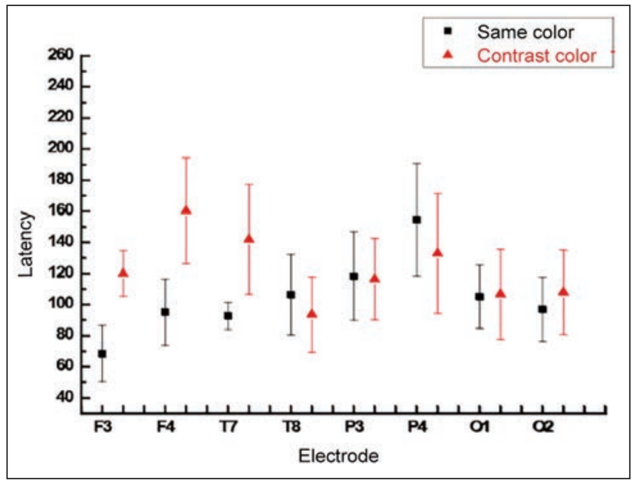
Table 2

P1 LATENCY ANALYSIS OF VARIANCE

Source	Type III square sum	df	Mean square	F	Sig.
Colour matching	10090.877	1.000	10090.877	51.502	0.000
Error (colour matching)	2938.967	15.000	195.931	-	-
Brain processing	13108.193	1.812	7235.708	8.737	0.002
Error (brain processing)	22504.963	27.174	828.181	-	-
Colour matching *Brain processing	21278.506	2.975	7153.407	24.841	0.000
Brain processing (Colour matching *Brain processing)	12848.775	44.619	287.967	-	-



a



b

Fig. 5. Graphical representations of:
a – Mean component amplitude images of P1; *b* – Average component latency of P1

the main effect on the amplitude was significantly differently, while the interaction was also significant. The external and internal factors had significant main effects on early component latency, and the interaction between the two types of factors was also significant.

According to a comparison analysis of the mean value, the same colour and contrast colour were combined to produce negative waves in the frontal and temporal regions, although the same colour system produced higher amplitude than the contrast colour system. Positive waves were produced in the top and occipital regions, and the contrast colour system induced higher amplitude. The amplitude changes induced by the same colour system and contrast colour were consistent in the process from the frontal area to the occipital area, and both are excessively positive waves from negative waves. In the frontal, temporal, and occipital areas, contrast colour matching induced greater latency than same colour matching, indicating that the latter information was transmitted more rapidly in the brain, and the top area information transmission speed is opposite, while the same colour line matches from the frontal area to the occipital area. The results indicating that the speed of information transmission was initially decreased and then increased, the speed of information transmission from the contrast colour matching area to the temporal area changed rapidly, and the top area and the pillow area are smaller.

Analysis of P2 component data

The main effects and interactions of the external and internal factors on the amplitude and latency of each component were explored. The results of amplitude and latency analyses and the main effects of external causes are shown in tables 3 and 4. The difference in amplitude was not significant, and the main effect of the amplitude and the interaction was significant different. Although the main effects of individual external and internal factors were not significant, but the interaction between the two types of factors was significant, indicating that the aesthetic values of different colour collocations during the late processing stage were the result of a combination of brain processing and colour matching. However, the impact of the incubation period duration was not significant.

According to the mean value chart, when two colours were matched, the amplitudes in the frontal and sputum area were negative and changed only slightly, whereas the amplitudes of the top and occipital areas were positive and changed only slightly. The amplitudes were greater in response to same colour matching than to contrast colour matching. When the

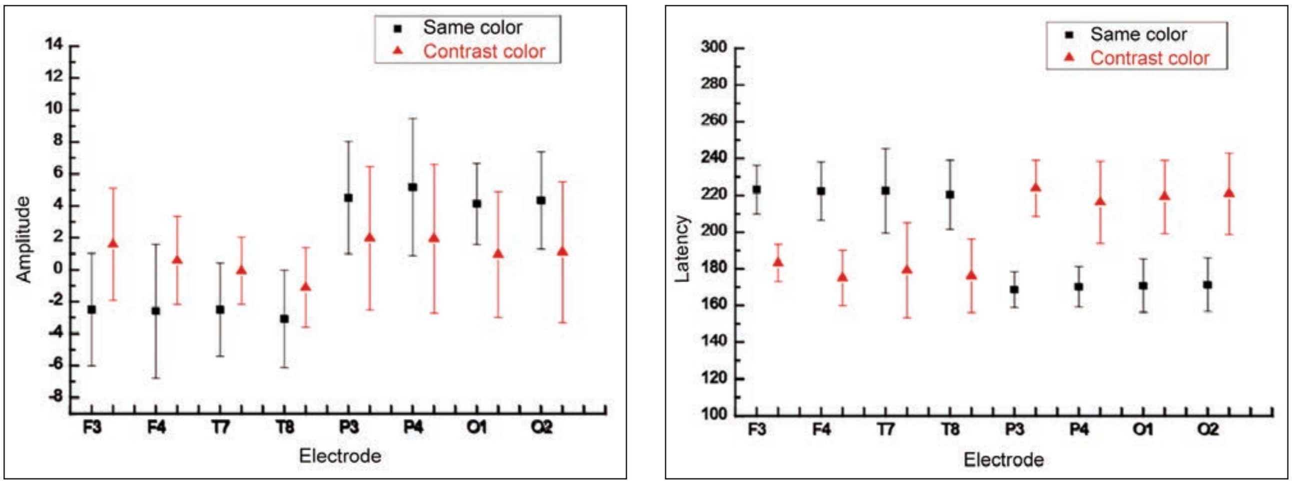
Table 3

RESULTS OF P2 COMPONENT AMPLITUDE VARIANCE ANALYSIS

Source	Type III square sum	df	Mean square	F	Sig.
Colour matching	0.129	1.000	0.129	0.006	0.938
Error (colour matching)	310.021	15.000	20.668	-	-
Brain processing	595.736	1.175	507.056	21.738	0.000
Error (brain processing)	411.083	17.623	23.326	-	-
Colour matching *Brain processing	292.817	1.536	190.676	16.589	0.000
Brain processing (Colour matching *Brain processing)	264.774	23.035	11.494	-	-

Table 4

P2 COMPONENT LATENCY ANALYSIS OF VARIANCE					
Source	**Type III square sum**	**df**	**Mean square**	**F**	**Sig.**
Colour matching	89.445	1.000	89.445	0.178	0.679
Error (colour matching)	7541.992	15.000	502.799	-	-
Brain processing	374.484	1.909	196.209	0.734	0.483
Error (brain processing)	7655.828	28.629	267.415	-	-
Colour matching *Brain processing	74350.352	1.529	48637.705	192.428	0.000
Brain processing (Colour matching *Brain processing)	5795.711	22.930	252.758	-	-



a *b*

Fig. 6. Graphical representations of:
a – Mean component amplitude images of P2; *b* – Average component latency of P2

amplitude of the top and bottom areas in the area began to change, more rapid matching periods were observed in the frontal and temporal areas during same colour matching relative to contrast colour matching. That indicating the transmission speed of contrast colour information was more rapid and that opposite patterns were observed in the top and occipital areas.

Analysis of P3 endogenous component data

The main effects and interactions of external and internal factors on the amplitude and latency were explored. Two external factor levels (same colour matching and contrast colour matching) and three internal factors (frontal area, top zone, and occipital zone processing) were included. The results of amplitude and latency variance analyses were shown in tables 5 and 6. The main effects of internal and external factors, and the interactions between the both did not have significant effects on either amplitudes or latencies of the P3 components. In other words, during the decision-making making stage, the speeds of colour information transmission did not differ significantly within different brain regions, and the information

Table 5

RESULTS OF P3 COMPONENT AMPLITUDE VARIANCE ANALYSIS					
Source	**Type III square sum**	**df**	**Mean square**	**F**	**Sig.**
Colour matching	1.000	5.875	0.307	0.588	
Error (colour matching)	287.059	15.000	19.137	-	-
Brain processing	34.465	2.000	17.233	2.727	0.082
Error (brain processing)	189.566	30.000	6.319	-	-
Colour matching *Brain processing	1.472	1.359	1.083	0.162	0.767
Brain processing (Colour matching *Brain processing)	136.061	20.390	6.673	-	-

Table 6

P3 COMPONENT LATENCY ANALYSIS OF VARIANCE					
Source	**Type III square sum**	**df**	**Mean square**	**F**	**Sig.**
Colour matching	166.251	1	166.251	0.239	0.632
Error (colour matching)	10439.841	15	695.989	-	-
Brain processing	5192.583	1.206	4307.095	3.692	0.064
Error (brain processing)	21096.972	18.084	1166.621	-	-
Colour matching *Brain processing	16.287	1.26	12.925	0.029	0.912
Brain processing (Colour matching *Brain processing)	8358.898	18.902	442.233	-	-

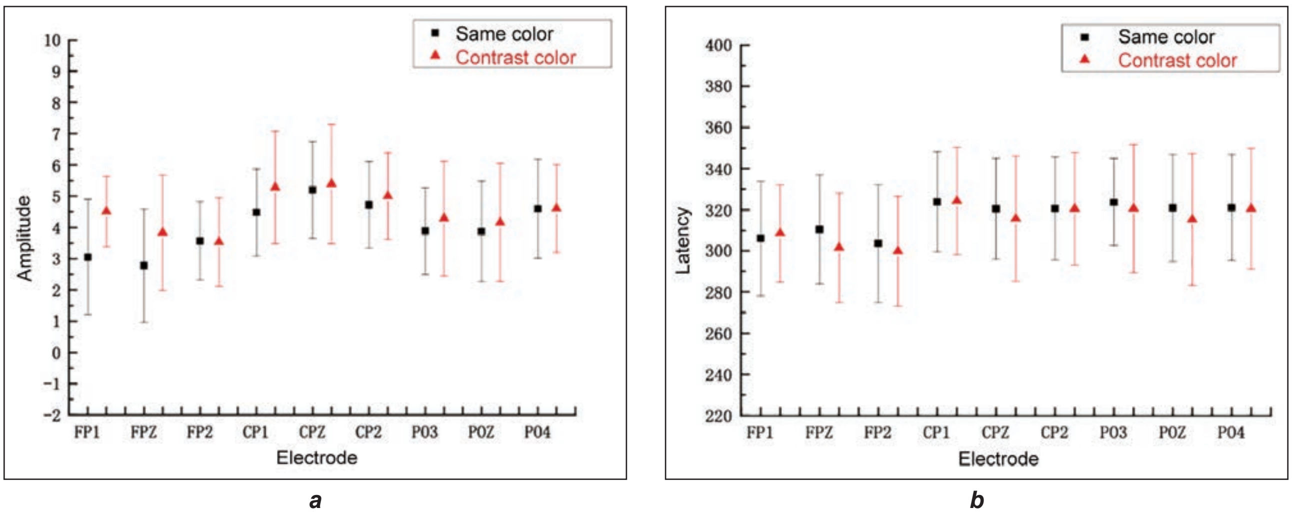


Fig. 7. Graphical representations of:
a – Mean component amplitude images of P3; *b* – Average component latency of P3

transmission speeds among different brain regions were highly similar.

The mean amplitude values suggest that in the decision-making stage, the contrast colour system induced greater than the same colour system in different brain regions. The average value of the amplitudes induced in different brain regions was positive, with the highest amplitude induced in the central-top region followed by the top-pillow area and frontal area. The same colour system induced a higher latency value than the contrast colour system, indicating that the former required a shorter information processing duration and yielded more rapid information transmission in different brain regions. Greater latency was observed in the central-top region and top-pillow region relative to the frontal region, indicating that information processing occurred mainly in the top and pillow areas.

CONCLUSIONS

In this paper, same colour and contrast colour matching tasks were explored by 16 subjects between 18 to 25 years old. The aesthetic evaluation involved both exogenous and endogenous components, each of which affected by different brain regions. The influence of internal and external factors on amplitude and incubation period of each component was different. For P1 component, the information transmission speed of homochromatic system collocation in brain area was faster than that of contrast system collocation. For P2 component, the information transmission speed of the contrast colour system was faster, and the same colour system was slower. For P3 component, the information processing time of the same colour system collocation in different brain regions was shorter, and the information transfer speed was fast. When the subjects evaluated the colour matching of silk fabrics, the top and occipital areas were more sensitive to the matching of the same colour system. The amplitude of P1 and P2 components was larger than that of the matching of the contrast colour system. The frontal and temporal areas were more sensitive to the matching of the contrast colour system. The amplitude of P1 and P2 components was larger than that of the matching of the same colour system. To summarize, the results indicated that, the EEG technology could provide objective visual cognitive aesthetic rules for silk fabric colour matching, and provide reference value for fabric manufacturers to timely understand consumers' preference for fabric colour categories.

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Evaluation of jobs in textile companies from Hidalgo-Mexico, through an instrument for job satisfaction

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ABSTRACT – REZUMAT

Evaluation of jobs in textile companies from Hidalgo-Mexico, through an instrument for job satisfaction

In the Mexican textile industries, State of Hidalgo's especially, conditions as high temperatures, the handling of chemical substances, high noise and vibration levels, humidity, dust and others, continuously exposes workers to associated risks. Diagnosing and proposing improvements by working conditions assessments are not easy to perform, especially if this is not an essential item in the culture of those responsible for carrying them out neither have honest opinions of employees about problems or risks during work hours, without posing a threat to their current labour status. This study aims to assess 420 worker's job post, using an occupational satisfaction instrument finding the lowest rankings in ironing area.

Keywords: *job evaluation, job satisfaction, company, industrial sector, work area*

Evaluarea locurilor de muncă în companiile textile din Hidalgo-Mexic, printr-un instrument de satisfacție profesională

În industria textilă din Mexic, în special în statul Hidalgo, condițiile precum temperaturile ridicate, manipularea substanțelor chimice, nivelurile ridicate de zgomot și vibrații, umiditatea, praful și altele expun continuu lucrătorii la riscurile asociate. Diagnosticarea și propunerea de îmbunătățiri prin evaluările condițiilor de muncă nu sunt ușor de realizat, mai ales dacă acest lucru nu este un element esențial în cultura celor responsabili de realizarea lor și nici nu au păreri oneste ale angajaților despre problemele sau riscurile apărute în timpul orelor de lucru, fără a reprezenta o amenințare asupra statutului lor actual la locul de muncă. Acest studiu își propune să evalueze 420 locuri de muncă, utilizând un instrument de satisfacție profesională, care identifică cel mai scăzut nivel în zona de finisare prin călcare.

Cuvinte-cheie*: evaluarea locului de muncă, satisfacția profesională, companie, sector industrial, zonă de lucru*

INTRODUCTION

This research is part of the Management and Business Development Academic Group's activities in Institute of Economic and Administrative Sciences of The Autonomous University of the State of Hidalgo (UAEH). It was conducted to assess job posts among 420 textile workers in Hidalgo State, Mexico, using an instrument for job satisfaction measurement.

Theoretical evidence has emphasized the importance of knowing factors that affects employees' performance in their jobs [1–3]. This study will contribute to sensitize managers and business owners to allow a larger investigation in a short term, to evaluate and qualify each job in a more technical way, looking to improve productive performance and reduce occupational risks of factors that negatively affect workers health and well-being.

JOBS EVALUATION

Modern businesspersons are more sensitive to technological advances and the environment where their employees carry out their duties in; however, just a few of them really concerns about examining how the job characteristics effects on workers' health. For this reason, it is important for directors, especially those responsible for personnel management, being aware of factors that affect the employees' health and safety, such as the attitudes of workers and accidents at work [4].

In companies, security provided by a healthy work environment implies a reduction in risks at work and suffering professional injuries or illnesses, so, can generate the perception of job satisfaction, physical and mental well-being in employees [5]. Although currently, the Secretary of Labour and Social Prevention in Mexico contemplates regulations and norms in this regard [6], in practice, work environments must ensure safety using different methods and techniques that allow evaluating prevailing conditions at present [7].

Awareness-building strategies are required for some textile companies' owners or managers in Hidalgo-México about importance of employee's safety & health and job satisfaction related to their work position in the company. In other words, before analysing or qualifying job posts in a more technical way, it is important to have initial evidence of signs or symptoms associated with tasks performed by employees in a specific section of the production process [8].

Initially in this research, the textile companies' owners declared that working conditions for their employees were mainly adequate. However, before doing any technical evaluation or qualification of job posts, it was proposed to them to obtain workers opinions and perceptions related to job satisfaction and general characteristics associated with their work positions, since, not only physical risk but also mental risk were important, this two factors combined become occupational well-being, significant for employees life and future [9]. Likewise, owners must understand that success and competitiveness in their organizations strongly depends on professional employee's performance [10].

Job satisfaction is the perceived balance of how and how much job characteristics adapts to worker expectations, causing a positive or negative affective orientation towards the job. It is also conceptualized as a positive emotional state result of a pleasant perception of work experience, alluding to aspects related to both content of the task and degree of interest, challenge, defiance, variety or learning opportunity, such as external conditions like salary, work hours and physical & environmental conditions [11].

Herzberg's motivational theory proposed two types of task-related factors, intrinsic and extrinsic, which produce satisfaction and dissatisfaction. The former are associated with personal development, interest in the task, achievement, recognition, creativity, responsibility and possibility of promotion. The latter refer to organization's policy, quality of supervision, relationships with colleagues, salary and physical or environmental conditions. In addition, other characteristics such as age, education, gender and non-labour circumstances may also affect the levels or degrees of job satisfaction [12].

The purpose of this research was to evaluate the job posts in textile companies in Hidalgo-Mexico, through a job satisfaction instrument in aim of giving recommendations for technical evaluation and care. The study employs a transactional, descriptive and correlational methodology. Data was collected from 420 workers from various textile companies in Hidalgo-Mexico. The job satisfaction scale used consist of 15 items on a 7 point Likert scale that range between "extremely dissatisfied" to "extremely satisfied" (1–7), based on the one created by Warr, Cook and Wall in 1979 and adapted to Spanish language by Pérez and Fidalgo in 1994 [11].

As can be seen in table 1, the means obtained from the 420 workers' opinion ranks below overall average in six factors, considering responses range from 1 to 7. For cases related to "The physical work conditions", "The recognition you get for good work", "Your rate of pay", "The opportunity to use your abilities", "The way the organization is managed" and "The amount of variety in your job"; workers are moderately dissatisfied.

Two factors ranked below 3, "Your chance of promotion/reclassification" and "The attention to suggestions you make", demonstrating that employees are clearly dissatisfied.

Table 1

JOB SATISFACTION IN WORKERS PER ITEM

Item description	Mean
The physical work conditions	3.43
The freedom to choose your own method of working	4.21
Your fellow workers	5.89
The recognition you get for good work	3.92
Your immediate boss	4.85
The amount of responsibility you are given	5.12
Your rate of pay	3.10
The opportunity to use your abilities	3.45
Industrial relations between management and staff	4.26
Your chance of promotion/reclassification	2.95
The way the organization is managed	3.71
The attention to suggestions you make	2.65
Your hours of work	4.62
The amount of variety in your job	3.85
Your Job security	5.20

Exceeding overall average, 7 factors presents satisfactory levels about "The freedom to choose your own method of working", "Your fellow workers", "Your immediate boss", "The amount of responsibility you are given", "Industrial relations between management and staff", "Your hours of work" and "Your job security".

Table 2 shows the employees' levels of satisfaction/dissatisfaction. It is observed that 36.7%, corresponding to 154 workers (sum of last three factors), are included in the range of job satisfaction, while 48.1%, referring to 202 employees (sum of the first three factors), presents levels of satisfaction that goes from very little to practically nothing. Finally, 64 workers (15.2%) have a neutral opinion.

Table 2

OVERALL JOB SATISFACTION IN WORKERS

Measurement factor	Number of workers	Percent (%)
Extremely dissatisfied	16	3.8
Very dissatisfied	54	12.9
Moderately dissatisfied	132	31.4
Not sure	64	15.2
Moderately satisfied	116	27.6
Very satisfied	32	7.6
Extremely satisfied	6	1.4
Total	**420**	**100**

Table 3 exhibits the means obtained in each working area inside the textile companies', finding the lowest scores in ironing, sewing and finishing areas. Only three areas show scores above average, protruding

Table 3

EMPLOYEES' JOB SATISFACTION PER WORKING AREA		
Working area	**N**	**Mean**
Spinning	55	3.62
Cutting	70	3.11
Sewing	82	2.44
Ironing	56	1.88
Finishing	42	2.80
Packaging	35	3.22
Designing	25	3.91
Warehouse	30	4.14
Others	25	3.57
Total/mean	420	3.23

the warehouse. General average of areas ranks below the mean, indicating that workers are not satisfied with the conditions they work in.

Finally, table 4 shows the regression analysis between levels of Job Satisfaction and the less qualified working area (Ironing). It presents a p-value (significance) less than 0.05, in "The physical work conditions", "Your immediate boss" and "Your rate of pay", which indicates a relation with the outcome (dependent) variable, ironing working area.

CONCLUSIONS

The Job Satisfaction scale used to collect data from 420 workers of various textile companies reflects work force's opinion. Obtained means were found below the elements or dimensions means (from lowest to least low), associated to the attention to suggestions, chance of promotion, salary, physical work conditions and opportunity to use own abilities.

In general, dissatisfaction levels perceived by the textile companies' workers is close to 50%, allowing to understand that, perhaps, employees' need to have a job is superior than the level of acceptance related to their expectations associated with the position they occupy, salary, general working conditions or another factors.

Considering that worst ranked area was ironing, its correlational analysis with each factor of scale's job satisfaction scale indicated a positive relationship with physical work conditions, your immediate boss and your rate of pay, supporting the first findings.

It is common for many textile companies in State of Hidalgo, Mexico being family businesses that managed their gradually growth based on their installed capacity, number of clients and assets or, at least, remaining within the field, nevertheless, operating conditions, both physical and environmental, have not improved in the same proportion.

This study reflects only the satisfaction levels comparison with one working area, so it is important to extend a research to the other areas and deepen into factors that could explain, more precisely, associated aspects to the managers or companies 'owners characteristics and profiles, which contributes to understand why growing has not been homogeneous.

In conclusion, based on these study findings, carrying out, in the short term, investigations that allows

Table 4

REGRESSION ANALYSIS TO EXAMINE THE IRONING WORKING AREA AS THE OUTCOME VARIABLE						
Item description	**Model 1**		**Model 2**		**Model 3**	
	Coefficient Std. β	**p**	**Coefficient Std. β**	**p**	**Coefficient Std. β**	**p**
The physical work conditions	–0.031	0.734			0.289	0.000
The freedom to choose your own method of working	0.302	0.610				
Your fellow workers	0.019	0.752				
The recognition you get for good work	0.043	0.605				
Your immediate boss	0.185	0.047	0.136	0.047	0.156	0.022
The amount of responsibility you arc given	0.063	0.445				
Your rate of pay			–0.158	0.022	–0.161	0.020
The opportunity to use your abilities	–0.023	0.823				
Your chance of promotion/reclassification	0.004	0.953				
The way the organization is managed	–0.085	0.190				
The attention to suggestions you make	0.006	0.931				
Your hours of work	–0.010	0.869				
The amount of variety in your job	0.091	0.161				
Your job security	0.045	0.496				

evaluating or qualifying job posts technically is the next step to follow, in order to lay foundations for every associated conditions and propose changes that allows improving employees' performance, decreasing health risks and increasing job satisfaction.

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Analysis of heat transfer and factors affecting the thermal properties on rib 1x1 knitwear

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ABSTRACT – REZUMAT

Analysis of heat transfer and factors affecting the thermal properties on rib 1x1 knitwear

Clothing comfort is very important feature which is considered as a result of different process of heat exchange between human body, clothing and environment. The purpose of this paper is to analyse the impact of clothing insulation on the heat transfer. The measurements were carried out on commercially 1x1 RIB knitted fabrics used for the production of next-to-skin shirts. The one group of samples are made from 100% cotton yarn and another with 96% cotton and 4% lycra. It is noticed that knitted material composition affected the change in heat resistance. Also, this paper presents and verifies the correlation between the measured values of thermal resistance (Rct) and the knitwear thickness (dpl), the covering factor (K), the porosity of the twists (ε) and the surface coefficient (δ_p). Based on these results, a mathematical model for calculating thermal resistance is proposed. Comparing the results obtained with the proposed equation and the measured results, we can see that the deviations are minimal. The highest deviation for sample C4 is 0.05%, while the largest deviation for sample CL4 is 4.6%.

Keywords: *RIB knitwear, heat transfer, thermal resistance, porosity, tightness factor, surface coefficient*

Analiza transferului de căldură și a factorilor care influențează proprietățile termice ale tricoturilor patent 1x1

Confortul vestimentar este o caracteristică foarte importantă, care este luată în considerare ca urmare a unui proces de schimb de căldură între corpul uman, îmbrăcăminte și mediu. Scopul acestei lucrări este de a analiza impactul izolației produselor de îmbrăcăminte asupra transferului de căldură. Măsurătorile au fost efectuate pe tricoturi patent 1x1 pentru producerea bluzelor care intră în contact direct cu pielea. Un grup de probe este realizat din 100% fire de bumbac și altul cu 96% bumbac și 4% lycra. Se observă că, compoziția tricotului influențează rezistența termică. De asemenea, această lucrare prezintă și verifică corelația dintre valorile măsurate ale rezistenței termice (Rct) și grosimea tricotului (dpl), factorul de acoperire (K), porozitatea (ε) și coeficientul de suprafață (δ_p). Pe baza acestor rezultate, este propus un model matematic pentru calcularea rezistenței termice. Comparând rezultatele obținute cu ecuația propusă și rezultatele măsurate, putem observa că abaterile sunt minime. Cea mai mare abatere pentru eșantionul C4 este de 0,05%, în timp ce cea mai mare abatere pentru eșantionul CL4 este de 4,6%.

Cuvinte-cheie: *tricot patent, transfer de căldură, rezistență termică, porozitate, factor de etanșeitate, coeficient de suprafață*

INTRODUCTION

Technological and scientific development largely enabled manufacturing of high quality textile products. In order to successfully participate in market competition, many manufacturers today are investing significant resources in research and development of products tailored to the needs of man. Clothing wear comfort is one of the key factors during the clothes selection, and a decisive factor in the evaluation of the clothing quality. The garments can be seen as a heat exchange layer between the body and its environment, and contemporary requirements regarding clothing comfort are much higher than in the past [1].
Thermal comfort, which is an important factor when designing a garment, is closely linked to the behaviour of heat transfer in clothes [2]. Thermo-physiological comfort is directly related to physiological processes of human body and is the result of the balanced process of heat exchange between the human body, the clothing system and the environment [1].
The body's heat control centre is located in the brain and regulates the transmission of heat by the flow of blood through blood vessels, capillaries to the surface of the skin and the sweat secretion. In order to control the heat exchange, we can protect the body against overheating as well as against freezing. In this case, physical regulation controls heat exchange, and chemical regulation controls thermal processes. The body is heated with thermal energy that is obtained from the energy from the degradation of the molecule, and fats. Heat transfer can occur by radiation R, convection C, conduction K, evaporation E, and respiration Eres (figure 1) [3, 4].
Radiation heat transfer occurs constantly between the body and the environment in which the body

resides, i.e. in both directions, depending on the difference in body temperature of the skin and the temperature of other surfaces. The average heat loss by radiation varies, and in moderate climatic reactions can range from 40 to 60%. Convection is the process of losing heat by moving air or water molecules through the skin [5]. The higher the speed of air movement, the greater the temperature difference between the body and the surrounding air, and the larger the surface area of the body, the greater the degree of heat transfer. If the air temperature is lower than the skin (and clothing) temperature, the heat convection is positive and the temperature is released from the body to the environment. If the air is warmer than the skin temperature, the heat convection is negative and the body receives heat from the air. Convection becomes more and more effective in removing heat as air temperature drops and air movement increases [6].

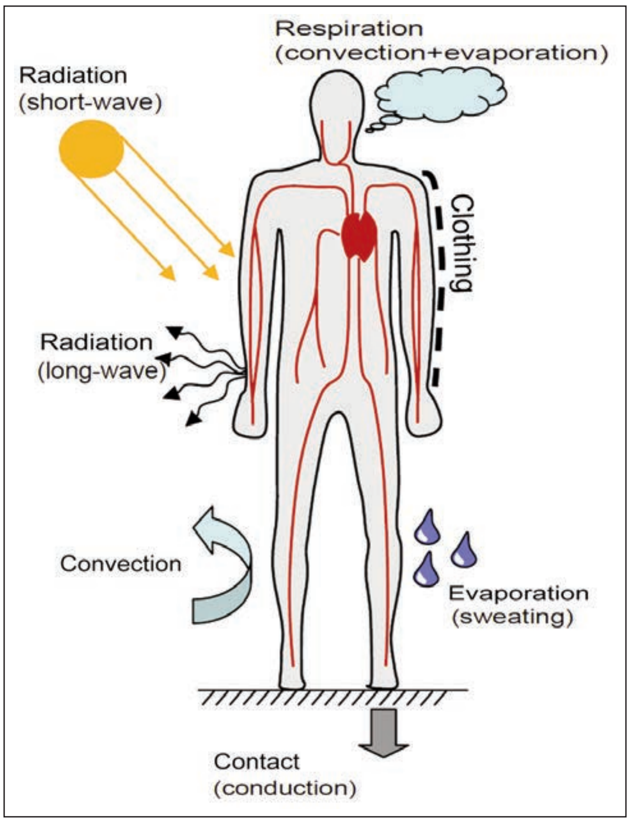

Fig. 1. Heat transfer over the human body [4]

Under normal conditions, about 30% of heat is exchanged by this type of heat transfer between the body and the environment. The amount of heat transmitted by conduction is much smaller than the amount transmitted by convection and it is essential when people are in contact with cold objects [7]. The exchange of heat by conduction is 15% of the total heat transfer, primarily depends on the subject and the material that is in contact with the skin [8, 9]. Conductivity allows us to lose heat over the soles or body when lying or sitting on a cooler surface. Heat transfer by sweat evaporation is always present and it increases in hot environment. If environment temperature rises over a comfortable body temperature, hot skin secretes depend on moisture quantity on the skin and the difference between water vapor pressures on the skin and in environment. In a human being, evaporation is always present [10].

The thermal properties of clothing that demonstrate the ability to transfer heat and moisture from the surface of the human body to the environment are the dominant determinants of the thermal comfort of clothing. The measuring values that are related to the ability to evaluate the heat exchange of the human body with the environment, and are related with the human perception of comfort are thermal resistance or thermal insulation (*Rct*) and resistance to water vapour flow on clothing (*Ret*). The impact of clothing and air trapped in clothing and around the body can be assessed by thermal comfort properties, which provide the ability to assess the effect of clothing on thermal balance in a particular environment [1].

Thermal balance in the body is achieved by balancing the amount of heat that the body produces and the heat that the body exchanges with the environment [11]. The equation that defines the thermal balance includes three terms: a term that defines the production of heat in the body, heat transfer and accumulation [3]. The thermal balance in the body is achieved according to the following expression [11]:

$$M_0 = W + R_t + K_v + K_D + E + L_v + S \qquad (1)$$

where M_0 is the total amount of produced energy calculated from the oxygen consumption, W – external work, R_t – heat loss by radiation, K_v – heat transfer, K_D – heat guidance, E – evaporation, L_v – warming and humidification of air caused by inhalation/exhalation, S – the accumulation of heat in the body.

The comfort zone in which a person feels comfortable ranges from 20 to 23 °C. This zone depends on many factors but the most important are: type of clothing, season, diet, gender, habits, etc.

Established body temperature balance does not automatically mean good comfort, as a person may feel uncomfortably warm due to sweating or uncomfortably cold due to low skin temperatures [12].

The aim of this paper is to investigate the influence of structural characteristics (knitwear's thickness, porosity, covering factor and surface coefficient) on the thermal resistance of *Rct* in ribbed 1×1 knitwear. The effect of incorporation of elastane fibres into the knit structure on thermal resistance was also analysed. For this purpose ribbed 1×1 knitwear are made with four different densities of yarn made from 100% cotton and from a mixture of cotton/elastane yarns.

Thermal resistance (Rct)

The thermal resistance (*Rct*) is the thermal insulation of the material and is inversely proportional to the thermal conductivity, as shown by the equation [13]:

$$Rct = \frac{h}{\lambda}\ (m^2 K/W) \qquad (2)$$

In dry materials or in materials containing very little water, it depends on the thickness of the material (*h*) and the conductivity of the fibres (λ).

MATERIALS AND METHODS

Experimental part of this paper was carried out using the knitwear that is commercially used for the production of clothes of next-to-skin-wear. This kind of clothes are worn either as one-layer summer wear or as the first layer that is in contact with human skin in cooler season of the year. The knitwear samples are produced with 1×1 RIB structure. Samples are made of 100% CO yarns and CO yarns in combination with Lycra (96% CO/4% LY). Linear density of Lycra which was used is 44 dtex. CO yarn was used in four linear densities: 20 tex, 17, 14 and 12 tex. Samples in the raw state and stained samples were examined (table 1).

Knitwear is made on a circular knitting machine type Fv 2.0 of company Mayer & Cie. Characteristics of the machine are as follows: cylinder diameter 19" (inch), the gauge is E18 and with 40 feeders, the knitting speed is 1.7 m/s. All of the samples are knitted under the same conditions on the same machine.

A measuring device used to test the thermal characteristics of knitwear samples was KES FB 7 – Thermo Labo II.

The correlation analysis is used to compare the relation between the resulting values of thermal resistance (*Rct*) and the resulting values of mass per unit area (*m*), porosity (ε), surface coefficient (δ_p) and tightness factor (*K*). The correlation coefficients present the strength of the association between two variables. The coefficient of determination (R^2), was used to measure the strength of the linear association between variables. The value of coefficient of determinations ranges between –1 and 1. The positive value of coefficient of determination means that the values obtained with two methods are proportionally linear. If the coefficient of determination is +1 this presents the maximum of positive correlation. If the correlation coefficient is zero, this means zero correlation.

RESULTS AND DISCUSSION

Experimentally obtained results of mass per unit area, porosity, tightness factor and volume coefficient and thermal resistance are presented in table 2.

The correlation between the thermal resistance and mass per unit area, volume coefficient, porosity and tightness factor are shown in figures 2–9.

It can be seen from the previous considerations that there is a correlation between the parameters of knitwear and the resistance to heat transfer of the same knitwear. Therefore, a suitable mathematical model is proposed to calculate the Rct values of the ribbed knit fabric samples tested, based on the experimentally measured values of knit thickness (*dpl*), coverage factor (*K*), surface coefficient (δ_p) and porosity (ε). The coefficients for the proposed formula are shown in table 3 and figure 10 and they are given separately for 100% cotton bleached ribbed knitwear made of cotton yarns 20, 17, 14 and 12 tex, for 100% cotton ribbed coloured knitwear knitted of cotton yarns 20, 17, 14 and 12 tex, for ribbed bleached knitwear of 96% cotton and 4% lycra woven from cotton yarns of fineness 20, 17, 14 and 12 tex and for ribbed dyed fabrics of 96% cotton and 4%

Table 1

BASIC CHARACTERISTICS OF ANALYZED KNITWEAR'S SAMPLES

Sample	Structure	Fibre composition	Linear density (tex/dtex)	Twists (m^{-1})	Finishing
B_1	1×1 RIB	100% CO	20	780	bleached
B_2	1×1 RIB	100% CO	17	804	bleached
B_3	1×1 RIB	100% CO	14	929	bleached
B_4	1×1 RIB	100% CO	12	977	bleached
BL_1	1×1 RIB	96% CO/4% LY	20/44	780/0	dyed
BL_2	1×1 RIB	96% CO/4% LY	17/44	804/0	dyed
BL_3	1×1 RIB	96% CO/4% LY	14/44	929/0	dyed
BL_4	1×1 RIB	96% CO/4% LY	12/44	977/0	dyed
C_1	1×1 RIB	100% CO	20	780	bleached
C_2	1×1 RIB	100% CO	17	804	bleached
C_3	1×1 RIB	100% CO	14	929	bleached
C_4	1×1 RIB	100% CO	12	977	bleached
CL_1	1×1 RIB	96% CO/4% LY	20/44	780/0	dyed
CL_2	1×1 RIB	96% CO/4% LY	17/44	804/0	dyed
CL_3	1×1 RIB	96% CO/4% LY	14/44	929/0	dyed
CL_4	1×1 RIB	96% CO/4% LY	12/44	977/0	dyed

Table 2

EXPERIMENTALLY OBTAINED RESULTS OF MASS PER UNIT AREA, POROSITY, TIGHTNESS FACTOR AND VOLUME COEFFICIENT AND THERMAL RESISTANCE

Sample	Knitwear thickness d_{pl} (mm)	Porosity ε	Surface coefficient δ_p	Tightness factor K ($\sqrt{tex}$/cm)	Thermal resistance R_{ct} (m^2Kw^{-1})
B_1	1.073	0.88	1.16	15.8	0.0726
B_2	1.062	0.89	1.23	14.4	0.0745
B_3	0.965	0.91	1.32	13.4	0.0772
B_4	0.914	0.92	1.40	12.4	0.0786
BL_1	1.217	0.85	0.84	15.9	0.0676
BL_2	1.171	0.86	0.90	14.6	0.0705
BL_3	1.205	0.89	0.92	13.2	0.0719
BL_4	1.164	0.89	0.96	12.2	0.0768
C_1	1.116	0.87	1.16	15.7	0.0711
C_2	1.036	0.89	1.11	14.4	0.0737
C_3	1.002	0.91	1.31	13.5	0.0763
C_4	0.920	0.91	1.38	12.5	0.0785
CL_1	1.225	0.85	0.86	15.9	0.0654
CL_2	1.228	0.87	0.86	14.5	0.0675
CL_3	1.196	0.88	0.93	13.0	0.07
CL_4	1.158	0.89	0.96	12.1	0.0774

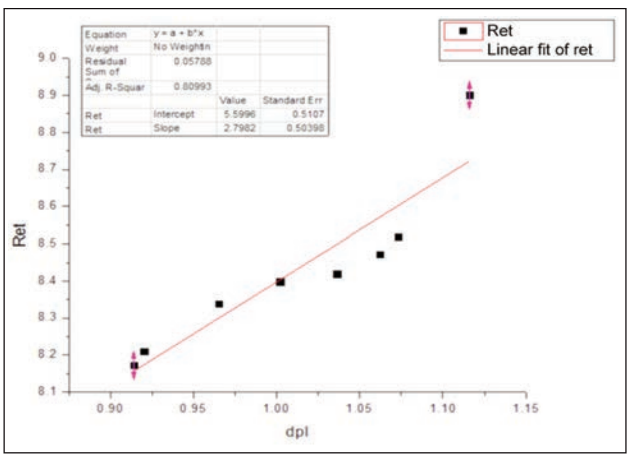

Fig. 2. Relationship between Rct and mass in 100% CO bleached and dyed knitwear, $R^2 = 0.8099$

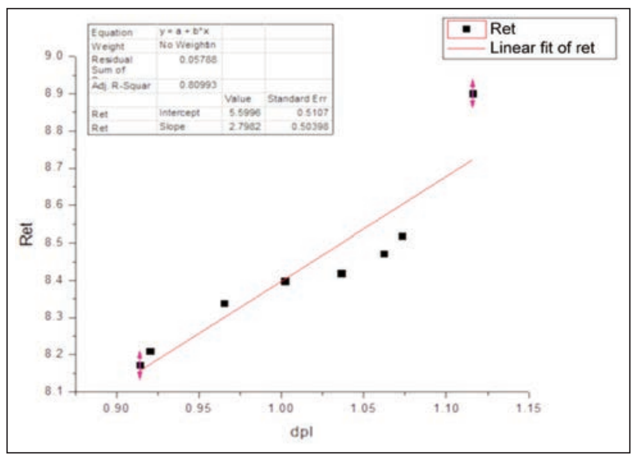

Fig. 3. Relationship between Rct and mass in 96% CO/4% LY bleached and dyed knitwear, $R^2 = 0.9675$

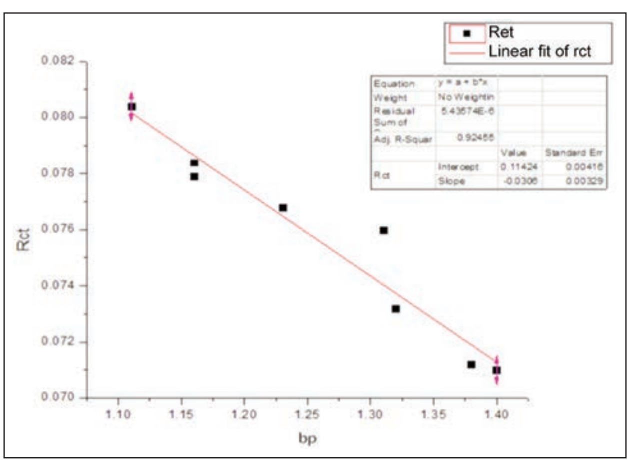

Fig. 4. Relationship between Rct and δ_p in 100% CO bleached and dyed knitwear, $R^2 = 0.92455$

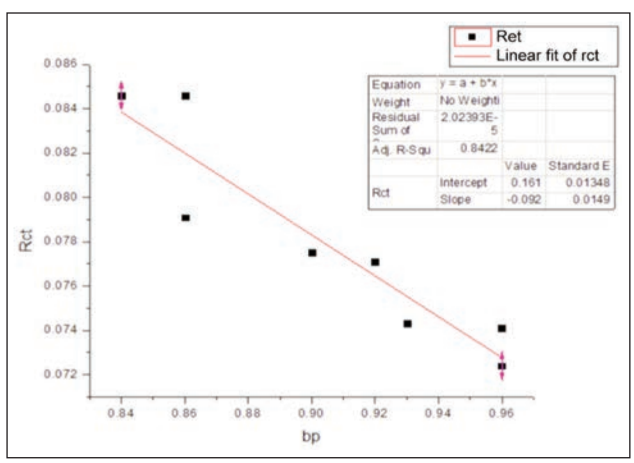

Fig. 5. Relationship between Rct and δ_p in 96% CO/4% LY bleached and dyed knitwear, $R^2 = 0.8422$

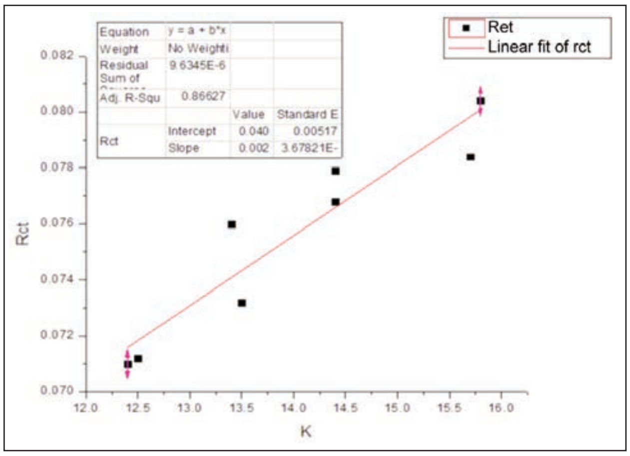

Fig. 6. Relationship between Rct and K in 100% Co bleached and dyed knitwear, $R^2 = 0.86627$

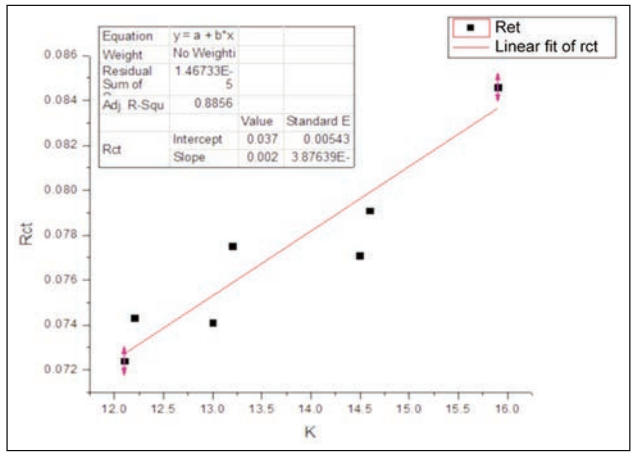

Fig. 7. Relationship between Rct and K in 96% Co/4% Ly bleached and dyed knitwear, $R^2 = 0.8856$

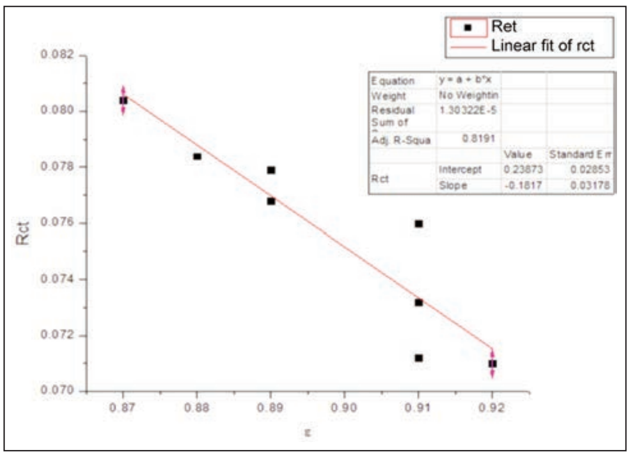

Fig. 8. Relationship between Rct and K in 100% CO bleached and dyed knitwear, $R^2 = 0.8191$

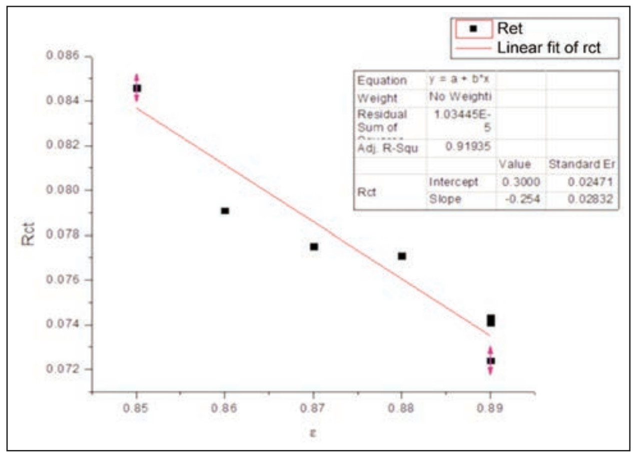

Fig. 9. Relationship between Rct and K in 96% CO/4% LY bleached and dyed knitwear, $R^2 = 0.9193$

Table 3

VALUES OF COEFFICIENTS USED FOR CALCULATING RCT BLEACHED AND COLORED RIBBED 1×1 KNITWEAR					
Sample	**Finishing**	**Coefficient c_1**	**Coefficient c_2**	**Coefficient c_3**	**Coefficient c_4**
BP1-BP4	bleaching	–0.000252	0.018443	0.016669	–0.35311
CP1-CP4	colouring	0.000089	0.000366	–0.00096	0.07245
BL1-BL4	bleaching	0.000038	0.01346	0.02263	–0.3662
CL1-CL4	colouring	0.00174	0.00225	0.1167	–1.5693

lycra woven from cotton yarn of fineness 20, 17, 14 and 12 tex.

The mathematical model for calculating the value of Rct has the following form:

$$Rct = c_1 \cdot d_{pl} + c_2 \cdot K + c_3 \cdot \delta_p + c_4 \cdot \varepsilon \qquad (3)$$

where c_1, c_2, c_3, c_4 are coefficients, d_{pl} – knitwear thickness, K – coverage factor, δ_p – surface coefficient, ε – knitwear porosity.

CONCLUSIONS

According to the conducted research of the impact of yarn thickness and raw material composition, i.e. the influence of lycra on thermal resistance in ribbed knitwear, following can be concluded:

- Knitwear that, beside cotton yarn, have lycra in their composition, are more compact and therefore heat resistance increases with these samples.
- With a change in the fineness of the cotton yarn i.e. with a decrease in the thickness of cotton yarn and thermal resistance decreases by 13% in cotton yarn knitwear and up to 16% in knitwear with lycra in its composition. From the obtained results we can conclude that in knitwear made from 100% cotton yarn, the fineness of 12 tex shows the lowest

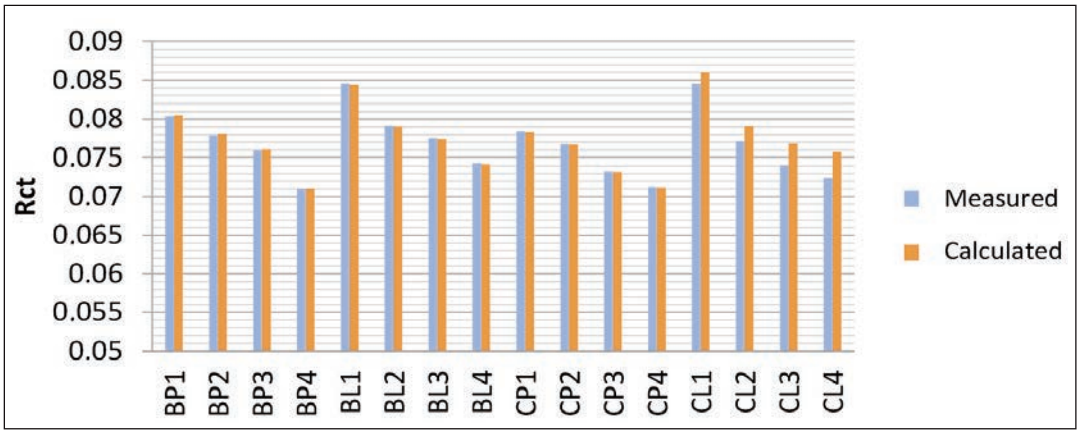

Fig. 10. Graphical representation of the deviations between calculated and measured values of Rct

thermal resistance. While the highest thermal resistance is observed in knitwear that has lycra and cotton yarns of fineness 20 tex in their composition.

Also, this paper presents and verifies the correlation between the measured values of thermal resistance (*Rct*) and the knitwear thickness (*dpl*), the covering factor (*K*), the porosity of the twists (ε) and the surface coefficient (δ_p). Based on these results, a mathematical model for calculating thermal resistance is proposed. Comparing the results obtained with the proposed equation and the measured results, we can see that the deviations are minimal. The highest deviation for sample C4 is 0.05%, while the largest deviation for sample CL4 is 4.6%.

Based on the results obtained, we can conclude that knitwear intended for wearing to the body are made of 100% cotton yarn have lower values of heat resistance and are recommended for wearing in warmer weather, while knitwear with lycra is recommended for wearing to the body in colder weather due to higher thermal insulation results.

