GLASILO SLOVENSKIH TEKSTILCEV • SLOVENE JOURNAL FOR TEXTILE AND CLOTHING TECHNOLOGY, DESIGN AND MARKETING

tekstilec

2/2022 • vol. 65 • 81–156
ISSN 0351-3386 (tiskano/printed)
ISSN 2350 - 3696 (elektronsko/online)
UDK 677 + 687 (05)

Univerza *v Ljubljani*
Naravoslovnotehniška fakulteta

http://www.tekstilec.si

tekstilec (ISSN: 0351-3386 tiskano, 2350-3696 elektronsko) je znanstvena revija, ki podaja temeljne in aplikativne znanstvene informacije v fizikalni, kemijski in tehnološki znanosti, vezani na tekstilno in oblačilno tehnologijo, oblikovanje in trženje tekstilij in oblačil. V prilogah so v slovenskem jeziku objavljeni strokovni članki in prispevki o novostih v tekstilni tehnologiji iz Slovenije in sveta, prispevki s področja oblikovanja tekstilij in oblačil, informacije o raziskovalnih projektih ipd.

tekstilec *(ISSN: 0351-3386 printed, 2350-3696 online) the scientific journal gives fundamental and applied scientific information in the physical, chemical and engineering sciences related to the textile and clothing industry, design and marketing. In the appendices written in Slovene language, are published technical and short articles about the textile-technology novelties from Slovenia and the world, articles on textile and clothing design, information about research projects etc.*

Dosegljivo na svetovnem spletu/*Available Online at*
www.tekstilec.si

Crossref

Tekstilec je indeksiran v naslednjih bazah/*Tekstilec is indexed in*
Emerging Sources Citation Index – ESCI (by Clarivate Analytics)
(2020: Journal Citation Indicator, JCI: 0.35)
Leiden University's Center for Science & Technology Studies
(2020: SNIP 0.705)
SCOPUS/Elsevier (2021: Q3, SJR 0.312, Cite Score 1.9, H Index 13)
Ei Compendex
DOAJ
WTI Frankfurt/TEMA® Technology and Management/
TOGA® Textile Database
World Textiles/EBSCO Information Services
Textile Technology Complete/EBSCO Information Services
Textile Technology Index/EBSCO Information Services
Chemical Abstracts/ACS
ULRICHWEB – global serials directory
LIBRARY OF THE TECHNICAL UNIVERSITY OF LODZ
dLIB
SICRIS: 1A3 (Z, A', A1/2); Scopus (d)

tekstilec

Ustanovitelja / *Founded by*
- Zveza inženirjev in tehnikov tekstilcev Slovenije / *Association of Slovene Textile Engineers and Technicians*
- Gospodarska zbornica Slovenije – Združenje za tekstilno, oblačilno in usnjarsko predelovalno industrijo / *Chamber of Commerce and Industry of Slovenia – Textiles, Clothing and Leather Processing Association*

Revijo sofinancirajo / *Journal is Financially Supported*
- Univerza v Ljubljani, Naravoslovnotehniška fakulteta / *University of Ljubljana, Faculty of Natural Sciences and Engineering*
- Univerza v Mariboru, Fakulteta za strojništvo / *University of Maribor, Faculty for Mechanical Engineering*
- Javna agencija za raziskovalno dejavnost Republike Slovenije / *Slovenian Research Agency*

Izdajatelj / *Publisher*
Univerza v Ljubljani, Naravoslovnotehniška fakulteta / *University of Ljubljana, Faculty of Natural Sciences and Engineering*

Sponzor / *Sponsor*
Predilnica Litija, d. o. o.

Revija Tekstilec izhaja štirikrat letno / *Journal Tekstilec appears quarterly*

Revija je pri Ministrstvu za kulturo vpisana v razvid medijev pod številko 583. Letna naročnina za člane Društev inženirjev in tehnikov tekstilcev je vključena v članarino.
Letna naročnina za posameznike 38 €
za študente 22 €
za mala podjetja 90 € za velika podjetja 180 €
za tujino 110 €

Cena posamezne številke 10 €

Na podlagi Zakona o davku na dodano vrednost sodi revija Tekstilec med proizvode, od katerih se obračunava DDV po stopnji 5 %.