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Effects of wetting and compression/recovering time on the compressional behaviour of sanitary napkin layers

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ABSTRACT – REZUMAT

Effects of wetting and compression/recovering time on the compressional behaviour of sanitary napkin layers

Sanitary napkins are technical textile products which are used by women. They are designed as layered structures to fulfil several end–use properties at the same time. One of the most important properties of sanitary napkins is absorption property and this is widely studied in the literature. On the other hand, formability and sensorial comfort of sanitary napkins are of great importance but they are ignored during scientific researches. During daily life, women sit or sleep for certain time intervals and their sanitary napkins are exposed to compressional forces. If the sanitary napkin will squeeze and not recover, this can result with poor sensorial comfort and low formability. Also, wetting of sanitary napkins during usage can worsen the compressional properties. Therefore in this study, effect of wetting and compression/recovering time on the compressional behaviours of sanitary napkins was evaluated. Study was focused on separate sanitary napkin layers in order to detect the most problematic layers. Two compression times and four recovering times were applied to samples for compression tests. Also, sanitary napkin layers were characterised by scanning electron microscopy, unit mass, thickness and bending measurements. According to results, top sheet layer was the most compressible layer in dry and wet states. This is expected to give a soft and resilience sense to the sanitary napkin. Absorbent layer was responsible for low compressibility of sanitary napkins under different compression/recovering times. Bending rigidity of absorbent layer was the highest in dry state but it exhibited a dramatic decrement after wetting.

Keywords: *sanitary napkin layers, dry compressibility, wet compressibility, thickness loss, compression-recovery time, bending behaviour*

Influența umectării și timpului de comprimare/revenire asupra comportamentului la compresie al straturilor tampoanelor igienice

Tampoanele igienice sunt produse textile tehnice care sunt utilizate de către persoane de sex feminin. Acestea sunt concepute ca structuri stratificate pentru a îndeplini mai multe cerințe de utilizare finală în același timp. Una dintre cele mai importante proprietăți ale tampoanelor igienice este proprietatea de absorbție și aceasta este studiată pe larg în literatura de specialitate. Pe de altă parte, formabilitatea și confortul senzorial al tampoanelor igienice sunt de o mare importanță, dar sunt ignorate în timpul cercetărilor științifice. În viața de zi cu zi, femeile stau în poziție șezând sau dorm în anumite intervale de timp, iar tampoanele igienice pe care le poartă sunt expuse forțelor de compresie. Dacă tamponul igienic se va stoarce și nu își va reveni, acest lucru poate avea ca rezultat un confort senzorial scăzut și o formabilitate redusă. De asemenea, umezirea tampoanelor igienice în timpul utilizării poate agrava proprietățile de compresie. Prin urmare, în acest studiu, a fost evaluat efectul umectării și al timpului de comprimare/revenire asupra comportamentului la compresie al tampoanelor igienice. Studiul s-a axat pe straturi de tampoane igienice separate pentru a detecta cele mai problematice zone. Doi timpi de comprimare și patru timpi de revenire au fost aplicați probelor pentru testele de compresie. De asemenea, straturile tampoanelor igienice au fost caracterizate prin microscopie electronică de scanare, determinarea masei, grosimii și capacității de îndoire. Conform rezultatelor, stratul superior a fost cel mai compresibil strat în stare uscată și umedă. Se așteaptă ca acest lucru să ofere un tușeu moale și rezistență tamponului igienic. Stratul absorbant a fost responsabil pentru compresibilitatea scăzută a tampoanelor igienice în diferite perioade de comprimare/revenire. Rigiditatea la îndoire a stratului absorbant a fost cea mai ridicată în stare uscată, dar a prezentat o scădere dramatică după umectare.

Cuvinte-cheie*: straturi ale tamponului igienic, compresibilitate uscată, compresibilitate umedă, pierderi de grosime, timp de revenire din compresie, comportament la îndoire*

INTRODUCTION

Sanitary napkins are a member of absorbent/disposable hygiene products and they are used by women to collect the menstrual fluids hygienically. Sanitary napkins are layered materials to fulfil different end-use properties at the same time. In an ordinary sanitary napkin, there are 4 distinct layers. These layers include textile and film structures. The first layer is the porous top sheet film that is in contact with the body. Top sheet layer is designed to transfer the menstrual flow to the inner parts of the sanitary napkin, faster. Under the top sheet, acquisition-distribution layer (ADL) exists. ADL is responsible of taking the menstrual fluid from the top sheet and transfer it to the absorbent layer. Absorption layer takes the fluid and usually stores it in the gel form. The composition and structure of the absorbent layer may change. The last layer is the back sheet film. Back sheet has additional adhesive tapes for preventing shifting [1–3]. For ADL and absorbent layers, nonwoven structures are used as they are faster to produce, they can absorb high amounts of liquid and they are comfortable [4].

A sanitary napkin should exhibit many properties such as absorbability, leakage prevention, odour prevention, comfort, mobility, fit to the body contour and etc. In the literature, researches are usually focused on the absorption and moisture management properties of absorbent layer. For example; Karakurd Elma et al. investigated the effect of absorbent layer thickness and the ratio of superabsorbent polymer particles on the acquisition time and liquid acquisition capacities [5]. Wijesingha and Perera examined the usability of corn-husk fibres as the absorbent layer [6]. Das et al. produced absorbent layers with different concentrations of superabsorbent viscose fibres and tested their properties [7]. Similar research works can be found in the literature on sanitary napkins, incontinence pads or baby diapers [4, 8–14]. In addition, there are some survey and field studies in the literature, which question the sanitary napkin usage, perception, accessibility etc. in local places such as African countries and India [15–22]. As seen from the literature search, the studies on sanitary napkins are frequent on absorption properties. But in fact, some other properties such as bending rigidity and compressional behaviour of sanitary napkins are of great importance but they have been ignored during scientific researches.

During usage, sanitary napkins are subjected to compressive forces as a result of moving, sitting, sleeping and other daily actions. The compression and subsequent thickness recoveries of sanitary napkins are repeated during the day. This can lead to fragmentations in nonwoven content and cause shape changes during usage. As a result, the wearer can feel discomfort and experience leakage. Also, compression can change the porosity, hydraulic and absorption properties of nonwoven layers. This can also adversely affect the absorptive performance of sanitary napkins [23–26]. In addition, compressibility is related to softness and fullness of the textile structures [27]. So the compressional behaviour like compressibility and thickness recovery should be provided in order to maintain the hand and sensorial comfort properties of sanitary napkins.

Another ignored research field for sanitary napkins is flexibility, in other terms, bending behaviour. Sanitary napkins are fixed to underwear by means of adhesive layer and wings. Because of the layered and voluminous structure of the sanitary napkin, it can resist getting the shape and it can give discomfort to the user. A sanitary napkin serves with partially dry and partially wet parts during menstruation. It is known that textile structures may exhibit different properties in dry and wet conditions [28]. So the properties of dry and wet sanitary napkins should be tested, separately.

In the context of this study, by considering the literature search, compressional properties and bending behaviour of sanitary napkin layers were investigated both in dry and wet states. To determine the time dependency, compressional behaviours were evaluated for 2 compression times and 4 recovering times. The research especially targeted the sanitary napkin layers to make comparisons between them and decide the main layer which affects the aforementioned mechanical properties of the end-product. It was aimed to close the lack about this subject in the literature.

MATERIALS AND METHODS

Materials

Materials of this study consisted of a commercial sanitary napkin and its separate 4 layers. The samples were supplied from a Turkish company (Kocaeli, Turkey). Properties of the layers and the sanitary napkin are given in table 1. Top sheet and back sheet layers were both polyethylene (PE) films but they were differed by the production technology. Other two layers, namely ADL and absorbent layers were nonwoven fabrics. They were composed of wood pulp and superabsorbent polymer (SAP).

Methods

Microscopic evaluation

Surface topographies of sanitary napkin layers were evaluated by using scanning electron microscope (SEM) (Jeol 6060). Energy of 5 kV was applied during operation. Both front sides and back sides of sanitary napkin layers were observed with 30 times magnification. Also 75 and 200 magnification levels were used for measurements.

Table 1

MATERIALS OF THE STUDY

Material	Layer name	Sample code	Raw materials	Production technology
1st layer	Top sheet	TS	PE	Perforated film
2nd layer	ADL	ADL	Pulp	Airlaid nonwoven
3rd layer	Absorbent layer	ABL	Pulp+SAP	Airlaid nonwoven
4th layer	Back sheet	BS	PE	Film
Sanitary napkin	Gathered	SN	-	-

Determination of unit mass and thickness

Unit mass of samples were determined according to TS EN 29073-1 standard by using an electronic balance [29]. Thickness of samples were determined according to TS 7128 EN ISO 5084 standard by using James Heal RxB Cloth Thickness Tester under 5 g/cm^2 thickness test pressure [30]. Thickness and unit mass measurements were repeated 5 times for each sample type.

All the tests were performed under standard atmosphere conditions (65 ± 4% relative humidity and 20 ± 2°C) after being conditioned for 24 hours.

Determination of thickness loss and compressibility

Sanitary napkins are exposed to compression loads while sitting, sleeping, walking and working for different time intervals during the day. In this study, an experimental setup was built in order to simulate the compressional forces on the sanitary napkin. According to a study [31], where the pressure maps of 68 people (36 of them were women) were obtained while sitting on a wood seat model, the maximum pressure was detected as 0.1059 kgf/cm^2 (105.9 gf/cm^2) and it dropped to 0.053 kgf/cm^2 (53 gf/cm^2) when sat to a pressure absorbing seat material. As the sanitary napkin partially faces the compression load during sitting, 50 gf/cm^2 load was selected for simulating real life conditions.

Samples were placed on a wood platform and a static load of 50 gf/cm^2 was applied on them. The duration of load application was selected as 2 h and 4 h. After the stated time intervals, the load was removed and thickness of samples were measured under 5 and 50 g/cm^2 thickness test pressures after predetermined time intervals (immediately after load removal (0 min.) and 2, 5 and 10 min. after load removal). Also thickness of samples was measured before loading. By using the measured thickness results, compressibility and thickness loss values of samples were calculated according to equations 1 and 2 [32, 33]:

$$\text{Compressibility} = C = \frac{t_5 - t_{50}}{t_5} \times 100 \ (\%) \qquad (1)$$

where t_5 is thickness measured under 5 g/cm^2 thickness test pressure, t_{50} – thickness measured under 50 g/cm^2 thickness test pressure.

$$\text{Thickness loss} = t_l = \frac{t_i - t_r}{t_i} \times 100 \ (\%) \qquad (2)$$

where t_i is initial thickness (thickness before loading), t_r – recovered thickness (thickness after 0, 2, 5 and 10 min. after load removal).

Compressibility values were calculated for all time intervals (before loading and 0, 2, 5 and 10 min. after load removal). Also, thickness loss values were calculated for all time intervals and for 5 g/cm^2 and 50 g/cm^2 thickness test pressures. t_i and t_r values are schematized in figure 1.

Determination of bending behaviour

Bending rigidity of sanitary napkin and sanitary napkin layers were determined according to ASTM D 1388-B standard (Heart Loop Method) [34]. Sample dimensions were 2.5 cm × 25 cm and test dimensions were 2.5 cm × 20 cm. Bending rigidity of samples was determined in the machine direction by considering the shape of the sanitary napkin.

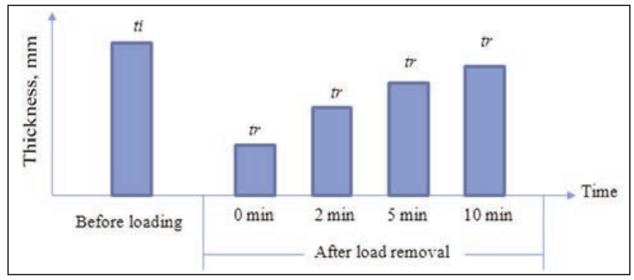


Fig. 1. Schematics of initial and recovered thickness values

Measurements were performed for two sides of each sample and the average was taken. For each sample type, tests were repeated for 4 times according to the standard. The measured loop lengths were used to calculate the bending rigidity values, according to equation 3. Bending length (c), $f_2(\theta)$ and θ were calculated according to equations 4, 5 and 6, respectively [35]:

$$\text{Bending rigidity} = G = 1.421 \cdot 10^{-5} \cdot w \cdot c^3 \ (\mu\text{joule/m}) \qquad (3)$$

$$c = 0.1337L \cdot f_2(\theta) \ (\text{cm}) \qquad (4)$$

$$f_2(\theta) = (\cos\theta / \tan\theta)^{1/3} \qquad (5)$$

$$\theta = 32.85 \cdot ((l - 0.1337L)/(0.1337L)) \ (°) \qquad (6)$$

where L is strip length in cm, w – unit mass in g/m^2 and l – loop length in cm. Measurement of loop length in heart loop method is schematised in figure 2.

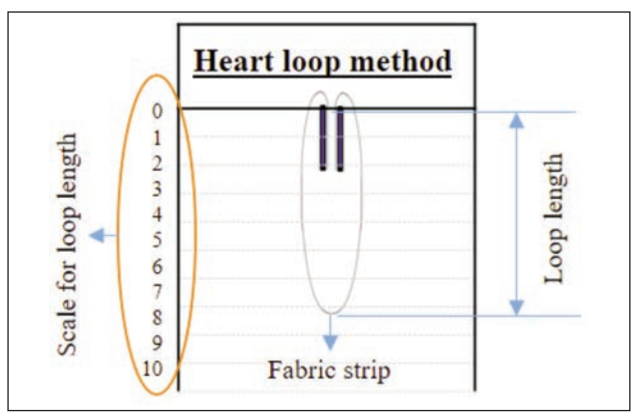


Fig. 2. Schematics of heart loop bending rigidity measurement

Wetting of samples for wet bending test and wet compression test

For the wet bending and wet compressibility tests, samples were wetted with synthetic urine (0.9% NaCl solution) [5, 10, 36] which was kept at standard atmosphere conditions for 48 h before the tests.

For the wet bending test, samples with 2.5 × 25 cm sizes were wetted with 10 ml of synthetic urine with the help of pipette. To wet the samples equally along the long side, 1 ml of synthetic urine was applied to every 2.5 cm length. The samples were kept in this situation for 5 min and then excessive solution was removed by putting the samples between two drying papers for 10–15 seconds. Before and after wetting, samples were weighed to calculate the average amount of absorbed solution.

Similarly, for wet compression test, 5×5 cm samples were wetted with 4 ml synthetic urine to keep the same ratio of wetting (0.16 ml/cm^2) with the wet bending test. After removing the excessive solution, weighing and thickness measurements were performed as in aforementioned tests.

RESULTS AND DISCUSSIONS

Microscopic evaluation

SEM image of the sanitary napkin cross section is given in figure 3. Front and back side views of sanitary napkin layers are given in figure 4. As seen from the figures, all the layers have different surface topographies and different structures. They are composed together to fulfil the requirements of a sanitary napkin.

According to SEM figures, top sheet had a voluminous perforated film structure. There were pores with 336.7 µ diameter (10 measurements) and they formed protruding holes from back side to front side. This mesh structure both provides the fast liquid transfer to inner layers and soft surface. The ADL and SAP layers were in the form of nonwoven structures but they differed in the surface morphology. Face side of ADL was covered with fibrous structure with 38 µ fibre thickness (10 measurements) and the backside had adhesive points with approximately 846 µ width and 536 µ height (4 measurements). Although having wood pulp again, surface topography of absorbent layer was different than ADL layer. The superabsorbent polymer particles could be seen in absorbent layer. The average fibre thickness was calculated as 35 µ by using 10 measurements. The back sheet was in the form of a solid film. This makes this layer waterproof. Some roughness of the back sheet surface could be

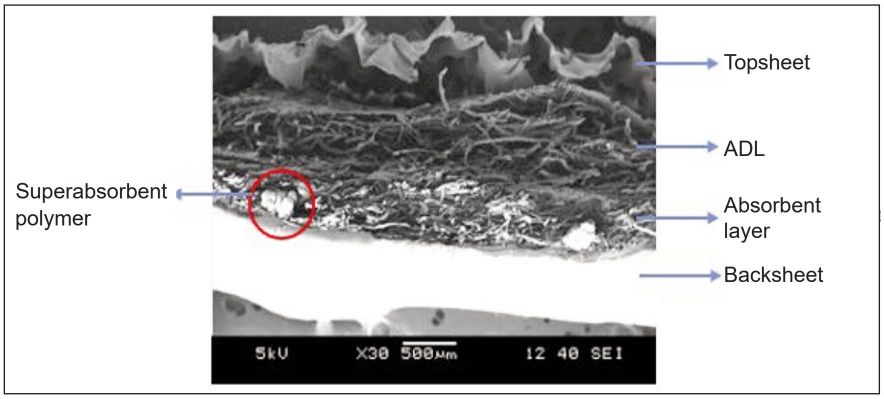


Fig. 3. Cross sectional view of the sanitary napkin

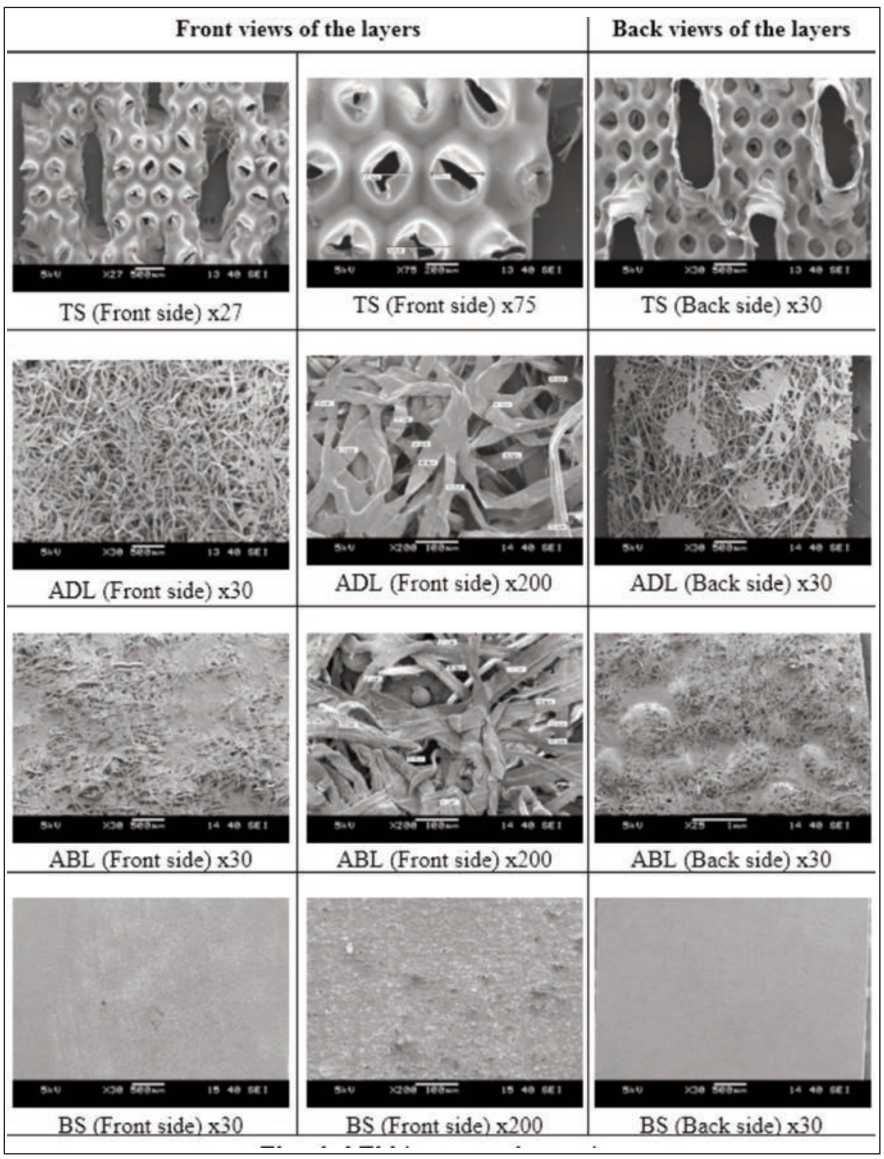
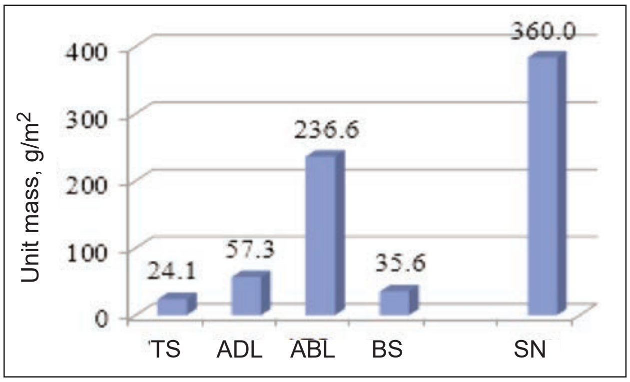
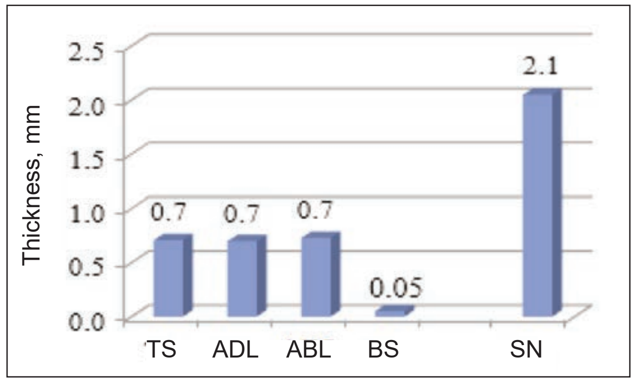


Fig. 4. SEM images of samples



a



b

Fig. 5. Graphical representations of: *a* – unit mass of samples; *b* – thickness of samples

observed from front side view with 200 magnifications.

Unit mass and thickness results of samples

Unit mass and thickness results of samples are given in figure 5, *a* and *b*, respectively. As seen in figure 5, *a*, unit mass of sanitary napkin layers varied in a wide range, from 24 to 236 g/m^2. The lightest layer of the sanitary napkin was top sheet. ADL and absorbent layer had heavier weights. But according to figure 5, *b*, the thickness of top sheet, ADL and absorbent layer was the same as 0.7 mm. This indicated compact structures for ADL and absorbent layer. Especially absorbent layer which included wood pulp and superabsorbent polymer had a very dense structure. Absorbent layer was 10 times heavier than top sheet. The back sheet layer was the thinnest layer and it was only 0.05 mm thick. But as back sheet was not in a perforated structure, it possessed a higher weight when compared to top sheet.

Sanitary napkin unit mass and thickness values were very high when compared to its separate layers. Sanitary napkin unit weight was about 360 g/m^2 which corresponded to total weight of layers. Sanitary napkin was a heavy weight textile structure and most of its weight was caused by absorbent layer. The thickness of sanitary napkin was 2.1 mm and again the total thickness of layers reflected to end-product thickness. With 2.1 mm thickness value, the sanitary napkin sample belonged to ultra-thin sanitary napkin class [1]. Unlike weight distribution of sanitary napkin layers; top sheet, ADL and absorbent layer had equal effects on the thickness of sanitary napkin.

Amount of wetting

For wet bending and wet compression tests, the samples were wetted according to aforementioned procedure. The mass increments of wet samples are given in figure 6.

According to the figure, average mass increments of wet samples were similar for bending test and compression test. For top sheet and ADL layers, mass increments after wetting were around 200–240 %. Back sheet nearly did not absorb any amount of synthetic urine that is most probably about the dense

Fig. 6. Mass changes of samples:
■ wet bending samples; ■ wet compressed samples

and hydrophobic structure of the film. Absorbent layer had the highest weight increments after wetting about 670–680%. This is caused by the superabsorbent polymer content of this layer. For the sanitary napkin, weight changes were obtained around 400 %. The mass changes after wetting is related to absorption characteristics of sanitary napkin layers [37] which are the most for absorbent layer and least for back sheet.

Compressibility behaviour of samples

As compressional properties, thickness loss (%) and compressibility (%) of samples were determined after 2 h and 4 h static load application (compression). It was aimed to mimic the sitting action in the experimental design. Tests were repeated for dry and wet samples. Back sheet layer was not included in this test as it was very thin and the changes in thickness could not be detected by the measurement device.

Compressibility values after 2 h and 4 h compression times are given in figure 7. According to figure, compressibility of top sheet was the highest for both dry and wet samples after 2 h and 4 h compression (40–50%). This is related to voluminous structure of top sheet which was observed in SEM images in figure 4. Top sheet includes high amount of free air which makes it more porous and compressible. This porosity of top sheet makes fluids able to flow through the fabric [38]. Compressibility of top sheet was followed by ADL and absorbent layer, respectively. For all samples, compressibility was higher

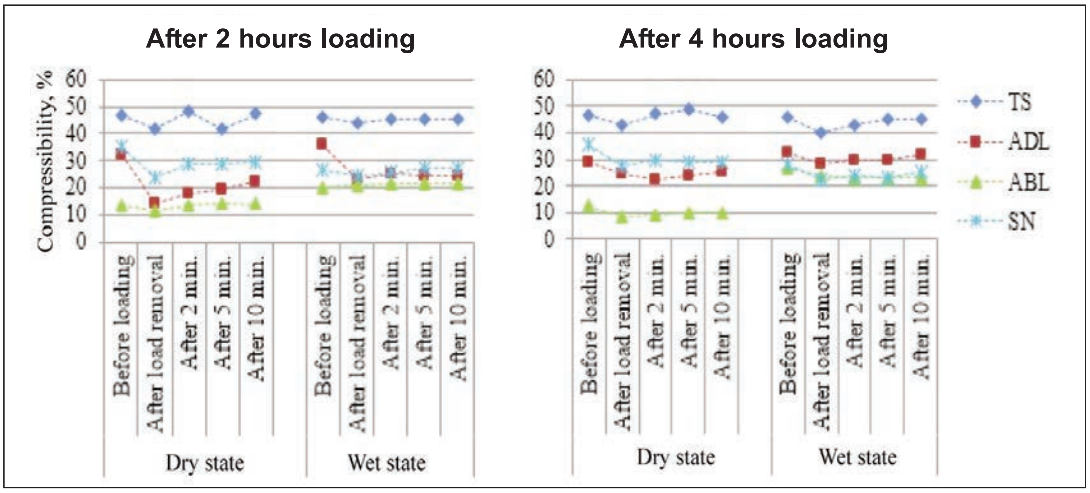


Fig. 7. Compressibility values after 2 h and 4 h compression

before static load application. After load removal, compressibility of samples started to increase by time and recovered mostly within 2 minutes.

Compressibility recoveries were more time dependent for dry samples. This is valid for both 2 h and 4 h compression times. For dry sanitary napkin, compressibility values were between top sheet and ADL layers for both 2 h and 4 h compression. After wetting, compressibility of sanitary napkin became closer to ADL or absorbent layer.

Thickness losses of samples after 2 h and 4 h compression times are given in figures 8 and 9. Thickness losses of samples in dry state are similar for 2 h and 4 h loading for 5 g/cm^2 and 50 g/cm^2 test pressures. In dry states, maximum thickness losses were obtained generally from ADL layer whereas absorbent layer exhibited the least thickness losses. Thickness losses of top sheet and sanitary napkin were similar for dry and wet states. Thickness losses of absorbent layer increased after wetting.

Interestingly, ADL layer started to swell after 5 min of load removal for 4 h compression. It is a good property as ADL layer will stay open under load, maintain void volume, resist wet collapse, enhance the desorption properties of the fabric, preserve void volume capacity and maintain rapid fluid uptake after applications of fluid [28]. The thickness loss results measured at 5 g/cm^2 thickness test pressure were in accordance with thickness loss results measured at 50 g/cm^2 thickness test pressure.

In general, for all layers, thickness loss values decreased after 10 min of load removal for both dry and wet states (after 2 h and 4 h compression). This indicates that, after load removal, thickness of sanitary napkin will recover and sanitary napkin will continue to serve with a more voluminous structure. In a study, Debnath and Madhusoothanan found out that initial thickness and compressibility of the polyester needle-punched fabrics decreased but thickness loss increased under wet condition when compared to the dry condition [28]. It can be understood that these

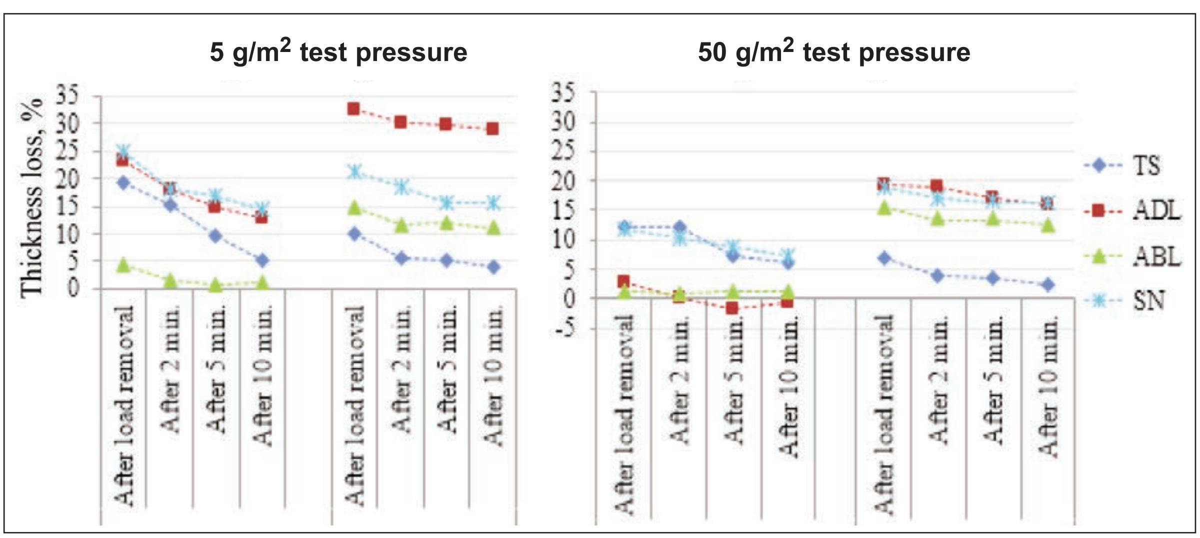


Fig. 8. Thickness loss values after 2 h compression

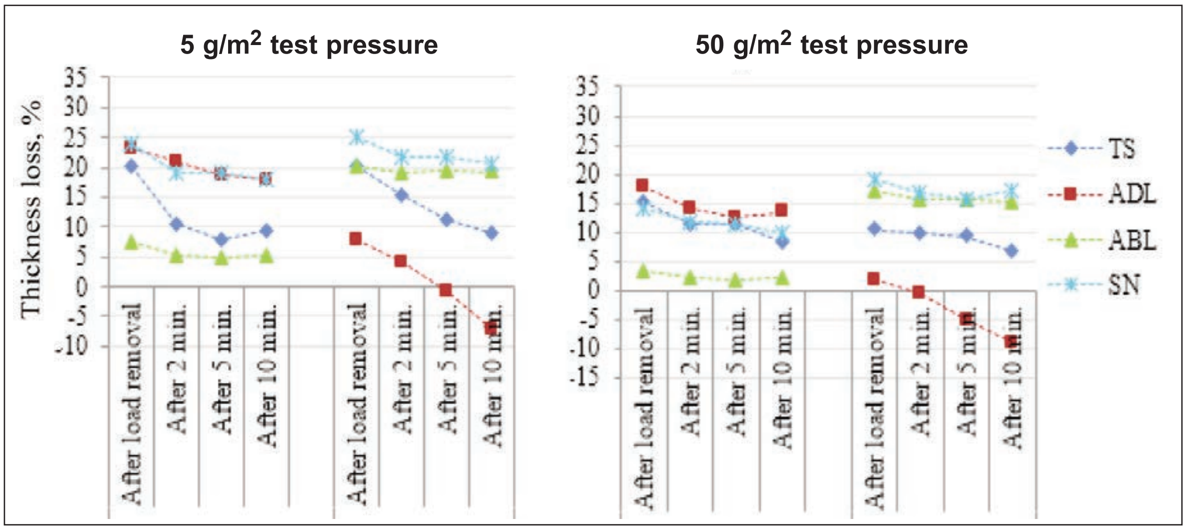


Fig. 9. Thickness loss values after 4 h compression

results do not fit with compressional behaviours of all sanitary napkin layers.

Although compressibility recoveries were mostly obtained after 2 min of load removal, samples exhibited some amounts of thickness losses even after 10 min of load removal.

Bending behaviour of samples

Bending results of samples are given in table 2. Also, average loop lengths measured during tests are schematized in figure 10. Bending lengths were calculated by using measured loop lengths.

Bending length results were between 1.46 cm and 3.41 cm before wetting and 1.02–2.04 cm after wetting. In general, bending lengths of sanitary napkin layers and sanitary napkin decreased after wetting and the loop lengths of samples increased after wetting.

Bending rigidity results are visualised in figure 11. Before wetting, absorbent layer owned the highest

Table 2

BENDING RIGIDITY RESULTS

Code	Dry bending properties		Wet bending properties	
	Bending length (cm)	**Bending rigidity (μJ/m)**	**Bending length (cm)**	**Bending rigidity (μJ/m)**
TS	2.15	3.4	1.52	3.5
ADL	2.80	17.5	1.30	5.7
ABL	3.41	128.6	1.02	27.4
BS	1.46	1.6	1.53	1.8
SN	3.19	177.3	2.04	235.9

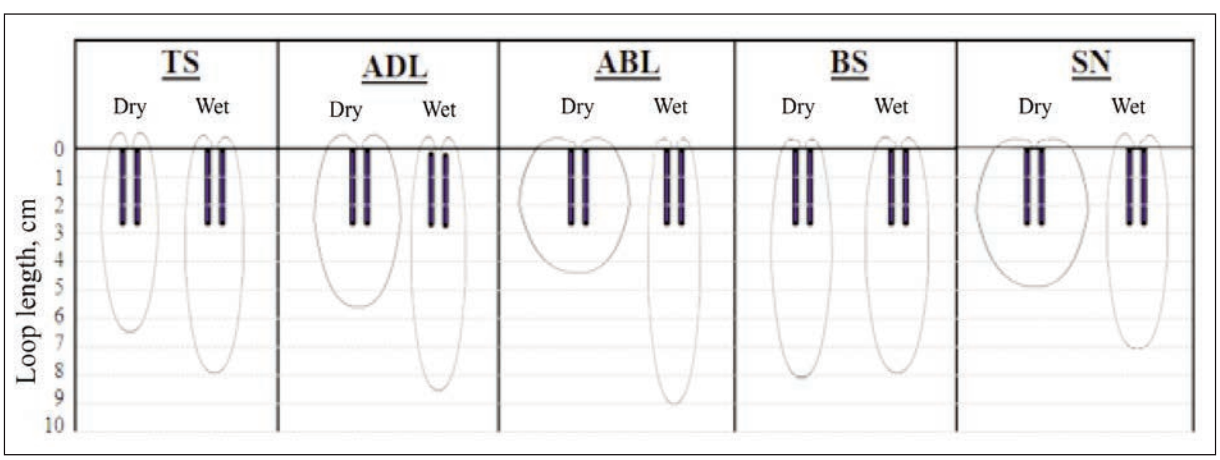


Fig. 10. Schematizing l (loop lengths) of samples in dry and wet states

bending rigidity among the sanitary napkin layers. Also, the loop length was the lowest for this layer. The lightweight top sheet, ADL and back sheet layers possessed ignorable bending rigidity results (1.6–17.5 µJ/m) when compared to superabsorbent layer (128.6 µJ/m) and sanitary napkin (177.3 µJ/m), before wetting.

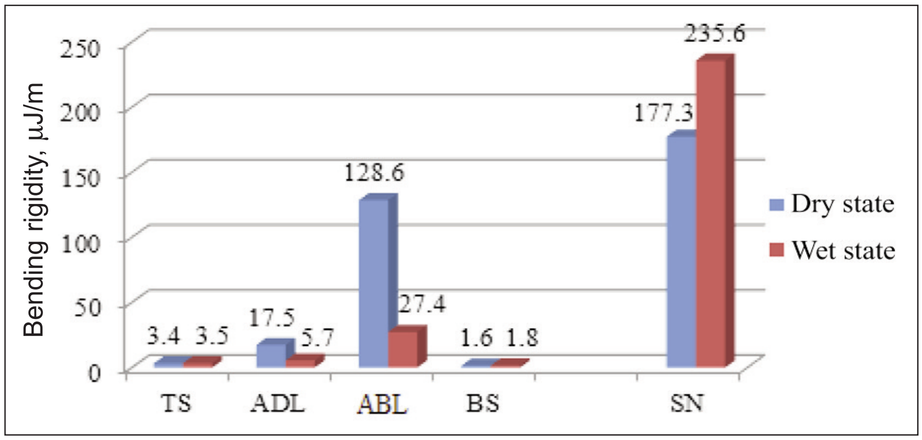


Fig. 11. Bending rigidity values of samples

Bending rigidity values of top sheet and back sheet layers almost did not change after wetting. For ADL and absorbent layer, bending rigidity values decreased importantly after wetting. The increased weight of sanitary napkin layers resulted with longer loop lengths and smaller bending lengths (figure 10 and table 2). In contrary, sanitary napkin bending rigidity increased after wetting. The multilayer structure of the sanitary napkin restricted the loop length of the sanitary napkin. Its loop length only increased to 7.03 cm in spite of getting 4 times heavier after wetting. This situation resulted with higher bending rigidity for sanitary napkin after wetting procedure.

CONCLUSIONS

In this study, bending and compressional behaviours of sanitary napkin layers were determined in order to make comparisons between them and make inferences about the formability and sensorial comfort of sanitary napkins.

According to SEM evaluations, it was clearly observed that all 4 layers of the sanitary napkin were specially structured for their individual mission in the sanitary napkin. The layers differed in raw material, construction and surface morphologies. According to unit mass and thickness results, although top sheet, ADL and absorbent layer were equal in their thickness, their densities and compactness were very different. Top sheet was very light and porous and it made this layer more compressible even in dry and wet states. In contrary, absorbent layer was 10 times heavier than top sheet in spite of being in the same thickness. Altogether, the layers' unit mass and thickness results determined the overall weight and thickness of the sanitary napkin.

The bending and compressional behaviours of samples were determined both in dry and wet states as wet textiles can exhibit different properties under wet conditions. Same amount of synthetic urine was applied to sanitary napkin layers but they hold the amount according to their absorptive capacities [37].

According to bending test results, wetting did not importantly affect the bending rigidities of top sheet and back sheet layers. But especially, bending rigidity of absorbent layer decreased dramatically after wetting. This indicates to a more formable absorbent layer when it got wet because of menstrual flow. But as the unit mass of sanitary napkin increased too much and the layered structure restricted the loop length of sanitary napkin, bending rigidity of sanitary napkin did not decrease after wetting. This can lead to low formability and make the user feel discomfort.

The compressional behaviour results showed that top sheet was the most compressible layer before and after being compressed with static load. So it can make the user feel a soft and dry surface. The compressibility of sanitary napkin was in somewhere around ADL and absorbent layer. The least compressible layer of the sanitary napkin was absorbent layer.

The thickness loss values after load application can be imagined as a sanitary napkins' compressional behaviour after a woman sits on it for 2 h and 4 h. After the load removal, the thickness of sanitary napkin starts to recover. In this study, compressibility and thickness changes of the sanitary napkin layers were determined within 10 min after load removal. The thickness loss values determined at 5 g/cm^2 represented the free recovering of sanitary napkin after load removal. The thickness loss values determined at 50 g/cm^2 may be considered as the woman sit on the sanitary napkin again after load removal within 10 min. So in this case, effect of repetitive sits on the sanitary napkin was tried to mimic. This setup of experiment was designed according to experiences and literature search but different setups may be made using different compression times or using dynamic loading cycles, in further studies.

As the back sheet material was only a few microns thick, the changes of back sheet could not be measured accurately by using the current test device. So the compressional behaviour results of back sheet were not added to the paper. In further studies, specially constructed gauges may be used to detect the thickness changes of back sheet. For this study, as the thickness changes of back sheet layer were very small when compared to other layers, back sheet layers compressional behaviours are omitted.

ACKNOWLEDGEMENTS

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This current study was focused on compressional properties of sanitary napkin layers and the study is improved and differed by adding new parameters and measurements to the experimental design.

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Analysing competitiveness of Denizli home textile sector

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ABSTRACT – REZUMAT

Analysing competitiveness of Denizli home textile sector

Turkey, which is the biggest home textile supplier for European Union, is the fourth biggest home textile supplier of the world. Besides, Denizli province is the place where this sector is clustered and strongly operated in Turkey. Therefore, Denizli home textile sector is a structure, which explicitly and accurately represents Turkish home textile sector. In this context, this research aims to analyse the competitiveness of Denizli home textile sector, which substantially contributes to Turkish textile and clothing sector. In accordance with the aim of the research, the competitiveness of Denizli home textile sector is analysed by using Porter's diamond model. According to the obtained results, competitiveness of Denizli home textile sector is determined as high.

Keywords: *home textiles, Denizli home textile sector, Porter's diamond model, competitiveness*

Analiza competitivității sectorului textilelor de uz casnic din provincia Denizli

Turcia, cel mai mare furnizor de textile de uz casnic pentru Uniunea Europeană, este al patrulea cel mai mare furnizor de textile de uz casnic din lume. În plus, provincia Denizli este locul în care acest sector este clusterizat și activ în Turcia. Prin urmare, sectorul textilelor de uz casnic din Denizli este o structură care reprezintă în mod explicit și precis acest sector din Turcia. În acest context, această cercetare își propune să analizeze competitivitatea sectorului textilelor de uz casnic din Denizli, ce contribuie substanțial la sectorul textil și de îmbrăcăminte din Turcia. În conformitate cu scopul cercetării, competitivitatea sectorului textilelor de uz casnic din Denizli este analizată utilizând modelul diamantului lui Porter. Conform rezultatelor obținute, competitivitatea sectorului textilelor de uz casnic din Denizli este determinată ca fiind ridicată.

Cuvinte-cheie*: textile de uz casnic, sectorul textilelor de uz casnic din Denizli, modelul diamantului lui Porter, competitivitate*

INTRODUCTION

Home textiles, can be defined as textile products, which are used to fulfil the indoor needs. Home textiles, generally involve textile and/or apparel products such as bedclothes, bed linens (sheets, pillowcases and duvet covers), curtains, upholstery fabrics, towels, bathrobes, tablecloths, swabs, carpets and rugs, blankets, quilts, pillows and cushions [1].

In this context, home textiles, constitute one of the product groups which are prominent in textile and clothing market and whose consumption is gradually increasing. Thus, Turkey, which is one of the most significant players and exporters of global textile and clothing market, is one of the leading countries in home textiles.

If the leading global home textile exporters are analysed, it can be seen that China takes the first place with 31.3 billion dollar exports. India follows China with 4.8 billion dollar home textile exports, whereas Pakistan takes the third place with 3.3 billion dollar exports. Turkey is the fourth biggest home textile exporter of the world with 2.8 billion dollar exports [2]. Turkish home textile sector, which has actualized 2.7 billion dollar exports in 2017, takes 4.5% share from global home textile market [3].

The global home textile market has reached to 90–95 billion dollar size in 2018 and the ranking of leading global home textile exporters has remained the same. Turkey, which is the biggest home textile supplier of European Union, has exported home textiles to more than 170 countries and has continued to be the fourth biggest home textile exporter of the world after China, India and Pakistan, with its design and production potential [4]. As it can be seen, Turkish home textile sector possesses a significant place in Turkish economy due to its export and added-value creation potential. Besides, Denizli province is the place where home textile sector is clustered and strongly operated in Turkey.

Approximately 57% of Turkey's towel, bathrobe, sheet and duvet cover exports are actualized from Denizli [3, 5]. In this context, this research, aims to analyse the competitiveness of Denizli home textile sector, which is the strongest home textile cluster in

Turkey, by using Porter's diamond model. There are many researches in the literature, which analyse the competitiveness of different nations/countries and dissimilar industries/sectors by using Porter's diamond model. Besides, there are studies, which analyse the competitiveness of textile and clothing sectors of different countries (China, India, Thailand, Iran, South Korea, Vietnam, Italy, Turkey) [6–18]. However, there are not any researches, which analyse the competitiveness of home textile sector, which is one of the most important sub-sectors of textile and clothing sector. At this point, this study differentiates from other researches and contributes to the literature by focusing on Turkey, which is one of the most significant global home textile exporters, and Denizli home textile sector, which is the strongest home textile cluster in Turkey.

THE PURPOSE AND THE METHOD OF THE RESEARCH

Turkish textile and clothing sector possesses a significant place in Turkish economy due to its production, exportation and employment potential. Besides, it is one of the leading global textile and clothing suppliers due to its export potential. In other words, it owns both national and international success and competitiveness. At this point, home textile sector appears as a sub-sector which substantially contributes to this success. In addition to this, Denizli, which possesses the highest home textile production and exportation in Turkey, is the province where home textile sector is clustered. Approximately 57% of Turkey's towel, bathrobe, sheet and duvet cover exports are actualized from Denizli in 2016 (the year when the research is actualized) [3, 5].The towel, bathrobe, sheet and duvet cover exports of Denizli home textile sector is actualized as 784,414,000 dollars in 2016, 797,563,000 dollars in 2017, 750,384,261 dollars in 2018 and 711,458,000 dollars in 2019 [5, 19, 20]. Similarly, about 52% of Turkey's towel, bathrobe, sheet and duvet cover exports are fulfilled from Denizli in 2019 [20, 21]. Turkey's average home textile unit export price per kilogram is actualized as 8.52 dollars in 2016. The unit export prices of towels and bathrobes and sheet and duvet covers, whose exports are mainly actualized by Denizli home textile sector, are fulfilled as 8.08 and 8.49 dollars per kilogram [22]. In 2019, Turkey's average home textile unit export price per kilogram is actualized as 8.41 dollars, whereas the unit export price of towel and bathrobe per kilogram is fulfilled as 8.25 dollars and unit export price of sheet and duvet cover per kilogram is actualized as 8.63 dollars [21]. As it can be seen, Denizli home textile sector has provided significant contributions to Turkey's home textile exports and has created added value in the year when the research is actualized and even afterwards. Therefore, Denizli home textile sector is a structure, which explicitly and accurately represents Turkish home textile sector. In this context, this research aims to analyse the competitiveness of Denizli home textile sector, which is the strongest home textile cluster in Turkey and therefore, which substantially contributes to Turkish textile and clothing sector with regard to home textile products.

In accordance with the aim of the research, the method is determined firstly. There are many methods in the literature, which can be used for competitiveness analysis. Porter's diamond model, which is one of these methods, is frequently and effectively used in competitiveness analysis. In this context, the competitiveness of Denizli home textile sector is analysed by using Porter's diamond model.

The diamond model is an economical model developed by Michael Porter in his book The Competitive Advantage of Nations, where, in 1990 he published his theory of why particular industries become competitive in particular locations [23, 24]. To investigate why nations gain the competitive advantage in partcicular industries, Porter conducted a four-year study of ten important trading nations and suggested the diamond model [8]. The model evaluates internal and external factors that create advantages in the global market [25]. Porter concluded that a nation succeeds in a particular industry if it possesses a competitive advantage relative to the best worldwide competitors [8]. Therefore, it provides an excellent framework to analyze the competitiveness of a particular industry within a country [9]. In other words, it is a framework that defines the rules of competition in an industry and highlights what is important in order to have long-term competitive advantage. Thus, it is widely used to establish a conceptual frame in competitiveness analysis of industries and nations [26].

Porter defines the competitiveness of a location as the productivity that companies located there can achieve. He believed that measuring competitiveness is a mapping of competitive environment of an organization which helps the nation to form a sound basis for business strategies and developments [6]. Porter argued that the competitiveness is created, not inherited and claimed that the source of competitiveness is the competitive advantage, which is created and sustained through a highly localized process [7]. According to Porter, competitive advantage in a given industry is a combination of the ability to innovate, to improve processes and products as well as to compete. To determine national competitive advantage in different industries, Porter developed a conceptual framework which he labeled diamond that consists of four interrelated determinants [27]. Those determinants, individually and as a system, constitute the diamond model of national advantage, which serves as a playing field that each nation establishes and operates for its industries. The competitiveness will increase when each of these determinants are improved [7].

According to Porter's diamond model, four main determinants that underlie conditions or platform for determination of the national competitive advantage are factor conditions, demand conditions, related and supporting industries and firms' strategy, structure and rivalry [7]. These elements interact with each other [23]. Porter also proposed government policies and chance as exogenous shocks (as auxiliary elements), which supported the whole system of national competitiveness with four above-mentioned determinants [7, 23].

Factor conditions implies the country's access to factors of production, or in other words, factor conditions refer to the production performance of a country's certain industry [23, 28]. Factor conditions represent the factor endowment of a country or industry and can be distingusihed in basic factors and advanced factors [27]. According to Porter, the availability of the basic factors of production (labor, land, natural resources, capital, infrastructure etc.) impacts the economic activity. It is the availability of these factors that will determine the balance between exports and imports. However, Porter considers the advanced factors (highly trained labor force, national communications infrastructure etc.) as more important to influence a country's competitive advantage. The existence of these advanced factors, as well as country's capability to develop them, will defien a country's competitive advantage [29].

Demand conditions refer to the domestic demand of a product or service which is provided by a certain industry [23, 27]. It concerns the size and nature of domestic demand [28]. Demand conditions in the home market can help companies create a competitive advantage, when sophisticated home market buyers push firms to innovate faster and create more advanced products than their competitors. Demand conditions can improve the industry's efficiency through the power of economies of scale. Meanwhile, the country' expected demand can lead to the improvement of industrial competitiveness [23].

Related and supporting industries concerns the presence or absence of supplier industries or related industries that are internationally competitive [28]. They provide a preponderant network for competitive advantage of industries. This network can be formed by a top-down spreading process [23]. The presence of related and supporting industries, which are internationally competitive, provides effective and efficient supply of cost-effective inputs. Also, it promotes innovation and improvements through the increased flow of information and technology [29]. Moreover, the relation between the related and supporting industries leads to sharing of know-how and encouraging each other by producing complementary products [30].

Firms' strategy, structure and rivalry are firms' organizational structure and management situations and the performance of competitors in domestic market [23]. In other words, it describes the conditions of a country determining how firms are organized and run [27]. The instensity of rivalry will push firms to review their operation, quality and innovation. Porter considers domestic rivalry to be more important than international rivalry because the former is more intense and direct [29].

Chance can affect the four key elements. Chance can come in different ways including; inventions in basic science and technology, the emergence of disruption in traditional technologies, a sudden increase in production costs caused by external factors, significant changes in financial markets or exchange rates, a surge in market demand and a government's major policy decisions or war. This external factor is important because it can create discontinuities in which some organizations gain competitive positions and some lose [23].

Government can influence factor conditions, demand conditions in the domestic market and competition between firms. Government intervention can occur at local, regional, national or supranational levels. Governments should influence conditions by creating new opportunities and reducing pressures within industry. The areas which government should directly invest in are those whereby firms cannot take strong action including; infrastructure development, opening up channels for capital and developing information integration capabilities [23].

After the research method is specified, the main and sub-factors of the model, which analyse the national and international competitiveness of the sector, are determined. According to this, the model consists of 6 main, 45 sub-factors (figure 1). In the third stage, a questionnaire form consisting of 45 questions is prepared for analysing these factors. The survey is conducted between September 2016 and December 2016 by using face to face interview method. The surveys are answered by senior managers [31].

The research universe consists of enterprises, which operate in Denizli home textile sector. According to the enterprise information, which is obtained from Denizli Chamber of Industry, 264 enterprises operate in Denizli home textile sector. However, when this information is analysed in detail, it is found out that 116 of these enterprises only produce woven fabrics, 25 of them actualize contract manufacturing, 2 of them only produce knitted fabrics, 6 of them do not produce home textile products anymore and 2 of them are closed. Due to these reasons, only 113 enterprises are incorporated in research universe [31]. The research aims to analyse the competitiveness of Denizli home textile sector. Therefore, the criteria, which reflect the research universe and actualize research's aim, are taken into consideration. These criteria are determined as; operating in Denizli home textile sector, being classified as big-sized enterprises according to annual turnover and employee number and possessing research and development and/or design departments/centres. Research sample has been consisted of the enterprises, which meet these criteria, because it is thought that, these enterprises can give accurate, explicit and objective information about the sector's competitiveness. Besides, most of the small and medium sized enterprises, which operate in the sector, supply products to big-sized enterprises, which meet the determined criteria. In this context, these enterprises possess knowledge accumulation, which can majorly analyse the competitiveness of small and medium sized enterprises. 12 enterprises out of 113

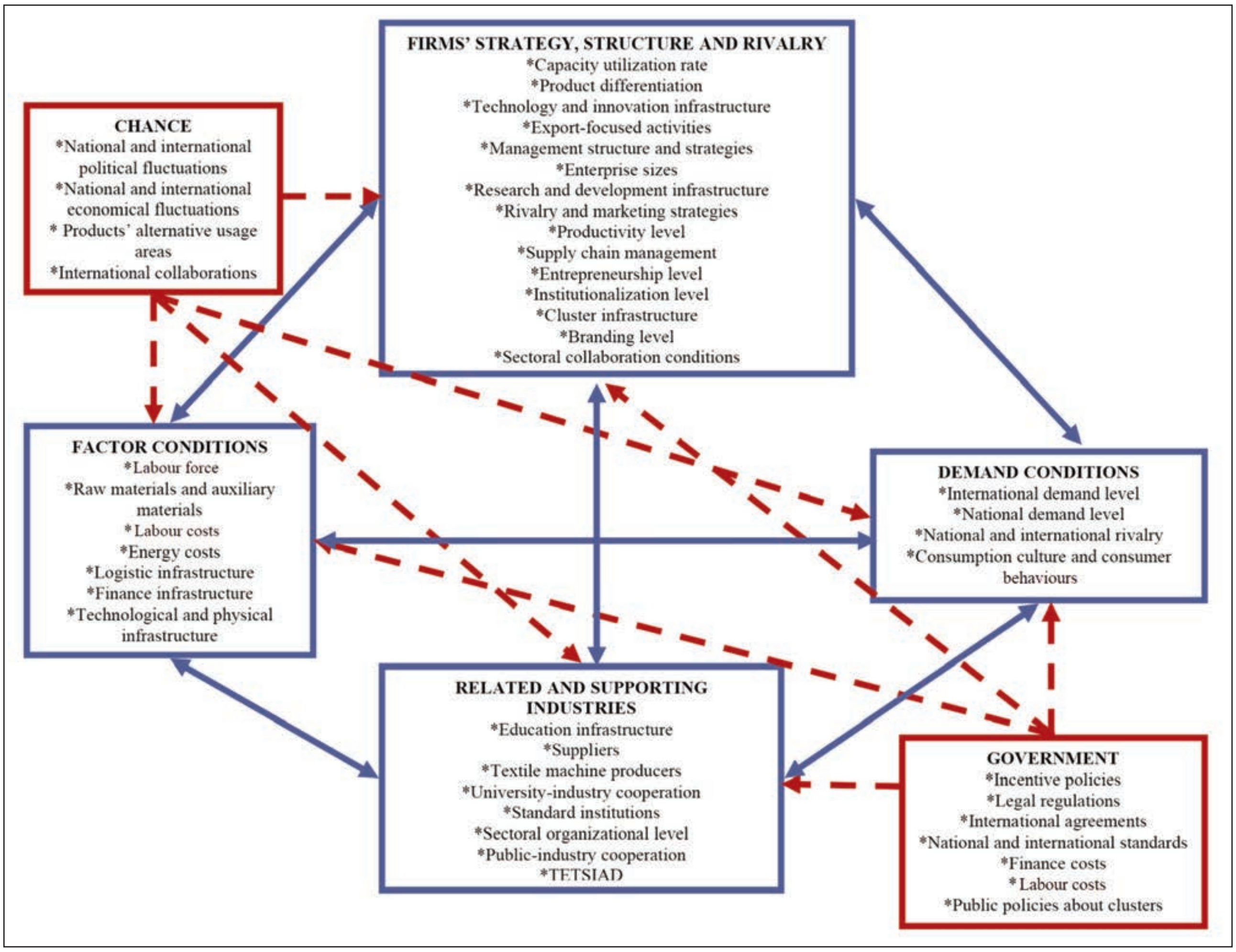

Fig. 1. The diamond model of the research

meet the determined criteria and 10 out of 12 enterprises have accepted to be participated in the research. After the repatriation and evaluation 10 questionnaires have incorporated to the research. Obtained data are analysed by using Porter's diamond model.

FINDINGS OF THE RESEARCH AND THEIR ANALYSIS

The survey offers 45 factors, which analyse the competitiveness of Denizli home textile sector. All participants (senior managers of home textile enterprises) are required to choose the sector's competitiveness level according to the quinary Likert scale. In other words, they are required to answer a question (How advantageous is the sector in this factor with regard to competitiveness?) for each factor. In quinary Likert scale, definitely advantageous is coded as 5, advantageous is coded as 4, neither advantageous nor disadvantageous is coded as 3, disadvantageous is coded as 2 and definitely disadvantageous is coded as 1. Afterwards, arithmetic means are calculated for each sub-factor and main factors' arithmetic means are calculated by using those means. Finally, general arithmetic mean is calculated by using main factors' arithmetic means. The findings are given in table 1.

As it can be seen from the obtained results, competitiveness of Denizli home textile sector is determined as high (3.98). In other words, Denizli home textile sector is specified as advantageous according to the factors, which analyse competitiveness. Sector is mostly advantageous (mostly competitive) in factor conditions (4.34). This main factor is followed by firms' strategy, structure and rivalry (4.11), chance (3.98), demand conditions (3.95), government (3.86) and related and supporting industries (3.61) respectively.

If the sub-factors of factor conditions (the most competitive factor of Denizli home textile sector) are analysed, it can be seen that, labour force is determined as the most advantageous sub-factor in terms of competitiveness. This sub-factor is followed by raw materials and auxiliary materials, technological and physical infrastructure, labour costs, finance infrastructure, logistic infrastructure and energy costs respectively. Turkish textile and clothing sector has maintained its importance within the national economy for many years due to its employment and added-value creation potential. Thus, Denizli home textile sector, which constitutes a significant part of this sector, is lucky and wealthy in terms of labour force. Sector, can easily find and employ qualified and low-cost labour (both blue and white collars), who has

Table 1

COMPETITIVENESS ANALYSIS OF DENIZLI HOME TEXTILE SECTOR				
Main factors	**Sub-factors**	**Arithmetic means of sub-factors**	**Arithmetic means of main factors**	**General arithmetic mean**
Factor conditions	Labour force	4.60	4.34	**3.98**
	Raw materials and auxiliary materials	4.50		
	Technological and physical infrastructure	4.50		
	Labour costs	4.40		
	Finance infrastructure	4.20		
	Logistic infrastructure	4.11		
	Energy costs	4.10		
Firms' strategy, structure and rivalry	Capacity utilization rate	4.67	4.11	
	Product differentiation	4.67		
	Technology and innovation infrastructure	4.56		
	Export-focused activities	4.44		
	Management structure and strategies	4.33		
	Enterprise sizes	4.22		
	Research and development infrastructure	4.22		
	Rivalry and marketing strategies	4.22		
	Productivity level	4.22		
	Supply chain management	4.00		
	Entrepreneurship level	3.88		
	Institutionalization level	3.80		
	Cluster infrastructure	3.63		
	Branding level	3.60		
	Sectorial collaboration conditions	3.22		
Chance	National and international political fluctuations	4.11	3.98	
	National and international economical fluctuations	4.00		
	Products' alternative usage areas	4.00		
	International collaborations	3.80		
Demand conditions	International demand level	4.60	3.95	
	National and international rivalry	4.00		
	Consumption culture and consumer behaviours	3.80		
	National demand level	3.40		
Government	Incentive policies	4.50	3.86	
	Legal regulations	4.00		
	International agreements	4.00		
	National and international standards	3.90		
	Finance costs	3.90		
	Labour laws	3.50		
	Public policies about clusters	3.22		
Related and supporting industries	Education infrastructure	4.60	3.61	
	Suppliers	4.20		
	Textile machine producers	4.10		
	University-industry cooperation	3.40		
	Standard institutions	3.30		
	Sectorial organizational level	3.22		
	Public-industry cooperation	3.20		
	TETSIAD (Turkish Home Textile Industrialists' and Businessmen's Association)	2.89		

been specialized on home textile production. The obtained results also support this argument. On the other hand, although the labour costs are the same or more feasible according to other sectors' labour costs, they are high with regard to their Far Eastern rivals. However, the sector differentiates from its Far Eastern rivals due to its qualified products and services and therefore, the sector can ignore the effect of relatively high labour costs on competitiveness.

Sector, can reach to necessary qualified raw materials and auxiliary materials with affordable prices by benefiting from the integrated structure of Turkish textile and clothing sector and therefore, it can be competitive in this factor. Similarly, it can be competitive in technological and physical infrastructure by benefiting from the integrated structure and Denizli home textile cluster. Besides, sector specifies itself as advantageous with regard to competitiveness in finance and logistic infrastructures due to the various and easily accessible financial resources and developed logistic sector which serves with high quality. In addition to these, sector determines that it is also competitive in energy costs. Although the energy costs in Turkey are relatively high according to the Far Eastern rivals, the diversity, productivity and quality of the energy is much more with regard to them. Therefore, the sector stated that its competitiveness is especially high in terms of national rivalry. The sector is also competitive in firms' strategy, structure and rivalry. Capacity utilization rate and product differentiation are determined as the most advantageous sub-factors in terms of competitiveness. If the Turkish textile and clothing sector is compared with other manufacturing industry segments, it can be seen that it possesses high capacity utilization rates Capacity utilization rate of manufacturing industry in 2016 is 77.36% whereas it is 77.71% in textile production and 78.46% in clothing production [32]. Therefore, Denizli home textile sector, which is a subsector of this sector, also possesses high capacity utilization rates and it can easily compete against its national and international rivals. On the other hand, sector gives necessary importance to research and development activities and product development activities and pays ultimate attention to product differentiation in order to differentiate from its rivals. The technology and innovation infrastructures of enterprises within the sector are generally in good state. Especially, the big-sized enterprises give great importance to technology and innovation and follow the current developments. Consequently, the sector's competitiveness in this factor is high.

Most of the enterprises within the sector operate as export-focused. As a matter of fact, approximately 57% of towel, bathrobe, sheet and duvet cover exports of Turkey are actualized from Denizli. Therefore, the sector's high competitiveness in export-focused activities is extremely usual. On the other hand, the sector possesses high competitiveness in other sub-factors such as management structure and strategies, enterprise sizes, research and development infrastructure, rivalry and marketing strategies, productivity level and supply chain management. Sector significantly contributes to both textile and clothing sector and national economy with its knowledge accumulation and labour, export, technology and management potential. The sector should be competitive in these factors in order to provide and maintain these contributions. The enterprises within the sector specify that their competitiveness is at intermediate level in entrepreneurship, institutionalization, cluster, branding and sectorial collaboration conditions. Most of the enterprises within the sector operate as small and medium sized enterprises and family business. Thus, the entrepreneurship capacities and institutionalization levels are found to be low. Besides, the branding levels are determined as insufficient due to the restricted budgets, which are spent to other important factors in terms of being competitive. Therefore, the sector's competitiveness is decreased in these factors. On the other hand, the enterprises within the sector persist in seeing each other as rivals and do not benefit from cluster synergy. Thus, both the cluster infrastructure and sectorial collaboration conditions are negatively affected.

Sector's competitiveness is determined as high in chance factor. Chance factor is existed as an auxiliary factor within the diamond model. However, this auxiliary factor is determined as very important (more important than other two main factors). This situation can be explained with variability of Turkey's economical conjuncture and the continuity of middle income trap. National and international economic and political fluctuations are specified as the most advantageous sub-factors in terms of competitiveness. The country has been used to political and economic crises due to its geographical location and its longstanding classification as a developing country. Therefore, the enterprises, which operate in the country, are experienced in turning the crises into opportunities, because frequent crises have educated enterprises in terms of adapting to alterations. Enterprises can be able to manufacture with small amounts in short deadlines by using flexible production techniques in order to satisfy the high product variety demand. Besides, they benefit from the price advantage, which is constituted due to the depreciation of Turkish Lira within international markets. Consequently, Denizli home textile sector specifies the economic and political crises as an opportunity and determines its competitiveness as high. Besides, the sector indicates that its products have alternative usage areas. In other words, home textile products are not only used by individuals in houses. They are also used in hotels, schools and public institutions. On the other hand, sector determines its competitiveness in international collaborations as intermediate-high. Although the enterprises within the sector give great importance to international collaborations, they refuse many opportunities due to loss fear (they believe that their confidential business information would be stolen by their partners and/or their enterprises would be bought by them).

Sector's competitiveness is also specified as high in demand conditions. International demand level is indicated as the most advantageous sub-factor in terms of competitiveness. The sector operates as export-focused. Therefore, the sector does not experience any difficulties in terms of international demands. Moreover, sometimes it misses some orders. On the other hand, the competitiveness level is determined as intermediate in national demands, because the sector gives more importance to foreign markets rather than domestic market. Also it mostly operates towards foreign markets. Thus, its competitiveness in national demands is found to be low. Besides, the sector determines its competitiveness as high in national and international rivalry and consumption culture and consumer behaviours. Sector's production and export figures can be shown as evidence to these competitive advantages.

Sector determines its competitiveness in government factor as intermediate-high. Incentive policies are determined as the most advantageous sub-factor in terms of competitiveness. Although the sector complains about the inadequate government incentives, it extremely benefits from the proper incentives. Moreover, the sector especially benefits from the incentives which are related with research and development and design centres. As it can be seen, sector benefits from existing government incentives and sees itself advantageous about this sub-factor. However, it continuously demands increments in these incentives. On the other hand, the sector possesses high competitiveness in legal regulations, international agreements, national and international standards and finance costs. As it can be seen, sector can turn the legal regulations' and international agreements' disadvantages and finance costs' highness into advantages. The sector decreases the finance costs by benefiting from long-term finance possibilities and by using equity capital in their investments as far as possible. In addition to these, it eliminates the disadvantages of international agreements' and standards' costly obligations by manufacturing high added-value products. Sector specifies its competitiveness in two sub-factors (labour laws and public policies about clusters) as intermediate. Sector defines the labour laws' legal obligations as loads and indicates that public policies about the clusters are inadequate.

Finally, sector determines its competitiveness in related and supporting industries factor as intermediate-high. Education infrastructure is determined as the most advantageous sub-factor in terms of competitiveness because the sector possesses qualified labour. Besides, it gives necessary importance to vocational education and allocates enough funds. In addition to these, the employees' educational level gradually increases and enterprises give great importance to continuous development. The sector has realized that qualified and issueless production requires qualified labour and qualified labour requires sufficient and qualified education. On the other hand, sector also specifies high competitiveness in terms of suppliers and textile machine producers. Turkish textile and clothing sector is an integrated and experienced sector. Therefore, Denizli home textile sector, which constitutes an important part of this sector, is advantageous in finding qualified and accoutred suppliers. Besides, the sector gives necessary importance to technological development and closely connects with machine producers (especially with foreign ones). Sector specifies its competitiveness in four sub-factors (university-industry cooperation, standard institutions, sectorial organizational level and public-industry cooperation) as intermediate.

Although the sector possesses developed and integrated infrastructure (production possibilities, raw material possibilities, technological infrastructure etc.) and cluster, it can't be able to reach to the desired level in university-industry and public-industry cooperation, which are the sub-factors of cluster. Therefore, the university-industry cooperation and public-industry cooperation are determined as unsatisfactory. In this context, Denizli home textile sector loses its competitive advantage (especially its international competitive advantage) in these factors. Besides, sectorial organizational level is found out to be low due to inadequate sectorial collaboration. The enterprises within the sector see each other as rivals. In addition to these, the sector indicates that TETSIAD (Turkish Home Textile Industrialists' and Businessmen's Association), which constitutes a significant part of sectorial organization, does not contribute to its competitiveness in any way.

RESULTS AND GENERAL EVALUATION

Turkish home textile sector, which constitutes an important part of textile and clothing sector which has been an essential and significant sector of Turkish economy for many years, significantly contributes to sector and national economy with its production and exportation potential. Besides, Denizli home textile sector constitutes the backbone of Turkish home textile sector due to its home textile cluster and strong activities. In this context, this study, analyses the competitiveness of Denizli home textile sector, which constitutes the backbone of Turkish home textile sector, by using Porter's diamond model.

As it can be seen from the obtained results, the competitiveness of Denizli home textile sector is determined as high. Approximately 62% of the 45 factors, which analyse the competitiveness of the sector, are found to be definitely advantageous or advantageous in terms of competitiveness. As a matter of fact, approximately 57% of towel, bathrobe, sheet and duvet cover exports of Turkey are actualized from Denizli and Turkey is the fourth biggest home textile supplier of the world. Therefore, this finding is extremely usual. If the sector's competitiveness is analysed in terms of main factors, it can be seen that, the sector possesses high competitiveness in four factors, whereas it owns intermediate-high competitiveness in two factors. Sector is mostly advantageous (mostly competitive) in factor conditions, whereas it is lowly advantageous in related and supporting industries. If the integrated structure and development of Turkish textile and clothing sector are taken into consideration, the high competitiveness of Denizli home textile sector, which constitutes a significant part of this sector, in factor conditions (in other words production factors such as labour, raw materials, auxiliary materials, technological and physical infrastructure, logistic infrastructure etc.) would not be surprising.

On the other hand, the sector possesses high competitiveness in firms' strategy, structure and rivalry. The enterprises, which operate in the sector, indicate that they can easily compete with their rivals in terms of export-focused activities, capacity utilization rates, productivity levels, management structures, rivalry and marketing strategies and supply chain management; because, they are very successful in these factors, which directly affect the enterprise success. Turkey is the fourth biggest home textile exporter of the world and can mostly compete with Far Eastern rivals (China, India and Pakistan) due to its high competitiveness in these two main factors (factor conditions and firms' strategy, structure and rivalry). As it is stated by the Denizli Home Textile Sector Analysis Report [33], which has been prepared by Turkish Republic South Aegean Development Agency, Turkey's competitiveness is higher than its Far Eastern rivals in certain factors such as; geographical closeness to European countries, products with high quality and standards (product differentiation), educated and qualified labour force, developed industry infrastructure, regulatory compliance to European Union's technical regulations, importance given to quality, health and environment.

Besides, the sector highly benefits from chance factor and it is very successful in turning the national and international economic and political fluctuations into opportunities. Sector has gained experience in this subject and has become skilled in turning crises to opportunities due to country's continuity in middle income trap, its long-standing classification as a developing country and its familiarity to economic crises.

According to other research results, sectors possesses high competitiveness in demand factors, whereas its competitiveness is determined as intermediate-high in related and supporting industries. Sector does not experience any difficulties in terms of international demands. However, its competitiveness level is lower in national demands. This situation can be explained with export-focused production. In other words, the sector gives more importance to foreign markets rather than domestic market. On the other hand, the sector specifies that it is competitive in terms of incentive policies, legal regulations and international agreements. Although the sector continuously demands increments in incentives, it extremely benefits from existing incentives. Besides, the sector does not give necessary importance to university-industry cooperation, sectorial organization and collaboration; because the enterprises see each other as rivals and find themselves adequate in terms of research and development and product development activities. In addition to these, they do not want to allocate funds for external stakeholders and they do not believe in the advantages of sectorial organization.

As it can be seen, Denizli home textile sector significantly contributes to national economy with its high competitiveness. Sector should give great importance to the factors in which its competitiveness is relatively low, in order to maintain and increase its competitiveness. In this context, sector should give great importance to institutionalization, sectorial collaboration, sectorial organization, university-industry cooperation, branding, international collaboration and domestic market and it should invest in order to fulfil these necessary needs. Sector's national and international competitiveness will increase after the fulfilment of these requirements.

Finally, this research has aimed to analyse the competitiveness of Denizli home textile sector and has used Porter's diamond model as a research method. In future researches, sector's competitiveness can be analysed by using different methods and the obtained results can be compared with this research's results in order to reveal the potential alterations on year basis and the possible differences and similarities between methods.

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The effect of service marketing mix elements and customer retention towards clothing store brands in China

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ABSTRACT – REZUMAT

The effect of service marketing mix elements and customer retention towards clothing store brands in China

The aim of this paper was to analyse the impact of service marketing mix (promotion, price, place, product, people, process, physical evidence and after sale service) on customer retention towards clothing store brands in China. Based on the analysis of past literature, it appeared that there were only few studies examining the empirical relation between the two constructs, particularly in the clothing sector in China. A comprehensive survey approach was used to collect data from a total of 385 customers visiting clothing stores in the middle part of China (Hubei). SPSS and PLS were used to analyse the obtained data. The findings showed that there were significant positive effects on customer retention in all dimensions of the service marketing mix. Finally, the findings suggested that after-sales service plays an important role in impacting the retention of customers. The contribution of this research was supporting the significance relationship of the marketing mix elements in influencing the retention of customers in the clothing industry with empirical data from China.

Keywords: *product, after sale service, price, physical evidence, process, clothing industry*

Influența elementelor mix de marketing pentru servicii și fidelizarea clienților față de mărcile magazinelor de îmbrăcăminte din China

Scopul acestei lucrări a fost de a analiza impactul mixului de marketing al serviciilor (promovare, preț, locație, produs, persoane, proces, dovezi fizice și servicii post-vânzare) asupra fidelizării clienților față de mărcile magazinelor de îmbrăcăminte din China. Pe baza analizei literaturii de specialitate, s-a constatat că au existat puține studii care să analizeze relația empirică dintre cele două concepte, în special în sectorul îmbrăcămintei din China. O abordare cuprinzătoare a sondajului a fost utilizată pentru a colecta date de la un total de 385 de clienți, care vizitează magazinele de îmbrăcăminte din partea de mijloc a Chinei (Hubei). SPSS și PLS au fost utilizate pentru a analiza datele obținute. Rezultatele au arătat că au existat influențe pozitive semnificative asupra fidelizării clienților în toate dimensiunile mixului de marketing al serviciilor. În cele din urmă, rezultatele au sugerat că serviciul post-vânzare joacă un rol important asupra fidelizării clienților. Contribuția acestei cercetări a susținut relația de semnificație a elementelor mix de marketing în influențarea fidelizării clienților din industria de îmbrăcăminte cu date empirice din China.

Cuvinte cheie: *produs, serviciu post-vânzare, preț, dovezi fizice, proces, industria de îmbrăcăminte*

INTRODUCTION

Customer retention is one of the most important advertising issues that has gained tremendous attention from many academics and business practitioners. Maintaining consumers is seen as an important goal in today's highly competitive market environments for several business organizations [1]. Many companies use their time and financial expenses extensively to establish long-lasting and beneficial relationships with potential and existing customers to enhance their performance in the marketplace [2]. Past research has shown that focusing on customer retention has been widely regarded as the most important goal for companies implementing marketing relationship strategy [3, 4]. While customer retention can be conceptualized and calculated differently from industry to others [5], a number of scholars conclude that the focus on customer retention can contribute to various financial benefits [6]. Therefore, designing and executing a marketing partnership strategy to retain business customers will allow companies to achieve competitive advantages that are sustainable [2].

Retention of customers has now become a very important marketing strategy, particularly in the clothing industry. This is because the clothing industry has experienced steady growth over the past couple of years as new clothing trends have emerged from the traditional markets through the growth of supermarket philosophy allowing the diversity of retail consumers in different parts of the world pleasure and distinctive shopping experience [7]. Shopping has recently become an interesting experience for consumers that can ensure their satisfaction and decrease their stresses as they are introduced under one roof to different brands and product categories where options are respected and handled with expertise and friendliness [8]. Recent research has shown that consumer retention in the clothing sector can be affected by numerous marketing factors such as promotion, price, place, product, people, process, physical evidence and after sale service. This is because in order to deliver consumer loyalty and satisfaction, these factors are considered essential [8].

There are some gaps in this area despite the increased importance in customer retention research. According to Zhengwei [9], over the past decades, customer retention has been widely accepted as an important topic, but there is limited research focusing on management processes associated with customer retention performance. In addition, various studies on customer retention and its key antecedents have been conducted in the developed countries.

Nevertheless, there are only a few studies that have been carried out in the developing world on customer retention. This study is planned to examine the impact of selected marketing mix elements on customer retention in the clothing industry based on the identified gaps. The findings would have beneficial implications for clothing industry decision-makers. For this study, the following section presents the literature review and the methodology and findings followed. After that, the last sections explain the discussion of the findings and conclusion.

LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

Customer retention

Undoubtedly, customer retention is considered one of the key goals for marketing partnerships. For several organizations, the emphasis on customer retention has been significantly appreciated in the current business environment. Therefore, it is important to empirically analyse the predictors of customer retention in order to effectively apply the advertising principles [6]. Some scholars Kofi et al [5] and Chen and Liu [1] viewed customer retention as an element of customer loyalty, whereas Han and Hyun [10] regarded retention as an effort to maintain a continuous partnership with a particular organization. The concept of customer retention refers to a customer's desire, belief, attachment, and dedication to a product and ability to recommend it to others. In other words, customer retention refers to the process that loyally produces the customer towards a certain product that can be expressed by repurchase behaviour [10]. Hanaysha [2] also claimed that customer retention occurs if a customer continues to buy a brand's products or services over a long period of time.

Furthermore, retention of customers suggests that a lasting relationship between a company and its customers can bring economic benefits for both parties [11].

When looking at past research, it indicates that customer retention has several advantages, such as superior business growth and higher profit margins [6]. For fact, customer retention can save the company a lot of money as the cost of getting new customers usually exceeds the cost of keeping current customers numerous times. Many researchers have also revealed that long-term consumers are likely to buy more, attract new customers, take less time from service providers, and be less prone to price changes [1, 12]. In addition, Eid [3] estimated that attracting new customers would cost seven times more than mainstreaming existing customers, and thus concentrating on customer retention could increase organizational income. It ensures that lifelong consumers are likely to have a higher level of satisfaction and, among others, will spread positive word of mouth [5]. Nonetheless, companies should provide outstanding services to their customers and manage any grievances from them effectively to improve the creation process of customer retention [10]. Han and Hyun [10] also pointed out that in order to maintain clients, service providers must make greater efforts to build the relationships of personal customers that may contribute to their loyalty to the company.

Relationship between service marketing mix and customer retention

Puluhulawa et al. [13] found that the marketing mix consists of a set of different marketing tools that companies can use to achieve their marketing objectives. The marketing decision factors in different marketing mix models offer input and advice to business plans that prioritize marketing tactics [14]. Marketing mix points out the key tasks that marketing managers will pursue. Once a target market has been established, marketing managers are then responsible for developing a marketing plan to sell their products/services to customers and create lasting relationships with them. Marketing plan involves important product, location, price and marketing decisions that are considered to be the most important aspects that include an efficient allocation of organizational resources in order to maximize sales and profit margins [15]. Similarly, seven marketing mix elements were incorporated in modern marketing practices by Yaghoubian et al. [16], which included product, place, promotion, price, process, people, and physical evidence. Some researchers added additional marketing mix elements such as variable building after-sales service. This study combines eight elements for calculating marketing mix in the clothing industry; promotion, price, place, product, people, process, physical evidence and after sale service. Based on several past studies coupled with conceptualization of a contemporary idea, this study suggests the following hypothesis:

H1: The service marketing mix has a positive effect on the customer retention.

The relationship between product and customer retention

It is MM's first and foremost component and heart, as long as there is no product or service, other SMM components lose their significance. In this respect, it should be attempted by visible mechanisms to mark the facilities as measurable [17]. In order to define a product, the concept of Jobhaarbima, [18] is used whereby "a product is anything that can be sold to a market for interest, acquisition, use or consumption that may fulfil a desire or need" [19]. Therefore, when designing a product/service, it is important that a customer's perspective should be given to the package of benefits in the service offer [20]. Hence, we propose the hypothesis of the study as follows:

H1a: The clothes product has a positive effect on the customer retention.

The relationship between promotion and customer retention

Promotion is considered to be a key marketing factor influencing consumer behaviour. Some researchers Shukor [21] have defined advertisement as a form of communication between a company and its consumers that is specifically designed to promote certain products and services. Nonetheless, advertising managers ' ability to create brand awareness of their products/services and convince or discourage potential customers to make buying offers depends on several factors in most situations, such as convenience, cost equality, as well as the effectiveness of promotional campaigns. The success of marketing campaigns depends on advertisers ' willingness and ability to clearly identify their target customers. Organizations spend a lot of money on research to be able to identify the features of their target audience, then develop the correct marketing campaigns and choose the most important outlets to convey the advantages of their products and services to potential clients. Advertising strategies are therefore aimed at shaping the reactions of customers to a brand's marketing activities and establishing successful relationships with them. Therefore the following hypothesis has been proposed:

H1b: The clothes promotion has a positive effect on the customer retention.

The relationship between price and customer retention

Price was also considered to be a crucial marketing tool for consumer purchases of a product or service [22]. Previously, the concept of price was defined in the literature as the monetary value of a product or service [23]. In other words, price is the financial value given to a commodity that includes both its cost and the expected income. Puluhulawa et al. [13] found that customers who are likely to be price sensitive tend to avoid buying from products selling at higher prices and not taking the interests of consumers at hand. Other scholars Aras et al. [24] have observed that when customers tend to make purchase decisions, they look at the price initially and give it high credit relative to other attributes. Similarly, Hiransomboon [25] reported that a particular service provider's product repurchase decisions rely on their previous purchasing experience in terms of value for money. Price was considered an important determinant of customer retention and satisfaction for this reason. Based on the following hypothesis, therefore, we can assume to test the relationship:

H1c: The clothes price has a positive effect on the customer retention.

The relationship between place and customer retention

Place or location is an essential marketing mix factor that can be described as where a company wants to sell their products or services to specific market segments in order to make them easily accessible. Thamrin [26] explained that place is the management judgements as to where the products or services are to be distributed to consumers, and may consist of digital or physical distribution channels. In addition, Octavia [27] has stated its stance as any way that consumers may access a certain brand's product or service. Obviously, a successful decision on the channel needs businesses to have clear knowledge of their target markets [20]. The location of the shop is considered the most important factor for business success and customer retention in the clothing industry. Location convenience plays a key role in shaping the choices made by the consumer about the services provided by the shop. Finally, by making the right decision to locate an intermediary's store for selling its products and services, a good place seems to be meeting the needs of consumers. Hence, the following hypothesis could be proposed:

H1d: The clothes place has a positive effect on the customer retention.

The relationship between people and customer retention

Considering the coexisting availability of facilities and the interaction between provider and servant, the importance of workers in the facility is fundamental and critical accuracy needs to be committed to the factors of staff-related recruitment, training, encouragement and other human resources [27]. It is important to observe the importance of employers in an organization with a focus on staff development. In Clothing Store Brands, the element of people is crucial and has an essential characteristic to influence branding and customer retention. On the other hand, there are a number of brand clothes that implement brand clothing technology. For example, another phase requires the appearance of service staff and travel agent services to be more professional and involve more methodological skills. Therefore, this hypothesis is proposed:

H1e: The clothes people have a positive effect on the customer retention.

The relationship between process and customer retention

The product management and marketing process has an influence on service quality. Possibilities, constraints and conditions of supply and demand are important factors that influence the service provision system. The simplicity of the service system is compatible with the comfort and satisfaction of consumers in terms of quick and easy delivery [28].

Somocor [23] defined the process as the procedures, mechanisms and activities needed to deliver services. Clothing Store Brands is generally considered to be a standard and unchangeable service location. Thus, we propose the following hypothesis:

H1f: The clothes process has a positive effect on the customer retention.

The relationship between Physical evidence and customer retention

In order to deliver programs and realize potential services, diversity of physical, material tools and facilities as elements of service organization are essential.

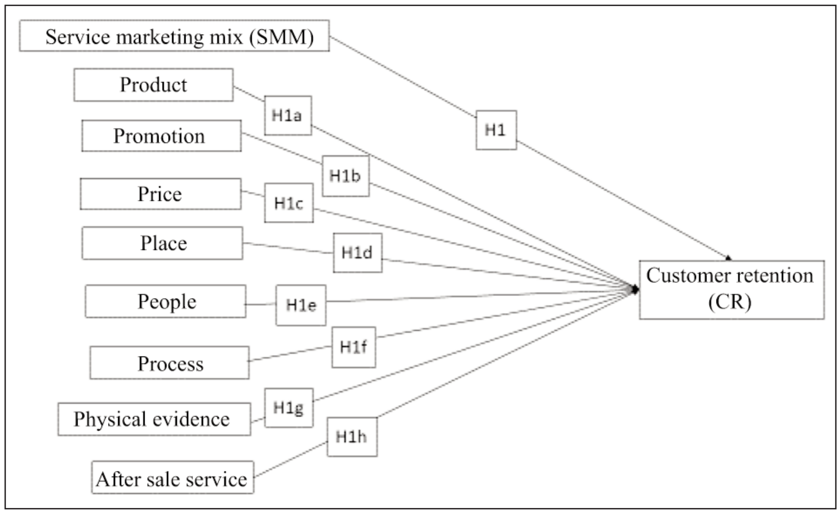

Fig. 1. Research framework

Customer retention is associated with up-to-date and more analytical services [28]. Clothing store brands could generally be considered a typical procedure, and the location of the service is unchangeable. Implementing brand clothing technology in services is a key element in reducing reliance on the human aspect and advancing for clothing store brands. Using software in clothing store brands helps provide day-to-day (twenty-four hour operation), time and transaction reliability, improved monitoring of clothing store brands, and online application assistance. Clothing store brands can be considered a place for cloth customers to learn, wear, and experience clothing store brands. Clothing store brands plays a major role in delivering facilities as a non-transferable central authority, so consumers can enjoy the facilities as clothing-style services. Appropriate delivery of physical evidence in clothing store brands therefore has a positive impact on customer experience and enjoyment during product use, including: processes, paperwork, office environment, and equipment. Thus, the following assumption has been stated:

H1g: The clothes physical evidence has a positive effect on the customer retention.

The relationship between after sale service and customer retention

Lastly, after sales service has changed market practices due to rapid technological advancement, intense demand, and increased profits [29]. Now, the after-sales service has shifted from a cost center to a major source of profit, reaching up to 45% of revenue in many businesses [30]. Service providers' after-sales service policy is influenced by specific terms such as service contracts, warranty, consumer characteristics and brand characteristics [29]. After sale service ensure that consumers' loyalty is fulfilled with the products they have provided. Of example, for both parties, the sale of tickets to consumers during holidays is not necessarily the completion of the selling business. Clothing store brands have to inquire about their satisfaction for after sale services from customers after the purchase. This will create a good image of clothing store brands and demonstrate genuine concerns about customer relationships [31]. Therefore, the following hypothesis has been proposed:

H1h: The clothes after sale service have a positive effect on the customer retention.

Based on the above literature, figure 1 shows details of the proposed study of this paper.

This study used the approach of quantitative research to gather data from respondents. For this study, the target population consisted of clothing store brands customers in China. The data was collected using a survey method from 267 customers in the specified part of China who have real experience buying clothing store brands shop. The survey tool enables response from large numbers of individuals to be collected at minimal cost and within a shorter period of time relative to other forms of data collection. The minimum sample size to analyse data using structural equation modelling (SEM) should be 200 [32]. The sample used in this study is therefore considered sufficient to use Smart PLS to analyse the data. After developing the questionnaire based on previous studies, the data collection process was initiated. Customer retention was assessed by adapting and adjusting a scale of four items from the [33]. Likewise, from previous studies, the measurement levels of the chosen service marketing mix have been modified. For example, product was calculated using Shareef et al. [34] to adapt four products. Four items have also been developed to measure the price based on previous research and literature. Also developed were the four items for measuring promotion based on the measurement scale used by [35]. In addition, place was measured using Shareef et al. [34] to adapt five items. The four items for measuring people were also developed on the basis of Ling's [35] measurement scale. Process was measured using four items from the Ling study [35].

Additionally, a five items scale was adapted from Yoo et al. [36] to measure physical evidence. Finally, after sale service was measured using five items being taken from the study of [35]. All items are measured on a Likert scale of five scales, ranging from strongly disagree to strongly agree.

ANALYSIS OF RESULTS

Profile of respondents

The quantitative analysis showed that 44.6% of the participants are male, while 55.4% are women. The research also showed that a degree credential was accessible to most participants. In terms of monthly income, an average income of 67 respondents was below 600$, defined by 25.1%, and an average income of 43 participants (16.1%) ranged from 601$ to 1000$. There are also 75 respondents whose monthly income ranged from 1001$ to 1500$ and accounted for 28.1%, and finally, 82 respondents (30.7%) had a monthly income of more than 15001$.

Assessment of measurement model

Table 1 describes the analysis of this study's build reliability and convergent reliability. As illustrated, the reliability of the composite for customer retention is 0.900, the product dimension is 0.940, while the service dimension after sale is 0.959. All of the above Composite Quality values indicate the internal consistency of the constructs. Essentially, the quality of Cronbach's alpha and composite is similarly perceived [37, 38]. Prior research indicates that the threshold level of 0.60 or higher is needed in exploratory research to demonstrate adequate composite reliability, but not to exceed 0.95 [37].

The next step is to observe the accuracy of the metrics where the analysis is to determine the degree to which a factor or group of variables is consistent with what it aims to calculate [39]. Sarstedt et al. [37] proposed that the charging of the indicator must exceed 0.7. Accordingly, the indicator reliability values ranged from 0.851 to 0.946, which surpassed the minimum value of 0.7, can be seen in table 1. The results obtained from this stage provide a significant indication that these buildings provide an adequate convergent validity resulting in no removal of objects based on low loads. In addition, the measurement template analysis also shows that all the AVE values of the build are above 0.7. The result shows that the study's AVE exceeded the minimum value 0.5 of the derived average variance (AVE) indicating that the items loaded into the respective constructs explain more than 50 % of the variance of the constructs [40]. In addition to the measurement model analysis, Fornell and Larcker [41] were performed to test the discriminating validity. Table 2 indicates the criteria of Fornell and Larcker. The results from this study show that for every construct the square root of AVE is greater than the construct's correlation estimate. Therefore, it is noted that the concepts contrast with each other according to the discriminating validity criterion of [41].

Hypothesis

In this subheading, analysis on the direct effects hypotheses between latent constructs has been made through PLS-SEM algorithm and bootstrapping of 5,000 subsamples iterations. The direct effect hypotheses are the hypotheses that predict direct connection to a latent construct with another as indicated by an arrow. The present study has eight direct effect hypotheses coded as H1a, H1b, H1c, H1d, H1e, H1f, H1g and H1h for testing. Table 3 shows the results of the direct effect of the hypothesis test. In testing the hypotheses, the path standardised estimate or beta (β), standard errors (S.E.), t-value and probability value were used and thus, presented in a parenthesis and also in diagram [40]. Suggestion by Chin [37], the β value of standardized paths should be around 0.20 but more ideally, the value has to be above 0.30 to be considered as meaningful. In the five direct effects, hypotheses of the study are discussed.

The data analysis results show that SMM positively and significantly affects the total sample CR ($\beta = 0.828$, $p = 0.000$) in support of Hypothesis 1. The data results also show that the dimension of the after-sale service has a positive and significant impact on the total sample CR (Beta = 0.137, $p = 0.000$). Hence, the proof is sufficient to support all the study hypotheses. It is therefore assumed that the CR is greatly and positively influenced by SMM and its measurements.

According to Hair [40], the primary assessment criterion of the structural model by PLS-SEM is the R^2 measures and to determine the significance level of the path coefficients. The reason is because the objective of the prediction-oriented PLSSEM approach is to explain the variance of endogenous latent variable and reasonably high R^2 value should be obtained. A rule of thumb in marketing research studies, R^2 values of 0.75, 0.50, or 0.25 for endogenous latent variables in the structural model can be represented as substantial, moderate, or weak, respectively. Accordingly, the obtained R^2 value can be used to interpret the quality of the structural model which indicates the explanatory variance by the exogenous variables contained in the endogenous variable. Assessment results it can be explained the R^2 was found to be 0.686 for CR, indicating that SMM can account for 68.6% of the variance in the CR, which was substantial level (figure 2).

Discussions

The idea is that the service marketing mix has a favourable and significant effect on customer retention, as can be seen in table 1, the findings show that SMM has a significant effect on customer retention ($\beta = 0.828$, t-value = 36.743, $p = 0.000$), so H1 is acknowledged. The findings of all sub-hypothesis testing indicate that the service marketing mix have a significant positive impact on the retention of customers. Factor contributing to the positive impact and significant marketing mix on customer retention,

Table 1

INTERNAL CONSISTENCY AND CONVERGENT VALIDITY					
Parameters	**Cronbach's Alpha**	**Items**	**Factor loading**	**Composite reliability**	**Average Variance Extracted (AVE)**
After sale service	0.946	AFSS1	0.923	0.959	0.824
		AFSS2	0.916		
		AFSS3	0.932		
		AFSS4	0.884		
		AFSS5	0.884		
Customer retention	0.851	CR1	0.777	0.900	0.692
		CR2	0.839		
		CR3	0.873		
		CR4	0.836		
People	0.942	PEP1	0.923	0.958	0.852
		PEP2	0.927		
		PEP3	0.929		
		PEP4	0.913		
Physical evidence	0.944	PHY1	0.906	0.957	0.818
		PHY2	0.911		
		PHY3	0.904		
		PHY4	0.907		
		PHY5	0.893		
Place	0.928	PLC1	0.872	0.946	0.778
		PLC2	0.908		
		PLC3	0.905		
		PLC4	0.840		
		PLC5	0.883		
Price	0.917	PRC1	0.914	0.942	0.802
		PRC2	0.905		
		PRC3	0.874		
		PRC4	0.888		
Process	0.905	PRO1	0.916	0.934	0.780
		PRO2	0.892		
		PRO3	0.915		
		PRO4	0.805		
Product	0.915	PRD1	0.871	0.940	0.797
		PRD2	0.922		
		PRD3	0.886		
		PRD4	0.891		
Promotion	0.876	PRM1	0.870	0.915	0.730
		PRM1	0.871		
		PRM1	0.868		
		PRM1	0.807		

based on the results of the focus group known causes of the positive and significant effect of the service marketing mix on customer retention, believed by customers that product is a quality cloth, provide competitive prices, good sales media communications, easily accessible dealer showroom, customer-sensitive staff and ample facilities and services available to cause high customer retention. The claim clarified that it is not possible to achieve the development of customer retention by a single dimension, but the entire dimension inherent in the marketing mix. In addition to the several areas of consumer buying behaviour in China, due to cultural factors, the result is customer retention. That in some tribes/communities in China they have a habit and conviction that it's a brand fabric, if not clothing store brands,

Table 2

FORNELL AND LARCKER CRITERION									
Parameters	**After sale service**	**Customer retention**	**People**	**Physical evidence**	**Place**	**Price**	**Process**	**Product**	**Promotion**
After sale service	0.908								
Customer retention	0.797	0.832							
People	0.848	0.751	0.923						
Physical evidence	0.875	0.807	0.834	0.904					
Place	0.817	0.749	0.811	0.828	0.882				
Price	0.749	0.712	0.735	0.807	0.784	0.895			
Process	0.882	0.800	0.861	0.906	0.827	0.809	0.883		
Product	0.776	0.690	0.745	0.798	0.774	0.814	0.860	0.893	
Promotion	0.811	0.739	0.801	0.842	0.839	0.816	0.841	0.800	0.854

Table 3

RESULTS OF HYPOTHESES					
Hypotheses	**Path**	**β**	**S.E**	**t-value**	**P Values**
H1	SMM → CR	0.828	0.023	36.743	0.000
H1a	AFSS → CR	0.137	0.004	33.013	0.000
H1b	PEP → CR	0.108	0.003	33.128	0.000
H1c	PHY → CR	0.138	0.004	33.143	0.000
H1d	PLC → CR	0.125	0.004	28.528	0.000
H1e	PRC → CR	0.099	0.004	26.207	0.000
H1f	PRO → CR	0.105	0.003	33.574	0.000
H1g	PRD → CR	0.096	0.004	26.051	0.000
H1h	PRM → CR	0.093	0.003	28.523	0.000

Note: AFSS = after sale service; PEP = people; PHY = physical evidence; PLC = place; PRC = price; PRO = process; PDT = product; PRM = promotion; SMM = service marketing mix; CR = customer retention.

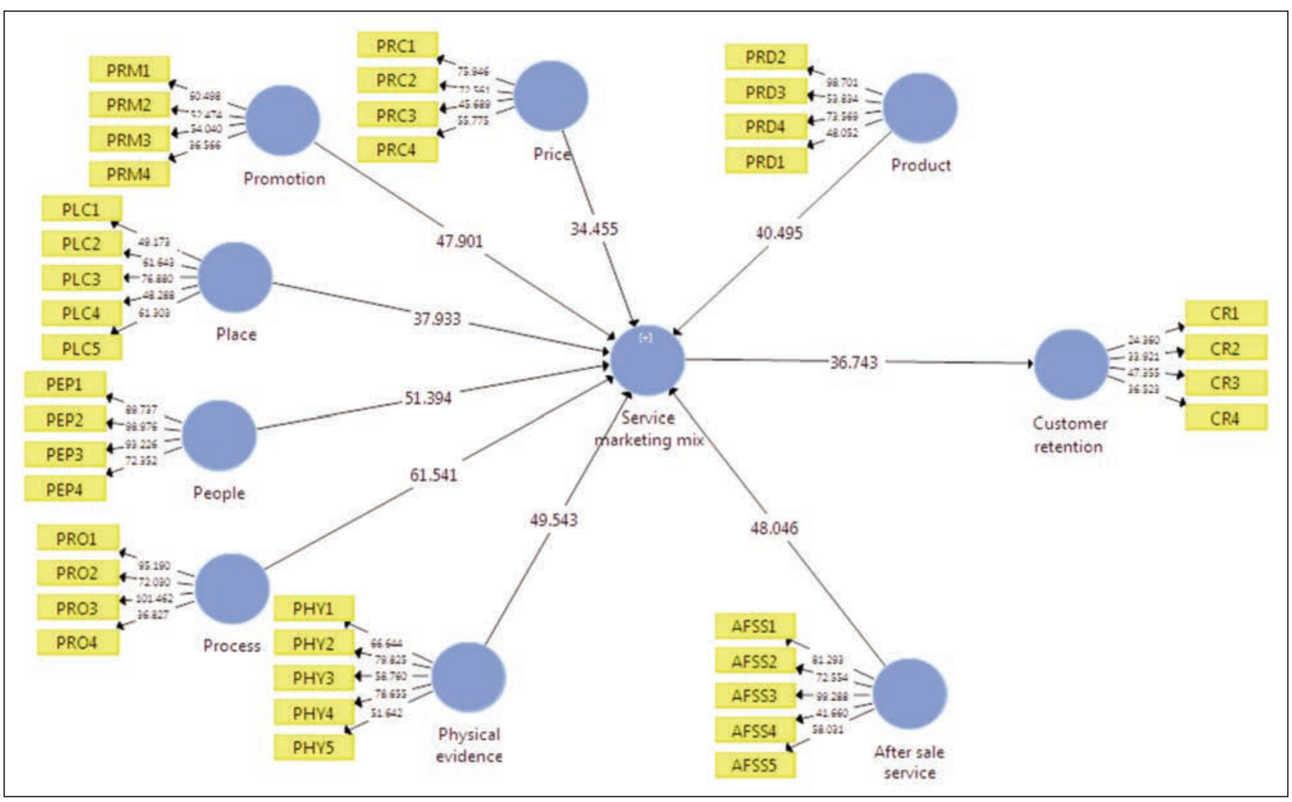

Fig. 2. PLS model path coefficient (bootstrapping at 500 resampling)

they don't look at it as a product, and consumers will still make purchase decisions by buying clothes for whatever reason.

Cultural factors influence consumer behaviour as far as possible and as far as possible. Marketing needs to know the role of communities, subcultures, and groups in society. Culture refers to the idea as members of society, symbols that have meaning to communicate, values, interpretation and evaluation. From the consumer's beliefs, views, and habits towards a product, culture can be seen. Higher product confidence and higher customer decision to purchase affect customer retention [19]. The results support the theory of assuming fidelity that assesses the customer's loyal or disloyal views of fidelity to buy back on a regular basis, always recommends reference to the experience of the services received to others and has shown a positive response to the services offered [42]. Support on previous researchers' results, targeting studies conducted [21, 43] that marketing mix elements (price, product, place and promotion) have a significant impact on customer retention. Then have a correlation with Han and Hyun [10], findings that the service has a significant effect on retention, whilst pricing, staffing and procedures have a negligible effect on retention of customers. This study supports the partial results Puluhulawa et al. [13] that there is no significant effect on customer retention on the product and price in the other dimensions of the place and promotion.

CONCLUSION

Customer retention is the fact that having conservation clients is of the utmost importance, and it is also crucial that the service marketing mix can really help the company provider understand what variables the consumer is searching for when purchasing clothing store brands apparel. The goal of this research effort is to observe the relation in clothing store brands between customer retention and service marketing mix. It is therefore very critical that the fashion industry's business suppliers have awareness of marketing needs, as well as attracting customers to clothing store brands, as well as concentrating on how to keep them loyal. However, this study aims to relate in literature to both theory and practice.

LIMITATION

This paper has some drawbacks that would offer future research opportunities. First, the study's main focus was on department stores and only customers concerned. Future studies can therefore broaden the scope and be carried out in different areas of the country by including department store workers to gain better insight into the important factors in the clothing industry. In addition, the data were collected using systematic questions through quantitative survey; therefore, future studies may use other study to validate the findings. Furthermore, this study examined only a service marketing mix of eight dimensions of independent variables; thus, future research may consider other factors that may affect customer retention in China's clothing industry, such as social media marketing and corporate social responsibility.

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Analysing portfolio diversification opportunities in selected stock markets of North and South America and their impact on the textile sector: An empirical case study

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ABSTRACT – REZUMAT

Analysing portfolio diversification opportunities in selected stock markets of North and South America and their impact on the textile sector: An empirical case study

This empirical study investigates the financial integration linkages among the sample stock markets of Canada, Mexico, United States (for both New York Stock Exchange, i.e. NYSE and NASDAQ), Panama, Brazil, Chile, Peru, Venezuela, Jamaica, Trinidad, and Tobago during the period from January 2001 to April 2019. This research study also examines the impact of selected stock market dynamics on the textile sector. International portfolio diversification has been an important subject of research in financial fraternity since the emergence of Modern Portfolio Theory in 1952. This study examines the portfolio diversification opportunities in the 11 stock markets of Americas.International diversification among stock market indices has proven to be fruitful in the past. Certain tests have been used to determine opportunities for diversification are correlation test, pairwise co-integration test, multiple co-integration test and granger causality test. The empirical results show that stock market indices share low correlation among other and they are not highly co-integrated whereas results of Granger causality test exhibit an unidirectional relationship among few stock markets in short run.