Transakcijski račun 01100–6030708186
Bank Account No. SI56 01100–6030708186
Nova Ljubljanska banka d. d.,
Trg Republike 2, SI–1000 Ljubljana,
Slovenija, SWIFT Code: LJBA SI 2X.

Naslov uredništva / *Editorial Office Address*
Uredništvo Tekstilec, Snežniška 5, SI–1000 Ljubljana
Tel./*Tel.*: + 386 1 200 32 00, +386 1 200 32 24
Faks/*Fax*: + 386 1 200 32 70
E–pošta/*E–mail*: tekstilec@ntf.uni–lj.si
Spletni naslov / *Internet page:* http://www.tekstilec.si

Lektor za slovenščino / *Slovenian Language Editor* Milojka Mansoor
Lektor za angleščino / *English Language Editor* Chris Bishop, Barbara Luštek-Preskar

Oblikovanje platnice / *Design of the Cover* Tanja Nuša Kočevar
Oblikovanje / *Design* Miha Golob
Oblikovanje spletnih strani / *Website* Design Jure Ahtik

Tisk / *Printed by* PRIMITUS, d. o. o.

tekstılec VOLUME 65 • TEKSTILEC 2 2022 ISSN 0351-3386 (tiskano/printed)
UDK 677 + 687 (05)

SCIENTIFIC ARTICLES/ *Znanstveni članki*

Christian Hellert [1], Michael Kieren [2], Andrea Ehrmann [1]
[1] Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, 33619 Bielefeld, Germany
[2] Karl Mayer Stoll R&D GmbH, 63179 Obertshausen, Germany

Time-Dependence of Stop Marks in Warp-Knitted Fabrics
Časovna odvisnost stopoznak snutkovnih pletiv

Preliminary communication/*Predhodna objava*
Received/*Prispelo* 1-2022 • Accepted/*Sprejeto* 2-2022

Corresponding author/*Korespondenčna avtorica:*
Prof. Dr. Dr. Andrea Ehrmann
E-mail: andrea.ehrmann@fh-bielefeld
ORCID ID: 0000-0003-0695-3905

Abstract
Stop marks are one of the most frequently occurring errors in warp-knitted fabrics. They become visible in a fabric each time a warp-knitting machine stops and restarts. Nevertheless, investigations of such stop marks are rarely found in scientific literature. Here, we report on time-dependent investigations of stop marks in warp-knitted fabrics. Microscopic examination of stop marks after stopping times ranging between 1 s and 7 weeks revealed a superposition of the common stop mark due to imperfectly matching rotational speeds of the warp beam and main shaft, and an additional effect due to relaxation in the machine.
Keywords: stop marks, warp knitting, microscopy, image evaluation.

Izvleček
Stopoznake so ene najpogostejših napak snutkovnih pletiv. V pletivu postanejo vidne vsakič, ko se snutkovni pletilnik ustavi in znova zažene. Raziskave o teh napakah kljub njihovi pogostnosti le redko najdemo v znanstveni literaturi. Članek obravnava časovno odvisnost napak v snutkovnem pletivu zaradi zaustavitev stroja. Mikroskopski pregled napak po določenem času od zaustavitve stroja, v obdobju od ene sekunde do sedmih tednov, je pokazal, da prevladujeta najbolj razširjena stopoznaka zaradi nepopolnega ujemanja vrtilnih hitrosti osnovnega valja in glavne gredi in dodatni učinek zaradi relaksacije pletiva na stroju.
Ključne besede: stopoznake, pletenje osnove, mikroskopija, vrednotenje slike

1 Introduction
Detecting and, if possible, avoiding defects in textile fabrics is an important task in order to improve the quality of fabrics. Various methods have thus been reported by different research groups, mostly based on optical inspection. Hanbay *et al.* give a comprehensive overview of different cameras, lenses, and light on the hardware side, and diverse automatic fault detection approaches with their respective mathematical background on the software side [1]. More reviews on fabric defect detection were published by other groups [2–4].