Keywords: *portfolio diversification strategy, co-integration, textile industry, Granger causality test, correlation coefficient, modern portfolio theory*

Analiza oportunităților de diversificare a portofoliului pe piețele bursiere selectate din America de Nord și de Sud, precum și impactul acestora asupra sectorului textil: Un studiu de caz empiric

Acest studiu empiric investighează integrarea financiară existentă între piețele bursiere incluse în clusterul format din Canada, Mexic, Statele Unite ale Americii (atât pentru piața bursieră din New York, adică pentru NYSE, cât și pentru NASDAQ), Panama, Brazilia, Chile, Peru, Venezuela, Jamaica, Trinidad și Tobago pentru intervalul de timp ianuarie 2001 – aprilie 2019. De asemenea, acest studiu de cercetare analizează impactul dinamicii piețelor bursiere selectate asupra sectorului textil. Diversificarea portofoliului internațional a fost un subiect important de studiu în domeniul financiar, încă de la apariția teoriei moderne a portofoliului în 1952. Studiul analizează oportunitățile de diversificare a portofoliului pe cele 11 piețe bursiere din America. Diversificarea internațională aplicată cu ajutorul indicilor bursieri s-a dovedit a fi profitabilă în trecut. Anumite teste au fost utilizate pentru a determina oportunitățile de diversificare, respectiv: testul de corelație, testul de cointegrare pereche, testul de cointegrare multiplă și testul de cauzalitate Granger. Rezultatele empirice evidențiază faptul că indicii bursieri analizați prezintă o corelație scăzută și nu există o relație puternică de cointegrare, în timp ce rezultatele testului de cauzalitate Granger prezintă relația unidirecțională manifestată între câteva piețe bursiere pe termen scurt.

Cuvinte cheie: *strategia de diversificare a portofoliului, cointegrare, industria textilă, testul de cauzalitate Granger, coeficientul de corelație, teoria modernă a portofoliului*

INTRODUCTION

Portfolio diversification among the global stock markets has long been a prominent practice among investors to diversify and minimize portfolio risk and maximize stock returns. It has also been a topic of continuous academic research to examine the integration among stock markets of various countries to see whether they provide diversification opportunity to investors or not. Stock markets that are segmented provide better opportunity of diversification as compared to stock markets that are integrated with each other [1, 2]. There have been studies that measure the integration of developed financial markets with developed markets [1], developed with emerging markets [3], emerging markets with emerging markets [4] and integration of regional financial markets [2]. Moreover, Spulbar et al. [5] investigated volatility spill over patterns between selected emerging

(Hungary, Romania, China, Poland and India) and developed (USA, UK, France, Canada, Spain, Germany and Japan) stock markets.

The Americas include countries from the continents of North and South America. This study examines the integration among the sample stock markets of Canada, Mexico, United States (for both New York Stock Exchange (NYSE) and NASDAQ), Panama, Brazil, Chile, Peru, Venezuela, Jamaica, Trinidad, and Tobago during the period from January 2001 to April 2019. The chosen sample allows us to examine the stock market integration among the markets that are in a similar geographical region but differ greatly in regulatory setting and are in various stages of development. For example, the NYSE and the NASDAQ are the largest first and the second largest stock markets in the world in terms of market capitalization and have been a focus of enormous research due to the US being a major investor in many countries, enforces a huge political influence on several countries in the world and is an important factor in influencing the world financial markets. The US market is also found to be a leading the world stock markets while Singh et al. [2] show that little diversification opportunities exist among the regional markets as their stock market movements are highly correlated. Xu et al. [6] suggested that US represents the most important textile import market in the world, but also one of the most important export targets of developing countries. Textile production is the result of long manufacturing and wet-processing stages [7], while these particular manufacturing steps include yarn, fabric and garments manufacturing and wet processing [8]. However, the textile sector is influenced by the dynamics of stock markets, especially in the case of developing countries. Olaru et al. [9] argued that competitive pressure of globalization is causing textile and garment manufacturers to lower production costs, increase their efficiency and to create leaner value-adding processes. For instance, Săliştean et al. [10] argued that risk operations aim at mitigating emergency situations but are only implemented when needed considering decision making in emergency response.

Our index level data were non-stationary therefore we used co-integration vector autoregression (VAR) lag length selection criteria to examine the interdependencies among the sample stock market indices. Similar to previous studies, we find that the two stock exchanges in the US (i.e. the NYSE and the NASDAQ) are highly integrated hence they do not provide a diversification opportunity. However, diversification opportunities exist among the other stock exchanges irrespective of their regional proximity or the level of market development. For example, the stock markets of Peru and Trinidad and Tobago, and Mexico and Panama are negatively correlated and provide fruitful diversification opportunities. Contrary to the results of previous studies [4], our results suggest that stock markets in North and South Americas present potential opportunities for diversification.

LITERATURE REVIEW

The modern portfolio theory by Markowitz [11] suggests that portfolio diversification can reduce the investment risk but the extent of which depends upon the correlations among the returns of the securities in the portfolio. The correlations between economies tend to move in unison. Levy and Sarnat [12] suggest that portfolios should be diversified internationally to avoid country specific risk. Grubel and Fadner [13] argue that investors tend to invest in stocks of foreign countries to avoid the effect of domestic business cycles and government policies. The era of 1970's experienced the start of globalization with changes in technology and innovations in financial markets. As a result, the trend of taking advantage from cross border diversification increased. This led the investors to diversify their portfolios by investing in the stocks of foreign countries. Also, investors may earn capital gain due to exchange rate fluctuations. World Bank reported in 1997 that the financial markets of world were becoming global market places where investors diversify their portfolios among various developing countries to minimize risk and achieve higher returns. It is argued that an internationally diversified portfolio has risk less than half of the risk of the portfolio that consists of the US based securities only [14]. On the other hand, Yildirim and Masih [15] suggested that if the emerging stock markets were fully integrated with the developed stock markets, there would not be any portfolio diversification benefit for either the developed and/or the emerging countries' investors.

The focus of many studies, have been on examining the causal relationship between United States and stock markets of other countries [16]. Reason being; the US has been a major investor in many countries and enforces a huge political influence on several countries in the world. Results of these studies show that the United States has been an important global factor that moved the world markets. Maldonado and Saunders [16] examined inter-temporal patterns of the correlation coefficients between monthly returns on United States stock index with monthly returns on indices of Canada, Germany, Japan and United Kingdom over a period of 22 years from 1957 to 1978. They concluded that a predictable relationship exists between these countries in short run. However, in the long-run, there are unstable correlations among the sample stock markets. While Bessler and Yang [1] add that, although the US markets lead, the US markets are also influenced by the UK, Switzerland, Hong Kong, France and Germany. These results may not be as surprising given the rate of integration of the world economy with the US economy. They further argue that the international financial markets are neither fully integrated, not fully segmented implying a potential opportunity for international diversification.

Various studies have been conducted to examine the integration of various stock markets across the world. Ripley [18] investigated the systematic covariance between stock prices of nineteen developed stock markets of the world. He explored the relationship between the stock prices using factor analysis and found that more than half of the movement in stock prices of a country is unique from other countries. Panton, Parker and Joy [19] examined the relationship between the weekly stock prices of twelve developed countries by applying cluster analysis over the period from 1963 to 1972. The results showed relatively strong relationship between stock markets of Canada, Netherlands, Switzerland, Belgium and the United States. However, less strong relationship existed between Germany and Netherlands, France and Belgium, and England and Australia.

Similarly, other researchers such as Trivedi et al. [20] investigated volatility spill overs and co-movements based on a cluster of European stock markets, such as developed (Spain, UK, Germany, and France) and emerging (Poland, Hungary, Croatia, and Romania) from January 2000 to July 2018. Arshanapalli and Doukas [21] analysed the stock markets of Japan, United Kingdom, France, Germany and the United States for the period from January 1980 to May 1990 using daily closing market index. They found that the interdependence among world capital markets have increased since the 1987 stock market crash, apart from Japan's Nikkei Index. Corhay, Rad and Urbain [22] examined the stock markets of Australia, Singapore, Japan, Hong Kong and New Zealand over the period from 1972 to 1992 and found that there is no evidence of a single stochastic trend among the sample countries. Cheung and Mak [23] examined the causal relationship between the emerging markets of Asia with the developed markets of the US and Japan. They found that emerging Asian markets are led by the United States Stock market except the stock markets of Korea, Taiwan and Thailand whereas Japanese market has less influence on emerging markets of Asia Pacific region. DeFusco et al. [24] examined the co-integration among US and emerging Asian stock markets of Thailand, Malaysia, Hong Kong, Taiwan, Korea, Singapore, and the Philippines in the 1980s and early 1990s and found that there is no integration between these emerging markets of Asia and the US. Korajczyk [25] tried to find relationship between twenty-four markets of the world and found that emerging markets are more segmented as compared to developed markets providing an opportunity of diversification.

Ghosh, Saidi, and Johnson [26] applied the theory of co-integration using daily closing values of stock market indices to investigate which stock markets of Asia Pacific are moved by the markets of Japan and the United States He found that stock markets of India, Hong Kong, Malaysia and Korea share a long-run equilibrium relationship with stock markets of the United States, while the stock markets of Singapore, Indonesia and Philippines are linked with the stock market of Japan. However, the stock markets of Taiwan and Thailand are not influenced by the stock markets of United States and Japan. Tuluca and Zwick [27] studied the stock indices difference by applying Granger-causality technique. He used factor analysis to study the stock indices returns before and after the Asian financial crises of 1997 among thirteen Asian and non-Asian stock markets. They concluded that the co-movement among these markets is stronger after the Asian financial crises of 1997. Wong et al. [28] measured the integration between stock markets of developed countries and emerging Asian markets. They found that the integration between these countries has increased after the 1987 stock market crash. This integration has increased even more after the 1997 Asian financial crisis.

Antonio [29] examined long run relationship among the stock markets of European region using co integration techniques and found no evidence of long run relationship between these countries' stock markets. Using co-integration analysis and error correction vector autoregressions (VAR) techniques to model the interdependencies on stock market indices of Latin American stock markets, Chen, Firth, and Rui [4] find limited potential for diversifying risk in those markets. On the other hand, using partial correlation-based networks to estimate the linkages between global equity markets Singh, Li, and Roca [2] show that regional markets are more correlated while the negative correlations exist in global markets providing diversification opportunities.

EMPIRICAL METHODOLOGY AND STATISTICAL DATA

This section contains the data and methodology. Data for 11 stock markets from 10 countries on the American continent have been downloaded from data stream. These countries are Canada, Mexico, USA (NASDAQ and NYSE), Panama, Brazil, Chile, Peru, Venezuela, Jamaica and Trinidad and Tobago. Stock market indices have been downloaded from 11 stock markets. The stock market indices are the following: S&P/TSX Composite Index (Canada), Mexico IPC (Mexico), NASDAQ Composite (USA), NYSE Composite (USA), PANAMA SE BVPSI (Panama), Brazil BOVESPA (Brazil), S&P/CLX IGPA CLP INDEX (Chile), S&P/BVL GENERAL(IGBVL), VENA, MERINVEST Composite (Venezuela), Jamaica SE main index (Jamaica) and S&P Trinidad & Tobago BMI (Trinidad and Tobago). Daily stock market indices have been downloaded for 11 stock markets from data stream. Time period of the data started from 3rd of January 2001 and ended on 30th of April 2019.

To examine the diversification opportunities among the stock markets, results of pairwise correlation, multiple and pairwise co-integration and causality integration will be examined.

Details of these tests are as follows:

Correlation Matrix measures the tandem movements of two stock indices in terms of dependency. It determines if two stock stocks are independent or dependent upon each other or not. Its value is from +1 to –1 which is called correlation coefficient.

Whereas, positive 1 correlation coefficient indicates that movements are tandem between two stocks and negative 1 correlation coefficient indicates that movements of two stock indices are not tandem and 0 correlation coefficient means that there is no relationship between two stock market indices. Correlation is a trivial part of global portfolio diversification and investors are recommended to diversify among stock market indices that have low correlation coefficient between them.

Variance of a portfolio is measured using following equation:

$$\sigma^2 p = \omega^2 A\sigma^2 A + \omega^2\sigma^2 B + 2\omega A\omega B\sigma A\sigma B\rho AB \quad (1)$$

where $\sigma^2 p$ is variance of portfolio, $\omega^2 A$ – weight of a security in portfolio and ρ – correlation coefficient.

Unit Root Test examines stationarity of a time series which characterizes stock market index is examined to run co-integration. Time series should be stationary at first level in order to run co-integration. According to Fama [30], stock prices reflect all available information in efficient market hypothesis (EMH). The author categorized stock market into week form EMH, semi-string form EMH and strong form EMH. In week form EMH, stock prices are non-stationary displaying a “fad” in the movements of stock prices. Unit root test is applied to check the stationarity of the data. Dickey Fuller test is used to examine stationarity through unit root test. The results of unit root test may display random walk in time series showing inefficiency in the stock market indices. The null hypothesis of unit root test is that data is nonstationary.

$$y_t = \rho y_{t-1} + \mu_t \quad (2)$$

where y_t is stock market index for a given day, y_{t-1} – stock market index for previous day, ρ – coefficient and μ_t – error term.

Johansen’s multivariate co-integration test

If two or more indices have tandem movements, they are integrated with each other. Johansen’s co-integration test is used to examine the tandem movements among stock market indices. It will be used to examine the long run and short run relationship among stock market indices. Following function will be used to examine multivariate co-integration among stock market indices:

$$\lambda \text{ trace} = -T \sum \ln(1 - \lambda i) \quad (3)$$

where λi is estimated Eigen value and λ trace is trace statistic.

Granger causality test

Granger causality test examines the impact of one market index on the other. The relationship between market indices can unidirectional or bidirectional. Unidirectional relationship means only one index is impacting the other index and bidirectional relationship means both indices are impacting each other.

EMPIRICAL RESULTS

The following table displays the descriptive statistics for selected 11 stock market indices. Total number of observations is 5042. The highest mean value is posted by Venezuela stock market which is 0.392% whereas the lowest mean value is 0.0190% posted by Canadian stock market. Highest standard deviation value means that stock market is extremely volatile. Venezuela stock market is a highly volatile market because of its high standard deviation value which is 8.2 whereas least volatile stock market is Trinidad and Tobago which is 0.69. It is interesting to note that Venezuelan stock market posts the highest mean return and it is also the most volatile stock market in the sample. The lowest minimum return is posted by Venezuela stock market which is –97.63% whereas highest “minimum” return is posted by Jamaican stock market. Lowest “maximum” return is posted by Jamaica which is 8.28%. Whereas highest maximum return is posted by Venezuela stock market which 498%. It is important to observe that Venezuela stock market is the one with highest mean

Table 1

DESCRIPTIVE STATISTICS

Sl. no.	Country	Obs.	Mean	Std. Dev.	Min	Max
1	Canada	5042	0.019075	1.058215	–9.32419	9.823324
2	Mexico	5042	0.044235	1.255072	–7.93483	11.00523
3	NASDAQ	5042	0.025638	1.549943	–9.66851	14.1732
4	NYSE	5042	0.019589	1.170759	–9.726	12.21624
5	Panama	5042	0.027358	0.663432	–12.647	14.56904
6	Brazil	5042	0.049143	1.722829	–11.3931	14.65784
7	Chile	5042	0.034988	0.733261	–5.80357	9.480726
8	Peru	5042	0.056721	1.30034	–12.4454	13.67299
9	Venezuela	5042	0.392427	8.230275	–97.6399	498.2278
10	Jamaica	5042	0.060879	0.795577	–6.12349	8.282775
11	S&P Trinidad & Tobago	5042	0.025458	0.694279	–7.7563	15.90086

Table 2

CORRELATION MATRIX											
Country	**Canada**	**Mexico**	**USA (NASDAQ)**	**USA (NYSE)**	**Panama**	**Brazil**	**Chile**	**Peru**	**Venezuela**	**Jamaica**	**Trinidad & Tobago**
Canada	1										
Mexico	0.5815	1									
USA (NASDAQ)	0.6705	0.6171	1								
USA (NYSE)	0.743	0.6579	0.8128	1							
Panama	–0.0172	–0.0184	–0.0237	–0.0304	1						
Brazil	0.5506	0.5952	0.5257	0.6055	–0.002	1					
Chile	0.4331	0.4681	0.3663	0.4706	–0.0089	0.4618	1				
Peru	0.4429	0.3817	0.3064	0.4237	0.0235	0.3961	0.4098	1			
Venezuela	0.0035	0.031	0.016	0.01	0.0268	0.0222	0.018	0.0205	1		
Jamaica	0.0429	0.0343	0.014	0.0311	0.0075	0.0289	0.0313	0.0394	0.0045	1	
Trinidad & Tobago	0.0132	0.0042	0.0065	0.0145	0.0102	0.0211	0.021	–0.0062	–0.0004	0.0217	1

return and it is also highly volatile (highest standard deviation value) whereas it also posts lowest and highest returns.

Table 2 includes the empirical results for the correlation matrix. The correlation coefficient displays if two sectors are independent or not? If yes, their movements are tandem or not. The correlation coefficient values show if the relationship between two stock market indices exists, if yes, then the relationship is strong or weak? The correlation coefficient value varies from +1 to –1. Moreover, +1 value indicates that two indices are dependent upon each other and share a strong relationship whereas –1 value indicates that there is no relationship or extremely weak relationship between two indices and two stock market indices do not dependent upon each other and their movements are not tandem.

Rahim and Masih [31] used correlation coefficient to examine the relationship between Islamic stocks and their trading partners for portfolio diversification. You and Daigler [32], Engle and Sheppard [33] and Capiello et al. [34] also used correlation coefficient in this regard. It is clear from the correlation coefficient results that all stock market indices do not strong correlation coefficient with each other except for two stock market indices from US whereas some stock market indices share negative correlation. NYSE and NASDAQ post highest correlation coefficient in the table which is 0.81%. It means that both stock market indices are dependent upon each other and their relationship is strong. Their price movements are in tandem. An increase in NYSE index will lead to an increase in NASDAQ index and vice versa. However, rest of the market indices share low correlation hence the relationship between them is weak. For instance, Canada's stock market index correlation coefficient with NYSE and NASDAQ is 0.67 and 0.74 respectively which shows that its relationship is weak and price movements of these indices are not tandem and they do not dependent upon each other. Canada and Panama share the weak and negative relationship. For instance, correlation coefficient of between Canada and Panama is –0.0172 which shows that they are independent of each other and their price movements are not tandem. Similar trend can be observed throughout the table.

In order to run co-integration time series must be stationary at the same level. If data i.e. stock market index is not stationary, then there will be a growth value in the time series. Therefore, all stock market indices in the data must be stationary at same level in order to run co-integration test. Dickey Fuller test is applied to examine the time series for stationarity at level (0). Bouri et al. [35] examined co-integration among India stock market and gold and oil sector and applied Dickey Fuller test to inspect for stationarity in the time series. Cheong [36] examined the weak form efficiency of stock market using unit root test. Alamet al. [37] applied stationarity test to examine the sectoral efficiency of Islamic stock indices. Moreover, Spulbar and Birau [38] examined the behaviour of selected emerging stock markets in Romania, Poland, Hungary and India but the empirical analysis results rejected efficient market hypothesis. On the other hand, Zulfiqar et al. [39] suggested that governance quality positively affects financial markets in the case of developed countries. Null hypothesis of Dickey Fuller test states that there is a unit root in the data which means that data is not stationary. For data to be stationary at 1% significance level with –3.430 as critical value, t-stat value must be less than –3.430 with p value less than 5%. Table 3 suggests that each t-stat value for each stock market index in the data is greater than critical value at 1% significance level leading to the interpretation that null hypothesis cannot be rejected and all stock market indices have unit

Table 3

STATIONAIRTY CHECK: UNIT ROOT TEST AT LEVEL 0 AND LEVEL 1							
Country	**1% Critical value**	**Level 0**		**Remarks**	**Level 1**		**Remarks**
		t-stat	**prob.**		**t-stat**	**prob.**	
Canada	–3.43	–1.198	0.6745	Non Stationary	–70.735	0	Stationary
Mexico	–3.43	–1.004	0.7517	Non Stationary	–66.141	0	Stationary
USA (NASDAQ)	–3.43	0.958	0.9938	Non Stationary	–71.897	0	Stationary
USA (NYSE)	–3.43	–0.725	0.8401	Non Stationary	–74.44	0	Stationary
Panama	–3.43	–0.271	0.9295	Non Stationary	–93.846	0	Stationary
Brazil	–3.43	–0.528	0.8865	Non Stationary	–73.449	0	Stationary
Chile	–3.43	–0.357	0.917	Non Stationary	–60.494	0	Stationary
Peru	–3.43	–0.948	0.7718	Non Stationary	–62.828	0	Stationary
Venezuela	–3.43	2.803	1	Non Stationary	–47.914	0	Stationary
Jamaica	–3.43	5.646	1	Non Stationary	–67.778	0	Stationary
Trinidad & Tobago	–3.43	–1.884	0.3395	Non Stationary	–71.404	0	Stationary

Note: 1% Critical value = –3.430

root which means that data is not stationary at level (0).

Dickey Fuller test is run to examine the stationarity at level (1) for the 11 stock market indices. To reject null hypothesis and for data to be stationarity, t stat value should be less than critical value of –3.430 at 1% level of significance. It is clear from table 3 that t-stat value of each stock market index is less than critical value with p value equal to zero which leads to a conclusion that data has no unit root thus rejecting null hypothesis. Therefore, 11 stock market indices are stationary at first order difference (1).

From the results included in table 4, we can observe that the lag length number is determined. Leg length number is necessary to run co-integration and granger causality test. VAR lag length selection test has been applied to determine lag length for co-integration and granger causality test. Five methods are used by this test to in this regard. These five methods are LR test Statistics, Final Predication Error, Akaike information criterion, Schwarz Bayesian information criterion and Hannan-Quinn information criterion. It is clear from the table that three tests are supporting lag length 3 whereas two tests are supporting lag length 2. Rule of thumb in quantitative research is that lag length supported by maximum number of tests is chosen for the purpose of co-integration and granger causality test. Therefore, lag length 3 has been selected to run the co-integration and granger causality test.

Multivariate co-integration exhibits if there is integration among stock market indices or not. In order to examine if there is multivariate co-integration, Eigen value or trace statistics value is monitored (table 5). Null hypothesis of trace statistics is that there is no co-integration among stock market indices whereas alternate hypothesis is that minimum one co-integration equation exists. Like trace statistics, there is a null hypothesis for Eigen value which states that there is no co-integration however its alternate hypothesis is different i.e. there is only one co-integration equation which makes it weaker than trace statistics test. Therefore, for multivariate co-integration test, trace statistics test is used because it is more powerful than Eigen value test because this study deals with more than one co-integration equations.

Trace statistics value should be less than the critical value of any given rank value. Value with the star sign (*) shows that there is integration among indices and rank represents the number of co-integrated equations. The table shows that at rank 3 there exists

Table 4

VAR LAG LENGTH SELECTION CRITERIA								
Lag	**LL**	**LR**	**df**	**p**	**FPE**	**AIC**	**HQIC**	**SBIC**
0	–47165.1				7.90E+06	18.7241	18.7246	18.7254
1	–31044.6	32241	1	0	13188.6	12.325	12.325*	12.3276*
2	–31044.6	0.07693	1	0.782	13193.6	12.3254	12.3267	12.3293
3	–31041.8	5.6877*	1	0.017	13184*	12.324*	12.3264	12.3298
4	–31041.8	0.00088	1	0.976	13189.2	12.325	12.3273	12.3315

Note: * indicates lag order selected by the criterion.

Table 5

MULTIVARIATE JOHANSEN'S CO-INTEGRATION TESTS					
Maximum rank	**Parameters**	**LL**	**Eigen value**	**Trace statistic**	**5% critical value**
0	253	–319805	0	370.0949	277.71
1	274	–319756	0.01924	272.1873	233.13
2	293	–319720	0.01427	199.7528	192.89
3	310	–319691	0.01149	141.5095*	156
4	325	–319670	0.00812	100.419	124.24
5	338	–319652	0.00723	63.8317	94.15
6	349	–319640	0.00493	38.9122	68.52
7	358	–319632	0.00317	22.9323	47.21
8	365	–319626	0.0023	11.3243	29.68
9	370	–319622	0.00149	3.814	15.41
10	373	–319620	0.00075	0.0093	3.76
11	374	–319620	0	-	-

Note: * indicates co-integrated equations.

co-integration. Trace statistics value is statistically significant at 5% level of significance and its less than critical value of rank 3. It means that at least 3 co-integration equations exist in this study. It means that some market indices are co-integrated with each other. The upside of multivariate Johansen's co-integration test is that it shows number of co-integration equations, but it does not exhibit the names of the co-integrated time series. To resolve this shortcoming, pairwise co-integration has been run.

Table 6 includes the empirical results on pairwise co-integration. Pairwise co-integration examines market

Table 6

PAIRWISE CO-INTEGRATION										
Country	**Canada**	**Mexico**	**USA (NASDAQ)**	**USA (NYSE)**	**Panama**	**Brazil**	**Chile**	**Peru**	**Venezuela**	**Jamaica**
Mexico	8.9126*									
	0									
USA (NASDAQ)	10.9677*	13.7620*								
	0	0								
USA (NYSE)	7.5111*	7.5632*	11.1370*							
	0	0	0							
Panama	11.5014*	**0.5480***	11.8242*	5.3700*						
	0	**1**	0	0						
Brazil	5.8712*	3.2170*	7.9450*	2.6678*	13.4753*					
	0	0	0	0	0					
Chile	6.7613*	5.3808*	11.1143*	4.7403*	**0.3163***	7.2288*				
	0	0	0	0	**1**	0				
Peru	5.8899*	4.7207*	7.4665*	3.2230*	**1.2035***	7.4111*	6.0292*			
	0	0	0	0	**1**	0	0			
Venezuela	5.0403*	4.4716*	11.2019*	5.9372*	10.2282*	7.5707*	3.9638*	3.0769*		
	0	0	0	0	0	0	0	0		
Jamaica	**3.4171***	**0.2816***	**3.7411***	**2.3631***	**0.0606***	**3.0098***	**1.0015***	**1.9470***	**42.5338**	
	1	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**n/s**	
Trinidad & Tobago	8.1431*	6.0598*	9.0300*	6.2334*	4.8608*	4.9229*	5.3160*	8.6180*	4.9057*	**3.4737***
	0	0	0	0	0	0	0	0	0	**1**

Note: 5% for rank (0) critical value = 15.41, for rank (1) critical value = 3.76, (0) indicates no co-inetgration, (1) indicates co-integration; where n/s stands for Not Significant.

Table 7

GRANGER CAUSALITY TEST-EXCLUDED SECTORS											
Country	**Canada**	**Mexico**	**USA (NASDAQ)**	**USA (NYSE)**	**Panama**	**Brazil**	**Chile**	**Peru**	**Venezuela**	**Jamaica**	**Trinidad & Tobago**
Canada	19.493*	0.63724	3.3901	19.406*	4.927	2.6133	7.2992*	0.99557	7.8805*	20.062*	
Mexico	6.355*		1.5127	1.291	9.2047*	29.757*	27.819*	9.5616*	10.114	30.201*	2.7863
USA (NASDAQ)	10.473*	3.2135		0.62668	2.0416	1.0447	2.7732	22.243*	2.7812*	12.819*	0.89365
USA (NYSE)	11.263*	23.543*	2.2704		18.17*	20.025*	14.399*	2.3267	3.809	9.3603*	17.121*
Panama	7.5846*	14.886*	6.2242*	1.5837		3.4298	3.4629	4.9913	9.2375	25.621*	1.0997
Brazil	1.9482	10.764*	1.087	9.5832*	1.1451		0.91882	11.683*	2.0039	1.6372	1.4061
Chile	2.9862	1.0867	1.1275	0.24387	9.0103	4.1031*		14.925*	6.2731	0.44037	1.5386
Peru	5.4972	0.23746	0.58877	2.9539	18.94*	5.2522	8.0175*		2.1752	0.69496	13.253*
Venezuela	1.7422	8.259*	5.9118	2.4076	7.9353*	13.673*	2.3829	3.3397		12.019*	0.83844
Jamaica	0.6894	21.264*	11.232*	7.8712*	5.5665	35.882*	29.885*	7.9598*	25.735*		21.043*
Trinidad & Tobago	11.618*	1.1076	3.6731	3.164	5.2051	2.9566	9.7358*	15.719*	2.8015	3.4225	

Note: * indicates value is significant at 5% and excluded sector causes equation sector.

indices for integration on one to one basis. The decision of co-integration is based on trace statistics with critical value of 15.41 at 5% level of significance. If the critical value of trace statistics is less than critical value, it means that there is no co-integration. It its value is greater than critical value, it means that there is co-integration among two market indices. The results from the table 6 exhibit that all values are statistically significant except Venezuela and Jamaica. The results show that most of the market indices are not co-integrated with each other which mean that they present an excellent diversification opportunity because movement in index will not affect the movement in other market index. However, market index of Jamaica does not present diversification opportunities because it is highly co-integrated with all market indices. Similarly, market indices of Mexico and Panama are highly co-integrated. The other stock market indices which are highly co-integrated are Panama and Chile and Panama and Peru which means that there are no diversification opportunities between the market indices of Panama and Chile and Panama and Peru. Canadian stock market index is not co-integrated with any of the market indices apart from stock market index of Jamaica. Similar trend can be observed with all other countries. It is evident from the table that there are excellent diversification opportunities in stock market of Americas included in the sample.

Table 7 presents the Granger Causality Test-Excluded Sectors Granger Causality. Test determines if stock market index is related to another market index. It can also be used to forecast other time series. Null hypothesis for granger causality test is that there is no causality among selected stock market indices. Null hypothesis is rejected when p value is less than 0.05 which exhibits that there is granger causality in two market indices. The upside of granger causality test is that it only shows if causality exists. However, its drawback is that it does not show the coefficient of granger causality. The results of above table show that Canadian stock market index shares a unidirectional relationship with market indices of Mexico, USA (NASDAQ), USA (NYSE), Panama and Trinidad & Tobago. It means that a change in Canadian stock market index would bring a change in the stock market indices of above-mentioned countries and stock markets. There is also granger causality between the stock market indices of Mexico and Canada. These two stock markets share bi-directional relationship with each other in short run. It is obvious from the table that some market indices share a unidirectional relationship with other stock market indices in short run. It means that there exists a short run relationship between two market indices.

CONCLUSIONS

This paper examines the international linkages among the stock markets in North and South America. These stock markets present significant investment opportunities based on international diversification strategy. The stock markets are not highly correlated which means that they are not dependent upon each other and present a portfolio diversification opportunity. The results of multivariate and pairwise co-integration also support diversification opportunities. Apart from few stock markets, most of the stock market indices are not highly co-integrated with each other which lend the support for portfolio diversification. The results of Granger causality test are also supporting the diversification opportunities in the selected stock markets of Americas. Future research should focus on diversification opportunities in the stock markets of Asia and

Europe. A better understanding of the linkages between selected stock markets in Americas is of great interest for foreign portfolio investment decision-making processes. Moreover, the textile sector is strongly influenced by stock market dynamics. Investment opportunities can lead to significant gains based on the implementation of efficient diversification strategies.

As a future direction of research, we will analyse the impact of the Covid-19 pandemic on the apparel and textile industry in Africa and Asia. In this regards, Batool et al. [40] argued that pandemics generate economic misery so countries must use rapid digitization in the context of the COVID-19 crisis.

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Enhancement of muscle's activity by woven compression bandages

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ABSTRACT – REZUMAT

Enhancement of muscle's activity by woven compression bandages

Electromyography (EMG) test, the recording of electrical activity in muscle, is a main tool usually used to evaluate the muscle's activation. This study aims to discuss and analyse the effect of woven compression bandage (WCB) on muscles' activation. Flexor Carpi (FC), Soleus (SO), and Medial Gastrocnemius (MG) muscles were selected to represent the wrist, ankle, and mid-calf muscles respectively, which were then evaluated by EMG electrical voltage test with and without wearing WCB. The standardized activities used to test the FC muscle were flexion-extension and squeezing a soft roll. While the protocol activities for MG and SO muscles were flexion-extension and walking actions. Wearing WCB significantly decreased the muscle's activation and was associated with higher median frequency for both SO and MG muscles during the tested activities. The EMG signals were analysed and filtered using MegaWin and MATLAB software. Root mean square (RMS) values confirmed that wearing WCB could improve the performance of FC, SO, and MG muscles and might reduce the muscle's fatigue during the selected activities.

Keywords: *Electromyography test, woven compression bandages, muscle activation, MegaWin and MATLAB software*

Îmbunătățirea activității musculare prin bandaje de compresie țesute

Testul de electromiografie (EMG), înregistrarea activității electrice în mușchi, este un instrument principal utilizat pentru a evalua activarea mușchiului. Acest studiu își propune să abordeze și să analizeze efectul bandajului de compresie țesut (WCB) asupra activării mușchilor. S-au selectat mușchii Flexor Carpi (FC), Soleus (SO) și Medial Gastrocnemius (MG) pentru a reprezenta mușchii încheieturii, gleznei și, respectiv, cei de la mijlocul gambei, care au fost apoi evaluați prin testul de tensiune electrică EMG cu și fără purtarea WCB. Activitățile standard utilizate pentru a testa mușchiul FC au fost cele de flexie-extensie și compresia unui rulou. Activitățile din protocol pentru mușchii MG și SO au fost cele de flexie-extensie și mers. Purtarea WCB a scăzut semnificativ activarea mușchiului și a fost asociată cu o frecvență mediană mai mare atât pentru mușchii SO, cât și pentru mușchii MG, în timpul activităților testate. Semnalele EMG au fost analizate și filtrate utilizând programele MegaWin și MATLAB. Valorile mediei pătratice (RMS) au confirmat că purtarea WCB ar putea îmbunătăți performanța mușchilor FC, SO și MG și ar putea reduce oboseala mușchiului, în timpul activităților selectate.

Cuvinte-cheie*: test de electromiografie, bandaje de compresie țesute, activare musculară, programe MegaWin și MATLAB*

INTRODUCTION

Compression bandages

Compression bandage (CB) consists of elastic textile that exerts pressure on muscles of any part of the human body, especially hand and lower leg muscles [1–3]. It can be produced as knitted (tubular and socks) or woven compression bandages (CBs) [4, 5]. These medical elastic structures can improve the athletics' performance and reduce sports injury, which exert compression and pressure on muscles to relieve muscle's stiffness and fatigue during sports or other activities [6–8]. Most of CBs are practically applied as forms of overlapping multiple layers. It can be applied at 50% spiral overlap to overlay the leg with two layers bandaging technique, CBs applied using 66% overlap achieve three bandage layers while CBs applied with the figure of eight at 50% overlap can overlay the leg with four layers [9, 10]. Compression therapy limits the flow of diseased surface veins and increases the flow through deeper veins and reduces swelling. It can significantly improve the ulcer healing rates and decrease rates of recurrence. Researchers thought that it is either correcting or improving the venous hypertension, due to the improvement of venous pump and lymphatic drainage. It could also improve the blood flow velocity through deep and superficial veins [11, 12]. Eight healthy men were selected to perform 40 min treadmill running trials, one with compression garment (CG) and the others with normal garment (NG). The muscles' activation were significantly smaller in CG than in NG condition for MG and semitendinosus (ST) at both initial and end stages during stance phase and for Rectus Femoris (RF) at both stages during swing phase. Participants wearing CG had lower muscle activation in MG, ST, and RF muscles, despite there are no additional benefits to the lactate clearance or perceived exertion rate [13].

Normal anatomy and physiology of lower extremity

The venous blood flow of lower extremity consists of 3 components: the superficial, communicating, and deep veins. The superficial venous system is connected to the deep venous system through smaller communicating or perforator veins. The deep veins are categorized as either intramuscular or intermuscular. These three venous systems are equipped with one-way bicuspid valves which open only toward the deep system, allowing blood to flow in a cephalad direction to prevent reflux. Blood is transferred through the leg toward the heart primarily by the pumping action of the leg muscles [14, 15].

Detection and analysis of muscles activation

EMG aims to measure the muscle's activation level and provides estimation for exercise intensity of selected muscles during activity. EMG signal can contribute to enhance the human body muscle's function [16]. It can be defined as the subject, which deals with the detection and evaluation of electrical signals resulting in skeletal muscles. These signals are known as the myoelectric signal which is produced from small electrical currents generated by the exchange of ions across the muscle's membranes and detected with the help of electrodes [17]. Some studies used EMG to evaluate the effect of compression garments (CGs) during sports and other activities. However there is a limited research explored that wearing CGs has positive influence on muscle's activation during running [3]. Most of research related to EMG test was performed on athletics or normal volunteers. Moreover some studies were using only knitted CGs or socks. There is no studies combined using the EMG test while wearing the woven compression bandages (WCBs) on real patients because every patient has clearly different case of bandage application and recovery time. So that the author applied the WCB on 6 healthy men to investigate an accurate comparison using the EMG test. Based on literature review it is essential to propose a research to analyse the effect of WCB on selected muscles of hand and lower leg and discuss the muscles' behaviour of FC, SO and MG muscles while wearing WCB using surface electrodes by e-Motion electromyography wireless tester.

EXPERIMENTAL

Materials

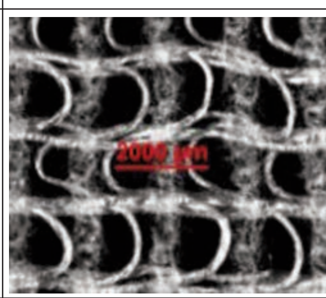
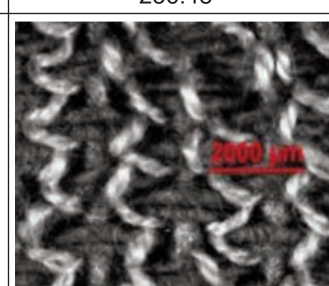
Three types of WCBs namely Viscose/Polyamide (VI-PA), bleached 100% Cotton, and Cotton/ Polyamide/Polyurethane (CO-PA-PU) bandages were used for FC, SO and MG muscles EMG tests respectively. Fabric structures of the three WCBs were plain weave. Other parameters such as yarn count, density, and weight per unit area were depending on the final end-use required properties, as shown in table 1. Each structure had different technique to achieve the required stretch. WCBs were produced with optimum stretch using highly twisted warp yarns, or elastomeric filament (Elastane or Lycra) with Cotton or Viscose, or using two or more polymeric yarns having different thermal properties such as VI-PA by shrinkage and heat setting.

Methods

There are two methods of using EMG in measuring muscle activity, needle EMG uses a needle sensor that penetrates the skin and subcutaneous adipose tissue or surface EMG using skin-mounted electrodes. The advantage of needle EMG is that the test administrator does not have to consider the effects of cross-talk between muscles or the superficial fat layer between the muscle and skin which can cause signal impedance. However, this method is invasive to the participant and is not practical during isotonic muscle actions, making surface EMG the most common method of measuring muscle activity. The advantages

Table 1

EXPERIMENTAL WOVEN COMPRESSION BANDAGES' CHARACTERISTICS

Sample	VI-PA bandage	100% Cotton bandage	CO-PA-PU bandage
Warp density (ends/cm)	12	8	11
Weft density (picks/cm)	14	15	18
Warp count	Viscose,16.5 tex Open end (OE)/PA, 7.8 tex	Cotton, 20x2 tex Ply twist 1200 turns/m, ZZ/S, SS/Z	Cotton, 10x2 tex PA, 7.8 tex/PU, 42.5 tex
Weft count	Viscose, 16.5 tex	Cotton, 75 tex, OE	Cotton, 36.9 tex
Fabric weight (g/m^2)	83.34	210.25	236.48
SEM image			

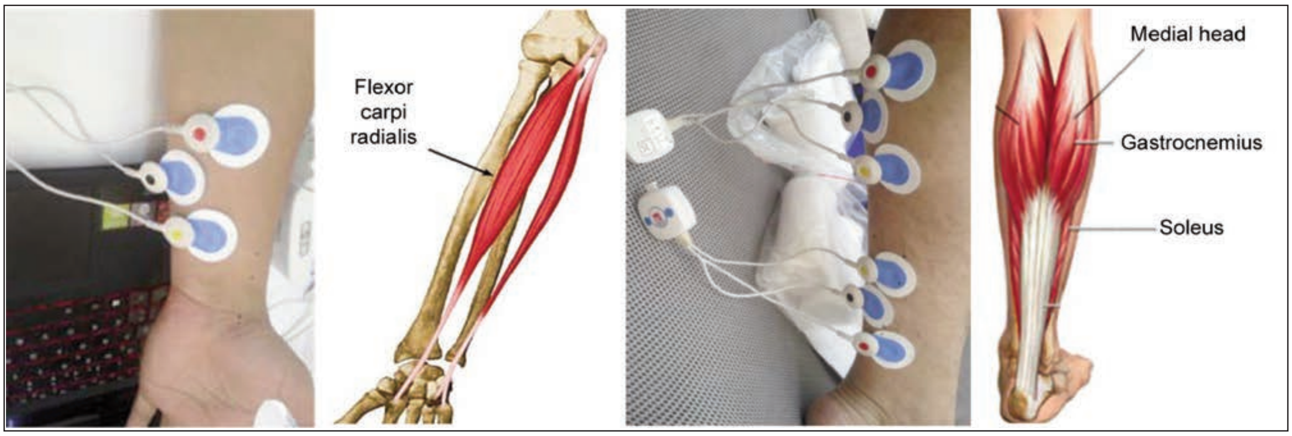


Fig. 1. Electromyography test for FC, SO and MG muscles [22, 23]

of surface EMG are that it is safe, easy, non-invasive, and has the ability to objectively quantify energy of muscle [18].

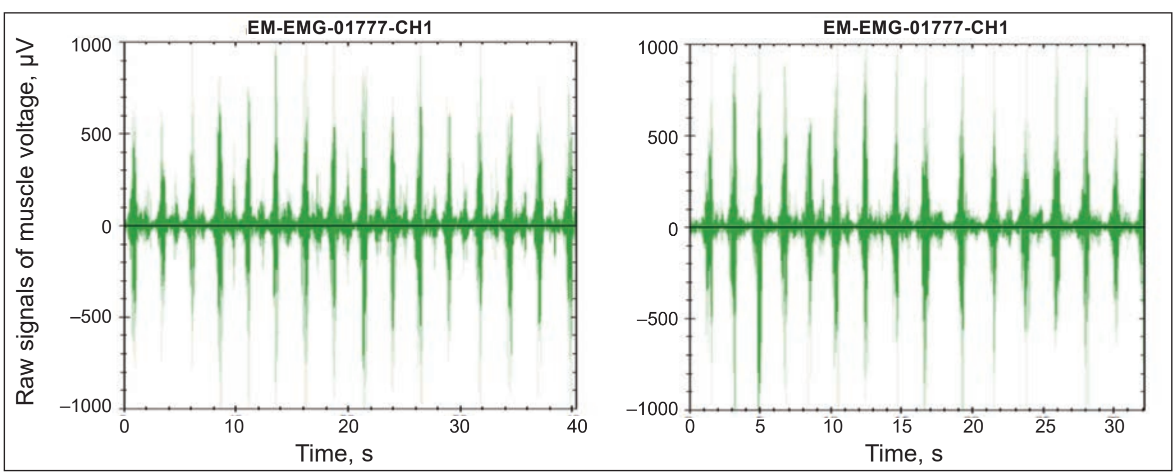
Viscose/Polyamide bandage was used to test the FC muscle's activation during flexion-extension and squeezing a soft roll action with and without using WCB (figure 1). VI-PA CB was adjusted and standardized to medium compression ranges 22±2 mmHg by 75% bandage extension and 50% overlap. CO-PA-PU and 100% Cotton bandages were used to test MG and SO muscles' voltage while walking and during flexion-extension actions. Both of the 100% cotton and CO-PA-PU bandages were worn on real leg to test and analyse the effect of WCB on bandage pressure using PicoPress at ankle and mid-calf positions during the previously mentioned activities. Bandage pressure of SO muscle was adjusted to 45 ± 3.4 mmHg, by 100% bandage extension and 66% overlap whereas MG muscle was 30 ± 1.9 mmHg, through 100% bandage extension and 50% overlap [1]. All compression and EMG tests were performed on 6 healthy men, age ranges 28–38 years, using e-Motion EMG system at different metronome beats 20, 30, and 40 beats/min (BPM). The average value of the minimum, maximum, and median values of the muscle voltage and RMS values for the 6 men were analysed and listed in tables 2–5. Surface electrodes were mounted on the selected muscles of human skin as shown in figure 1, three trials for each activity were carried out [19].

There are four basic filter types defined by De Luca (2003) including low-pass, high-pass, band-pass, and band-stop. Low-pass filters the frequencies higher than the selected amplitude, while high-pass filters all frequencies below the set amplitude. The band-pass filters all the frequencies below and above the set amplitudes, while band-stop filters all frequencies higher than the low amplitude and frequencies lower than the high set amplitude [20]. A band-pass filter however only allows a selected frequency range often between 25–500 Hz [21]. For evaluation of the muscles activity, RMS values were processed by exporting the filtered signals to MATLAB software using band-pass filtering between 20–500 Hz.

RESULTS AND DISCUSSION

Muscle voltage test for Flexor Carpi

The EMG raw signals of the FC muscle voltage with and without wearing the VI-PA compression bandage during the standardized action (flexion-extension) are illustrated in figure 2. For accurate comparison the



a *b*

Fig. 2. FC muscle voltage with and without WCB, flexion-extension action, Raw signals:
a – with bandage; *b* – without bandage

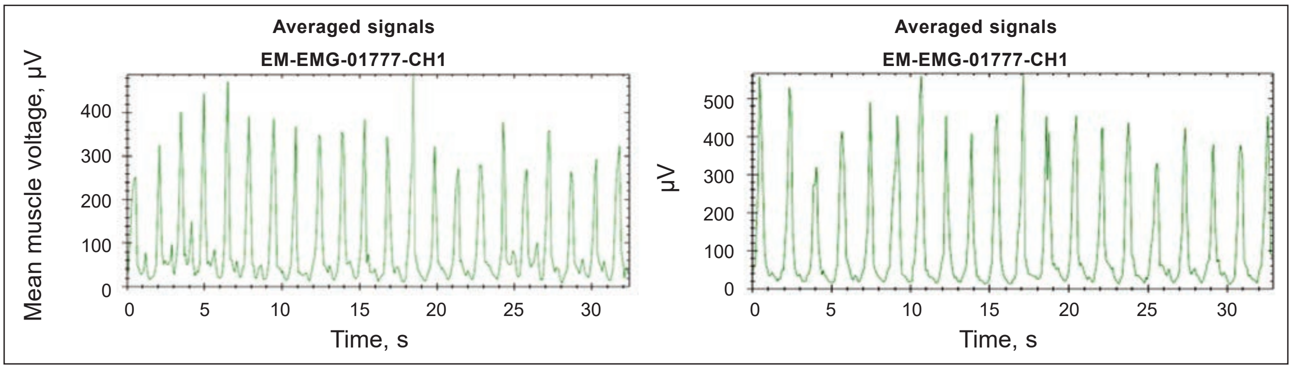


Fig. 3. Average FC muscle voltage with and without WCB, flexion-extension action, 40 BPM

average signals should be used. Figure 3 displays the average FC muscle voltage using the VI-PA CB during flexion-extension action at 40 BPM, average muscle voltage was 85.11 and 93.33 µV respectively, wearing WCB decreases muscle's activity by 8.81%, as illustrated in table 2.

Figure 4 displays the FC muscle's activation using the VI-PA WCB while squeezing a soft roll action, the average EMG voltages were 90.67 and 97.44 µV respectively, so that wearing WCB decreases muscle's activation by 6.96%, as listed in table 2. Obtained results in figures 3 and 4 and statistical

Table 2

EMG AVERAGE VOLTAGE FOR THE FC MUSCLE

Tested action	Metronome beats (BPM)		Mean voltage (µV)			Average 1 (µV)	S.D. (µV)
Flexion-extension action	With bandage	20	74	83	78	78.33	3.68
		30	85	80	87	84.00	2.94
		40	93	88	98	93.00	4.08
		Average (Average 1)				85.11	3.57
	Without bandage	20	81	85	77	81.00	3.27
		30	90	86	78	84.67	4.99
		40	115	106	122	114.33	6.55
		Average (Average 1)				93.33	4.93
Squeezing a soft roll action	With bandage	20	77	72	76	75.00	2.16
		30	81	85	78	81.33	2.87
		40	110	116	121	115.67	4.50
		Average (Average 1)				90.67	3.17
	Without bandage	20	76	79	72	75.67	2.87
		30	93	97	104	98.00	4.55
		40	125	119	112	118.67	5.31
		Average (Average 1)				97.44	4.24

Table 3

EMG MEAN VOLTAGE FOR LEG MUSCLES WEARING CO-PA-PU WCB

Activity	Case	Soleus Muscle		Medial Gastrocnemius	
		µV	S. D.	µV	S. D.
Flexion – extension	with bandage	25.00	2.94	22.33	2.49
	without	32.33	4.92	30.00	3.74
	Reduction (%)	22.68	40.18	25.56	33.33
While walking	with bandage	83.33	4.11	82.00	4.55
	without	126.00	6.98	86.00	5.35
	Reduction (%)	33.86	41.09	4.65	15.09

Table 4

EMG MEAN VOLTAGE FOR LEG MUSCLES WHILE WALKING USING 100% COTTON WCB					
Case	**Beats/min**	**Soleus Muscle**		**Medial Gastrocnemius**	
		µV	**S. D.**	**µV**	**S. D.**
With bandage	20	74.00	2.94	75.33	2.87
	30	88.00	3.74	76.00	4.32
	40	117.33	4.99	103.00	6.98
	Average	93.11	3.97	84.78	4.59
Without bandage	20	96.00	5.35	80.67	3.68
	30	111.33	5.44	94.00	4.55
	40	134.33	7.04	110.33	7.04
	Average	113.89	5.94	94.89	5.09
Reduction (%)		18.24	33.26	10.66	9.82

Table 5

ROOT MEAN SQUARES AND S. D. OF FC ACTIVATION							
Tested action	**Beats/min**		**RMS value**			**Average 1**	**S. D.**
Squeezing a soft roll action	With bandage	20	136.98	139.8	133.7	136.83	2.49
		30	161.78	155	165.9	160.89	4.49
		40	185.7	180.43	173.78	179.97	4.88
		Average (Average 1)				159.23	3.95
	Without bandage	20	135.8	132.1	128.8	132.23	2.86
		30	179.7	189.11	198.4	189.07	7.63
		40	210.9	200.4	189.7	200.33	8.65
		Average (Average 1)				173.88	6.38
Flexion-extension action	With bandage	20	123.68	127.86	131.57	127.70	3.22
		30	132.36	125.68	138.87	132.30	5.38
		40	164.72	155.97	173.74	164.81	7.25
		Average (Average 1)				141.61	5.29
	Without bandage	20	152.45	147.7	143.21	147.79	3.77
		30	164.15	155.44	146.87	155.49	7.05
		40	195.46	184.27	206.67	195.47	9.14
		Average (Average 1)				166.25	6.66

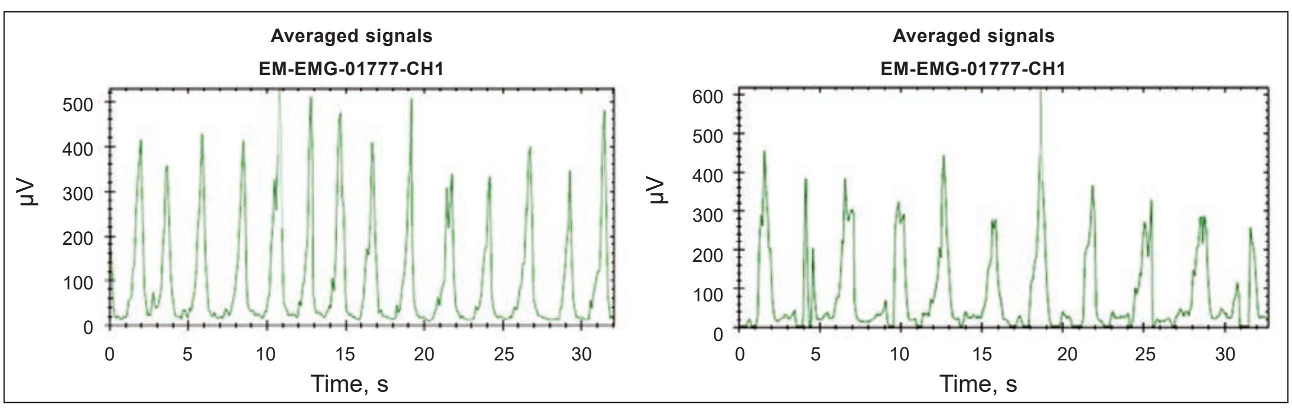


Fig. 4. Mean voltage of FC muscle with and without WCB, squeezing a soft roll action, 30 BPM

Table 6

SUMMARY OF ANALYSIS OF VARIANCE (ANOVA)			
Standardized action	**Dependent variable**	**Sig.* (with or without bandage)**	**Sig.* (Metronome beats)**
Squeezing a soft roll	Mean voltage	0.048	0.000
	RMS values	0.019	0.000
Flexion-extension	Mean voltage	0.045	0.000
	RMS values	0.000	0.000

Note: * Significance at confidence interval 95%.

analysis in table 6 conclude that wearing VI-PA WCB significantly enhances the FC muscle's performance at the protocol activities. It may be summarized as the frequency of flexion and extension actions are similar, hence the WCB causes a reduced muscle oscillation which might improve the muscle's efficiency and performance.