One of the fabric defects that is of high importance due to its large dimension is the stop mark, also named stop line or start mark. This defect occurs in different textile fabrication methods upon stopping and restarting a machine. Most often, it is investigated in cases of woven fabrics. Wimalaweera and Tang discussed the influence of machine stopping time, warp yarn tension, weave pattern, etc. on the severity of stop lines [5]. Karasan and Erdogan mention the importance of correct keel settings to avoid stop marks in woven fabrics [6]. Patil *et al.* report on stop marks occurring in the form of increased

or decreased pick spacing, i.e. thin or thick places. They mention the importance of correct cloth fell position to reduce or even avoid such stop marks [7]. Other authors reported on the effect of shed geometry [8] or concentrated on optical investigation methods to detect and classify stop marks [9–11].
Similar investigations regarding stop marks in warp and weft knitted fabrics, however, are scarce. Au mentioned stop marks in circularly knitted fabrics and described them as straight horizontal streaks, occurring due to different yarn tensions [12]. Wijesingha and Jayasekara mention stop-lines as one of eight defect types in warp-knitted fabrics and discuss their possible detection by self-organizing maps, finding nearly an 80% detection rate [13]. Earlier, Orchard and Barker discussed high-speed photography as a possibility to detect stop lines in circularly and warp-knitted fabrics [14].
A more detailed examination of the reasons for stop marks in warp knitted fabrics was reported by the ITA of RWTH Aachen University [15, 16]. They described the stop marks as being the actual stop line plus additional lines before and after the row of machine stopping and identified these additional lines as stopping (larger stitches) and starting (smaller stitches) lines, which they attributed to a difference in the time-dependent rotational speeds of the warp beam and main shaft. The small number of scientific publications, however, is in contrast to the importance of solving this problem for warp-knitting machines.
Here, we report on a superposition of common stop marks and a time-dependent effect which became evident due to longer stopping periods of a warp-knitting machine due to Covid-19 restrictions in our university.

2 Materials and methods

Experiments were performed on a warp knitting machine HKS 3-M-EL, 42'' with gauge E28 (Karl Mayer Textilmaschinenfabrik GmbH, Obertshausen, Germany). The simple warp knitted structure reverse locknit (1-2 / 1-0 // 1-0 / 2-3//) was selected to enable a relatively simple investigation of the pore sizes between the yarns (cf. Figure 1).
Stop lines were produced for different nonoperation periods between t = 1 second and t = 7 weeks. Microscopic images were taken in the middle of each stop mark as well as on the left and right side of the fabric, approximately 10 cm from the outer borders, by a digital microscope Camcolms2 (Velleman, Gavere, Belgium).
These images were evaluated by ImageJ 1.53e (National Institutes of Health, USA) in the following way: Firstly, the scale was defined, enabling the conversion of pixels to lengths. Next, a threshold filter was applied in the histograms of the images to differentiate between yarns and "holes" between them, i.e. all pixels brighter than the threshold were defined as yarn, while all pixels darker than the threshold were defined as pores (cf. Figure 1). In this way, the images were converted into black-and-white images where all black areas showed yarn, and all white areas showed pores. Next, the function "analyze particles" was applied to measure the open areas between the yarns. In this way, all pore sizes were separately measured, usually more than 300 pores per image. These quantitative evaluations were performed on the microscopic images taken in the middle of each stop line, while the images taken near the borders will be discussed qualitatively.

3 Results and discussion

A first impression of the stop marks after short and long nonoperation periods is given in Figure 1. Here the stop line is clearly visible after 49 days (7 weeks) without working on the machine (Figure 1b). Even slight color changes are visible, which can be attributed to a light rust film having developed on the needles, caused by the unplanned duration in which working on the machine was not possible. While such long nonoperation periods are uncommon in the textile industry, investigating them is nevertheless important since here effects become more clearly visible, which may already occur after much shorter periods of nonoperation, albeit to a smaller extent.