Muscle voltage test for Medial Gastrocnemius

Average EMG signals of the SO and MG muscles were measured using the pre-amplified bipolar surface electrodes [24]. Figures 5 and 6 show MG muscle's voltage with and without using CO-PA-PU bandage for flexion-extension action and wearing 100% Cotton bandage during walking action. As a result, wearing WCB achieves significant decreases in MG muscle's voltage during flexion-extension action by 25.56% and 4.65% when walking action, as listed in table 3. That reduction may be due to the increase in mean muscle's fascicle length and the decrease in mean muscle's thickness and average pennation angle [25]. Recent studies concluded that the muscle's force being exerted for limb's motion and stability may be wasted on muscle's flexion-extension, while CG might prevent muscle vibrations during sports activities which could enhance the athletic performance [16].

Muscle's voltage test for Soleus muscle

Figures 7 and 8 show SO muscle's average signals with and without using the CO-PA-PU and 100% Cotton WCBs during flexion-extension and walking standardized actions respectively at 20, 30, and 40 BPM. Using WCB decreases SO muscle's activation

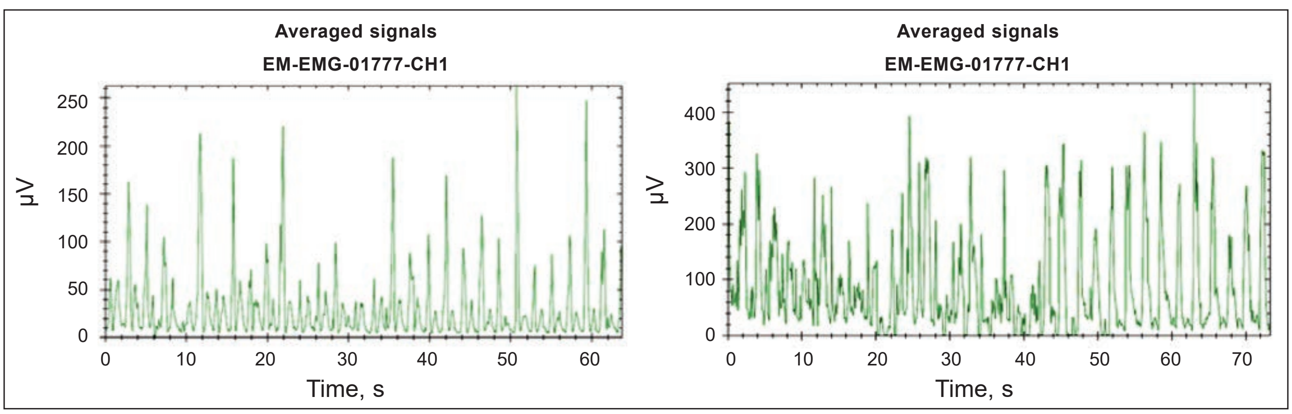


Fig. 5. Medial Gastrocnemius average signals, CO-PA-PU CB, flexion-extension, 30 BPM

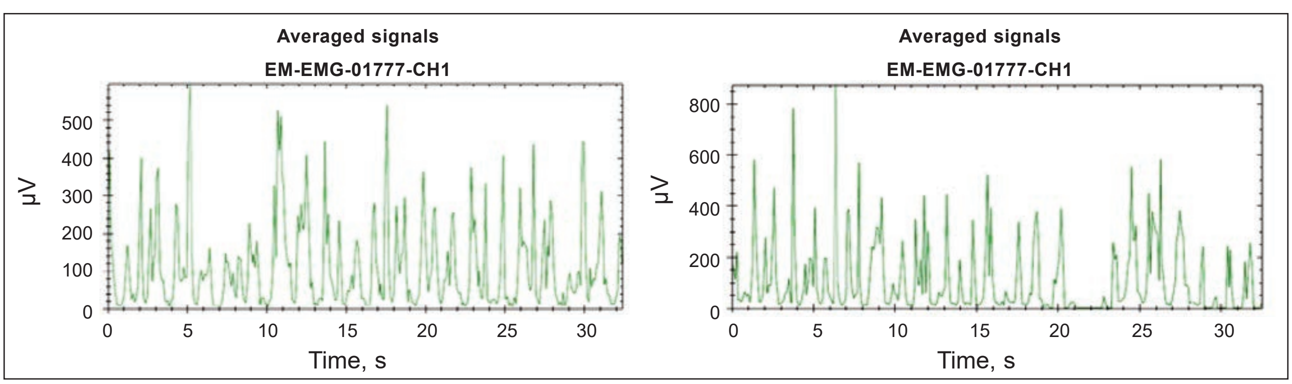


Fig. 6. Medial Gastrocnemius average signals, 100% Cotton CB, walking action, 40 BPM

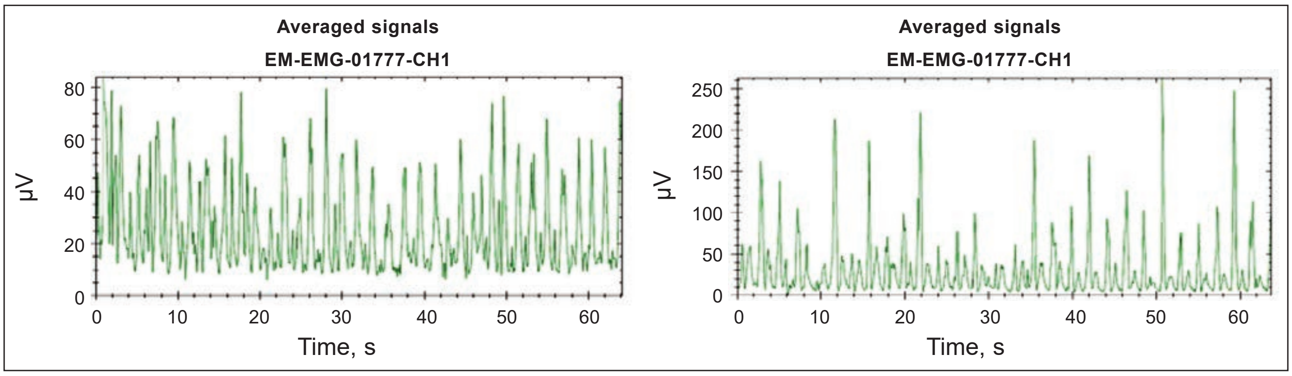


Fig. 7. Mean voltage of Soleus muscle, CO-PA-PU CB, flexion-extension action, 30 BPM

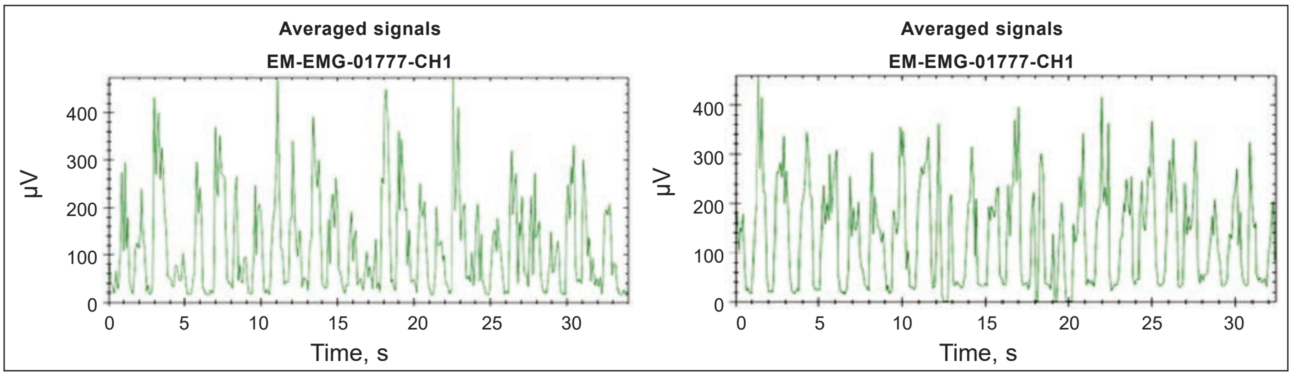


Fig. 8. Mean voltage of Soleus muscle, 100% Cotton CB, walking action, 40 BPM

at flexion-extension action by 22.68% and 33.86% during walking as concluded in table 3.

EMG mean voltage for Flexor Carpi muscle

E-Motion EMG and MegaWin software were used to analyse the relationship between three types of WCBs and muscles activation. The average voltage of FC muscle and standard deviation (S. D.) during flexion-extension and squeezing a soft roll actions are listed in table 2. Average FC muscle's voltages with bandage decreased by a percent 8.81% for flexion-extension action. Meanwhile wearing WCB decreases muscle activation by 6.96% while squeezing a soft roll action. Statistical analysis of the obtained results confirms that both wearing WCB and metronome beats have significant effects at confidence level of 95% on the FC muscle's activation, as illustrated in table 3.

Mean voltage for SO and MG muscles

Mean activation of SO and MG muscles wearing CO-PA-PU and 100% Cotton WCBs during flexion-extension and walking activities at 20, 30, and 40 beats/min are concluded in tables 5 and 6. Using CO-PA-PU bandage during flexion-extension action decreases SO and MG muscles activation by 22.68 and 25.56% respectively (table 3). Moreover using 100% Cotton WCB while walking was associated with a decrease in average SO and MG muscles activation by 18.24 and 10.66% respectively (table 4) while wearing CO-PA-PU WCB decreases SO and MG muscles' activation by 33.86 and 4.65% respectively (table 3).

Analysis and calculation of RMS values

Thanks to MATLAB software that enables to filter the obtained signals and calculate RMS values for all selected muscles, as summarized in tables 7–9. Average RMS and standard deviations of the FC muscle wearing VI-PA WCB are concluded in table 5. Using VI-PA WCB decreases the muscle's activation by 8.43%, as confirmed with low average RMS values, 159.23 compared to 173.88 without WCB, for squeezing a soft roll action. And 141.61 compared to 166.25 without WCB for flexion-extension activity, reduction percent 14.82%. Moreover the S. D. of the average RMS values is lower when wearing the WCBs for all selected activities.

Table 9 illustrates RMS of SO and MG muscles wearing 100% Cotton WCB for walking action. Using WCB reduces the muscle's activation as confirmed by lower average RMS for SO and MG EMG signals. Table 9 concludes RMS values of SO and MG signals using CO-PA-PU WCB. Using WCB reduces the muscle's fatigue (average RMS decreased by 14.36 and 19.86% for SO and MG signals respectively for flexion-extension, meanwhile 22.48 and 5.72% for walking actions). This improvement for muscle's behaviour using WCB might be resulting in little increase of intramuscular pressure in combination

Table 7

RMS OF SO AND MG MUSCLE SIGNALS, WHILE WALKING, 100% COTTON BANDAGE					
Case	**Metronome beats (BPM)**	**Soleus Muscle**		**Medial Gastrocnemius**	
		RMS value	**S. D.**	**RMS value**	**S. D.**
With bandage	20	151.66	4.83	137.68	6.09
	30	145.98	6.79	147.46	6.19
	40	191.58	11.09	183.30	7.23
	Average	178.03	6.75	156.15	6.50
Without bandage	20	165.92	6.98	165.56	5.03
	30	205.65	9.50	181.48	9.21
	40	236.46	8.63	191.11	11.13
	Average	202.68	8.37	166.11	7.34

Table 8

ANOVA FOR TABLES 3 AND 6 (AVERAGE VOLTAGE AND RMS OF SO AND MG MUSCLE SIGNALS)			
Tested muscle	**Dependent Variable**	**Sig.* (with or without bandage)**	**Sig.* (Metronome beats)**
Medial Gastrocnemius	Mean voltage	0.011	0.000
	RMS values	0.000	0.000
Soleus	Mean voltage	0.000	0.000
	RMS values	0.000	0.000

Note: * Significance at confidence interval 95%.

Table 9

RMS OF SO AND MG MUSCLE SIGNALS USING CO-PA-PU WCB					
Activity	**Bandage**	**SO Muscle**		**MG muscle**	
		RMS value	**S. D.**	**RMS value**	**S. D.**
Flexion – extension	with bandage	35.42	3.29	31.56	2.43
	without	41.36	4.83	39.38	3.76
	Reduction %	14.36	31.95	19.86	35.44
While walking	with bandage	144.41	5.06	112.92	5.33
	without	186.28	8.13	119.77	8.98
	Reduction %	22.48	37.78	5.72	40.72

with the suggested reduction of muscle's oscillation [26–28].

Relation between bandage pressure using PicoPress and EMG signals

All bandage pressure testing are measured on the same group of 6 men for Soleus and MG muscles. Figure 9 confirms significant changes of WCB pressure for walking action, which is vibrating as (27–43 mmHg) for Soleus, (18–27 mmHg) for MG muscle when wearing the Cotton CB. While using CO-PA-PU WCB, the oscillations are (20–35 mmHg) for Soleus, (18–25 mmHg) for MG muscle [1, 29]. The main factor which influences these oscillating ranges during walking and flexion-extension activities may be due to the significant changes of muscles voltage, as previously discussed for figures 5–8.

CONCLUSIONS

Both of the EMG muscle's voltage and the PicoPress pressure tests were carried out together on the same group at same conditions. The 100% Cotton CB pressure was oscillating between (27:43 mmHg) for SO and (18:27 mmHg) for MG muscle. This vibration while walking must be taken into consideration before using the WCB for long time to achieve the optimum compression therapy. Using 100% Cotton WCB decreased the muscle activation of SO and MG muscles by 18.24 and 10.66% respectively for walking action. Wearing CO-PA-PU bandage significantly

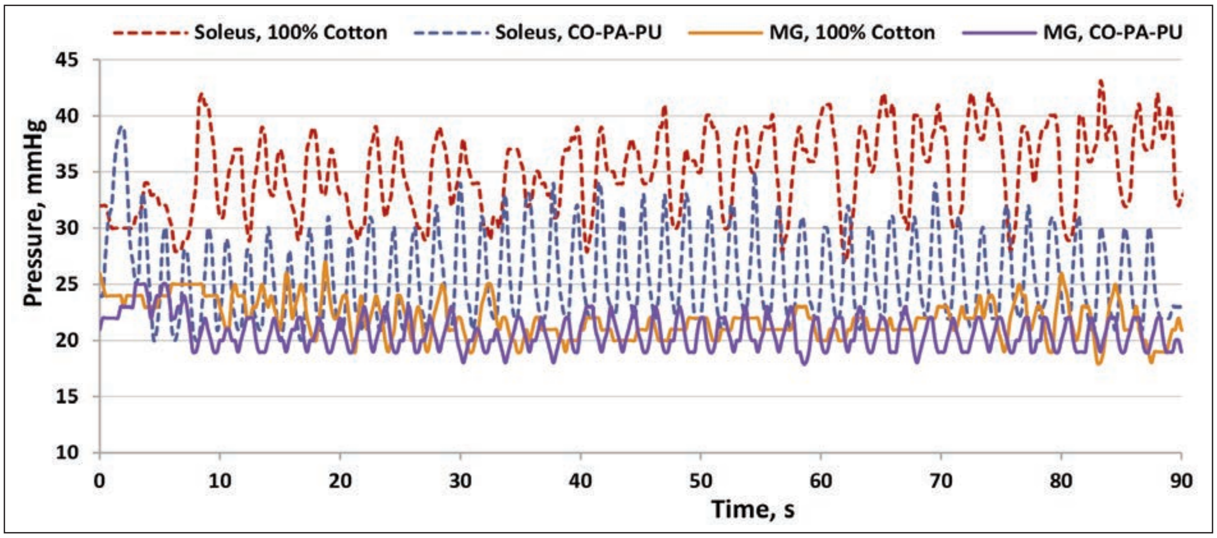


Fig. 9. Bandage pressure while walking action using 100% Cotton and CO-PA-PU WCBs

reduced the muscle's voltage of SO and MG by 22.68 and 25.56% for flexion-extension. Statistical analysis and RMS values ensured that wearing WCB could enhance muscle's behaviour that might improve athletic performance and decrease muscle's activation.

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The comparison of classical weaving and laser technology in denim fabric's design

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ABSTRACT – REZUMAT

The comparison of classical weaving and laser technology in denim fabric's design

Denim fabrics became a preferred product by many people, because of especially being a symbol of comfort. In this study, the aesthetic and physical design of denim fabrics were carried out. It was aimed to compare the surface designs and structural parameters of denim fabrics obtained by weaving and laser technologies. Besides the design steps of weaving and laser technologies were explained and compared. Twelve denim fabrics having different surface designs were obtained with the intersection of indigo dyed warp and non-dyed weft yarns based on the theme of "contrast" by using derivatives of twill weave. Besides, these surface patterns were applied to classical denim fabrics by laser technology. The surface properties of denim fabrics produced by weaving technology were different for each surface designs because of different floatings. However, weaving is a time-consuming method and the design steps are more complicated. On the other hand, surface patterns of fabrics obtained by laser technology were found similar to woven ones and it had advantages as having greater design capacity, being a simpler, faster and eco-friendly method.

Keywords: *denim fabric, design, laser technology, weaving*

Comparația între tehnologia clasică de țesere și tehnologia laser în proiectarea țesăturii din denim

Țesăturile din denim sunt preferate de către multe persoane, datorită faptului că sunt în special un simbol al confortului. În acest studiu, s-a realizat proiectarea estetică și fizică a țesăturilor din denim. S-a urmărit compararea designului suprafeței și a parametrilor structurali ai țesăturilor din denim obținute prin tehnologia de țesere și tehnologia laser. Pe lângă etapele proiectării de țesere, au fost explicate și comparate și tehnologiile laser. Douăsprezece țesături din denim având design de suprafață diferit au fost obținute prin intersectarea firelor de urzeală vopsite indigo și a firelor de bătătură nevopsite pe baza temei "contrastului", prin utilizarea derivaților de legătură diagonal. În plus, acest design de suprafață a fost aplicat țesăturilor clasice din denim prin tehnologia laser. Proprietățile de suprafață ale țesăturilor din denim produse prin tehnologia de țesere clasică au fost diferite pentru fiecare design de suprafață, din cauza flotărilor diferite. Cu toate acestea, țeserea este o metodă care consumă mult timp, iar etapele de proiectare sunt complicate. Pe de altă parte, designul de suprafață al țesăturilor obținute prin tehnologia laser a fost similar cu a celor țesute și avantajul acestora a fost capacitatea de proiectare extinsă, fiind o metodă mai simplă, mai rapidă și ecologică.

Cuvinte-cheie*: țesătură denim, design, tehnologie laser, ţesere*

INTRODUCTION

Denim products preferred by miners in the United States at the beginning due to their strength became globally recognized clothes with their comfortable nature. Denim products are in great demand in markets around the world. Classical denim fabric is a cotton woven fabric produced by using indigo dyed warp yarns and non-dyed weft yarns, especially in 2/1 or 3/1 twill weave types. Today, various kinds of denim fabrics are produced and used in different clothes (blue-jeans, skirts, dress, etc.), accessories (shoe, bag, etc.) and home textiles (upholstery, curtain, etc.) by the influence of fashion.

Denim fabrics are generally produced by using cotton yarns. However, when looking at the structural design of denim fabrics it was observed that different types of fabrics produced by using different raw materials (such as polyester, linen, bamboo, lyocell, modal, etc.). The variation in the usage of materials enables denim to have a wide-ranging assortment of fabrics [1]. In the past few years, elastane-containing denim fabric has seen an exponential increase in demand due to its unique weave structure and surface design. Denim is generally woven by using open-end and carded ring-spun yarns produced in Ne 5 and Ne 17 number range. Warps are usually thinner than wefts and have more twist in order to ensure strength during weaving [2]. The effect of different yarn spinning technologies such as ring, compact, sirospun, Open-End (OE) rotor and vortex were studied to investigate the performance properties of denim fabrics. It was observed that although they had a similar fading view after the abrasion test, the breaking strength, tear strength, abrasion resistance, stiffness and stretch properties of denim fabric produced by different yarn technologies were different [3]. In fabric construction, the warp setting designed higher than the weft setting. 2/2 twill and plain weaves are also used [4]. The mass per unit area of fabric depends on the usage area of the product.

Denim fabrics were classified as lightweight, mid-weight and heavyweight fabrics. Lightweight fabrics are under 12 oz, mid-weight fabrics are between 12–16 oz and heavyweights are over 16 oz.

The production processes of denim are different from classical woven fabrics because of the indigo dyeing process. Different colour of denim fabric is produced but most preferred one is indigo. In the manufacturing of denim, the warp yarns are dyed by either rope or slasher dyeing methods. The indigo dyeing process is actualized by the oxidation phenomenon of warp yarns passed through consecutive dying vessels [5]. Indigo never penetrates completely into the yarn, so dyeing of the yarn is repeated on more than one vessel. The colour of indigo is changing over time due to the low fastness of the friction. Denim fabrics having a low washing fastness, medium-light fastness and low dry friction fastness are produced thanks to indigo dying. The fact that denim fabrics have friction fastness has always been regarded as a disadvantage yet, as time passed, this trait has become a desired aspect of the denim design. Thus, the colour and friction fastness in denim fabrics have been looked at in a positive light as the colours wearing off helps add a new fashionable dimension to the fabric. Products made from this fabric are subjected to various physical and chemical ageing methods to create an outdated, fading and worn-out effect on the product.

Industrial denim finishing treatments include various dry and wet processes. Dry processes are sanding, sandblasting, brushing, whiskering and destroying treatments. Wet processes include prewashing, rinsing, stone washing, sand-washing, bleaching, enzyme washing, stone washing with enzymes, permanganate spray, resin wash, desizing, and other special finishes [6–12]. Structural properties and finishing operations of denim affect the performance properties of the end product [12]. The influence of different washing techniques on fabric properties such as structural characteristics, shrinkage, air permeability, bending rigidity, breaking force and elongation, shear rigidity was investigated and the results of washing techniques were compared. It was observed that silicone softening has the most effect on denim properties such as shear, bending [6]. The special finishing processes such as wax, soft resin, leather, and spide finish decrease the breaking force and change the spectral characteristics of denim, but result in attractive patterns [7]. It is noted that using enzymes in denim finishing have advantages comparing different conventional denim treatments. These are being efficient, biodegradability, easy control, acting on a specific substrate exclusively and being an environmentally-friendly process [7–8]. The effect of enzymes on performance properties (tensile, colour) of denim fabrics and products were investigated to find optimum denim finishing conditions by using different enzyme combinations [8–10] and process parameters [11]. Enzyme washing recommended as an optimum treatment than other conventional methods creating less deformation on the product [12].

The denim finishing processes using conventional treatments cause pollution of the environment. Recently, the laser engraving treatment applied to denim products as an alternative to conventional technologies. The denim washing processes that were manually carried out depending on manpower (sanding, ageing fading and spraying, etc.) can be performed using laser and robot systems. The principle of the laser engraving process is to remove various amounts of the surface fibres and dye molecules from the fabric surface. This cause change in the colour quality values of denim fabric [13]. It is possible to achieve fading, worn-out effect or different surface designs by laser technology without using water and chemical agents [13–16]. Being a dry process make laser-engraving treatment a low cost [15] and an environment-friendly method [16–18]. Other advantages of laser engraving over traditional methods are denoted as laser technology has higher working speed [18]. It reduces waste and labour. It saves time, energy, water and chemicals [13–19]. Controlled treatment with a lower risk of product damage can be applied by laser process [13, 17, 19]. Laser engraving treatment creates different surface designs in a short time with various size and intensity [13, 17, 21]. The patterns can be applied surface of the product by using graphic design and CAD-CAM systems to increase the variety, accuracy, repeatability and standardization of design [13, 17–20]. To summarize, the application of laser engraving to denim is preferred due to being accuracy, efficiency, simplicity, automation, low cost, desired variety and environmentally friendly method.

There are two types of commercially used laser technology as solid-based (wavelength of 1 μm) and gas-based (wavelength of 10 μm) [13]. The CO_2 laser is the most preferred one as an effective method for the treatment of denim surface in a short time. In laser technology, a pair of high-speed mirrors controlled by a computer system drives the laser beam on the product and the beam fade the denim surface according to design. Any image created graphically can be transferred on a denim surface by a suitable laser process. Fading phenomena occurs as a result of the decomposition of the dye and removal of the decomposed dye by evaporation. Various fading effects can be created by changing the parameters of the laser. Some of the important laser parameters defining the degree of fading are the wavelength, power density, and pulse width, etc. [13, 19].

Researchers investigated the effect of laser parameters on some structural and performance properties of denim fabrics [13–16, 21–23]. Laser and different treatment methods were also compared [15, 18, 21]. The effects of laser power intensity on colour change and surface properties of denim samples were investigated by applying various combinations of resolution and pixel time. It is noted that the prolonged pixel time and high resolution increases the laser power energy and the high laser power density increase the fading effect [13, 15, 23]. Changing speed, power, step parameters creates different effects. For instance, the increase in power increased colour change. Increasing laser speed decreased colour change. On the other hand, the step had the lowest impact on colour change [22]. In another study, different wavelength and power density of laser are applied to denim optimum parameters were defined [14, 24]. Various combination of laser parameters such as output power, speed of engraving, frequency, etc. was changed and an enzymatic process was applied after laser treatment [16]. The fading effect after both laser and enzymatic treatments were different according to laser parameters. Laser treatment was also compared with manual fading processes [18], sand-blasting and washing processes [21], and cellulose treatment [15]. In all studies, the colour change was measured by using a spectrophotometer and morphological analysis were done by scanning electron microscope [13–15, 20, 22, 23]. Increasing laser intensity increase colour loss on denim [13, 18, 21, 23]. The colour levelness was found independent of the direction of laser irradiation [23]. The colour change in warp and weft direction was also found different [22]. The morphology of the fibre was also different after treated with various laser parameters. It is noted that the increase in power density creates a sponge-like structure [13, 15, 23]. The structural (weight and thickness), strength properties after laser treatment were also changed after fading treatments especially laser process having higher intensity [18, 21, 24]. The strength of fabrics treated by laser technology was found greater than manual ones [18]. The effect of two different yarns produced with different spinning technologies (torque-free ring-spun and conventional ring-spun) on laser treatment of denim was investigated and colour fading of torque-free ring-spun yarn is better after laser treatment [15]. In another study, the same design was applied to denim product by laser treatment and pigment printing. The tensile strength of fabrics was similar for both methods. Comparing with printing technology the laser technology was defined as a faster method [25]. In previous studies, it is noted that with careful selection and control of laser parameters, different degrees of colour fading could be achieved without important strength lose and any damage. [13–15, 18, 21–24]

Innovation is very important in the denim market. In this study, the surface patterns of fabrics produced by weaving and laser technologies were compared. There are many studies about the comparison of laser and other classical denim treatment methods. This is the first study that compared the appearance and structural parameters of denim fabrics obtained by weaving and laser technologies. Firstly, the aesthetic design studies were carried out according to the defined theme. Surface patterns of denim were formed by using derivatives of twill weave. Then, the physical designs of the fabrics were studied and the structural properties of fabrics were defined by calculations. Some constraints about the production were also considered during physical design studies and the structural properties were rearranged according to these limitations. Designed fabrics were woven by a sample loom. Besides, created patterns were applied on the surface of a classical denim fabric woven with 3/1 twill weave by using laser technology. The structural properties and surface patterns obtained from these two technologies were compared.

MATERIAL AND METHOD

Aesthetic design

In this study, a new perspective on the denim fabric design was brought. When designing on a denim fabric it is common to use techniques of denim finishing processes. Unlike classic denim production, it is aimed to design different surface effects and these surface designs were applied by both weaving and laser technology.

The intersections of indigo dyed warp yarns and non-dyed weft yarns create a clear-cut visual difference between the two sides of the fabric. The contrast property of denim fabric is selected as the theme of this aesthetic design study. Contrast is a concept that is encountered every day, but ironically, it is accepted as something ordinary that we see in our lives. Examples of contrast are; night-day, hot-cold, black-white, old-young. As can be seen from examples, although the contrast between the two things that create contrast seems to separate them, their differences complement each other to form the whole. Increasing contrast effect at any application increase the attention of the viewer and adds an aspect of excitement to the art. Contrast happens when two different things with different characteristics are brought to the same application. For instance, a light colour on a dark textile surface or vice versa.

Surface designs were formed to increase the colour contrast created by the use of different coloured warp and weft yarns. In classical denim fabrics, warp yarns are dominant on the surface of the fabric. In this study, twelve different surface patterns were designed by using derivatives of twill weave in order to create the concept of contrast by weaving technology. These derivative weaves are; shaded, zigzag, diamond, herringbone, and wavy twills. The unit weave reports are given in figure 1. As seen in figure 1, the contrast effect is achieved on the surface by using long warp or weft yarn floatings having light and dark colour in the weave unit.

Designed weave units were also applied on the surface of a classical denim fabric by laser technology. The surface designs were provided by the repetition of each weave unit in both warp and weft directions as seen in figure 2. These screen views were transferred to the laser machine and the process was carried out.

Physical design

The structural properties of fabric such as yarn linear density, settings and mass per unit area should be defined in order to produce the designed fabric.

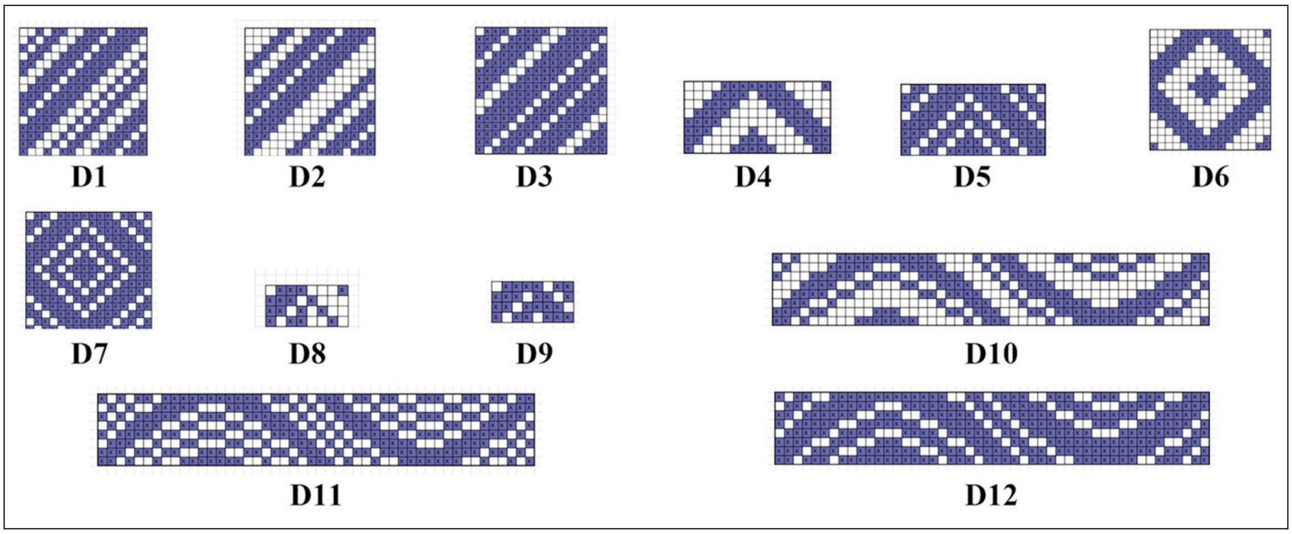

Fig. 1. Unit weave reports of surface designs

100% cotton-carded yarns were used in warp and weft direction. The linear density of warp and weft yarns was 30 tex and 37 tex, respectively. The warps were indigo dyed and wefts were non-dyed cotton yarns. Theoretical warp and weft settings of finished fabrics were calculated according to Ashenhurst's formula given in equation 1 [26]. In this equation, S is setting, k is crimp factor, F_w is weave factor, K is yarn coefficient according to yarn technology (K is 8.3 for cotton yarns), N is yarn count in metric system (Nm). The weave factor (F_w) was calculated for each design according to the weave unit by using equation 2. In equation 2, y is the number of yarns in the weave unit and i is the number of intersections in the weave unit. The weave factor was calculated for both warp and weft direction. In this study, the crimp factor, which was the ratio of un-crimped yarn length to crimped yarn length, was estimated as being 1.05 for both weft and warp direction. The estimated mass per unit area of finished fabric (w) was calculated depending on yarn count, setting and crimp factor by using equation 3. The subscripts 1 and 2 were used for warp and weft directions, respectively. Settings of fabrics at loom-state were also calculated theoretically for each design by using equation 4. Here, S_L is the loom setting. The theoretical warp loom settings were calculated at the range of 32–39 thread/cm depending on weave types. The mean value of the theoretical loom setting was found as 34 threads/cm along the warp direction in order to produce all fabric types with the same warp.

$$S = kF_w K\sqrt{N} \quad (1)$$

$$F_w = \frac{y}{y+i} \quad (2)$$

$$W = \frac{100\,k_1 S_1}{N_1} + \frac{100\,k_2 S_2}{N_2} \quad (3)$$

$$S_L = F_w K\sqrt{N} \quad (4)$$

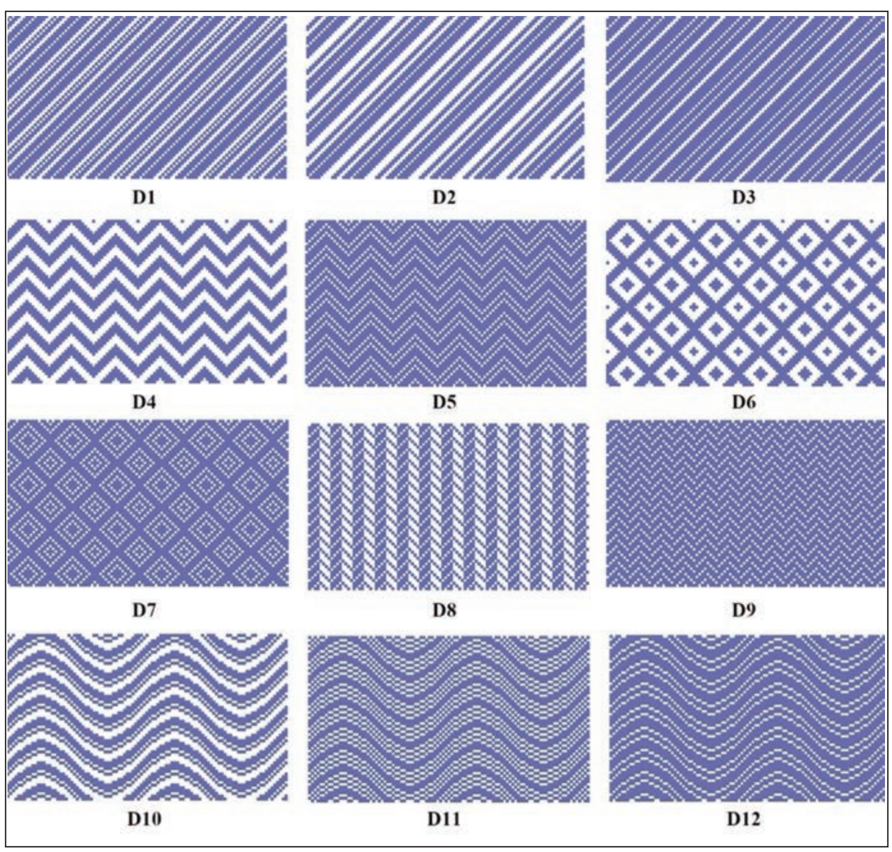

Fig. 2. Applied surface patterns by laser application

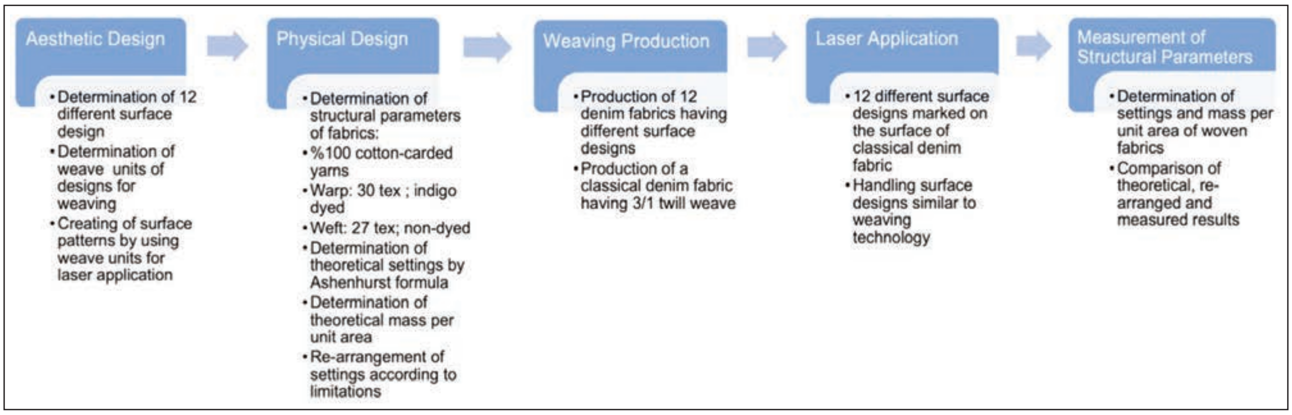

Fig. 3. Design, production and evaluation steps of the study

There could be some technical limitations in the physical design stage of the fabric. In this study, fabrics were woven on CCI dobby sampling loom and the count of used reed on the machine (R_n) was 100. Therefore, the production parameters were changed according to this reed count and a certain setting reduction ratio was applied to the theoretically calculated warp and weft setting of designed fabrics. Besides, a classic 3/1 twill denim fabric was also produced in order to apply the surface designs by laser technology. The weave factor of 3/1 twill weave is 0.67 in both warp and weft directions.

In figure 3, the design, production and evaluation steps of this study are summarized.

RESULTS AND DISCUSSION

Theoretically calculated results of settings and mass per unit area of finished fabric by using equations 1–3 are given in table 1. It can be observed that the weave factor, namely the weave type, affects the settings. In the study, there was a technical limitation at the weaving production because of used weaving reed. Therefore, the loom setting of the fabrics was re-designed as 30 threads/cm along warp direction and the warp setting of finished fabrics was estimated as being 32 threads/cm according to the supposed crimp factor. It can be assumed that a setting reduction between the ranges of 5–21% was applied for the theoretically calculated settings according to weave type. However, the break of warp yarns was higher during the weaving operation with 32 threads/cm warp setting and 29 threads/cm weft setting. Therefore, the weft setting of produced fabrics was decreased to decrease the tension on the warps and rearranged weft setting at was defined as being 20 threads/cm.

Setting and mass per unit area measurements of woven fabrics were done at standard atmospheric conditions. As seen in table 1, the measured warp settings are different from theoretically calculated ones. But after settings were rearranged according to the limitations such as used reed and breaking problem of warp estimated values were similar to measured ones. The mass per unit area of finished fabrics was lower than the theoretically calculated ones. The structural parameters of classical denim fabric having 3/1 twill weave were measured as 32 threads/cm warp setting, 20 threads/cm weft setting and 176.43 g/m^2 mass per unit area.

Table 1

THEORETICALLY CALCULATED, REARRANGED AND MEASURED STRUCTURAL PARAMETERS OF THE FINISHED FABRICS

Design code	F_{w1}–F_{w2}	Theoretically calculated results			Rearranged setting		Measured results		
		S_1 (cm^{-1})	S_2 (cm^{-1})	w (g/m^2)	S_1 (cm^{-1})	S_2 (cm^{-1})	S_1 (cm^{-1})	S_2 (cm^{-1})	w (g/m^2)
D1	0.67–0.67	34	30	224.12	32	20	31	20	176.26
D2	0.72–0.72	36	33	240.85	32	20	32	20	175.86
D3	0.72–0.72	36	33	240.85	32	20	32	20	179.59
D4	0.80–0.80	40	36	267.61	32	20	30	22	179.98
D5	0.67–0 .67	34	30	224.12	32	20	30	20	174.20
D6	0.80–0.80	40	36	267.61	32	20	32	22	185.97
D7	0.67–0.67	34	30	224.12	32	29	32	22	185.05
D8	0.67–0.67	34	30	224.12	32	20	32	20	174.99
D9	0.67–0.67	34	30	224.12	32	20	32	20	171.65
D10	0.75–0.67	38	30	236.80	32	20	31	20	176.35
D11	0.67–0.57	34	26	206.52	32	20	32	20	180.24
D12	0.75–0.67	38	30	236.80	32	20	32	21	182.43

In figure 4, examples for some surface view of designed denim fabrics obtained by weaving and laser technologies were given. Surface views obtained by two different techniques were very similar to each other. Only, D9 design could not be applied by the used laser machine. Because there are thinner lines on the patterns which could not be applied with the used laser beam.

Two production technologies have advantages and disadvantages when compared to each other. The surface designs were applied successfully by weaving technology. However, weaving technology is a long, stressful and costly process because of weaving preparation operations. Firstly, the design calculations for weaving should be done for each weave type in order to define settings and to estimate mass per unit area of the product. But these calculations are so complicated and take more time. Besides, the results to be revised for each weave type according to limitations on the production stage. The drafting plan of the complicated weave designs are also difficult and can cause some permanent faults on the fabric. The elimination of such faults required more cost due to labour and time. It was seen that designs obtained by weaving technology have a three-dimensional effect and the surface properties of all designs are different because of the long floatings of warp and weft yarns. These created different handle properties at all fabrics having different surface designs. The handle properties of fabrics produced by weaving technology were evaluated better. In this study, the mass per unit area and settings of all designed fabrics produced with weaving technology were different. On the other hand, as denoted in previous studies [13–19] surface designs are acquired in a shorter time and less labour by using laser technology. Laser technology is a computer-controlled process with a lower error rate [13–19]. Besides, surface designs can be applied to a classical denim fabric by using laser technology without the need for new design calculations. This means the production of a denim fabric having a surface pattern can be started in a shorter time. The structural parameters such as settings and mass per unit area of fabric are the same for all type of different surface designs created by laser technology. Although these structural parameters are different in each woven design. Besides, there can be some damage problems of laser technology applied to very light fabrics. Therefore, the machine parameters should be chosen well [13–15, 20, 22, 23]. It is known that the performance properties such as strength properties decrease after laser treatment [18, 21, 24]. But surface patterns can be achieved successfully by weaving technology, without loss of strength.

Laser technology provides a more flexible working space for designers. The designer is unlimited in developing the pattern. However, weaving technology has some limitations about the weave capacity of the loom, especially in dobby looms. In this study, fabrics were woven with a maximum of 18 heald shafts including edges. Besides, the dimensions of patterns have limitations in weaving technology because of design capacity. However, the dimension of patterns can be changed in laser technology, so the design capacity is higher in this system [13, 17–20]. On the other hand, in this study, laser technology has limitations about applying very light lines on fabric surface which can be obtained with weaving technology by the floating of one or two threads. Consequently, in recent years, laser technology is popular in the fading of denim fabrics by having a huge design capacity and being a simpler and faster treatment. Comparing with other denim finishing treatments it is an eco-friendly production method because of being a dry treatment without the use of

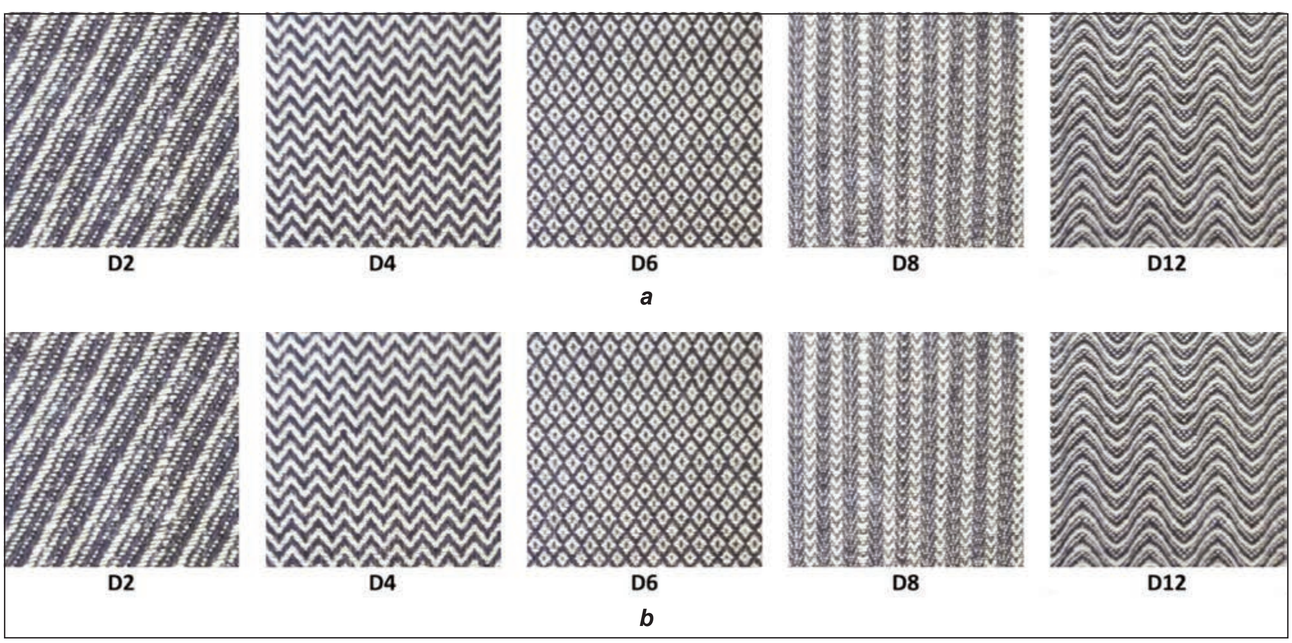

Fig. 4. Same design patterns applied by: *a* – weaving technology; *b* – laser technology

water and chemical agents [13–16]. So, it can be preferred in the production of different surface designs.

CONCLUSION

In this study, a design study was carried out in order to design denim fabrics having different surface patterns. The contrast was the theme of aesthetic design studies. Designed surface patterns were produced by using two different technologies: weaving and laser. The design steps of these two technologies were explained in detail to compare these technologies. The surface views of the two techniques were found similar to each other. The structural parameters of different designs such as settings and mass per unit area were different for each fabric produced by weaving technology. On the other hand, all structural properties were the same for laser technology. The design and production processes of weaving technology were more complicated than laser treatment. The designs drawn on the computer screen easily created on the surface of the denim fabric by laser technology. Laser technology has advantageous in fast production, less error rate, less effort, higher design capacity, and great production. It is also an eco-friendly finishing process comparing with other denim fading processes. As a result, laser technology can be preferred as an efficient method for the surface design of denim fabrics. However, surface designs achieved by weaving technology have also advantages as both having no damage of fabric after production and having various surface properties because of different floatings. In further studies, it is aimed to compare the performance properties of denim fabrics produced by weaving and laser technology.

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Information technology integration and the competitiveness of textile industry in China

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ABSTRACT – REZUMAT

Information technology integration and the competitiveness of textile industry in China

The aim of study is to analyse the relationship between the competitiveness and integration of Information technology (IT) into textile industry. This research has constructed a theoretical framework to explore how the textile industry integrating IT can improve the competitiveness. A regression model was established for analysing the relationship between them by using the data of textile industry in China from 2004 to 2015. The empirical results revealed that the integration of textile industry and IT industry not only enhanced the temporary competitiveness but also contributed to the sustainable competitiveness of the textile industry. Thus, the findings suggest that the textile industry integrated with IT industry will promote competitiveness of China's textile industry and it will be new trend of industrial development.

Keywords: *textile industry, information industry, industrial integration, coupling coordination degree, competitiveness*

Integrarea tehnologiei informației și competitivitatea industriei textile din China

Scopul studiului este de a analiza relația dintre competitivitate și integrarea tehnologiei informației (IT) în industria textilă. Această cercetare a dezvoltat un cadru teoretic pentru a analiza modul în care industria textilă ce integrează IT-ul poate înregistra o creștere a competitivității. S-a stabilit un model de regresie pentru analiza relației dintre acestea utilizând datele industriei textile din China din perioada 2004–2015. Rezultatele empirice au arătat că integrarea industriei textile și a industriei IT nu numai că a îmbunătățit competitivitatea temporară, ci a contribuit și la competitivitate durabilă a industriei textile. Astfel, rezultatele sugerează că industria textilă integrată în industria IT va promova competitivitatea acesteia și va reprezenta o nouă tendință de dezvoltare industrială.