For a very short stop, by switching the machine off and directly on again, the stop line is much harder to detect (Figure 1a). Indeed, the microscopic images do not fully reveal the impression to the human eye, which makes quantitative examinations more complicated than in cases involving woven fabrics.
For the quantitative evaluation of the structure, it must be mentioned that unit cells of warp knitted patterns normally contain min. 2x2 stitches [17–19]. This is also partly visible in Figure 1, where alter-

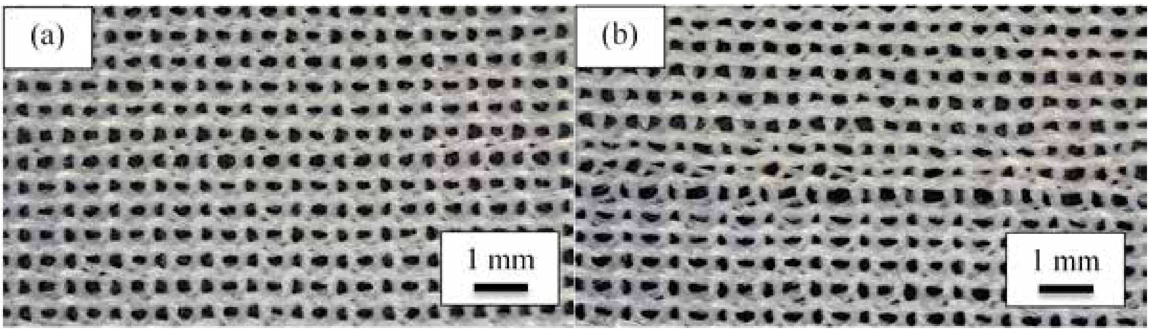
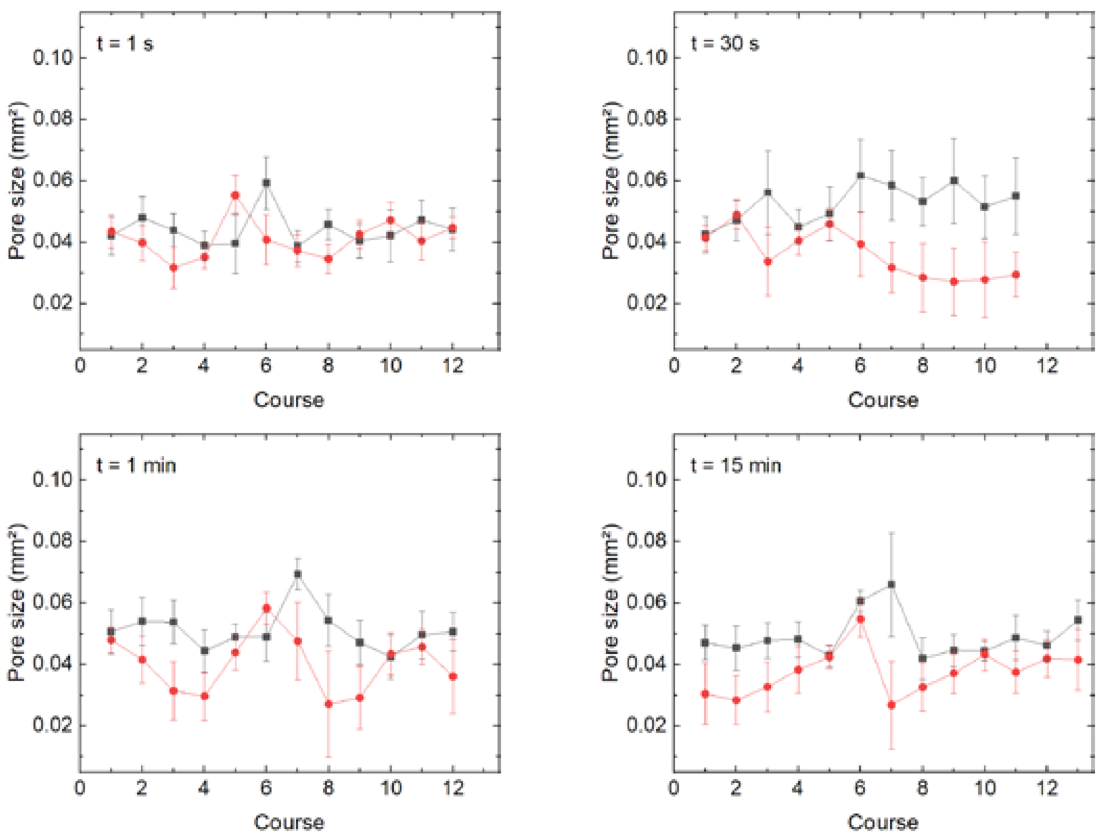


Figure 1: Microscopic images of stop marks, taken after nonoperation periods of the machine of (a) 1 s; (b) 49 d

natingly smaller and larger pores are visible coursewise. A deeper look reveals also alternating shapes of the pores walewise.

On the one hand, this means that evaluations must take into account the alternating pore sizes by averaging them separately. On the other hand, it cannot be excluded that the visibility of a stop mark depends on whether it occurs in the first or the second line of the pattern used here, and that this effect becomes much more pronounced for more sophisticated patterns. To avoid leveling out any important effects due to overly averaging, Figure 2 shows the raw data (averaged over alternating wales) of all image evaluations. Black and red lines indicate alternating pores in the coursewise direction (i.e. alternating parallel to the stop marks, or in other words, alternating horizontally). It must be mentioned that the areas of the microscopic images were chosen "by eye", trying to position the stop mark in the middle of the image, i.e. at course 7 of 13 visible courses. The marks occurring after very short stopping durations are especially hard to see under the microscope (cf. Figure 1a) as that there are only small deviations of this positioning, so the main deviations from the average pore size are visible in the graphs around courses 6–8.



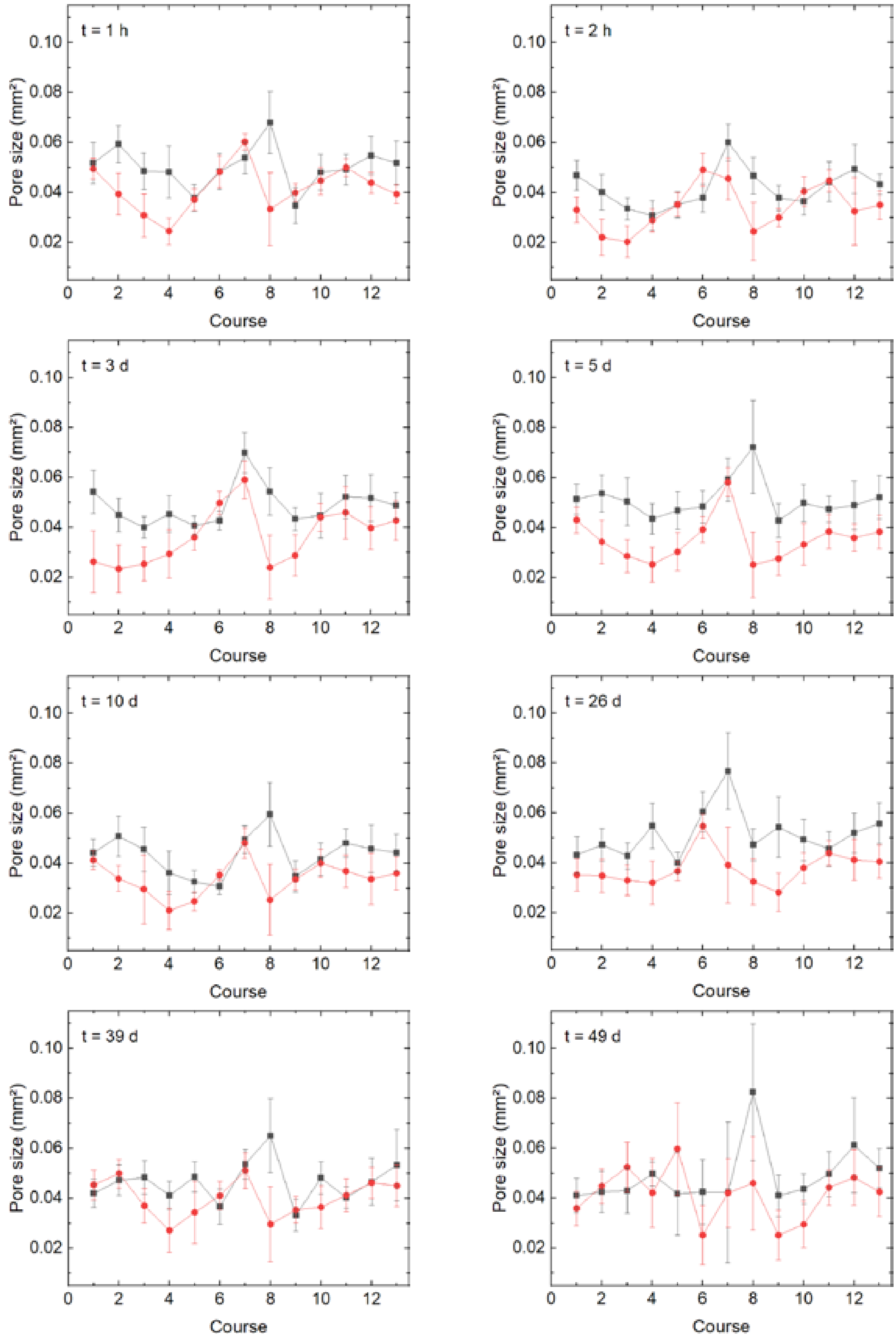


Figure 2: Pore sizes averaged for alternating wales (black and red dots), depending on the courses around a stop mark. The stop marks are located around columns 6-8 in the microscopic images

Comparing these results from a broad range of nonoperation periods, the following statements can be made:

- A maximum pore size can, in most cases, be found roughly in the middle of the image, i.e. at the position where the stop mark was located with the human eye. In most cases, the maxima of the red and the black lines, indicating alternating wales, differ by one course. This finding underlines that not all pores in one course should be averaged.