Cuvinte-cheie*: industria textilă, industria tehnologiei informației, integrarea industrială, gradul de coordonare a asocierii, competitivitate*

INTRODUCTION

The textile industry is an important sector of Chinese economy. China is one of the largest producers and exporters of textile and apparel products in the world. In recent years, in order to enhance the competitiveness of textile products, the Chinese government has proposed a series of measures such as the development of the industrial Internet, the promotion of intelligent manufacturing, and the encouragement of scientific and technological innovation. The implementation of these policies has strengthened the informatization level of China's textile industry. However, whether the enhancement of the competitiveness of the textile industry coincides with the improvement of the level of informatization still needs practical proof.

The purpose of this article is to investigate the relationship between the degree of IT integration into the textile industry and competitiveness of textile industry under the circumstances of implementation of big data and artificial intelligence. The article organized as follows. The first section conducts a literature review and forms a number of hypotheses on the relationship between industry integration and textile industrial competitiveness. The second section introduces the methodology to calculate the competitiveness index of textile industry and the integration degree of IT into the textile industry respectively. The third section analyses the relationship between the competitiveness of the textile industry and IT integration by using a regression analysis method. The last section provides a discussion of the obtained results and some conclusions.

LITERATURE REVIEW

The competitiveness has long been a popular topic for scholars to discuss in industrial performance research. Some of the researches focused on the measurement of competitiveness. Havrila and Gunawardana [1], Yilmaz and Karaalp-Orhan [2], Tripa et al. [3] respectively employed Balassa index, Vollrath index, Grubel-Loyd index, Lafay index as the measurements to reveal comparative advantage. Shafaei analysed competitiveness by using a method based on Porter's diamond of competitive advantage to measure the competitive performance of Iranian companies in sectors of the textile industry [4]. Other researchers attempted to explore the determinants of competitiveness in the textile industry. The results of studies indicated that many intra-industrial factors, such as investment, product diversity, domestic market share, foreign market development, would foster the competitiveness. Moreover, firm networking, industrial clustering, technological externalities, participating in the industry associations and availability of government's incentives also had a large effect on the competitiveness of the firms [5–9].

With IT and knowledge-based economy being the theme of the time, the concept of industrial competitiveness had been expanded. Innovation, energy efficiency, environmental impact and sustainable development were considered to create the competitiveness of textile industry. The concept of competitiveness in this paper consists of temporary competitiveness and sustainable competitiveness.

Temporary competitiveness is achieved through cost savings and efficiency improvements, whereas sustainable competitiveness is possessed by valuable, inimitable and non-substitutable attributes resources, such as intelligent capital and innovation capabilities accumulation [10]. From temporary competitiveness aspect, manufacturing technologies applied in textile industry boosts the labour productivity to gain the market share [11]. Meanwhile, managerial innovation, as an essential element for enterprise competitiveness, is created by the combination of management and technology. The simplicity and easiness of using information technology paves the way for managers to make an accurate and opportune decisions through sharing internal information of enterprises from the textile sectors, reducing decision-making cost and improving managerial efficiency [12]. IT utilized in textile industry motivates learning processes within organization by facilitating exchange of skills and knowledge across functional sections, hence enhancing the internal communication supports to decentralized decision structure, which, in turn, is associated with higher financial performance [13, 14]. In addition, interface integration and operation information sharing between organizations lowers the information transfer cost. Information transparency and collaborative capacity between up-stream and down-stream organizations has made the entire structure more flexible and competitive. Intranet and extranet solution provided by IT improved the communication with suppliers and clients. Due to the rapidly response speed of supply chain, more customers and business partners would be attracted, which creates added-value in supply chain to enhance industrial competitiveness [15]. As for sustainable competitiveness, IT applied in textile industry spurs innovation activities to meet the customer demand. Technological convergence results in completely new types of products [16]. New market opportunity is created because IT accelerates flow of knowledge shifting from knowledge-centred high-tech industry to traditional industries. For the requirements of high-quality products, development of intelligent products, and customized service platform construction, an innovation system will be developed simultaneously [17]. Additionally, IT can help generate competitive advantage by leveraging human resources. Human capital comprises knowledge, skills and entrepreneurship. E-learning technology has positive influence in organizational learning effectiveness, while on-job management education may provide entrepreneurs specific information on the applications of IT to improve the operation efficiency [18–20]. In this way, more employers with knowledge and skills could be attracted and intellectual capital accumulated, thus promoting the long-term competitiveness.

Based on the above theories, this paper proposes the following hypotheses: integration of textile industry and IT industry enhances textile industrial competitiveness through improving temporary competitiveness and fostering sustainable competitiveness.

There are three paths to foster the textile competitiveness (figure 1). Firstly, IT applied in textile industry increases the labour productivity, saves the cost

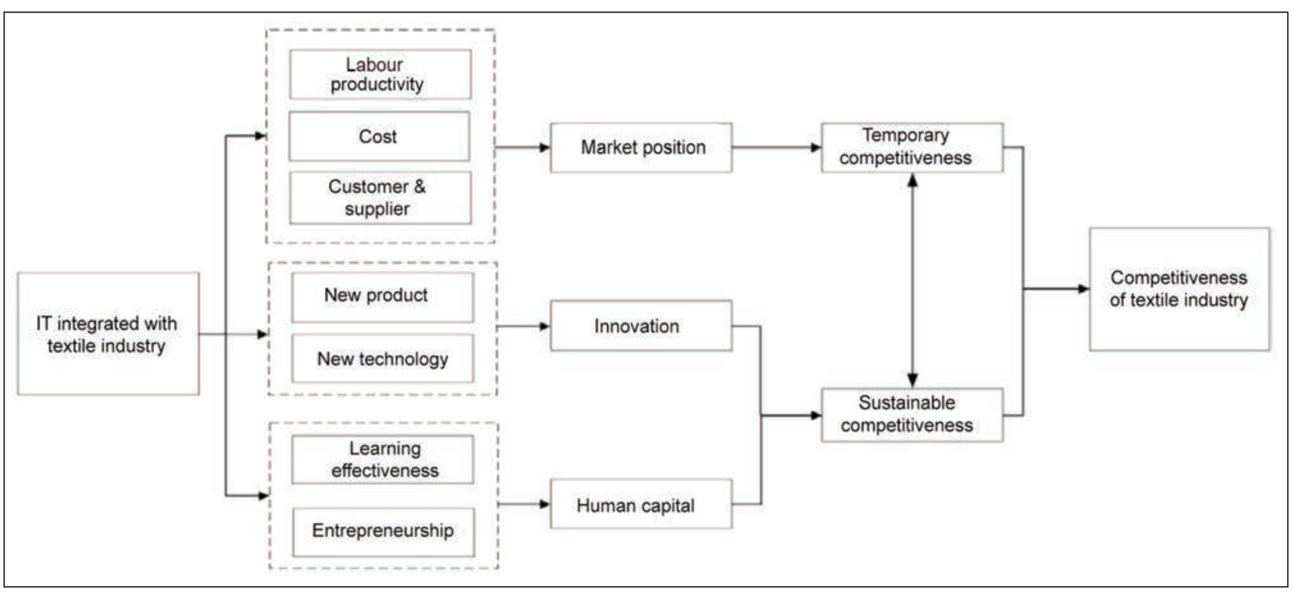

Fig. 1. The paths to improve the competitiveness by integration of IT in textile industry

and integrates the supply chain to get profit and market share. The application of IT in textile industry improves productivity and reduces production and decision-making cost. Participants in the supply chain, coordinating their activities through information sharing mechanisms, obtain the market status to heighten temporary competitiveness. Secondly, IT moderates existing process and brings new solutions to facilitate the process innovation. For the adoption of IT machinery, the time that elapses from order placement to the customer is reduced, thereby increasing product innovation. Finally, on-job training system assisted by IT speeds up the diffusion of tacit knowledge, and knowledge spill over effect has emerged. The knowledge spill over effect enhances learning efficiency and accelerates the accumulation of human capital. IT introduced into products and embedded in organizational management may allow for faster flow of knowledge, information and innovations, which may ultimately enhance the entrepreneurial cultures, and thus enhance the retention of talented and skilled employees. In this way, human capital would be maintained for obtaining sustainable competitiveness.

RESEARCH METHODOLOGY

In order to investigate the relationship between competitiveness of textile industry and integration of textile industry with IT industry, the calculation of the textile industry competitiveness index and Integration degree of the degree of industrial integration are the most critical variables. The detailed calculation method is as follows.

Construction of Textile Industrial Competitiveness Index

This study considers that competitiveness of textile industry consists of two aspects: temporary competitiveness and sustainable competitiveness.

Temporary competitiveness is mainly determined by the market position, and sustainable competitiveness is highly correlated with innovation and human capital levels. Therefore, selling value of industry is chosen to measure the temporary competitiveness, since this indicator explains the economic performance of textile industry. Sustainable competitiveness is measured by innovation and human capital. In terms of innovation, the number of patents is selected to estimate innovation capability. As for the human capital, which is difficult to be assessed according to available data, this study adopts a simplified method to evaluate it. Human capital is generally strongly correlated with income of the employees. The higher is the income, the higher is the level of human capital. Therefore, this research employs the average wage of the textile industry as an indicator to measure human capital. All data is separately obtained from China Textile Development Report, China Industry Economy Statistical Yearbook, China Labour Statistical Yearbook and Patent Information Service Platform.

Different evaluation indicators have distinct dimensions. In order to eliminate the dimensional influence between indicators, this study adopted Min-max normalization method to normalize the raw data. The formula for calculation is as follows:

$$Z^*_{qit} = \frac{Z_{qit} - min\, Z_{qit}}{max\, Z_{qit} - min\, Z_{qit}} \times 100 \qquad (1)$$

where Z^*_{qit} is the value of the indicator after normalization, Z_{qit} – the value of the indicator before normalization, $min\, Z_{qit}$ – the minimum value of the indicator within certain year, $max\, Z_{qit}$ – the maximum value of the indicator within certain year, q – the type of indicator, i – the province and t – the year.

The component score is calculated after normalization, given in the equations as follows:

$$\begin{bmatrix} com_{1it} \\ com_{2it} \\ \vdots \\ com_{nit} \end{bmatrix} = \begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1m} \\ w_{21} & w_{22} & \cdots & w_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ w_{n1} & w_{n1} & \cdots & w_{nm} \end{bmatrix} \begin{bmatrix} z^*_{1it} \\ z^*_{2it} \\ \vdots \\ z^*_{mit} \end{bmatrix} \qquad (2)$$

where com is the component score, w – the weight of each indicator, n – the amount of retained components and m – the amount of variables.

Finally, the total component score can be calculated as follows:

$$COM_{it} = \sum_{j=1}^{n} W_j com_{jit} \qquad (3)$$

where $j = 1, 2, 3, ..., n$. COM is the dimension score of competitiveness, that is competitiveness index. W is the weight of each component.

Therefore, from equations 1 to 3, competitiveness index of the textile industry is calculated by computing dimension score of each province within t year. The results are illustrated in table 1.

The results presented in table 1 show that the nationwide competitiveness of the textile industry, in general, declined from 2004 to 2015. From the regional

Table 1

COMPETITIVENESS INDEX OF TEXTILE INDUSTRY

Region	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
East	38.12	38.59	37.33	36.03	34.18	32.67	33.74	33.69	33.34	33.04	33.14	33.34
Central	22.71	22.87	21.88	21.63	21.33	20.36	21.17	22.19	23.81	24.28	24.88	24.81
West	16.51	15.83	14.25	15.31	12.85	12.46	12.61	11.80	12.11	11.84	13.53	12.18
Nationwide	26.41	26.40	25.11	24.91	23.28	22.30	22.98	22.97	23.39	23.31	24.10	23.69

perspective, competitiveness index of the eastern region is highest in China. It is about 2.6 times than that of the western region, approximately 54% higher than the central region, and nearly 45 percent above the national average. From the time perspective, competitiveness index of textile industry of the eastern region decreased slightly from 2004 to 2015. By contrast, due to underscoring the strategic position of the central region, and designating it as the country's key advanced manufacturing centre and key area for comprehensive opening up, competitiveness index of the central region has increased rapidly since 2010.

Calculation of the integration degree

This paper, based on industry integration theory and coupling coordination degree model, constructed the evaluation index system and used coupling analysis method to calculate the integration degree of textile industry and IT industry. The first step for calculation is to establish the evaluation index systems for assessing integration degree of the two industries. According to the principles of efficiency, scale and industrial development, major indicators affecting industry integration are selected for estimating the integration degree of textile industry and IT industry, and then, the evaluation index systems for assessment are established, which are shown in table 2.

Table 2 tabulates the indexes of indicator layer for estimation. The efficacy coefficient of each system can be calculated by following equations:

$$E_{ij} = \frac{x_{ij} - x_{ij}^{s}}{x_{ij}^{H} - x_{ij}^{s}} \tag{4}$$

where E_{ij} is the efficacy coefficient of indicator j of order parameter i, $E_{ij} \in [0, 1]$, x_{ij} is each index value of indicator j of order parameter i , x_{ij} is a positive indicator that contributes positive efficacy to the system, therefore, the greater the value of x_{ij}, the better the system efficiency, x_{ij}^{s} – the minimum value of the indicator, x_{ij}^{H} – the maximum value of the indicator.

The integration value of subsystem of textile industry and IT industry can be calculated as follows

$$u_{ki} = \sum_{j=1}^{m} \theta_{ij} E_{ij} \tag{5}$$

where u_{ki} is the integration value of subsystem of k industry, θ_{ij} – the weight of each order parameter (based on our previous research the weights are equally distributed), i – the order parameter, j – the number of indicators of each system.

The comprehensive efficacies of the textile industry and the IT industry system are calculated separately by using an integrated methodology. The expression of the comprehensive efficacy is:

$$U_k = \sum_{i=1}^{n} \lambda_{ki} u_{ki} \tag{6}$$

where U_k stands for the comprehensive efficacy of k industry, λ_{ki} – the weight of each order parameter of k industry. This paper adopted the Delphi and AHP method to reflect the weight of factor layer, since

Table 2

INDICATORS FOR EVALUATING TEXTILE INDUSTRY AND IT INDUSTRY SYSTEMS

System layer	Factor layer	Weight (λ)	Indicator layer
Textile Industry System (TIS)	Scale (X_1)	0.33	Selling Value of Industry (X_{11})
			Number of Enterprises (X_{12})
			Annual Average Employees (X_{13})
			Tax from Principal Business (X_{14})
	Efficiency (X_2)	0.33	Ratio of Profits to Total Industrial costs (X_{21})
			Ratio of Profits, Taxes and Interests to Average Assets (X_{22})
			Labour productivity (X_{23})
	Development (X_3)	0.34	Growth rate of Selling (X_{31})
			Growth rate of Annual Average Employees (X_{32})
			Growth rate of Tax (X_{33})
Information Technology Industry System (ITS)	Scale (Y_1)	0.33	Selling Value of Industry (Y_{11})
			Number of Enterprises (Y_{12})
			Annual Average Employees (Y_{13})
			Tax from Principal Business (Y_{14})
	Efficiency (Y_2)	0.33	Ratio of Profits to Total Industrial costs (Y_{21})
			Ratio of Profits, Taxes and Interests to Average Assets (Y_{22})
			Labour productivity (Y_{23})
	Development (Y_3)	0.34	Growth rate of Selling (Y_{31})
			Growth rate of Annual Average Employees (Y_{32})
			Growth rate of Tax (Y_{33})

semi-structured interviews and questionnaire data from the managers of enterprises, industry experts and policy makers are collected in our previous research.

Then the integration degree can be calculated through coupling coordination degree model, and the equations are given as follows:

$$D = \sqrt{C \times T} \tag{7}$$

$$C = \left[\frac{U_{TIS} \times U_{ITS}}{(U_{TIS} + U_{ITS})^2} \right]^{\frac{1}{2}} \tag{8}$$

$$T = \alpha \times U_{TIS} + \beta \times U_{ITS} \tag{9}$$

In equation 7, D is the coupling coordination degree, i.e., integration degree, $D \in [0,1]$, C – the coupling degree, T – the comprehensive coordinating index of the coupling system. Coupling degree can be calculated by equation 8, U_{TIS} and U_{ITS} respectively stands for the comprehensive efficacy of textile industry system and IT industry system. Equation 8 indicates $C \in [0,1]$. Coupling degree represents the degree of dependency or interaction between the two systems. When $C = 0$, the textile industry system and the IT industry system are uncorrelated. When $C = 1$, the textile industry system and the IT industry system are coordinated. In equation 9, T reflects the overall level of the textile industry system and the IT industry system. α and β respectively represent the contribution of the textile industry and the IT industry, and $\alpha + \beta = 1$. As the revenue from principal business of the IT industry is about 2.7 times than that of the textile industry, therefore, in this case, $\alpha = 0.37$ and $\beta = 0.63$. U_{TIS} and U_{ITS} in equations 8 and 9 can be separately calculated by equation 6.

The statistical data is chosen from China Textile Development Report and Year Book of China Information Industry for calculating the integration degree of textile industry and IT industry according to equations 4 to 9. The computational results are shown in figure 2.

Figure 2 displays that the integration degree of textile industry and IT industry systems had been raising rapidly from 2004 to 2015. It increased steadily from 0.533 to 0.612 and then dropped slightly since 2007, due to the impact of the international financial crisis. Whereas, with the adjustment of domestic manufacturing industry structure and implementation of IT industry policy, the integration degree increased considerably to approximately 0.7 in 2011. Due to the promotion proposal of Made-in-China 2025, the integration has further increased to 0.731 after 2014.

In terms of distinct regions, integration degree has its own characteristics. Figure 2 also reflects the differences of integration degree among different regions in China. From 2004 to 2010, the integration degree of textile industry and IT industry system in the eastern region is generally higher than that of the central and western regions. Since 2009, the implement of industrial upgrading and relocating policy has made great progress in the central region. Therefore, the integration degree in the central region had shown a trend of substantial growth, and the growth rate is significantly higher than that in the eastern and western regions. The strategy of large-scale development of the western region also accelerated integration of textile industry and IT industry. In 2015, the integration degree of the western region surpassed that of the eastern and central regions.

Regression model

In order to understand the way by which textile industry and IT industry integration affects competitiveness of textile industry, we establish linear regression models. The metrological expression of the industry integration degree and industry competitiveness can be constructed as follows:

$$COM = \alpha_1 D + V \tag{10}$$

where COM is competitiveness index of textile industry, D – integration degree of textile industry and IT industry systems, V – the control variable, including local economic development, financial, human capital and innovation.

On both sides of the logarithm, equation 10 can be written as follows:

$$\ln COM_{i,t} = \beta_1 \ln D_{i,t} + \beta_2 \ln GDP_{i,t} + \beta_3 \ln GFE_{i,t} + \beta_4 \ln HC_{i,t} + \beta_5 \ln INNO_{i,t} + \varepsilon_{i,t} \tag{11}$$

Where GDP is the local gross domestic product, GFE represents local government fiscal expenditure, HC reflects human capital, $INNO$ is the quantity of patents, i stands for the certain province and t represents the time. The data originates from China Statistical Yearbook, China Labour Statistical Yearbook and Patent Information Service Platform.

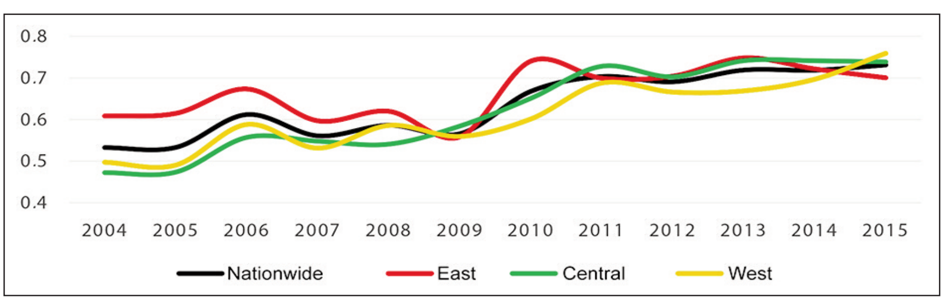

Fig. 2. Integration degree of textile industry and IT industry (2004–2015)

This study adopts panel data for analysis, and uses four models to carry out regression. Model 1 employs pooled ordinary least squares (OLS) to make regression analysis. Considering heteroscedasticity and autocorrelation of panel data, before the regression, heteroscedasticity and autocorrelation tests are carried out. The test results show that group wise heteroscedasticity exists. Therefore, panel-corrected standard error method is adopted for estimation. Model 2 and Model 3 are random-effects and fixed-effects regression respectively. Hausman test conducted those fixed-effects regression is the best model. By considering the endogeneity of key variables in our regression models, we applied Davidson-MacKinnon endogeneity test for endogeneity. The results (Davidson-MacKinnon test of exogeneity: 8.543, P-value = 0.0037) show that we should utilize a panel Instrumental Variable Generalized Method of Moments (IV-GMM) estimation. Since this method allowed for arbitrary heteroscedasticity, we adopted IV approach and GMM method to resolve the problem of endogeneity (Model 4). The lagged logarithm values of integration and the output value of IT industry are used as instrumental variables for estimation.

RESULTS AND DISSCUSSION

The regression results are shown in table 3.
The results from the estimated model are presented in table 3. The regression results illustrated that:

- The regression coefficients of are positive, and significance tests of regression coefficients at $p < 0.01$ in FE models. The empirical results show that integration degree of textile industry and IT industry has a positive and significant impact on competitiveness of textile industry. This implies that a 1% rise in integration degree of textile industry and IT industry increases textile competitive index by about 0.6% without considering the endogeneity of the data. When taking endogeneity into account, the coefficient of $\ln D$ increases to 4.58, which hints that a 1% rise of integration of the two industries causes the increase of textile industrial competitiveness by around 4.58%.
- The findings are partly consistent with that of Li and Huang study for the mechanism of the integration of textile industry and electronic information industry to promote the competitiveness of textile industry, which pointed out that the improvement of the level of industrial integration plays an important role in promoting quality of textile industry [21]. The main difference lies in that the level of industrial integration has direct effect instead of lag effect on competitiveness.
- As for control variables, the coefficients of local government fiscal expenditure and human capital are negative in all models, although statistical significance fails to reach the significant requirement. The result implies that fiscal expenditure of government has a negative effect on competitiveness of textile industry. Human capital, which occupies an important position in knowledge economy, plays a limited role in promoting the competitiveness of the textile industry, because the textile industry is still a labour-intensive industry in China.

CONCLUSIONS

This paper has investigated the relationship between competitiveness of textile industry and integration of textile industry and IT industry in China. The empirical results indicate that integration of textile industry and IT industry has a significant role in promoting the

Table 3

RESULTS OF ESTIMATES OF THE TEXTILE INDUSTRY COMPETITIVENESS EQUATION

VARIABLES	Model 1	Model 2	Model 3	Model 4
	OLS	RE	FE	IV-GMM
lnD	0.652***	0.545***	0.617***	4.580**
	0.233	0.190	0.190	2.265
lnGDP	0.150	1.175***	0.267	–1.049
	0.376	0.343	0.445	1.065
lnFM	–0.563**	–0.972***	–0.418*	–0.106
	0.259	0.164	0.246	0.476
lnHC	–0.481*	–0.220	–0.532*	–0.517
	0.269	0.246	0.287	0.582
lnINNO	0.0949	0.126	0.128	–0.165
	0.0743	0.0956	0.0980	0.234
Constant	–78.81	1.402	9.410**	-
	56.00	2.456	3.693	-
Observations	348	348	348	319
Number of num	29	29	29	29
Hansen J statistic	-	-	-	1.346
Chi-sq(1) P-value	-	-	-	0.2460

Note: Standard errors in parentheses in the second row: * significant at 0.1 level, ** significant at the 0.05 level, *** significant at the 0.01 level.

competitiveness of textile industry. From 2004 to 2015, integration degree of textile industry and IT industry had increased dramatically from 0.533 to 0.731. When considering the endogeneity, the integration degree of textile industry and IT industry rises 1%, the competitiveness of textile industry increases by around 4.58%.

The mechanism via which the industrial integration promoted the competitiveness of textile industry can be summarized as follows: on the one hand, industry convergence between textile industry and IT industry optimizes industrial efficiency and expands the market, thus increasing the temporary competitiveness of textile industry. On the other hand, industrial integration of textile industry and IT industry also enhances the sustainable competitiveness of textile industry. With IT has infiltrated into textile industry, industrial restructuring and upgrading of textiles taken place frequently, and consequently innovation activities emerge and new enterprises are established. Thus, the competitiveness of textile industry is boosted with the innovation ability strengthening and human capital accumulating.

Since some statistics are not available, this paper only selected the data from 2004 to 2015 for analysis, but some of the other supporting data showed that the degree of integration and competitiveness of the textile industry are still positively correlated from 2016 to 2019. Hence, the results still have considerable credibility. Due to the limitation of length, this paper mainly analyses the relevance of integration degree and competitiveness of textile industry with the method of linear regression. Although this study considers endogeneity of the data, the research concerning pathways to enhance competitiveness is insufficient.

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Study on soil burial biodegradation behaviour on polylactic acid nonwoven material as a replacement for petroleum agricultural plastics

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ABSTRACT – REZUMAT

Study on soil burial biodegradation behaviour on polylactic acid nonwoven material as a replacement for petroleum agricultural plastics

Currently, the issues related to environmental pollution with plastics are a major concern. Agriculture is a vital area for human existence, but it generates large amounts of plastic waste. These result from agricultural practices that use systems and support materials which help facilitate the work of farmers and offer a better yield of production and quality of crops, in relation to the smaller areas of agricultural land. An alternative can be the use of sustainable textiles that can bring multiple benefits to the agricultural sector, including: pollution reduction, biodegradation potential, reduced consumption of agricultural inputs like pesticides, herbicides, fertilizers and water, high retention potential for water and good ventilation, increased productivity and quality for the agricultural crops, etc.

First of all, this paper discusses the potential use of bio-based and eco-friendly polymers, such as polylactic acid (PLA), in the form of fibres for the production of non-woven textile structures that can be used as a support element in agricultural practices and for the replacement of conventional plastics obtained from oil resources. Secondly, considering the advantage of the biodegradation property of this material, the durability and the influence of the location depth in a degrading natural environment such as soil, were the target of experiments to highlight the positive aspects of polylactic acid use in the context of the circular economy. To demonstrate the proposed objectives, different physico-mechanical analyses were performed to determine the morphological characteristics of the fibres, the tensile strength, the material thickness and the possible loss of mass due to microbial activity.

Keywords: *agro-plastics, polylactic acid fibres, mulching material, biodegradability, life expectancy, waste reduction*

Studiu privind comportamentul la biodegradarea prin îngropare în sol a unui material nețesut din acid polilactic ca înlocuitor al materialelor plastice pe bază de petrol utilizate în agricultură

În prezent, problemele legate de poluarea mediului cu materiale plastice sunt o preocupare majoră. Agricultura reprezintă un domeniu vital pentru existența umană, dar care generează cantități mari de deșeuri din plastic. Acestea rezultă din practicile agricole care utilizează sisteme şi materiale suport ce ajută fermierii şi care oferă un randament mai bun al producţiei şi al calitatii recoltelor, în raport cu suprafeţele tot mai reduse ale terenurilor agricole. O alternativă poate fi utilizarea textilelor durabile, care pot aduce multiple beneficii sectorului agricol, inclusiv: reducerea poluării, potențial de biodegradare, consum redus de input-uri agricole precum pesticide, erbicide, îngrășăminte și apă, potențial ridicat de retenție a apei și o bună ventilație, creșterea productivității și calității culturilor agricole etc.

În primul rând, această lucrare aduce în discuţie potenţialul de utilizare al polimerilor bio şi ecologici, precum acidul polilactic (PLA), sub formă de fibre pentru realizarea de structuri textile de tip neţesut ce pot fi folosite ca element suport în practicile agricole și pentru înlocuirea materialelor plastice convenţionale obţinute din resurse petroliere. În al doilea rând, luând în considerare avantajul proprietăţii de biodegradare al acestui material, durabilitatea şi influenţa adâncimii de amplasare într-un mediu natural degradant precum solul, au reprezentat ţinta experimentărilor efectuate, pentru a evidenţia aspectele pozitive ale utilizării acidului polilactic în contextul economiei circulare. Pentru a demonstra obiectivele propuse, au fost efectuate diferite analize fizico-mecanice pentru a determina caracteristicile morfologice ale fibrelor, rezistența la tracțiune, grosimea materialului și posibila pierdere de masă datorată activității microbiene.

Cuvinte-cheie: *agro-plastice, fibre de acid polilactic, material de mulcire, biodegradabilitate, speranță de viață, reducerea deșeurilor*

INTRODUCTION

Agriculture is an essential field that must keep pace with global change, both from the perspective of ensuring a sufficient amount of food for the increasing population, but also from the perspective of ensuring an optimal quality of food offered to consumers. In this sense, there are more and more common agricultural practices that use systems and support materials to help farmers, to facilitate their work, and provide a better yield of production and quality of crops, concerning the smaller areas of agricultural land.

Greenhouse cover structures, cover materials for seed bed protection, mulching materials, shading nets, harvesting systems, etc., are only a few such auxiliary elements which, being made of plastics, at the end of their use require an extra effort to clean the environment of the remaining waste.

Large amounts of plastic waste are generated by the agricultural sector every year. In 2018, 5% of the total post-consumer plastic waste (from 29.1 million tons) in the European Union came from agriculture, immediately after the packaging sector that holds power [1]. Most agricultural plastics are used in only one season and frequent replacement is the key problem of large waste production.

In general, three ways of disposing of petroleum plastic waste are mainly practiced: burial in the ground, incineration and landfilling or disposal along watercourses, ways that have harmful effects on natural ecosystems.

A series of strategies are required to reduce the difficult circumstances generated by the use of plastics in agriculture and to implement a new economy based on the principles of the circular economy, including:

- correct procedures for the collection, disposal and recycling of post-consumer plastics;
- increasing lifetime and performance;
- the introduction and promotion of bio-based materials [2].

In the context of the use of bio-based materials, this study focuses on the potential use of polylactic acid (PLA), one of the many existing biopolymers, in the form of fibres from which nonwoven textiles can be made and used in the agricultural sector (agro-textiles), more exactly to protect and support the growth of crops in the form of mulching material. Mulching foils represent a good part of the total plastic films used by agriculture. According to the report by the Environmental Investigation Agency, in 2018 mulch foils accounted for 40% of the total agro-plastics market [3], often presenting difficulties in their proper disposal after usage because of contamination with soil. Therefore, the use of bioplastics with the capacity to biodegrade, for such agricultural structures would have a significant contribution to the sustainable development of the sector.

Polylactic acid is thermoplastic polyester produced by the fermentation of a carbohydrate source. The raw materials used to produce PLA can be corn starch, tapioca roots or sugar cane. Its properties are similar to those of conventional plastics, but the advantage is, in particular, the low negative impact on the environment, by its renewable plant nature and biodegradation property. These characteristics triggered its rapid evolution in the textile market as a competitive product with the designation by the FTC as a new type of fibre in 2002 [4, 5].

To declare whether this type of material offers a good performance from the point of view of durability in accordance with the environmental usage conditions and with the functions that it must fulfil as mulching material, it is necessary to study the biodegradation behaviour. It is noted that in the literature there are numerous studies and various approaches that have been performed on the aspect of biodegradation of polylactic acid (PLA) in different biological environments (e.g. composting, soil, seawater) [6] and under different forms. It is most often found in the form of films [7, 8] for testing the biodegradation behavior, but also other forms of PLA material have been studied, depending on the uses: yarns [9], fibres [10], brushes [11], pellets [12], and less in the form of textile material [13].

Biodegradability testing media have shown different results on the mode and the time of evolution, from process initiation to full biodegradation. For example, in soil, under laboratory controlled conditions, a film of polylactic acid goes through a difficult and long process of biodegradation, while in compost it has a much faster rate of biodegradation, due to differences in microbial activity in these environments, according to [14, 15]. But, in addition to the influence of the presence of microorganisms, equally important for the decomposition process are the humidity and temperature appropriate to the type of microorganisms. In the work realized by M. Karamanlioglu, the tensile strength of a piece of PLA container was lost in 30, 36 and 48 days at 50°C in compost, soil and sterile water, respectively. However, little or no degradation occurred at lower temperatures (25°C and 37°C) over 12 months [16], thus demonstrating the importance of microbial communities, humidity and higher temperature.

The reaction of the material to the biodegradation conditions in the compost was also investigated along with the presence of several types of bacteria additionally added to the test environment to observe which type has a stronger and faster influence on the biodegradation process to remove it from the environment. It was found that the presence of microorganisms such as *A. sulfonivorans* and the *Fungus L. laccata* together with S. viminalis may be an effective tool in accelerating the process of biodegradation of PLA [17]. Another study showed that the action of the bacterium Alcaligenes sp. from the soil caused the complete degradation of a PLA film with the size of 2×2 cm^2 after only 20 days [18]. To assess the degree of biodegradation, most studies have used the analysis of CO_2 content resulting from the decomposition process [19–24]. Although carbon dioxide is a greenhouse gas that has an impact on climate change, in agriculture, the carbon dioxide released by the decomposition of biodegradable plastics, along with other resulting substances, would also contribute to a great extent in improving soil fertility and supporting plant growth.

In an attempt to contribute to the sustainable development, this article offers a new approach for the valorisation of the potential for use of materials. It is necessary to increase the awareness of the population on the destructive actions generated on the planet, and a first step is to reduce the excessive consumption of resources and materials and to find ways to remedy this fact. By being able to use materials for multiple purposes and by interconnecting areas, such as textiles and agriculture, and using less harmful materials, we will be able to reduce much of the pressure on the environment. Thus, the study aimed to test the aerobic biodegradation of a non-woven PLA fibre material in laboratory conditions using as a biodegradation medium a mixture of commercial soil and manure compost, to see if it is a good solution for use as mulch material in terms of durability and elimination of the use of seasonal materials. Also, the influence of burial depth in the soil on the process was verified, as a solution to reduce the effort to remove the material at the end of its useful life.

EXPERIMENTAL PART

Materials

A nonwoven material manufactured from 100% bio based PLA fibres with different lengths and bonded together by a thermic treatment was bought from Toray Industries Company and used in this study.
To assess the material stability and life expectancy, many samples of a similar size were taken from the purchased nonwoven material and were buried into the soil. The soil was a commercial soil type bought from local landscape materials suppliers. This type of soil is composed of 100% natural soil obtained by black peat processing and improved with natural compost, obtained from manure. It is also a good medium for vegetable growing, ensuring the plants a good supply of water and nutrients. The soil benefit from a 6.5–7.0 pH, a humidity grade of 60–70% and a composition (table 1).

Table 1

SOIL COMPOSITION

Nitrogen (%)	Phosphor (%)	Potassium (%)	Organic matter (%)	C org (%)
1.78	0.21	0.82	34.48	13.96

Methods

Soil burial method

The applied soil burial method for testing biodegradability in the study did not follow any standards. Three sets of samples were created, with 6 individual samples each, and put into three different containers, according to the test time intervals, in a sandwich soil-fabric structure to evaluate the influence of burial depth on samples. Each sample was covered by 1 cm of soil, the one at the bottom being covered by 6 cm of soil. The containers were kept in aerobic conditions according to the time intervals established for the recovery of the samples, listed in the table 2 along with the codification of the samples according to the time and burial depth.
The samples were cut from the original material in the longitudinal direction in a rectangle form with a dimension of 16 × 29 cm. Also, a set of reference samples with the same size were taken and subjected to the initial physico-mechanical testing methods (tensile strength and elongation, mass and thickness measurements, morphology evaluation) to make a good appreciation of the degree of biodegradability between samples (table 2).
Biodegradation tests were carried out in a chamber with a temperature in the range between 15 and 30°C according to the period of the year, in order not to limit the microbial growth and activity of mesophilic microorganisms. Also, the atmospheric humidity was between 40–50%. The room benefited also from the presence of natural light to a certain degree because light also has its influence on the degradation of materials.

Biodegradability testing methods

- Visual inspection and scanning electron microscopy analysis (SEM)

Each sample was macroscopically analysed after their recovery from the soil to identify any possible changes in their aspect, colour, fragmentation, or any other changes. SEM analysis was used to inspect the morphology of the PLA fibres in the samples before (Nt 0) and after soil burial (Nt 1, Nt 2 and Nt 3). A Quanta FEI 200 equipment was used to record the morphology changes at different levels of magnification.

- Mass variation evolution after biodegradation and thickness measurement

The reweighing of the recovered samples after the end of each proposed degradation interval to evaluate the mass variation is an essential analysis. This determines the possibility of degradation as an effect of destroying the integrity of the material due to the presence of microorganisms and mass loss. After each collection of the samples from the biodegradation medium, they were lightly washed with distilled

Table 2

CODING OF SAMPLES AND RECOVERY TIME INTERVAL FROM SOIL

Coding of samples		Samples recovery time interval from soil
Nt 0	Reference sample	-
Nt 1	Nt 1.1 (the deepest buried), Nt 1.2, Nt 1.3, Nt 1.4, Nt 1.5, Nt 1.6 (the lowest burial depth)	8 months after soil burial
Nt 2	Nt 2.1 (the deepest buried), Nt 2.2, Nt 2.3, Nt 2.4, Nt 2.5, Nt 2.6 (the lowest burial depth)	9 months after soil burial
Nt 3	Nt 3.1 (the deepest buried), Nt 3.2, Nt 3.3, Nt 3.4, Nt 3.5, Nt 3.6 (the lowest burial depth)	10 months after soil burial

water and then dried at room temperature. The mass variation was determined using equation 1:

$$MV\,(\%) = \frac{W_0 - W}{W_0} \cdot 100 \qquad (1)$$

where MV is the mass variation (%), W_0 – the initial mass (g) of the sample and W – the mass (g) of the sample after degradation.

Thickness measurement was done according to standard SR EN ISO 5084:2001. Determining the thickness of textile materials and products on digital equipment for measuring fabric thickness, Sylvac S 229. Five measurements were realized for each of the biodegraded samples and also for the reference sample, according to the standard. Measuring points were randomly chosen from the surface of the samples.

• Tensile strength and elongation measurement

The entire tests were done in the Laboratory of physical-mechanical tests for textile materials of INCDTP Romania. Tensile tests were done according to the standard ISO SR EN 29073-3:1998. Textile materials. Nonwoven test methods. Part 3. Determination of tensile strength and elongation. The used equipment was an electronic tester James Heal-Titan (load cell 5 kN).

The samples subjected to biodegradation were tested from one direction, namely nonwoven delivery direction, only the reference material was tested from both directions, nonwoven delivery direction and cross direction (CD). The test pieces for the tensile measurements had a length of approx. 29 cm and width of 5 cm. The recommended number of replicates for the test, according to the standard, was 5 pieces per testing direction. The number of test pieces was 3 instead of 5 for the each of samples recovered from soil, according to the surface area. Only the reference sample (Nt 0) was tested on 5 pieces per direction.

RESULTS

Visual inspection

The visual inspection of the recovered samples from the soil after the established time intervals for testing the possible degradation indicated some signs of biodegradation, shown in figure 1 and 2.

In the case of Nt 1 set, recovered at 8 months after the burial in the soil, no significant signs of degradation could be seen at the macro scale, the colour did not change, fragmentation did not occur and the structure was quite rigid, similar to that of the reference samples. An aspect to be mentioned would be that the fibres broke due to the biodegradation process, many ends of the fibrils standing out from the plane of the nonwoven material, more or less for each of the 6 variants, producing a flaky type effect, the most accentuated in the case of sample Nt 1.6, the one located at the lowest depth relative to the soil surface (figure 1).

The Nt 2 and Nt 3 variants registered the same effects as the previous variant, samples Nt 2.6 and

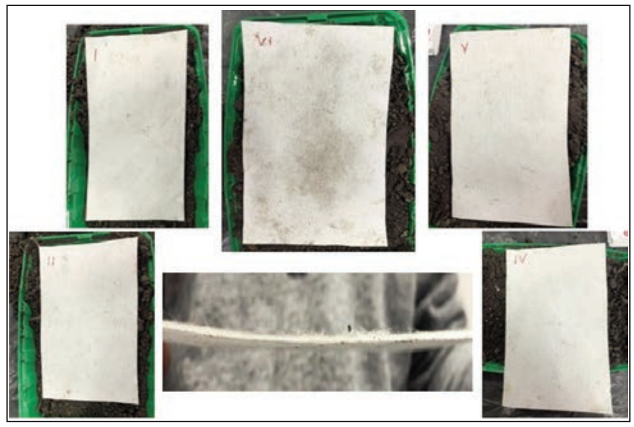

Fig. 1. Sample set Nt 1 as recovered from the test container

Nt 2.3 having the most fibrous surface. But, in this case also an accentuated state of biodegradation it was seen for these samples with a weakened structure (figure 2, *a*). None of the samples of the Nt 3 variant presented an accentuated fibrous surface; just a few fibres were out of the structure, not necessarily because of the degradation. Nt 3.2 and Nt 3.1 also had a weakened structure, as can be seen from figure 2, *b*.

The morphology of the fibres in the sample sets

The reference sample Nt 0 verified under SEM presents in general perfect smooth cylindrical fibres with a very long length. The measured diameter of the fibres was situated between 9 μm and 12 μm.

All the samples from the set Nt 1 verified after the 8 months of storage in the soil underwent structural changes in the form of thinning, thickening, rupture of the fibres or other deformations, more or less, but the overall diameter of the fibres did not change.

For the Nt 1 set of samples, the most pronounced degradation as a result of many fibres that underwent physical changes was registered in the case of sample Nt 1.3 followed by Nt 1.2 and Nt 1.1. In the case of Nt 1.6 only in a certain portion, there was a lot of damage produced to the fibres. The depth of burial could influence the degradation phenomenon, as we identified that the first three samples Nt 1.6, Nt 1.5 and Nt 1.4 presented only minor deteriorations in the morphology of the fibres, and the last three ones which are buried at a greater depth showed the most damage.

In the case of the Nt 2 set of samples recovered at 9 months after soil burial, the same morphology changes took place as in the case of the Nt 1 sample set, but more pronounced. Of these, samples Nt 2.1, Nt 2.3, Nt 2.4 and Nt 2.6 showed the most degradation and deformation of the fibres. The rest registering only a few such changes, the sample Nt 2.2 is keeping its appearance almost intact. It seems that in the case of the Nt 2 set the degradation phenomenon did not occur according to a certain rule, the samples being degraded preferentially, not depending on the depth of burial.

a ***b***

Fig. 2. Sample sets as recovered from the test container: *a* – Nt 2; *b* – Nt 3

For the samples set Nt 3 more fibre deteriorations were identified than in the previously analysed sets, by the longer exposure time of biodegradation. Also, the samples Nt 3.5 and Nt 3.6 presented many fibre deteriorations than the rest located deeper in the soil. However, we must mention that the general degree of biodegradation of the samples cannot be estimated accurately based on the images obtained under the microscope, because we analysed only a small portion of each sample, in which we found or not fibre deteriorations, but which probably in the rest of the structure could have shown deteriorations or not, contrary to what we observed under the microscope. Figure 3 highlights the damage caused by bacterial

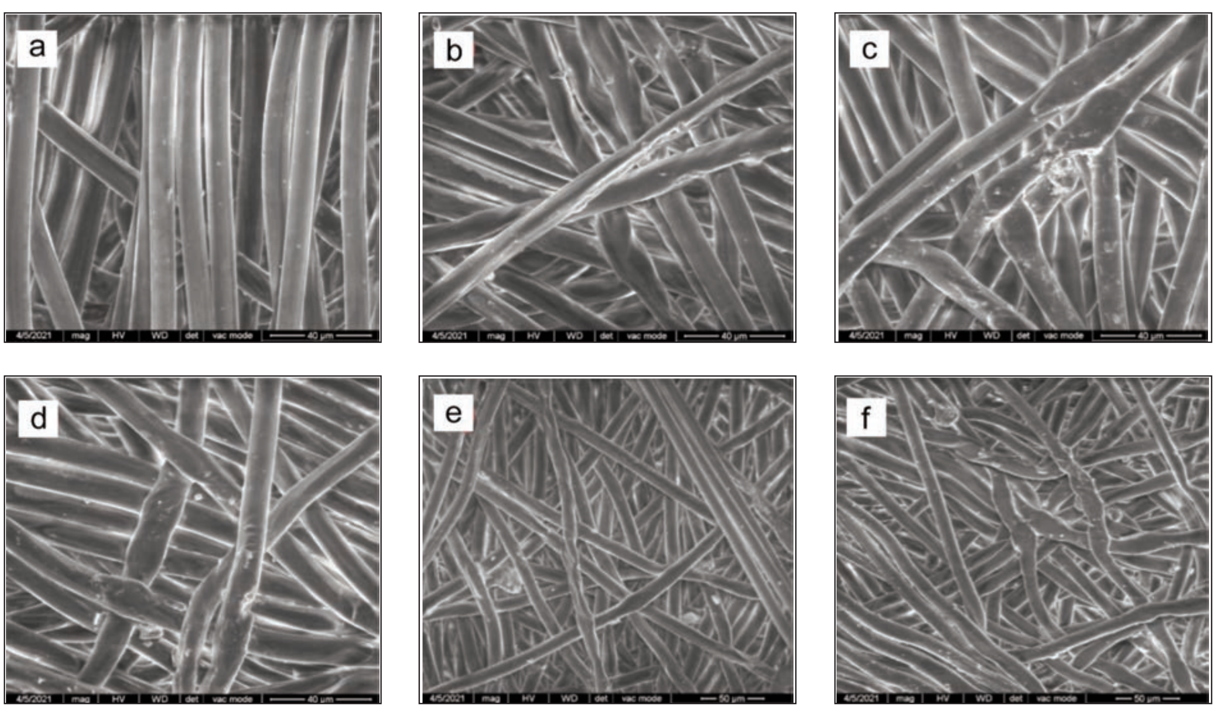

Fig. 3. Morphology of the fibres in the samples: *a* – Nt 0 at 2000× magnification; *b* – Nt 1.1 at 2000× magnification; *c* – Nt 1.3 at 2000× magnification; *d* – Nt 1.6 at 2000× magnification; *e* – Nt 2.1 at 1000× magnification; *f* – Nt 3.1 at 1000× magnification

activity on the fibres for some of the samples compared to the morphology of the fibres in the reference sample Nt 0 represented in figure 3, *a*.

Physical characteristics – mass variation, nonwoven thickness

The mass variation calculated by equation 1 could be a representative indicator of the biodegradability of the samples and the results may be observed in figure 4. As we mentioned above, samples had a dimension of 16×29 cm and the measured mass according to this dimension was 9.057 grams before their burial in the soil (figure 4).

When the mass variation is positive, an increase in mass above the initial measured value occurred. However, negative variations are associated with mass loss due to microbial activity which destroyed the fibres, as we saw from the SEM micrographs.

Only a few samples (Nt 1.3, Nt 1.6, Nt 2.3, Nt 3.2) from each set corresponding to the three stages of analysis recorded a negative mass variation, for the rest obtaining quite high positive values of the mass variation. This fact can be explained by the intake of soil particles that adhered to the surface of the fibres and filled some of the gaps created by the fibres in the structure, although the samples were carefully washed and dried.

We cannot assume that the burial depth had an influence on the mass loss of the samples and neither the time of burial in the soil which should have provided a significant mass loss compared to the initial mass if the samples had been degraded. Unlike other studies in which plastic films were used to evaluate their degree of biodegradation by mass variation and which after removing the soil allow a more accurate measurement of the mass after biodegradation, in our case, the main problem to the large mass variation measurements remains the residual soil from the structure of the samples.

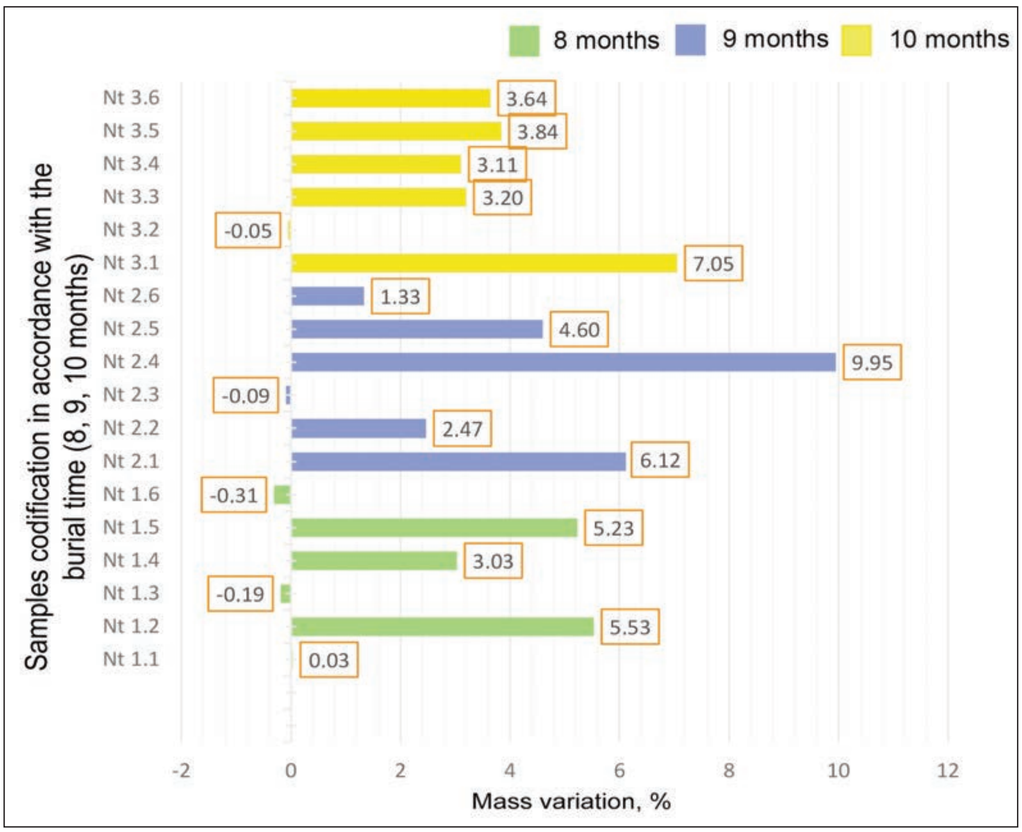

Fig. 4. Mass variation data of the biodegraded samples

Another physical characteristic that could indicate the state of biodegradability could be the thickness of the samples after recovery from the soil. Therefore, the thickness was measured for all the three sets recovered from the soil and for the reference set and the results are indicated in table 3.

The samples did not manifest a significant change in their thickness after soil burial in comparison

Table 3

THE AVERAGE THICKNESS OF THE REFERENCE AND BIODEGRADED SAMPLES

Sample code	Thickness (mm)	Sample code	Thickness (mm)	Sample code	Thickness (mm)	Sample code	Thickness (mm)
Nt 0	0.69	Nt 1.1	0.69	Nt 2.1	0.69	Nt 3.1	0.69
		Nt 1.2	0.67	Nt 2.2	0.67	Nt 3.2	0.70
		Nt 1.3	0.67	Nt 2.3	0.67	Nt 3.3	0.68
		Nt 1.4	0.67	Nt 2.4	0.70	Nt 3.4	0.68
		Nt 1.5	0.68	Nt 2.5	0.69	Nt 3.5	0.68
		Nt 1.6	0.70	Nt 2.6	0.70	Nt 3.6	0.67

with the reference sample Nt 0, even a slight exceedance of its thickness value occurred. One cause of these small variations in thickness may be rather the not very flat surface of the samples, which in some places showed many wrinkles and not because of the biodegradation process.

Mechanical properties – tensile strength and elongation

Of all the analyses performed, the tensile test, a mechanical strain, should be the best indicator of the degree of degradation, because if the fibres have gone through a phenomenon of deterioration due to soil microorganisms, but also other environmental factors, such as soil temperature and humidity, atmospheric temperature and humidity, the presence of oxygen or light, the overall strength of the nonwoven structure would have weakened, and the values of breaking strength should be lower than those of the non-degraded sample. In table 4 are presented the average results of the breaking strength measurement (N), along with the elongation at break (%).

It is mentioned that all the samples buried in the soil were cut in nonwoven delivery direction from the basic fabric, so the results were compared with the results from Nt 0 in this direction. In the case of Nt 1 set the breaking strength is lower than that of the reference sample Nt 0, as well as the elongation, except for Nt 1.5, but it can be considered that degradation of the overall structure of the samples has taken place. The lowest breaking strength was obtained in the case of the Nt 1.6 sample, which also recorded a negative mass variation meaning a mass loss compared to the initial mass of the reference sample, but for which we identified only limited deteriorations on the fibres. Also, a low result for the breaking resistance was obtained for Nt 1.3 sample, which corresponds to the loss of mass and even thickness. Even if the other samples did not suffer a mass loss, the lower breaking strength than the reference sample indicated that a certain degree of biodegradation occurred, and it seems that for those buried deeper the results are better. The same cannot be said for the Nt 1.6 sample, which was buried at the lowest depth in the container, but for which we assume a major influence on its damage was the action of ambient sunlight.

The same phenomenon occurred in the case of sample Nt 2.6, for which a much lower result of the breaking strength compared to Nt 0 was obtained. Good results were also obtained for the Nt 2.3 and Nt 2.2 samples, according to the burial depth. The sample Nt 2.2 contrary to the unaltered morphology of the fibres had poor tensile strength compared to Nt 0, and even the thickness decreased. A special case is the Nt 2.1 sample which did not show a decrease in tensile strength and elongation at break compared to the Nt 0 sample, although it was buried deepest in the soil, and damage to the fibres identified under the microscope would have indicated significant biodegradation.

Good results were also obtained for the samples of the Nt 3 set, all the values of the tensile strength were below the reference sample tensile strength or even close, like in the case of Nt 3.1 sample, which also had the same thickness as Nt 0 sample, and no significant morphological changes of the fibres were observed under SEM analysis. Like the Nt 2.1 sample, this one does not necessarily conform to the influence of burial depth.

It should be noted that after calculating the coefficients of variation (CV) for the realized measurements, in some cases (Nt 2.3, Nt 2.6 and Nt 3.2) this indicator recorded high values indicating a large dispersion of the recorded data, which is normal in the case of nonwovens with a high degree of thinness (<1 mm) and with possible non-uniformities in the nonwoven mass, although they showed the lowest tensile strength. The best value was obtained for the sample Nt 3.4 with a tensile strength of 380.75 N and an adequate CV.

According to the tensile test, for the Nt 3 set of samples, it seems that the burial period of 10 months had a much better influence than the burial depth. It took a minimum of 10 months for all the samples to show a decrease in tensile strength.

Table 4

AVERAGE MEASUREMENTS OF THE TENSILE STRENGTH AND ELONGATION OF THE REFERENCE AND BIODEGRADED SAMPLES

Samples	Breaking strength (N)	Elongation at break (%)
Nt 0	Nonwoven delivery direction results	
	493.05	7.61
	Cross direction results	
	118.73	5.1
Nt 1.1	414.65	5.45
Nt 1.2	441.81	6.54
Nt 1.3	416.68	6.75
Nt 1.4	458.31	7.26
Nt 1.5	510.07	8.59
Nt 1.6	402.54	6.29
Nt 2.1	511.43	8.91
Nt 2.2	451.03	6.50
Nt 2.3	331.96	4.59
Nt 2.4	525.66	8.35
Nt 2.5	500.10	7.73
Nt 2.6	337.87	4.40
Nt 3.1	491.09	7.29
Nt 3.2	347.29	5.56
Nt 3.3	430.89	7.79
Nt 3.4	380.75	5.94
Nt 3.5	456.82	6.68
Nt 3.6	461.41	8.34

CONCLUSIONS

PLA fibres are currently a sustainable solution for the development of agro-textiles used as filtration and/or support media for the harmonious growth of crops, both at underground levels or even laid on the soil surface. The developed analyse underline the following:

- The biodegraded nonwoven samples did not change colour and do not lose their shapes due to degradation.
- PLA nonwoven changed only at the surface level where the fibres came out of the structure, creating a flaky type effect.
- All the analysed samples went through some internal structure degradation, which was best manifested by the loss of mechanical properties.
- The results showed that for this type of textile material, tensile strength decline does not necessarily correlate with mass measurements after degradation because due to the structure of nonwoven, it retains a large amount of residual soil among the spaces between the fibres which cannot be cleaned.
- The best tensile strength results were obtained for Nt 3 set of samples, which indicates that the 10-month burial period had a significant influence compared to 8 and 9 months of burial.
- Overall, the material under study withstood the biodegradation process quite well during the 10 months, only after this period registering a substantial decrease in mechanical properties.
- Thus, we can mention that the mixture soil-compost as a biodegrading medium, without well controlled process conditions and without the addition of inoculant material, is a medium that does not favour rapid degradation of the material.

The applicability of such material from polylactic acid fibres in agricultural practices, as mulching material, could be an environmental-friendly and cost-effective solution for crops growing. Moreover, the reaction products, CO_2 and H_2O, from the biodegradation process will help the crops to develop harmoniously. In addition, according to this study, it can be used for a relatively long period, for at least two cultivation cycles, if we consider that one cycle begins in March and ends in November. At the end of its use, it can be disposed of at ground level or buried; it will finally degrade, leaving no residues in the environment and thus becoming biomass for future crops.

Further research work can be done on this matter for the enrichment of knowledge. Other types of bio-based polymer fibres can also be considered for the production of textile structures that can be integrated into agricultural activities for the intelligent and sustainable valorisation of the agricultural lands, of the labour force and the improvement of the crops productivity and quality. Moreover, biodegradability in open environment, under real testing conditions will be a major step in the appreciation of the full potential of the use of these polylactic acid nonwovens as agro-textiles. The correlation of the data obtained in the laboratory tests with those obtained in the open environment tests, will allow the establishment of a realistic evaluation on the impact of this material on the environment. It is necessary to obtain more data that will allow seeing exactly how the material will resist in terms of durability and if it ensures the optimal conditions for crops growth.

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Agglomeration and total factor productivity of China's textile industry

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ABSTRACT – REZUMAT

Agglomeration and total factor productivity of China's textile industry

Agglomeration is an important characteristic in China's textile industry development. But regional textile industry is seriously unbalanced, only eastern location entropy (LQ) is greater than 1 and is the highest of all, followed by the central, western and north-eastern regions. Total factor productivity (TFP) is an important indicator to measure the economic growth efficiency. The average annual growth rate (AAGR) of eastern textile industry TFP is the least and central TFP growth rate is the fastest. In order to investigate the relationship between agglomeration and TFP of China's textile industry, especially at region level, this paper applies panel model to study how agglomeration influences TFP during 2005–2018. The results show that increasing agglomeration degree restrains the TFP growth of China's textile industry. The coefficients of LQ on textile industry in China and four regions are all negative. There exists crowded effect in eastern textile industry. It has not formed the significant agglomeration effect in western and north-eastern textile industry for very low agglomeration degree. So it implies that eastern textile industry can accelerate the implementation of industrial transfer and structural adjustment to lower agglomeration and maintain sustained profitability of textile enterprises. Western textile industry can strengthen agglomeration by undertaking industrial transfer from eastern region to form agglomeration effect to promote TFP growth.

Keywords*: industrial agglomeration, location entropy, total factor productivity, DEA-Malmquist method, crowded effect*

Aglomerarea și productivitatea totală a factorilor aferenți industriei textile din China

Aglomerarea este o caracteristică importantă în dezvoltarea industriei textile din China. Dar industria textilă regională este grav dezechilibrată, doar entropia de localizare estică (LQ) este mai mare decât 1 și este cea mai ridicată dintre toate, urmată de regiunile centrale, vestice și nord-estice. Productivitatea totală a factorilor (TFP) este un indicator important pentru a măsura eficiența creșterii economice. Rata medie anuală de creștere (AAGR) a TFP din industria textilă din est este cea mai mică, iar rata de creștere a TFP din regiunea centrală este cea mai ridicată. Pentru a investiga relația dintre aglomerare și TFP-ul industriei textile din China, în special la nivel de regiune, această lucrare aplică modelul de panou, pentru a studia modul în care aglomerarea influențează TFP în perioada 2005–2018. Rezultatele arată că creșterea gradului de aglomerare limitează creșterea TFP a industriei textile din China. Coeficienții LQ pentru industria textilă din China și din cele patru regiuni sunt negativi. Există un efect de aglomerare în industria textilă din est. Nu s-a format efectul de aglomerare semnificativ în industria textilă din vest și nord-est, pentru un grad de aglomerare foarte scăzut. Prin urmare, rezultă faptul că industria textilă din est poate accelera implementarea transferului industrial și a ajustării structurale pentru a reduce aglomerarea și a menține profitabilitatea susținută a întreprinderilor textile. Industria textilă din vest poate întări aglomerarea prin efectuarea unui transfer industrial din regiunea estică cu scopul a forma efectul de aglomerare pentru a promova creșterea TFP.

Cuvinte-cheie*: aglomerare industrială, entropie de localizare, productivitate totală a factorilor, metoda DEA-Malmquist, efect de aglomerare*

INTRODUCTION

Industrial agglomeration is the forming process of industrial cluster and it's one of the important characteristics of regional economic development. As a pillar industry of the national economy, China's textile industry progresses with the emergence of a large number of industrial clusters. But regional textile industry is seriously unbalanced. The agglomeration degree in the eastern region is much higher than that in the central and western regions, even a certain degree of crowded effect emergences at present.

Traditional views believe that factor input is the main force to drive the economic growth, textile industry, like other light industries, relies on high level of investment and extensive use of cheap labour to achieve rapid growth. But factor input cannot maintain for a long time with the decline of marginal productivity. China's textile industry, dominated by labour-intensive enterprises, is facing a series of pressures, seriously restricting its sustained profitability. Only efficiency-driven growth is the backbone to maintain textile industry long-term sustainable development.

Total factor productivity (TFP) is an important indicator to measure the economic growth efficiency, which refers to the contribution of the technical factors and non-technical factors, including technical progress, management improvement and institutional innovation, to economic growth after deducting labour and capital input. Industrial agglomeration brings scale economies to promote the industrial efficiency. It is proved that the promotion effect of industrial agglomeration on total factor productivity is mainly through the external economic effect [1, 2], specialization division [3, 4], technology spill over [5–7], optimizing resource allocation [8], adsorption of labour resources [9] and so on to achieve the improvement of production efficiency ultimately. And Duranton and Puga [10] summarize that into three types of mechanisms for why productivity may be enhanced in industrial agglomerations: sharing, matching and learning. The bulk of the existing literature is based on aggregate spatial or sector data [11]. However, some studies have noticed that industrial excessive agglomeration may cause crowded effect and have negative influence on regional economic development [12, 13]. The crowded effect is mainly manifested that the relative scarcity of production factors in a certain region leads to the rise of the price and the decline of production efficiency at last.

Through searching the literature, there are many researches on textile industrial agglomeration, but the scholars pay less attention to TFP of China's textile industry [14–16]. Only Liu et al. [17] analysed the relationship between agglomeration and labour productivity of Jiangsu textile industry, lack of national data comparative study.

Given that the relevant research is inadequate and regional textile industry is seriously unbalanced, it's meaningful to investigate the relationship between agglomeration and TFP of China's textile industry, especially at region level. So this paper firstly measures the agglomeration degree by LQ and TFP by nonparametric DEA-Malmquist method of China's textile industry at region and province level during 2005–2018. According to the classification standard of the National Bureau of Statistics, China is divided into the four regions: eastern region (Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan), central region (Shanxi, Anhui, Jiangxi, Henan, Hunan, Hubei), north-eastern region (Liaoning, Jilin, Heilongjiang), western region (Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang). Then it studies how industrial agglomeration influences the TFP of textile industry with panel model. Finally, some relevant policy suggestions are put forward.

METHODOLOGY AND DATA SOURCES

Measurement of agglomeration

The main indicators of agglomeration are location entropy (LQ), Gini coefficient, industry concentration ratio, Herfindahl-Hirschman Index (HHI) and so on. Industry concentration ratio and HHI are calculated with the data at the enterprise level. Gini coefficient doesn't take into account the scale differences of the enterprises; even it's greater than 0, which doesn't indicate the existence of agglomeration. The LQ can eliminate the scale differences and reflect the spatial distribution of geographical factors more realistically. So LQ is applied in this study to measure textile industrial agglomeration degree at region and province level. The equation is as follows:

$$LQ_{it} = \frac{\text{Textile Industry Total Assets}_{it} / \text{Industry Total Assets}_{it}}{\text{Textile Industry Total Assets}_{t} / \text{Industry Total Assets}_{t}} \quad (1)$$

where LQ_{it} represents the location entropy of region *i* in *t* period and it's the ratio of textile industry total assets proportion of region *i* and the proportion of China in *t* period. If $LQ_{it}>1$, the agglomeration degree of textile industry in region i is higher than the national average and it has a tendency to agglomerate.

Measurement of TFP

Since the concept of TFP has been proposed, Solow production function analyses, stochastic frontier analysis (SFA) and data envelopment analysis (DEA) are developed to the most commonly used methods to measure TFP. The disadvantage of Solow production function analysis is that perfect competition, constant returns to scale and Hicks neutral technological progress are hardly compatible with the actual conditions. SFA is a parametric method based on the regression analysis. The production function and the probability distribution of the stochastic disturbance term should be assumed in advance in SFA. But DEA doesn't require any assumptions about the production function, avoiding the problems caused by the wrong function.

So the nonparametric DEA-Malmquist method is applied in this study. This method is used to dynamically analyse TFP change based on the nonparametric DEA model. At given technology frontier, TFP change is obtained by calculating the ratio of Shephard distance function of two production units. In order to avoid the random selection of technology frontier, Fare et al. [18] constructed the TFP Malmquist index (TFP index) from *t* to *t*+1 period:

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{D_0^{t+1}(x_{t+1}, y_{t+1})}{D_0^{t+1}(x_t, y_t)} \times \frac{D_0^{t}(x_{t+1}, y_{t+1})}{D_0^{t}(x_t, y_t)} \right]^{\frac{1}{2}} \quad (2)$$

TFP index represents the ratio of TFP in period *t*+1 and period *t*. If $M_0(x_t, y_t, x_{t+1}, y_{t+1}) > 1$, it indicates that *TFP* increases from period *t* to period *t*+1, otherwise decreases.

In addition, if the *TFP* index in the base period is 1, the accumulated *TFP* ($ATFP_t$) in the t period also can be calculated. The equation is as follows:

$$ATFP_t = \prod_{t=0}^{n} TFP_n \ index \quad (3)$$

Two sets of input data (labour and capital) and one set of output data (effective output) are required to calculate the *TFP* index. Gross industrial output value represents the effective output and is adjusted flat down to the price in 2004 by the industrial producer price index. Average number of regional textile industry workers represents labour factor, instead of working time, due to the missing items of China's statistical system, compared with developed countries. And capital stock represents capital factor and is calculated by perpetual inventory method. The equation is as follows:

$$k_t = k_{t-1}(1 - \delta) + I \quad (4)$$

where k_{t-1} and k_t represent capital stock at constant price of t–1 and t period, δ – depreciation rate, 9.6% [19] and I represents fixed capital investment at current fixed price. Similar to most of the relevant literature, fixed capital formation represents fixed capital investment and is adjusted flat down to the price in 2004 by the fixed asset investment price index. Referring to Cao Yuequn's research on capital stock of service industry, fixed capital formation in base period(2004) dividing 10% is used as the initial capital stock [20].

Empirical model

This study constructs the following panel model to analyse the effect of agglomeration on total factor productivity at region and nation level, for its advantages of large sample size, more reliable parameter estimation and reduced multi-collinearity:

$$\ln(ATFP_{it}) = C + \beta_1 \ln(LQ_{it}) + \beta_2 \ln(OPN_{it}) + \beta_3 \ln(URB_{it}) + \beta_4 \ln(INF_{it}) + \beta_5 \ln(MRT_{it}) + \mu_{it} \quad (5)$$

where i and t represent the region i and period t, respectively.

The explained variable *ATFP* represents the accumulated *TFP*. The explanatory variable *LQ* represents location entropy. The control variables *OPN* represents the opening-up level and is the ratio of total value of imports and exports to GDP. *URB* represents the urbanization rate and is the ratio of the urban population to the total population. *INF* represents the infrastructure construction level and is the ratio of length of highways to area. *MRT* represents the market opening level and is marketization index.

The timing length of the above data is 2005–2018. All the data are obtained from China Statistical Yearbook, China Industry Economy Statistical Yearbook, Provincial Statistical Yearbook, China Statistical Yearbook on Science and Technology and Marketization Index of China's Provinces: Neri Report (2006–2019). The statistical description of the data is shown in table 1.

Table 1

DESCRIPTIVE STATISTICS OF VARIABLES (2005–2018)

Statistics	ATFP	LQ	OPN	URB	INF	MRT
Max	181.778	3.159	0.896	1.721	2.111	11.710
Min	0.337	0.015	0.207	0.017	0.036	0.000
Mean	8.129	0.597	0.526	0.302	0.817	6.354
S.D.	15.747	0.664	0.146	0.370	0.495	2.092
Obs.	434	434	434	434	434	434

RESULTS AND DISCUSSIONS

Results of LQ

Regional textile industry LQ during 2005–2018 is shown in table 2. Due to space limitation, provincial textile industry LQ is not listed.

LQ of the four regions is in ladder distribution, the highest is eastern region, followed by the central and western region, and the lowest is north-eastern region. Eastern LQ is greater than 1, indicating that eastern agglomeration degree is higher than the national average, for its large industry scale and advanced technology. Eastern LQ rises from 1.374 in 2005 to 1.521 in 2010, but decreases to 1.253 in 2018. This shows that eastern textile industry began to ease agglomeration degree through industrial transfer under the pressure of rising production cost. Central LQ has been rising from 0.576 in 2005 to 0.851 in 2018, benefitting from actively undertaking industrial transfer from eastern region. But it's still below the national average and has a large gap with eastern region. Western LQ is less than half of the national average, much smaller than eastern region, indicating that it has a long way to catch up with eastern region. North-eastern LQ is very low, only 0.2 or so. Because north-eastern region is the concentration area of heavy chemical industry and textile industry is less developed, compared with other regions.

Results of TFP

Also due to space limitations, provincial textile industry TFP index and ATFP are no longer listed. Regional textile industry TFP index and ATFP during 2005–2018 are shown in table 2.

The average annual growth rate (AAGR) of TFP in the eastern, north-eastern, central and western regions are 6.95%, 9.92%, 16.12% and 15.26%, respectively, showing that TFP of all the regions has been growing during 2005–2018. Average annual growth rate (AAGR) refers to the average annual growth rate of an indicator in a certain period of time and its computing method is:

$$AAGR = \left(\frac{\textit{Ending Value}}{\textit{Beginning Value}}\right)^{\frac{1}{n}} - 1 \quad (6)$$

Central TFP growth rate is the fastest and the eastern has the slowest growth, illustrating the distribution trend of "middle in the high and low on both sides", obviously different from that of LQ. Eastern TFP declines only in 2017–2018 and keeps growing in the rest, for the advanced technical and management level of local enterprises. But its average TFP index is only 1.089, the lowest in four regions, showing that eastern TFP growth encounters a certain bottleneck problem. The average TFP index and AAGR of central region are both the highest, followed by western region, because central enterprise actively eliminates backward production capacity gradually, accelerates the upgrading of machinery and equipment and improves management level. North-eastern textile industry is easier to achieve the rapid and

Table 2

THE LQ, TFP INDEX AND ATFP OF REGIONAL TEXTILE INDUSTRY DURING 2005-2018												
Year	**LQ**				**TFP index**				**ATFP**			
	ER	**CR**	**NER**	**WR**	**ER**	**CR**	**NER**	**WR**	**ER**	**CR**	**NER**	**WR**
2005	1.374	0.576	0.249	0.397	1.035	1.217	1.092	1.210	1.035	1.217	1.092	1.210
2006	1.376	0.578	0.241	0.390	1.088	1.139	1.328	1.134	1.126	1.386	1.450	1.372
2007	1.381	0.588	0.221	0.392	1.015	1.205	1.367	1.211	1.143	1.670	1.982	1.662
2008	1.433	0.563	0.209	0.357	0.988	1.186	1.223	1.009	1.129	1.981	2.424	1.677
2009	1.430	0.604	0.195	0.367	1.082	1.121	1.231	1.180	1.222	2.221	2.985	1.978
2010	1.521	0.638	0.193	0.373	1.049	1.076	1.146	1.067	1.282	2.389	3.420	2.111
2011	1.398	0.716	0.182	0.368	1.043	0.996	0.952	0.969	1.337	2.380	3.256	2.046
2012	1.440	0.787	0.194	0.388	1.155	1.250	0.927	0.988	1.544	2.975	3.018	2.021
2013	1.403	0.844	0.212	0.392	1.124	1.025	1.101	1.022	1.736	3.049	3.323	2.065
2014	1.383	0.860	0.197	0.418	1.212	1.137	0.969	1.048	2.103	3.467	3.220	2.165
2015	1.277	0.831	0.191	0.389	1.162	1.242	1.465	1.753	2.444	4.306	4.718	3.795
2016	1.340	0.894	0.189	0.463	1.178	1.262	1.345	1.193	2.879	5.434	6.345	4.527
2017	1.319	0.920	0.187	0.465	0.656	1.698	0.256	0.998	1.889	9.227	1.624	4.518
2018	1.210	0.851	0.138	0.464	0.789	0.880	1.442	0.892	1.490	8.120	2.342	4.030
Mean	1.253	0.679	0.210	0.398	1.089	1.176	1.166	1.175	1.597	3.559	2.943	2.513

Note: ER is short for Eastern Region, CR for Central Region, NER for North-eastern Region, WR for Western Region.

coordinated development, due to its small scale and poor foundation.

Empirical analysis

This study applies Durbin-Wu-Hausman test to estimate both fixed effect model and random effect model of every region and test which one is more appropriate. The test results are shown in table 3. Due to space limitations, results of robustness check are not listed. Estimation results of the effect of agglomeration on textile industry ATFP are shown in table 3.

Firstly, increasing agglomeration degree restrains the TFP growth of China's textile industry. The coefficients of LQ on textile industry ATFP in China and four regions are all negative, illustrating that industrial agglomeration does not promote textile industry TFP nationwide, but inhibits it on the contrary. The main reason lies in the crowded effect of China's textile industry, especially in the eastern region which accounts for the largest proportion.

Excessive industrial agglomeration leads to the rise of factor cost such as labour, land, electricity and seriously restricts the sustained profitability of textile enterprise. So it's unable to maintain the factor-driven growth and should be transferred to the efficiency-driven growth. The coefficient of central region has not passed the check and it's unable to make the effective analysis. The coefficients of western and northe-astern are –0.516 and –1.201. They have the least textile industry scale and the mean LQ are 0.398 and 0.210, far below the national average level. It has not formed the significant

Table 3

THE ESTIMATION RESULTS OF THE EFFECT OF AGGLOMERATION ON TEXTILE INDUSTRY ATFP					
ln(ATFP)	**National**	**Eastern**	**Central**	**North-eastern**	**Western**
ln(LQ)	–0.337***	–0.387***	–0.099	–1.201***	–0.516***
	–10.265	–6.852	–0.998	–4.184	–10.277
ln(URB)	0.055	0.426	0.612	15.977***	1.337***
	0.251	0.847	0.779	7.240	4.591
ln(OPN)	0.274***	–0.265*	–0.029	0.051	0.173***
	4.959	–1.874	–0.171	0.149	2.318
ln(INF)	–0.236***	–0.050	0.195	–1.533***	–0.245***
	–3.969	0.258	0.768	–5.069	–4.464
ln(MRT)	0.340**	0.194	–0.080	–0.428	0.200*
	2.481	0.429	–0.102	–0.475	1.788
C	0.588*	0.871	0.799	7.370***	1.506***
	1.686	0.841	0.484	3.452	3.599
Obs.	432	140	84	42	166
R^2	0.731	0.872	0.434	0.895	0.863
Model	FE	FE	FE	FE	FE

Note: ***, **, * represent significance levels of 1%, 5% and 10%, respectively, *t* values are shown in the second row.

agglomeration effect, so increasing agglomeration degree doesn't promote TFP growth, but restrains it because of various cost input, instead.

Secondly, the effect of control variables on textile industry TFP varies from region to region. Increasing opening-up level and marketization level promotes the TFP growth of textile industry nationwide. This means that the reform & opening up and the development of non-public economy are of great significance to improve textile industry TFP. But it also can be seen that increasing opening-up level restrains the TFP growth of eastern region. The reason may lies that FDI of eastern textile industry does not bring obvious spill over effect. The more intense market competition and higher agglomeration degree lead to a certain degree of crowded effect and restrain the TFP growth. The coefficients of urbanization rate on TFP in north-eastern and western China are both greater than 1, showing that with the increase of urban population, the number of skilled labour force is also expanding and it's helpful for the TFP growth of textile industry.

CONCLUSIONS

This paper firstly measures the agglomeration degree by LQ and TFP by DEA-Malmquist method of China's textile industry, respectively, at region and province level during 2005–2018. Then it investigates how industrial agglomeration influences the TFP of textile industry with panel model. The following conclusions are obtained:

LQ of the four regions was in ladder distribution, the highest is eastern region, followed by the central and western region, and the lowest is north-eastern region. Only eastern LQ is greater than 1. The AAGR of TFP in the eastern, north-eastern, central and western regions are 6.95%, 9.92%, 16.12% and 15.26%, respectively during 2005–2018. And central TFP growth rate is the fastest.

Increasing agglomeration degree restrains the TFP growth of China's textile industry. The coefficients of LQ on textile industry ATFP in China and four regions are all negative. There exists crowded effect in eastern textile industry. It has not formed the significant agglomeration effect in western and north-eastern textile industry for very low agglomeration degree. So it implies that eastern textile industry can accelerate the implementation of industrial transfer and structural adjustment to lower agglomeration and maintain sustained profitability of textile enterprises. Western textile industry can strengthen agglomeration by undertaking industrial transfer from eastern region to form agglomeration effect to promote TFP growth.

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Design of a small-scale UAV textile wing fluid-structure numerical modelling

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ABSTRACT – REZUMAT

Design of a small-scale UAV textile wing fluid-structure numerical modelling

This paper depicts the early phase in the research development for an integrated UAV (Unmanned Aerial Vehicle) support system tailored for emergency response actions and remote sensing. The support system is envisioned as an integrated Unmanned Aerial System (UAS) system that consists of one or more ultralight multifunctional aerial units with a configuration that can be adapted to the nature of the intervention: monitoring, mapping, observation, logistics etc. These aerial units comprise of para-motor type UAVs that use textile paraglider wings of a special design.

The overall development and theoretical design aspects that are involved in this research is subject of change been part of an ongoing research study. Starting from wing airfoil and material selection, a design phase is under development for a single sail paraglider wing that can meet the operational demands for the envisioned system. The wing is designed mainly to have an easy handling, predictable deployment at all times and good aerodynamic characteristics. The paper tackles in particular the stretch effect on the wing and the influence on these aerodynamic characteristics as well as means of minimizing the adverse effects.

Keywords: *Unmanned Aerial System (UAS), parachute, paraglider, SingleSkin sail, technical textiles*

Proiectarea unui UAV la scară redusă cu aripă textilă, modelare numerică a interacțiunii fluid-structură

Această lucrare descrie faza incipientă a dezvoltării unui sistem integrat UAV pentru suport adaptat acțiunilor de răspuns în caz de urgență și teledetecție. Sistemul de asistență este conceput ca un sistem integrat aerian fără pilot (UAS), care constă din una sau mai multe unități aeriene ultraușoare multifuncționale cu o configurație, care poate fi adaptată la natura intervenției: monitorizare, cartografiere, observare, logistică etc. Aceste unități aeriene sunt UAV-uri de tip para-motor, care utilizează aripi textile de tip parapantă cu un design special.

Aspectele generale de dezvoltare și de proiectare teoretică, care sunt implicate în această cercetare sunt în curs de dezvoltare, făcând parte dintr-un studiu de cercetare în desfășurare. Începând de la selecția materialelor și a aripilor aerodinamice, este în curs de dezvoltare o fază de proiectare pentru o aripă textilă de tip parapantă, care poate satisface cerințele operaționale pentru sistemul prevăzut. Aripa este proiectată în principal pentru a avea o manevrabilitate ușoară, o desfășurare previzibilă în orice moment și caracteristici aerodinamice ridicate. Lucrarea de față abordează în special efectul de întindere asupra aripii și influența asupra acestor caracteristici aerodinamice, precum și mijloacele de minimizare a efectelor adverse.

Cuvinte-cheie*: Sistem Aerian Fără Pilot (SAFP), parașută, parapantă, aripă SingleSkin, textile tehnice*

INTRODUCTION

In the current industrial context, information technology contributes preponderantly to the development of applications through rapid design and prototyping, digital and virtual production, modelling and simulation.

The design of most modern ram-air wings involves a large number of prototypes (sometimes more than 15 is possible) The reason is that the shape of the real wing is so much different from what is designed in the computer that many real life tests are needed to trim and fine-tune the wing to get the desired flight characteristics [1–3].

The accepted method to design and build ram-air wings is to make a design in the computer that is based on a previous model. This design is built and test flown. It is trimmed and tuned to improve its characteristics. These changes are incorporated in the next prototype, which is also trimmed and tuned to further improve the flight characteristics. And so on until the design is good enough to put it on the market [4].

The difference between the computer model and the real wing comes from the fact that accurate calculation and simulation of the deformation of a ram-air wing is very difficult and requires a large amount of computing power. Ideally, a ram-air wing would be designed by means of fluid-structure interaction (FSI). This is a combination of finite-element analysis (FEA) of the fabric wing and computational fluid dynamics (CFD) analysis of the flow around and inside the wing.

In this article, we will analyse the effect of fabric stretching in the aerodynamic shape of the wing for a UAV support system tailored for emergency response actions and remote sensing [5]. Basically it's a scaled down paraglider wing of about 6 m span.

MATERIALS AND METHODS

The creation of a prototype starts with pre-dimensioning, everything is done with a software program developed within the institute, which includes a SQL database (figure 1, *a* and *b*) that can easily be edited and stores the characteristics of the materials commonly used in making parachutes. This database is populated with the existing stock of materials from which to select the parachute fabric. Material selection can be done manually or automatically by the program based on the physical parameters of the required material obtained from the calculation and/or on the basis of the existing stock.

The implementation methods in software for the initial pre-dimensioning phase derive from the empirical and interpolation graphical methods currently used for parachute design, then on the virtual model additional computational checks are iterated using the finite element methods, on the behaviour of the parachute from deployment, flight attitude and landing.

Using the data obtained with the pre-dimensioning program, the drawing of the three-dimensional model (figure 1, *c*) is automatically made as input in the 3D modelling script. After generating the 3D model, it undergoes the simulation and structural phase check for all phases of the flight, starting with the launch, stabilized flight or turbulent atmosphere and then landing. Estimation of the maximum loads in the canopy is done at launch, because at this moment the forces acting on the constructive elements of the parachute can exceed tens of times the forces in the stabilized flight, depending on the velocity and the launching altitude. For paragliders this is no longer valid, for this is set the launching altitude at 0 m and the speed at 20 km/h, in this particular case in order to obtain the maximum forces simulation is made at the maximum speed of a paraglider, namely on a slope flight of 80 km/h. In this phase of the design we can estimate how fabric stretching generally affects the aerodynamics of a wing. A case was implemented in software for NACAxx12 wing profiles using as a template model of the NACA0012 airfoil for which we had prior experimental measurement data.

After the simulation, changes to the dimensional parameters can be adjusted slightly if so desired. The 3D model is then discretized automatically in its component parts and broke down into the patterns. After this, the necessary markings are made on the width of the fabric (figure 1, *d*) for cutting the parts.

Embodiments of the parts are sent to the cutting machine which performs the automatic cutting (figure 1, *e*) of the parts. They are then picked up by an operator, marked and then stitched, usually with two needle seams.

RESULTS AND DISCUSSION

When a ram-air wing is inflated the ribs will give the wing its aerodynamic shape [6]. The space in between the ribs will billow out due to the internal overpressure (stagnation pressure) in the wing. At the cell centres the wing won't have the shape that was intended by the designer. Looking in span-wise

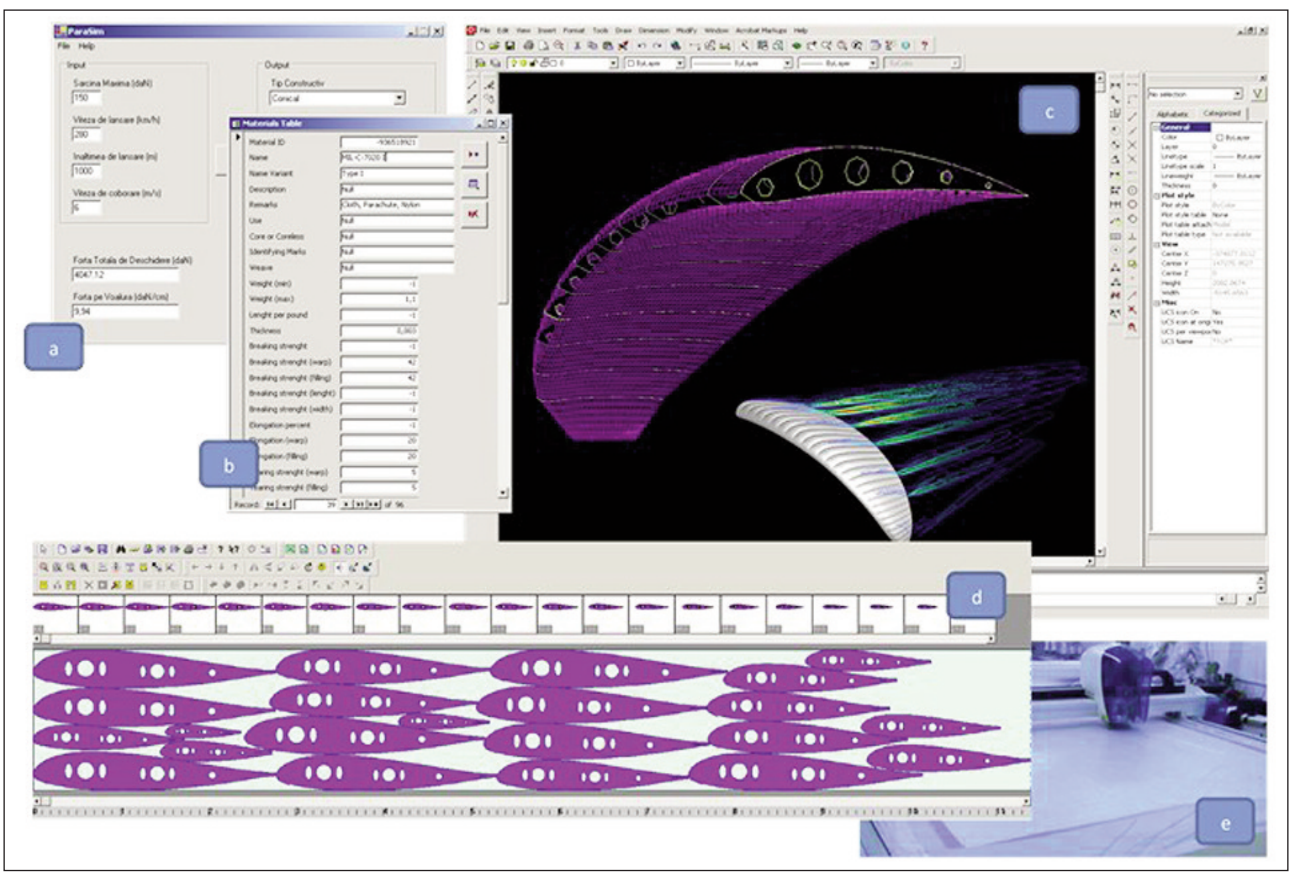

Fig. 1. Textile wing design and manufacture workflow

direction the wing has bumps at the cell centres and grooves at the ribs.
Computational Fluid Dynamics (CFD) is a method of solving the governing equations of fluid and gas flow, the Navier-Stokes equations, in a finite number of discrete volumes.
The first step in CFD is to create a volume around the wing geometry in which the fluid calculations are performed. This volume is discretized into small volumes that, in this case, have the shape of tetrahedra and prisms. This is the grid or mesh. An unstructured grid with prisms and tetrahedra is used because this allows easy and quick grid generation with good control over the grid density. Especially later when the whole wing will be analysed with CFD the flexibility of an unstructured grid may be advantageous compared to a structured grid.
For turbulence modelling the k-omega SST model is used with transitional flow and enhanced wall treatment.
Enhanced wall treatment is used instead of wall function, because it is anticipated that there is premature flow separation on the stretched wing. Wall functions predict separation far worse than enhanced wall treatment. Also, using enhanced wall treatment the grid resolution is much higher in the boundary layer. This allows a more detailed analysis of the flow. The price is more cells and more computation time.
Wrinkles that normally occur in the fabric are not modelled. To model the small wrinkles an enormous amount of cells would be required to capture their shape accurately. Another option would be to model the wrinkles with a certain surface roughness. Using sand grain roughness requires the wall functions boundary layer treatment.
Figure 2 illustrates the influence of the free stream turbulence intensity and length scale. The difference is in the different shades of blue in between the inlet on the left side and the leading edge of the airfoil. The colour scale represents the turbulence intensity.
The computational model is constructed from the predimensioned layout of canopy fabric panels and suspension lines (they are assumed rigid and its aerodynamics is obtained from empirical data). This is the un-deformed configuration used to start the simulation.
The simulations used in the background are conducted using version 971 of the LS-Dyna solver.

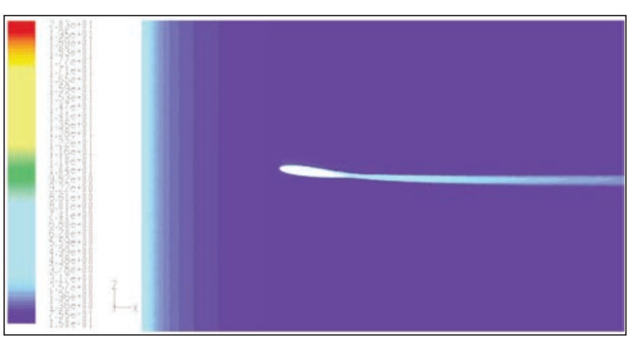

Fig. 2. 10% turbulence intensity, 0.5 mm turbulence length scale

Structural modelling

The structural solution uses a large-displacement small-strain FE formulation with explicit time integration. This approach is quite accurate (only small tensile strains are expected) and allows an efficient coding. The solver models membranes, cables and solid bodies using linear elements. Since cables and membranes lack bending stiffness and buckle under compressive loads, a wrinkling model is used to correct the elemental stresses. Structural components with negligible deformation can be modelled as rigid bodies. This greatly reduces the computational cost with no effect on the structure dynamics.
The time integration is performed with an explicit second-order scheme, which despite the inherent time increment limitations, provides a robust and fast solution for highly non-linear problems.
Note that the complete dynamics of the deformable parachute payload system subject to inertial, aerodynamic and gravity forces is obtained because the trajectories of all the grid points are integrated in time. Some guidelines for tuning these parameters are given in [7].

Aerodynamic modelling

Potential flow aerodynamics was considered cost-effective in this work because no extensive detached flow is expected under nominal operation of gliding parachutes. Hence, the flow solution is obtained with an unsteady panel method using low-order doublets and sources. The constant strength panels lower the complexity and computational cost, while the addition of sources improves the accuracy compared to a doublet-only method [8, 9].

FSI Coupling procedure

A 2-way staggered scheme is used to couple the aerodynamic and structural solvers, with one fluid solve and one structure solve per time step. Since the mesh is the same, no interpolation of results is required during the simulation. This allows obtaining both the transient and steady-state response of the structure in a very efficient way. In typical calculations, the stability limit of the structural solver is small; therefore several structural time increments are performed per aerodynamic step. Although this could affect the high-frequency response, it is not a serious limitation because these modes usually have low amplitude, and affect only small parts of the structure.
The mechanical properties of the materials used for the canopy (figure 3) and suspension lines are those of the real textile materials obtained from the material database of the program.
In order to obtain the steady descent characteristics of the parachute system, the simulations are started with the un-deformed model and continue until the equilibrium flight configuration is reached. The model is released with an initial velocity. Due to the unsteadiness of the problem, the steady flight condition is determined in an approximated manner (total system acceleration below a given threshold).

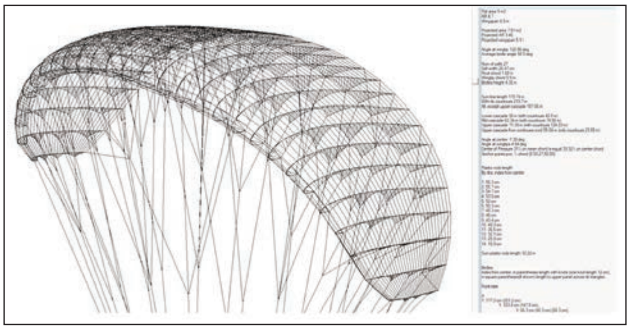

Fig. 3. 3D model of the UAV canopy

First, the influence of side slip on lift and drag is analysed. Figure 4 shows the polar of lift coefficient versus angle of attack for slip angles of 0, 10 and 20 degrees of the normal NACA0012 profile without stretching. For reference additional curves are shown: X-foil low turbulence, X-foil high turbulence (3%), data from Abbot [10] and data form McCroskey [11].

The first thing to notice is the spread of the data. Clearly the different sources give different outcomes. The NACA0012 profile is very sensitive to Reynolds number and free stream turbulence.

The difference between the fluent simulation and X-foil is likely to come from the various differences of the numerical models. First of all X-foil is a 2D simulation. In Fluent a quasi 3D simulation was used. That means that a slice of wing was simulated between two symmetry planes. The consequence is that also out of plane turbulence affects the flow. Furthermore, the way in which a turbulent boundary layer is treated is different. X-foil calculates with a transition point on the upper and lower surface. The Fluent flow is fully turbulent and is initialized with certain free stream turbulence. The maximum lift coefficients of the two approaches differ by 6.5%.

In figure 5 the lift coefficients of the normal NACA0012 profile and the quasi 2D stretched NACA0012 wing are compared. The trends in this figure are that stretching decreases the lift slope in all cases. In the cases of side slip the stall point is postponed and stall is more gradual.

Further on, the model was split into two configurations M1 for a classic closed cell wing and the second M2 for a single skin type paraglider wing. The intention was to observe the actual rib deformation in both of these wing types to better choose the output model, shown in figure 6.

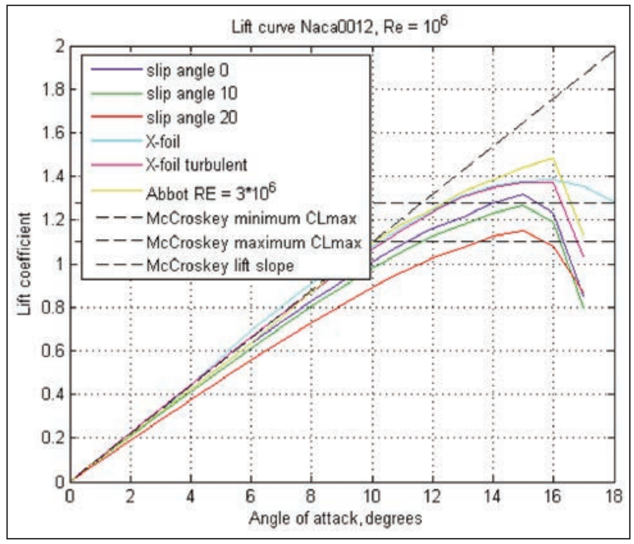

Fig. 4. Lift coefficients of the NACA0012 profile (not stretched) for 0, 10 and 20 degrees slip angle. All reference data are at 0 degrees slip angle

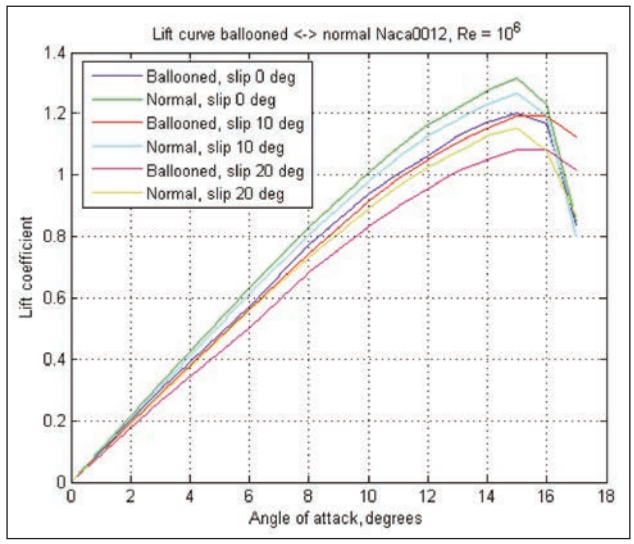

Fig. 5. C_L comparison of the normal and stretched NACA0012 wing

Based on these models the single skin rib deformation was smaller but overall flight characteristics were worse in every department. However the single skin construction is simpler and gives more predictable

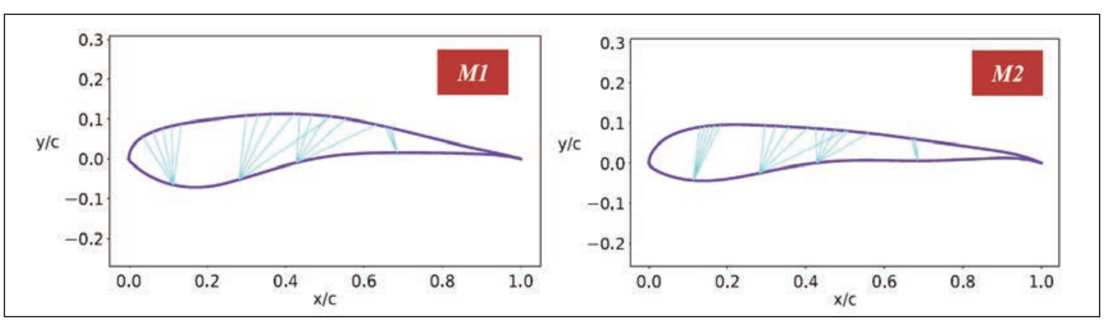

Fig. 6. Dynamic deformation of the ribs in the case of the two aerodynamic models M1 (classic cell wing) and M2 (single skin wing)

results on small scale wings at low Reynolds numbers than a classic pressurized cell wing.

CONCLUSIONS

From the CFD analysis of the normal and stretched NACA0012 wing it can be concluded that fabric stretching has the following influence on the wing:

- reduced maximum lift coefficient;
- reduced lift slope;
- reduced lift-to-drag ratio;
- increased drag at a given lift coefficient;
- increased flow separation at the trailing edge;
- increased turbulence production and energy dissipation in the grooves;
- when air flows at a certain side slip angle over the wing, fabric stretch causes more gradual stall behaviour;
- rib deformation on single skin wings is lower than in that of classic pressurized cell wing.

In truth the error of these values is quite small but when the wing is also small any small deformations translate to large flight characteristics variations. Thus corrections in fabric patterns can be made prior to the next manufacturing phase in order to minimize these adverse effects in the final product.

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Optimising the amount of base material used for manufacturing garments with creases, during their design stage

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ABSTRACT – REZUMAT

Optimising the amount of base material used for manufacturing garments with creases, during their design stage

The clothing and fashion industry is known as a wasteful industry. Despite its target, producing fashionable and beautiful items to fulfil the needs of different consumer categories consumes a considerable quantity of raw materials, energy, water, labour force, etc. Every year, natural resources become more limited, hard to find and expensive; in these terms, the producers are forced to find either alternative solutions to replace as much as they can the needed primary raw materials or to try to maximise their use (which means to reduce the quantity of waste) or to use the waste to produce other things. The consumption of raw materials is determined during the development stage of the new model: the designer analyses the sketch of the selected model, then establishes and applies the needed steps to design the model pieces, creates the 3D virtual or supervises the manufacturing process of the physical prototype to verify the design solution, applies changes after analysing the prototype if it is necessary, obtains the production patterns and then he/she is doing the markers to determine the consumption of raw materials for one item and the whole order. Garment models with creases, pleats or folds are the most challenging ones because the designer has to have the ability to understand and to evaluate the shadows or the number of grouped lines of the model into values of distances or angles, to be used to change the element surface for their realisation. In these cases, it is essential to balance what the model requires and the needed amount of raw materials to produce it. This paper proposes some variants of how to resize the surfaces of the elements for designing creases but with an optimal raw material consumption level. The results are based on the analysis of different men jacket models', with straight silhouette and creases between the hemline and its hem band.

Keywords: *optimised consumption, element surface, depth creases, pattern modelling*

Optimizarea consumului specific de material de bază pentru modele de produse de îmbrăcăminte ce prezintă cute, din etapa de proiectare conceptuală a acestora

Industria de îmbrăcăminte și de modă este cunoscută ca o industrie în care se produc multe deșeuri. În ciuda obiectivului său, de a produce articole frumoase și în tendințe pentru a satisface nevoile diferitelor categorii de consumatori, în confecționarea produselor se consumă o cantitate considerabilă de materii prime, energie, apă, forță de muncă etc. În fiecare an, resursele naturale devin mai limitate, greu de găsit și costisitoare; în aceste condiții, producătorii sunt obligați să identifice soluții alternative de surse primare de materii prime necesare confecționării noilor modele, sau să maximizeze modul de utilizare al suprafeței acestora (implicit cu reducerea cantității de deșeuri) sau să folosească deșeurile pentru a fabrica alte produse. Consumul de materii prime este determinat în etapa de dezvoltare a noului model: proiectantul analizează schița modelului selectat, apoi stabilește și aplică pașii necesari pentru proiectarea pieselor modelului, creează prototipul virtual 3D sau supraveghează procesul de fabricație al prototipului fizic pentru verificarea/validarea soluției de proiectare, aplică modificările necesare, dacă prototipul nu îndeplinește condițiile impuse, obține tiparele de producție și apoi realizează încadrări pentru determinarea consumul de materii prime pe produs și total comandă. Modelele produselor de îmbrăcăminte cu pliuri, cute sau creți sunt modele care ridică mari probleme, deoarece proiectantul trebuie să aibă capacitatea de a înțelege și de a evalua umbrele sau numărul de linii grupate ale modelului în valori care să exprime distanțe sau unghiuri, pe care le utilizează în prelucrarea suprafeței reperului de produs în care apar acestea. În aceste cazuri, este important să se găsească un echilibru între modul de transformare a suprafeței elementului de produs pentru obținerea creților și consumul de materii prime necesar fabricației acestuia. Această lucrare propune câteva variante de prelucrare a suprafețelor elementelor de produs pentru proiectarea cutelor, dar cu optimizarea nivelului de consum al materialului de bază, necesar fabricației acestuia. Studiul are la bază modele de jachete pentru bărbați, care au cute pe linia de montare a beteliei.