- Oppositely, no evidence can be found that the severity of the stop line is influenced by the course in which it occurred – if the alternating courses had an effect, there should be two different slopes or maximum heights or the like visible in some of the graphs.
- A tendency towards higher maxima and also slightly larger pore sizes far away from the main stop line is visible for the "black" line. Due to the large error bars, however, this finding cannot be regarded as significant.
- For long nonoperation periods, the error bars of the values near the stop line are increased, and the slopes of the curves vary strongly, corresponding to the quite chaotic impression of Figure 1b.
- Even the relatively small effect after stopping the machine for 1 s, hardly visible in Figure 1a, can be quantified and shows maxima in the red and the black line.
- In many cases, the maxima in the curves seem to be accompanied by small neighboring minima, before, several courses apart from the maxima, the base value is reached again. This is not perfectly identical with the findings reported in [15, 16].

It must be mentioned, however, that some observations do not fit into this idealized description. The following deviations can be found:

- For t = 30 s, the black curve does not show a clear maximum, and both curves differ more strongly for higher course numbers than in the other cases.
- For t = 3 d, both maximum pore sizes occur in the same course.
- And finally, for t = 49 d, the fabric is already damaged so severely that the error bars become quite large, as previously mentioned.

The first two problems may be attributed to the manual handling of the fabrics during image acquisition under the microscope. It cannot be excluded that while trying not to pull the fabric into any direction, it has nevertheless been slightly elongated or sheared erroneously. Such undesired manipulations of the fabric can possibly be counteracted by fixing the fabric on a frame before taking images. Alternatively, stretching the fabric by a defined small ratio may be a good alternative to increase the reliability of the microscopic images.