Cuvinte-cheie: *consum optimizat, suprafața elementului, adâncimea cutei, modelare tipar*

INTRODUCTION

The ongoing pandemic has influenced all aspects of our lifestyle due to the quarantines, restrictions upon travel and professional activities, school closures, supply chain disruptions, online work, and shopping, etc. Our daily lives have been dramatically changed, and we have arrived at a point when society has to adapt to this situation in all aspects: personal, social, professional, economic, etc. [1].

The manufacturers have had to change their business approach by focusing on producing items on-demand at optimised costs and becoming better at predicting future demands. This situation is quite tricky because it requires predicting the customers' needs, targeting sales, and estimating the number of items that have to be manufactured in the future. To be competitive, manufacturers must digitalise their production process by using IT solutions and ensure that they have highly skilled employees who can exploit this virtual reality to the best possible extent by being creative, innovative, and original in their work. In a digitalised world, some manufacturing tasks are automated; machine sensors are used increasingly often, the customers can communicate with the manufacturers and get updates regarding their orders. Producers can keep their business efficient and in line with the customers' demands by employing predictive analysis (by forecasting future or otherwise strange events), robotics (by using artificial intelligence and customisable technologies in order to meet business and customer demands), machine learning(in order to identify and anticipate the factors that impact daily operations, such as the speed and the quality of the assembly lines), enterprise resource planning (by automating different types of manufacturing operations under a straightforward system), B2B eCommerce i.e., business-to-business electronic commerce(in order to boost sales), cloud-driven network solutions(by employing flexible IT network platforms in order to adapt to the rapidly changing nature of business and customers' demands) [2–4].

Digitalisation provides the opportunity to explore diversified solutions for one problem to select the best one while adding value to the produced items without creating waste, carbon footprint, etc. In a virtual environment, designers are provided with the proper tools, functions, and instruments for developing personalised models by integrating the customer's data and preferences: the body measurements (either scanned or specified by the customer), the dimensions of the model, and types of material and accessories (co-design process). One can also check the designed model's dimensions to determine whether it meets the technical specifications or estimates the manufacturing cost for a component [5].

The following factors influence the amount of raw material that is required in the production process: the type of the model, the size, structure and purpose, fashion lines and restrictions (volume, number of pieces, shape), manufacturing process, physical properties of the materials, and the geometry of the outline contour lines of the garment pieces. For a designer, the most challenging part in the development process of a model is to estimate its volume in order to be able to create the required creases, folds, or pleats. The sketch of the model also includes some shadows or group of lines, and these signs have to be interpreted in terms of distances or angles. Using their technical experience and knowledge, a designer might estimate these distances' values, but the latter can be validated after the model has been manufactured (model prototype). The virtual prototype of the designed model is obtained with 3D modules of CAD's software. The prototype fitting degree is analysed when dressed on the adequate virtual mannequin (client avatar) by considering the materials' properties in its structure and types of seams. The designer analysis the volume of the model or the level and the shape of the necessary cutting lines, evaluates its balance on the virtual avatar, and decides if something has to be changed (validating the adopted design solution). Afterwards, they realise markers to determine the necessary quantities of raw materials and estimate the model's price. The person in charge of elaborating the model's technical documentation decides if the model has been well-designed; if the model meets the customer's requirements, it will continue its "journey" to the production lines.

In the markers, the designer analysis the geometry and shape of the element, the one designed for creases, because its bigger surface influences the model consumption. Based on his/her technical experience, he/she decides if there are any possibilities to improve the material usage by optimising the piece surface in its design phase. If something is changed in the 2D shape of the piece, then it is necessary to generate the 3D virtual prototype, put it on the avatar and see if the new shape of the pieces (or pieces) conduct to the desired model [6, 7].

The produced garment model has to fulfil the customer's needs: it has to be of good quality, fashionable, well-fitted, comfortable, and affordable. The comfort is influenced by its size, silhouette, volume, and types of materials used in the manufacturing process. Any garment exerts pressure on its support area because it depends on its volume and structure. If the garment has pleats, creases, or folds, it must also contain oversized elements in its structure to facilitate its realisation, which means that it will be heavier and require larger quantities of material. The designer must balance the garment volume and the necessary amount of material to produce a sustainable item for the client while following all the model specifications [8].

This paper presents the results of a study involving a garment model with creases, whose aim is to illustrate how one can resize the surface of its components to obtain these pieces while also optimising the amount of material used in the manufacturing process. The study has been carried out on a jacket model for men, with creases between the hemline and its hem band.

RESEARCH DEVELOPMENT STAGES

The research has been carried out in two main stages:

- Designing the patterns of the established models.
- Determining the necessary amount of base material and analysing the results to decide which option is best suited for manufacturing sustainable products

and optimising the amount of material used in the production process.

Designing the garment model patterns

The designer must construct the model's patterns and determine the necessary amount of base material for multiple design options. By analysing the results, the designer decides the best way the patterns have to be changed to optimise the necessary amount of material (base material). The model patterns are designed in a customised manner (by using the functions provided by the Gemini CAD Made-to Measure module) because their shape and size will automatically change when the data used in the design algorithm is altered [9–12].
Figure 1 presents the basic model for a men's jacket, which is used for developing different models with creases on the hemline. The patterns of the selected model are designed using the geometric method.
Model details: The jacket is of medium length, has a straight silhouette and a knitted hem band. Knitted material is also used for the collar and for the sleeve cuffs too. The width of the latter is about 7 cm, and their length is standard. The front and the back parts of the jacket have individual yokes. The jacket has a long zipper placed on the front middle line. The back side consists of two pieces- the yoke and the main element, while the front side is made of two pieces- the yoke and the front. The jacket's structure consists of the following layers of materials: base, lining, and interlining.

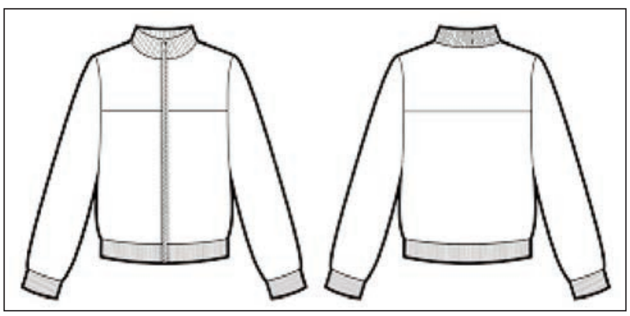


Fig. 1. The basic model of the men jacket

The men jacket patterns are designed using mathematical relations. The design solution is choused by considering the garment type, customer gender and age, and model silhouette. The main points of the patterns are positioned in the geometric layer by the written mathematics relations. The points are connected with lines (straight or curves) to obtain the element shape.
The garment model pieces are designed in the geometric layer, too. In this way, the user controls the established values of the needed modifications related to the model features and customer size. The sleeve patterns are drafted following the front and back elements to obtain the armhole's desired shapes and the sleeve heads (figure 2).
Figure 3 shows the models used to reach the paper goal. These models have creases with different

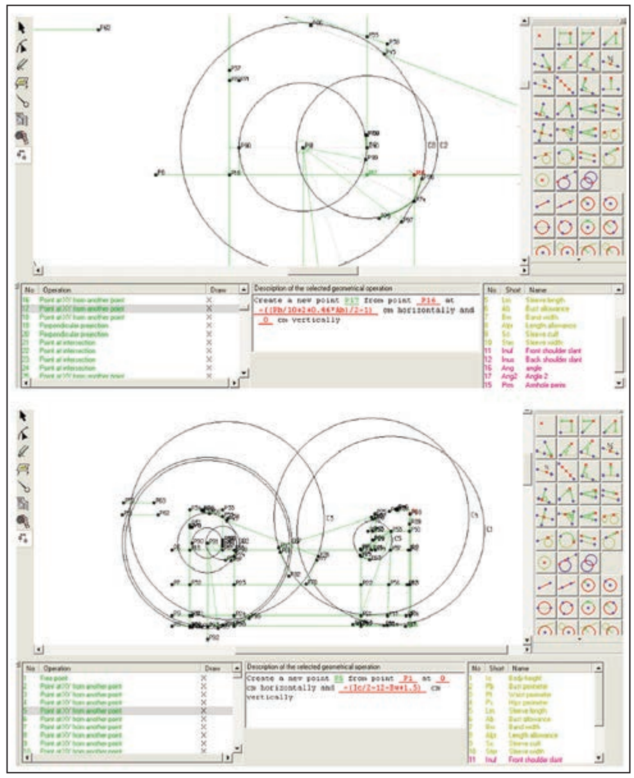
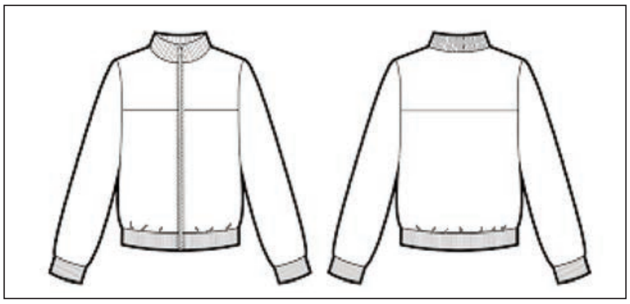


Fig. 2. Design scenario within the Made-to-Measure module (GeminiCAD)

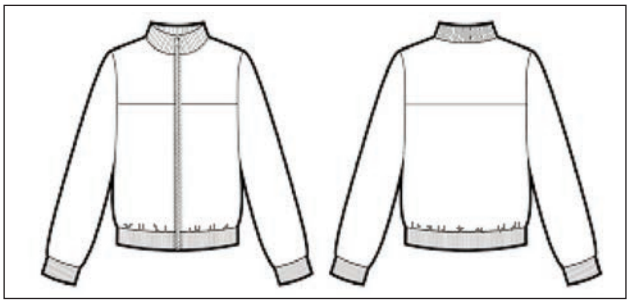
depths, uniformly distributed on the front and back sewing lines with the hem band.
The shape of the pieces with different depths is obtained by applying the isometric principle of altering the components' surface: front and back (figure 3). By the sketch of the model, the surface of the front and back elements is altered by using different combinations of values from 4 cm to 20 cm (the designer analyses the sketch and selects the values according to the number of lines that are grouped in the same place). The distances mentioned above are computed as angles and declared as initial data, and used to change the piece surface for obtaining creases. These values are customised by taking the garment size into account [9–13].
The basic shape of the front and the back pieces (designed in MTM scenario, as it is sown in figure 2) are changed with different angles (figure 4) to obtain the models from figure 3. After that, the model patterns are transformed into production patterns and used to do the markers.

Determining the necessary amount of base material

To realise the markers, one considers the following: the same value for the width of the base material, the same number of sizes, the material has no restriction regarding the orientation of the pieces on warp direction. There were choused and analysed 61 possibilities of models with different values of crease depths; the creases were uniformly distributed on the hemline in the front and back main pieces (figure 5). The values of the needed depths were from 4 cm to



a



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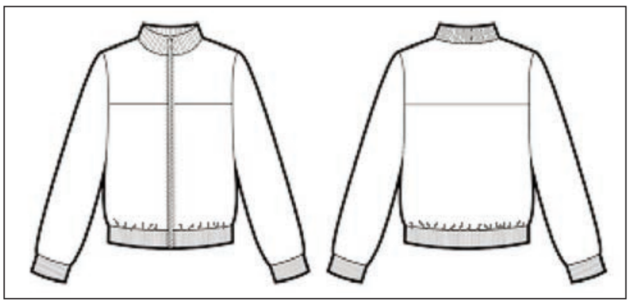

c

Fig. 3. Men jacket models: *a* – small number of creases, with a small depth, uniformly distributed on the front and back; *b* – medium number of creases, with a small or medium depth, uniformly distributed on the front and back; *c* – significant number of creases, with a small or medium depth, uniformly distributed on the front and back

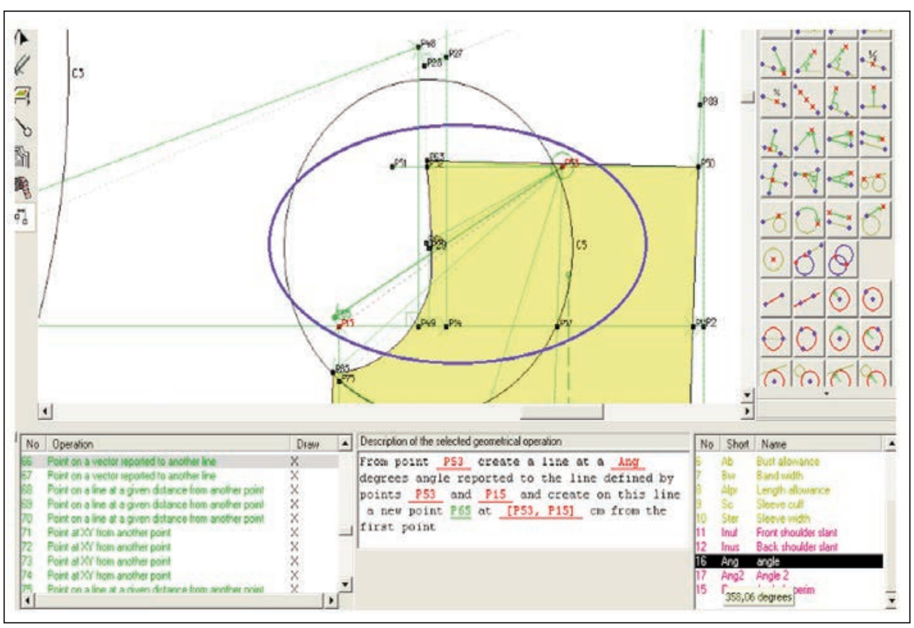

Fig. 4. Modifying the position of the inferior point of the back armhole

20 cm. It was avoided using the maximal value for the smallest size of the model or the minimal value for its biggest size [10].

The marker length is influenced by the number of sizes placed in the marker, the width of the material, the number of pieces that comprise the garment model, and the components' geometry; it strictly determines the usage index of the material. If in a marker are placed small pieces that belong to a different model, the value of the usage index is improved (the waste index is small).

The results obtained after doing all the markers were analysed using the TC3D program [14]. The influence of increasing the areas of the front and the back pieces on the material surface usage index was studied as well. The program generates a list of different mathematical models which represent the correlation between the selected variables: X → the percentage increase of the back; Y → the percentage increase of the front; Z → the usage index of the material surface. The mathematical model that expresses the relation between the aforementioned parameters was selected by taking into account some criteria: Fstatistic > Fstd error. The model coefficients' values had to be significant from a statistical point of view (95% confidence level). In the end, we selected the model from the generated list, which best fits the experimental data (figure 6).

CONCLUSIONS

The person who designs the patterns for the garment models with a reduced number of pieces and with creases must be proficient in patterning, understanding and interpreting all details of the sketch of the model, comprehending the impact of the physical properties of the materials from the garment structure on its final shape, and he/she must also be able to visualise the 3D image of the model garment with what he was done before or selected.

If the designer decides to increase the length of a pattern outline contour to make the required creases, they have to be aware of the impact of this increment on the volume of the model and the necessary amount of material.

According to the results from figure 6, for a jacket model with small creases uniformly distributed along the seamline between the main elements (front and back) and the hem band, an average value of the percentage increase of the area of the front and back components (around 25%) determines a good level for the usage index of the base material.

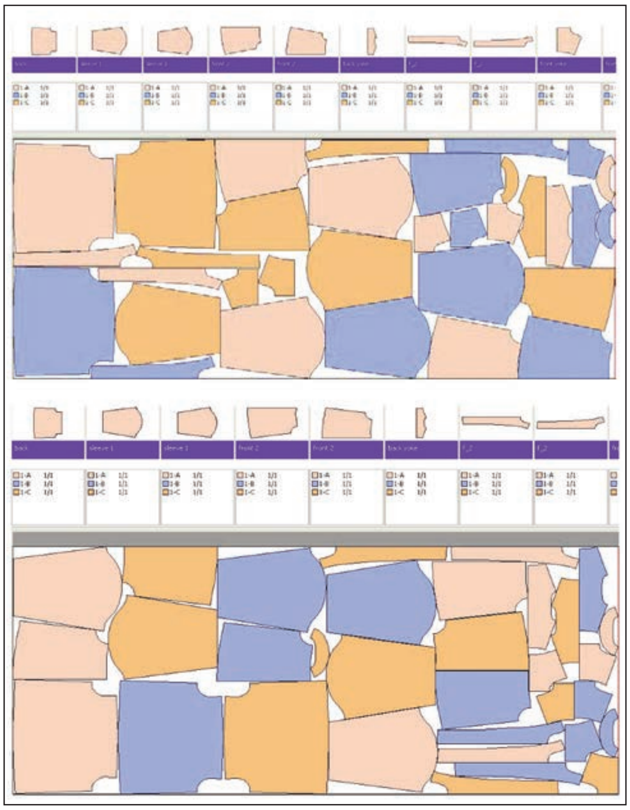

Fig. 5. Markers for the base material

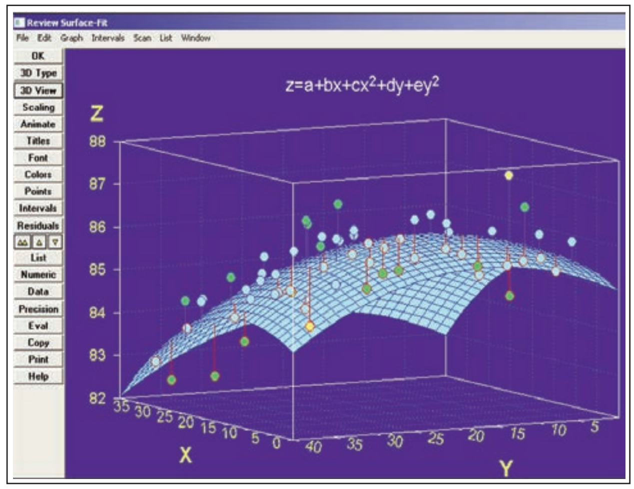

Fig. 6. The correlation between the selected variables

This percentage corresponds to a distance of 9–12 cm, by which the length of the contour line is increasing (along the back and front pieces). It is recommended to use appropriate values when designing the front and the back components because in this way, the lateral sideseam will have a correct position, and the volume of the model will have the desired value. The largest value of the interval 4 cm to 20 cm interval (percentage of 35–40%), may be used if the model has numerous creases, but only for the largest size. For the smaller sizes of the model, it is recommended to use a value from [6–8] cm interval (percentage between 10–15 %); if one uses larger values, the shape of the model will look strange (it will have many creases along the sewing line between the front and back components with the hem band, and this will have an impact on the silhouette and the balance of the model while it is worn.

The graph shown in figure 6 illustrates the evolution of the usage index values when some components (front and back) increase or decrease. One can notice that the mathematical model is accurate, and it expresses the correlation between the selected elements. It is an initial evaluation of how the front and back surfaces' changes influence the base material usage index usage. Before manufacturing the pieces of the model, the designer will be able to get an idea regarding the garment model's technical information: volume, the necessary amount of material, and its usage index. They can use this as a starting point in developing a model with creases and won't have to look for or test other options.

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Comparative analysis of superabsorbent properties of PVP and PAA nanofibres

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BUKET GÜLER FUNDA CENGİZ ÇALLIOĞLU

ABSTRACT – REZUMAT

Comparative analysis of superabsorbent properties of PVP and PAA nanofibres

This study presents the comparative analysis of production, characterization and absorption properties of Polyvinylpyrrolidone (PVP) and Polyacrylic acid (PAA) nanofibres. Firstly, optimization studies about polymer (PVP and PAA), superabsorbent additive (waterlock)(WL) and crosslinker agent (sodium persulfate and glutaraldehyde) concentrations were achieved. Then solution properties such as conductivity, surface tension and viscosity were determined. Electrospinning was carried out under the optimum process parameters (voltage, distance between the electrodes, solution feed rate etc.) to obtain superabsorbent nanofibrous surfaces. Surface and fibre morphologies were analysed with Scanning Electron Microscopy (SEM) and thickness of nanoweb and weight in grams of nanofibres were also measured. Lastly, optimized PVP and PAA nanofibres were compared in terms of absorption properties with water and synthetic urine with various times from 5 to 86400 seconds. According to the results, generally fine, smooth and uniform nanofibres were obtained. It was observed that the solution viscosity, conductivity, and average fibre diameter increase with waterlock (WL) and cross-linker additions while surface tension was not change. In addition, PAA nanofibres' absorption capacity with water and synthetic urine was higher than PVP nanofibres, while PVP nanofibres' absorption rate is higher. It is possible to say that electrospun nanofibrous surfaces that are ultra-thin, light, porous and with high specific surface area to volume ratio are promising for new superabsorbent materials.

Keywords: *polyvinylpyrrolidone, polyacrylic acid, electrospinning, nanofibres, superabsorbent*

Analiza comparativă a proprietăților superabsorbante ale nanofibrelor de PVP și de PAA

Acest studiu prezintă analiza comparativă a proprietăților de absorbție a nanofibrelor de polivinilpirolidonă (PVP) și de acid poliacrilic (PAA). În primul rând, s-au realizat studii de optimizare cu privire la concentrațiile de polimer (PVP și PAA), aditiv superabsorbant (blocaj de apă) (WL) și agent de reticulare (persulfat de sodiu și glutaraldehidă). Apoi au fost determinate proprietățile soluției, cum ar fi conductivitatea, tensiunea superficială și viscozitatea. Electrofilarea fost efectuată sub parametrii optimi de proces (tensiune, distanță între electrozi, viteza de alimentare a soluției etc.), pentru a obține suprafețe de nanofibre superabsorbante. Suprafața și morfologiile fibrelor au fost analizate prin microscopie electronică cu scanare (SEM) și au fost determinate grosimea nanomaterialului și greutatea în grame de nanofibre. În cele din urmă, nanofibrele de PVP și de PAA optimizate au fost comparate în ceea ce privește proprietățile de absorbție a apei și urinei sintetice, cu diferite perioade de la 5 la 86400 de secunde. Conform rezultatelor, în general s-au obținut nanofibre fine, netede și uniforme. S-a observat că viscozitatea, conductivitatea soluției și diametrul mediu al fibrelor cresc odată cu blocarea apei (WL) și adaugarea agenților de reticulare, în timp ce tensiunea superficială nu a fost modificată. În plus, capacitatea de absorbție a nanofibrelor de PAA, în ceea ce privește apa și urina sintetică a fost mai ridicată decât cea a nanofibrelor de PVP, în timp ce rata de absorbție a nanofibrelor de PVP este mai ridicată. Este posibil să se concluzioneze că suprafețele nanofibrelor electrofilate ultra-subțiri, ușoare, poroase și cu un raport suprafață – volum specific ridicat sunt promițătoare pentru noile materiale superabsorbante.

Cuvinte-cheie*: polivinilpirolidonă, acid poliacrilic, electrofilare, nanofibre, superabsorbant*

INTRODUCTION

Superabsorbent materials have high liquid absorption capability that has biocompatibility provide specific functionality for biomedical, wound dressing, agriculture, horticulture, drug release, waste water treatment and hygienic products for instance disposable diapers and sanitary napkins [1–4]. It is possible to produce textile surface using superabsorbent polymers (SAPs) (PVP, PAA, polyurethane, cellulose acetate, carboxymethylcellulose etc.) and additives (waterlock) (WL) with various methods [5]. Electrospinning is an effective method to produce ultra-thin and light superabsorbent nanofibrous surfaces that has high porosity, small pore size, small fibre diameter, high loading capacity, and high specific surface area to volume ratio [6–8].

In this study, PVP and PAA polymers were used as the polymers to produce superabsorbent nanofibrous surfaces with electrospinning. PVP is a Food and Drug Administration (FDA) approved water-soluble polymer with excellent biocompatibility and high capacity of liquid absorption up to 40% of its own weight [9, 10]. Polyacrylic acid is also well known superabsorbent and pH sensitive polymer that forms hydrogels with a swelling behaviour depending on its easily ionisable carboxyl groups [11]. All these properties play vital roles in hygienic textiles and biocompatible materials, that's why these were chosen as the raw materials for this research. In literature, there are some studies about superabsorbent nanofibres production and characterization. In 2005, Li and Hsieh studied PAA and polyvinyl(alcohol) (PVA) nanofibre production and they determined that nanofibrous material absorbed liquid up to 31 times of its weight [12]. In the other study, Hansen et al. produced polyurethane nanofibres with waterlock superabsorbent additive and observed that nanofibre-based surfaces reached 400–5000 % of absorption capacity in water, while it reached 500–1250 % of absorption capacity in synthetic urine [13]. In addition, Martinova and Lubasova, developed superabsorbent electrospun material by needle electrospinning method using PAA polymer and compared with commercial superabsorbent fibres. They determined that nanofibrous material has higher absorption rate than commercial superabsorbent fibres due to superior properties of nanofibres [1]. In addition, Lubasova et al. studied about PVP and PAA mixture of nanofibre production with dimethylformamide (DMF) solvent and investigated swelling capacity of both nanofibrous surfaces. They observed that PVP and PAA blend nanofibres reached higher absorption capacity than from pure PVP nanofibres [9]. On the other hand, in the last studies, one research team from Iran studied about PAA superabsorbent nanofibres and characterizations with different electrospinning principles such as needleless and gas-assisted electrospinning [14, 15]. Furthermore, there is no study about comparative analysis of absorption properties of cross-linked PVP and PAA nanofibres with superabsorbent additive (waterlock) in literature. For this reason, the focus was on this subject in the paper.

EXPERIMENTAL

Materials

In this study, PVP (Mw~360.000, Sigma Aldrich) and PAA (Mw~450.000, Sigma Aldrich) were used as the polymers, ethanol (Merck Millipore) was used as a solvent, waterlock (Veskim Chemistry) was used as a superabsorbent additive, glutaraldehyde (GA) (Sigma Aldrich) and sodium persulfate (SP) (Sigma Aldrich) were used as the cross-linker agents.

Method

Firstly, PVP/ethanol and PAA/ethanol solutions were prepared under the same conditions by magnetic stirring at room temperature for two hours. The PVP and PAA polymer concentrations were used as 10 wt % and 5 wt % respectively. WL was then added to the prepared PVP and PAA polymer solutions at 15 wt % concentration. WL concentration was determined from the optimization studies in terms of fibre morphology and spinning performance. Finally, the cross-linkers (GA and SP) were added to the PVP and PAA polymer solutions and electrospun under the same process parameters. The concentration of GA and SP were used 3 wt % for both polymer solutions. Cross-linker concentration was also chosen from our preliminary studies. Polymer sample codes and contents were given as table 1.

Table 1

SAMPLE CODES AND CONTENTS OF PVP AND PAA POLYMER SOLUTIONS

Sample code	Polymer concentration (wt %)	WL concentration (wt %)	Cross-linker concentration (wt %)
PVP01	10	0	0
PVP02	10	15	0
PVP03	10	15	3
PAA01	5	0	0
PAA02	5	15	0
PAA03	5	15	3

In this study, solution properties (conductivity, viscosity, surface tension) of all polymer solutions prepared under the same conditions were determined. As it is known from the literature, solution properties have great importance in terms of both electrospinning performance and fibre morphology [16]. Selecta CD-2005 conductivity meter was used for conductivity measurements, Lamy Rheology (B-one Touch) viscometer was used for viscosity measurements under 5 s^{-1} shear rate and Biolin Scientific Attension was used to determine surface tension by Wilhelmy Plate Method. Afterwards, electrospinning was achieved under the same process parameters (table 2). All nanofibres were produced for half an hour and were collected on aluminium foil.

Table 2

PROCESS PARAMETERS OF ELECTROSPINNING

Voltage (kV)	Distance between electrodes (cm)	Feed rate (ml/h)	Needle diameter (mm)	Ambient humidity (%)	Ambient temp. (°C)
26.4	16.5	0.8	0.8	30±2	22±2

Surface morphology of superabsorbent nanofibre membranes was analysed with SEM (FEI Quanta 250 FEG). One hundred of different measurements were taken from each SEM image, and then the average and weight average values were calculated to determine the fibre diameter uniformity coefficient. The method used to calculate the fibre diameter uniformity coefficient is based on the molar mass distribution in chemistry [17].

The number and weight average values were calculated by using the following equations:

$$A_n = \frac{\sum n_i d_i}{\sum n_i} \quad \text{(average number)} \qquad (1)$$

$$A_w = \frac{\sum n_i d_i^2}{\sum n_i d_i} \quad \text{(average weight)} \qquad (2)$$

where d_i is fibre diameter, n_i – the number of fibres. The fibre diameter uniformity coefficient was determined by the ratio of *Aw*/*An* and the optimum value should be close to 1 to obtain uniform nanofibres [17].

Thickness measurement of nanofibrous web was carried out with Mitutoyo digital micrometer with an accuracy of 0.01 mm. Weight in grams of nanofibres measurements were achieved using 2×2 dimensions of nanowebs.

Maximum absorption capacity of PVP and PAA nanofibres was determined with the method which was defined by Hansen et al. in literature [13]. The absorption test was carried out with water and synthetic urine for 5, 10, 60, 300, 600, 1800, 86400 (24 hours) seconds. Before the absorption tests, PVP and PAA nanofibre surfaces were cross-linked by fixing in an oven at 90°C for 3 hours and 97°C for 4 hours, respectively.

Firstly, dry weight of the nanofibre sample was weighed. After nanoweb was immersed in the beaker containing water and synthetic urine for 5 seconds and then excess water on the nanoweb surface was removed and wet weight of nanoweb was weighed again. This process was repeated by dipping the sample at different times to determine the absorption rate. 25 g of urea, 9 g of sodium chloride, 2.5 g of sodium phosphate, 3 g of ammonium chloride and 3 g of sodium sulphite were used for the preparation of synthetic urine. All materials were mixed with distilled water until the total volume was completed to 1 l and dissolved in distilled water [13]. Absorption is defined as given in equation 3 [13]:

$$Q = (W_2 - W_1) / W_1 \qquad (3)$$

where Q is absorption, W_1 – initial weight and W_2 – wet weight.

RESULTS AND DISCUSSION

Firstly, solution properties such as: conductivity, viscosity and surface tension were determined. The results showed that conductivity and viscosity increased while surface tension was not related with the addition of WL and cross-linkers for both PVP and PAA (figure 1). In addition, PVP and PAA solutions surface tension results are very close to each other. In literature, it has been also reported that the cross-linker causes increasement in solution viscosity and conductivity [16]. Therefore, it is possible to say that results obtained from this study are compatible with literature.

SEM images and fibre diameter histograms of electrospun nanofibres produced with PVP and PAA polymers are given in figures 2 and 3. It is possible to say that, in general, fine and uniform (bead free) nanofibres were produced and unimodal histogram curves were obtained except PVP01.

It is clearly evident from figure 4 that average fibre diameter increases with WL and cross-linker addition for both PVP and PAA. As it is well known from the literature, there is a strong relation between solution viscosity and fibre diameter [17]. The range of average fibre diameter obtained from this study is between in 345–506 nm. The average fibre diameter of pure PVP nanofibres was measured as 353.56 nm and increased to 431.07 nm with WL and 491.98 nm

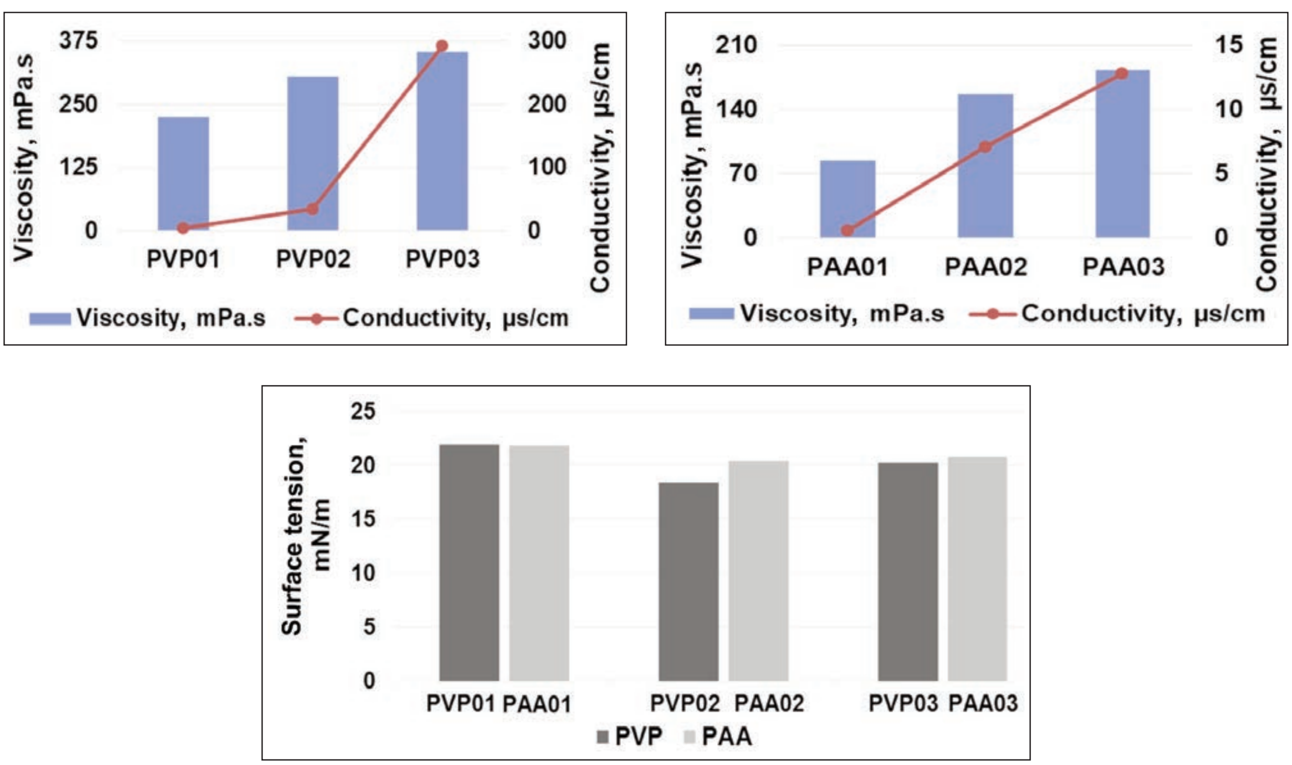


Fig. 1. Solution properties (conductivity, viscosity and surface tension) of PVP and PAA

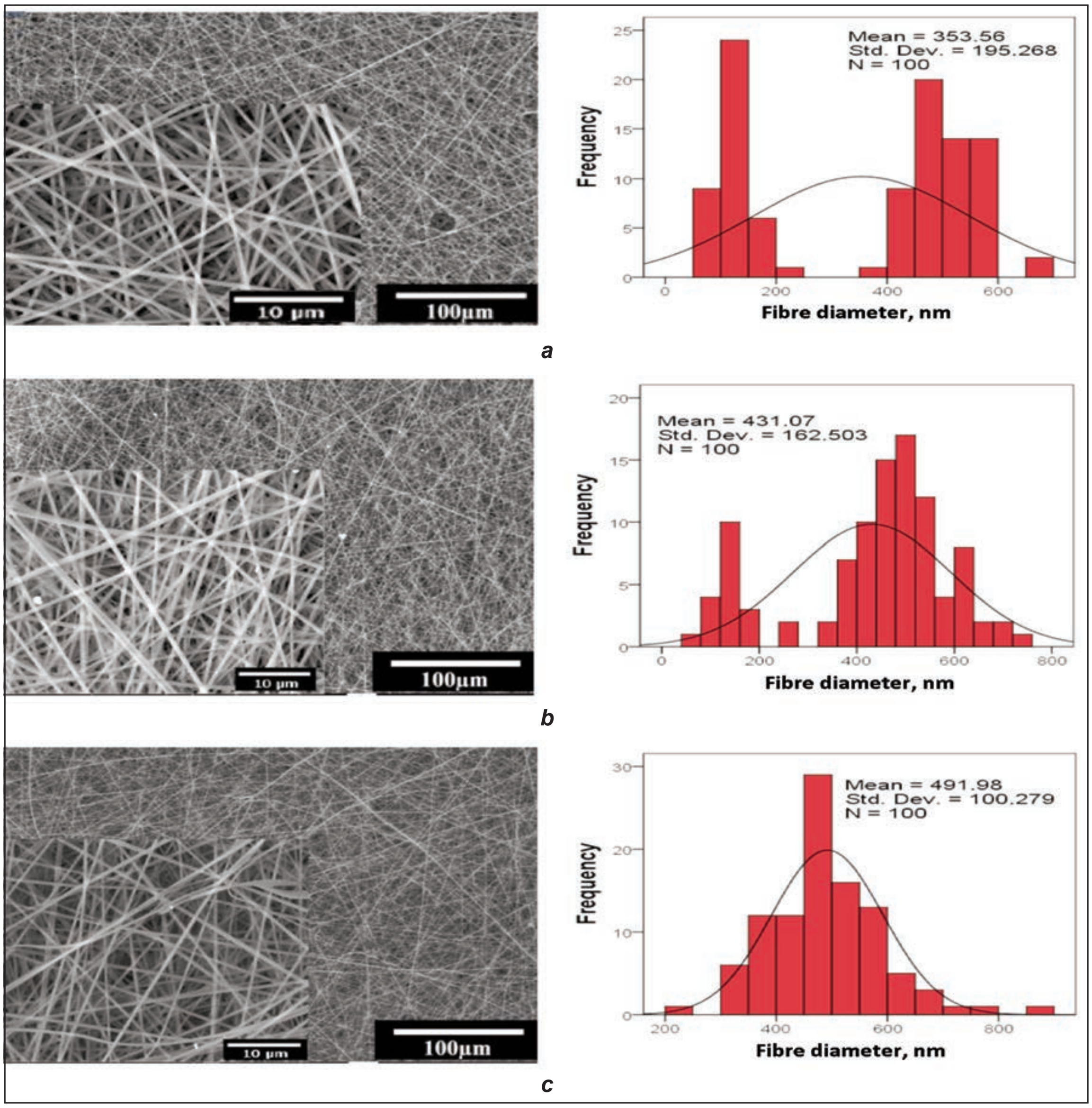


Fig. 2. SEM images (1.000×–10.000×) and histograms of PVP nanofibre samples: *a* – PVP01; *b* – PVP02; *c* – PVP03

with sodium persulfate addition. The most uniform (1.04) fibres were produced from PVP03 sample produced with sodium persulfate.

While average fibre diameter of pure PAA nanofibres was calculated as 345.38 nm, it increased to 484.76 nm with WL and 506.88 nm with glutaraldehyde addition. The most uniform (1.027) fibres were obtained from PAA01 sample (table 3). The presence of cross-linker into the polymer solution effects fibre morphology slightly as reported in the literature [18]. All the results of solution and fibre properties of PVP and PAA samples were given in table 3.

Table 3

RESULTS OF SOLUTION AND FIBRE PROPERTIES OF PVP AND PAA SAMPLES

Sample	Conductivity (µs/cm)	Viscosity (mPa.s) (5 s^{-1})	Surface tension (mN/m)	Number average diameter A_n (nm)	Weight average diameter A_w (nm)	Fibre diameter uniformity coefficient A_w/A_n	Standard deviation
PVP01	4.6	225	21.9	353.6	460.3	1.3	195.3
PVP02	34.7	305	18.4	431.1	491.7	1.1	162.5
PVP03	292.0	354	20.2	492.0	512.2	1.0	100.3
PAA01	0.6	84	21.8	345.4	354.8	1.0	57.3
PAA02	7.1	156	20.4	484.8	522.5	1.1	135.9
PAA03	12.8	183	20.7	506.9	539.1	1.1	128.5

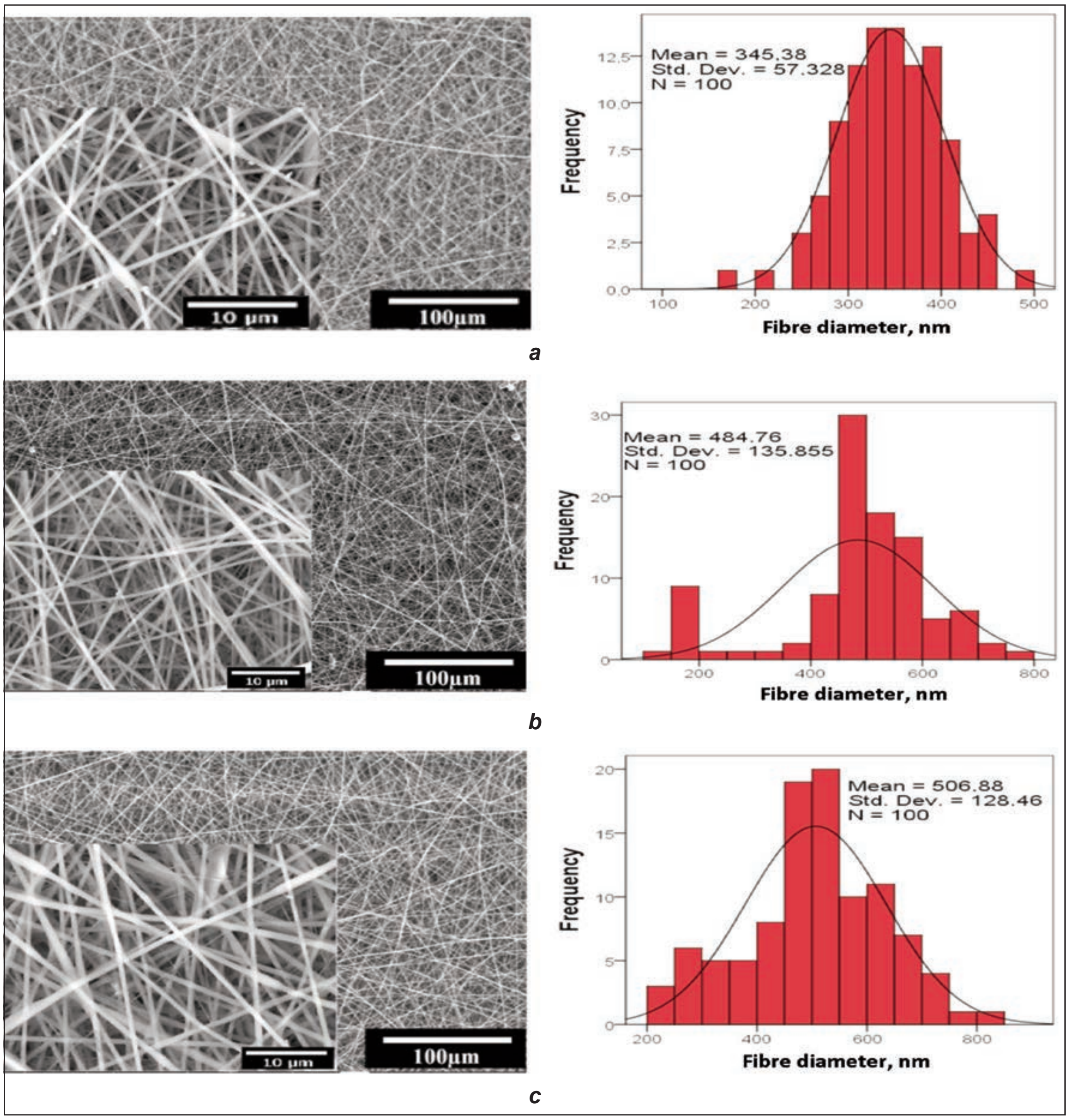


Fig. 3. SEM images (1.000×–10.000×) and histograms of PAA nanofibre samples: *a* – PAA01; *b* – PAA02; *c* – PAA03

Table 4

THICKNESS AND WEIGHT IN GRAMS VALUES OF ELECTROSPUN PVP AND PAA NANOFIBRES

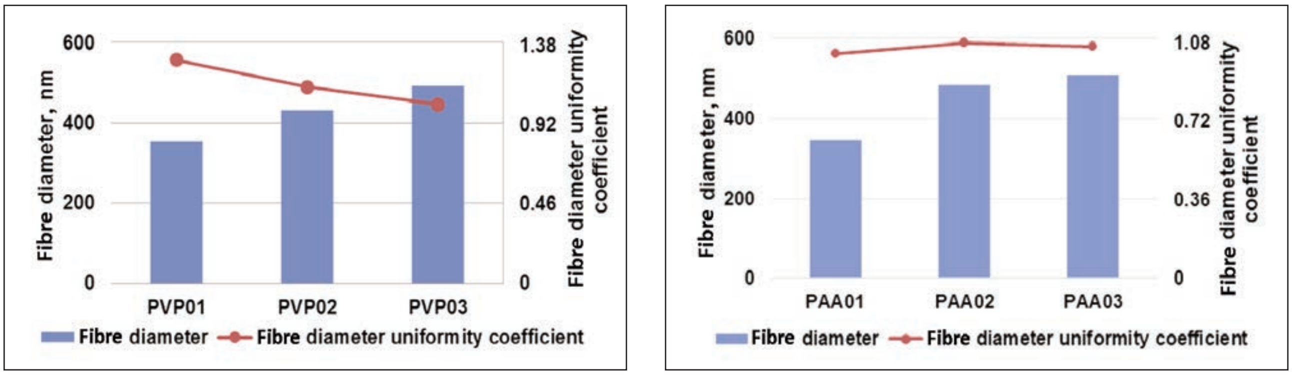
Sample codes	Thickness (mm)	Grammage (g/m^2)
PVP01	0.09	22.10
PVP02	0.14	37.90
PVP03	0.13	39.60
PAA01	0.08	22.00
PAA02	0.07	29.50
PAA03	0.07	32.20

Thickness and weight in grams measurement results of electrospun PVP and PAA nanofibres are given in table 4.

According to the results of table 4, thickness and weight in grams of nanofibres values were compatible with each other. Weight in grams of nanoweb increases with WL and cross-linker addition while thickness was not change noticeably.

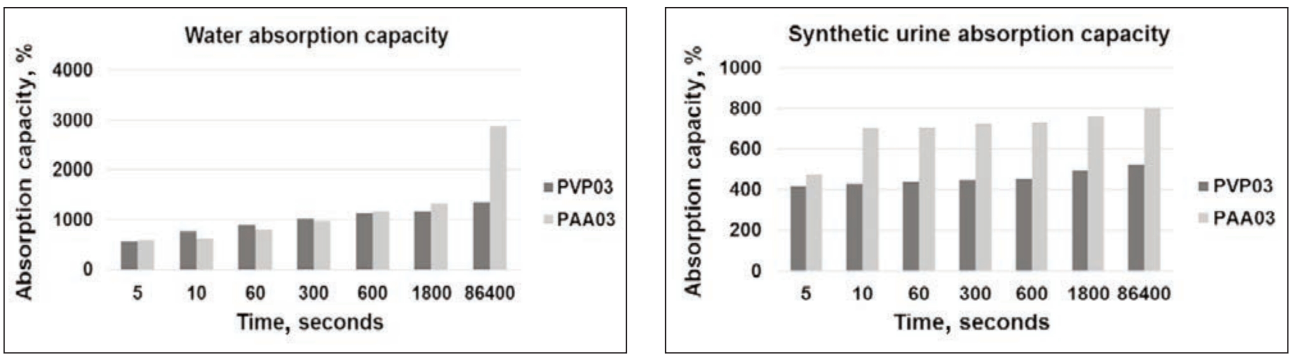
The absorption capacity of the produced cross-linked PVP and PAA nanofibres was tested with both water and synthetic urine for various times and results were given in figure 5.

According to the figure 5, *a*, PVP nanoweb structure exhibited absorption from 560 to 1363 % while PAA nanoweb structure has absorption from 599 to 2876 % in water. Therefore, absorption capacity of PVP and PAA nanofibres increases with time, while PAA nanofibres absorption capacity is noticeably higher than PVP especially for 86400 seconds (24 hours). In water absorption tests, PAA nanofibres reached 50% of the absorption capacity in the first 1800 seconds (30 minutes) and reached maximum water absorption capacity in 86400 seconds (24 hours). On the other hand, PVP nanofibres reached approximately 90% of their absorption capacity in the first 1800 seconds (30 minutes). In addition, it is possible to say that PVP



a *b*

Fig. 4. Average fibre diameter and diameter uniformity coefficient results of PVP and PAA nanofibres



a *b*

Fig. 5. Absorption capacity of electrospun PVP and PAA nanofibres for: *a* – water; *b* – synthetic urine

nanofibres absorption rate is higher than PAA. It was also specified in the literature that high surface area to volume ratio and porous structure of the nanofibre surfaces result in higher absorption capacity [19]. According to the figure 5, *b* results, PVP nanoweb structure showed absorption from 416% to 523% in synthetic urine, and absorption from 477 to 797% for PAA nanofibres. It was obviously seen that PAA nanofibres' absorption percentage increases significantly at 10 seconds. After then absorption values increase slightly between 10 and 86400 seconds. Moreover, absorption values of PVP nanofibres increase slightly between 5 and 86400 seconds. In general, absorption capacity of PAA nanofibres of synthetic urine is higher than PVP. It was also observed that PVP and PAA nanofibres absorption capacity of water is higher than synthetic urine. This result is compatible with literature [13].

CONCLUSIONS

In the present study, superabsorbent nanofibrous surfaces with PVP and PAA were produced by electrospinning and absorption capacity of water and synthetic urine with various times was analysed. This study contributes to the literature concerning the comparative analyses of absorption capacity of PVP and PAA nanofibres.

According to the results, solution conductivity, viscosity and average fibre diameter increased with WL and cross-linker addition while surface tension was not change for both PVP and PAA. In general, fine, smooth and uniform nanofibres were determined. The water absorption test results showed that PAA nanofibres reached 50% of the absorption capacity while PVP nanofibres reached 90 % of the absorption capacity in the first 30 minutes. It is possible to say, PVP nanofibres absorption rate is higher than PAA. On the other hand, it is concluded that PAA nanofibres have higher water and synthetic urine absorption capacity than PVP nanofibres. The authors expect that polymer based superabsorbent nanofibrous materials which are ultra-thin, light, porous, with high specific surface area to volume ratio were developed in this study will have a significant application potential for biomedical and hygienic textiles such as sanitary napkin and diaper.

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