It must be underlined that in normal use, a warp knitting machine's downtime is normally quite short, so that the case depicted in Figure 1b will usually not occur. However, this artificially produced error is instructive to get an idea of the possible error due to stopping the machine for some hours or even days. In addition, while Figure 1a – taken after the shortest stopping duration of only 1 s – shows nearly no disturbance of the fabric in the microscopic image, the stop mark is, even for this shortest possible stopping time, well visible in reality, if the fabric can be moved, and its shine can be recognized by eye. In this way, there is no "negligible" stopping time as the stop marks become visible at once. The same effect was found in preliminary tests with other patterns produced on the same machine.

This effect is even stronger if the sides of the fabric are taken into account. Figure 3 exemplarily depicts two images taken on the left side, on the fabrics with minimum and maximum nonoperation periods.

For the image taken after stopping the machine for 1 s (Figure 3a), only a small deviation from the desired 90° angle between course and wale orientation is visible. For the longest nonoperation period, however, a strong angle between the wale direction in the "new" part of the fabric (i.e. above the stop mark) and the wale orientation in the "older" part (below the stop mark) is visible. This clearly shows the effect of dry relaxation in the machine, which apparently not only influences the stitches in the stop mark (cf. Figure 1b), but also the residual fabric.

Previous investigations suggested tailoring the time-dependent rotational speeds of the warp beam and main shaft [15, 16]. The aim of the recent study, however, was to define a quantitative description of the stop marks to enable further investigations of possible solutions of this problem.

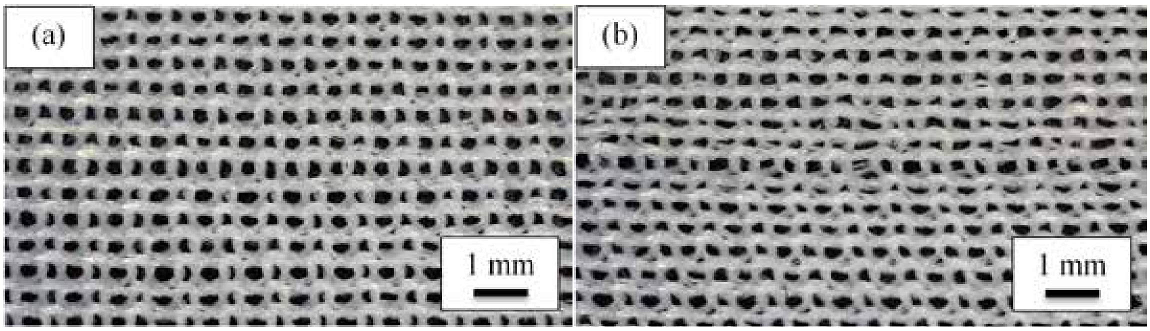


Figure 3: Microscopic images of stop marks near the left borders of the warp knitted fabrics, taken after nonoperation periods of the machine of (a) 1 s; (b) 49 d

4 Conclusion

Stop marks in a warp-knitted fabric were evaluated by taking microscopic images and measuring the pore sizes around the stop lines. By evaluating alternating wales separately, maximum pore sizes were found in two adjacent courses near the optically visible stop mark. In most cases, these maxima were surrounded by smaller minima. Deviations from this systematic description can most probably be attributed to inaccurate handling of the stretchable and shearable fabrics during microscopy.
For the next steps, more reliable handling is thus necessary, as well as taking more measurements on different warp-knitted structures in order to develop a general description of the stop marks and neighboring courses, and finally an approach to reduce the intensity of these fabric defects for different nonoperation periods. The recent study serves as a base for the quantitative evaluation of different approaches to reduce these stop marks.

References

1. HANBAY Kazim, TALU, Muhammed Fatih, ÖZGÜVEN, Ömer Faruk. Fabric defect detection systems and methods – a systematic literature review. *Optik*, 2016, **127**(24), 11960–11973, doi: 10.1016/j.ijleo.2016.09.110.
2. NGAN, Henry Y. T., PANG, Grantham K. H., YUNG, Nelson H. C. Automated fabric defect detection – a review. *Image and Vision Computing*, 2011, **29**(7), 442–458, doi: 10.1016/j.imavis.2011.02.002.
3. RASHEED, Aqsa, ZAFAR, Bushra, RASHEED, Amina, ALI, Nouman, SAJID, Muhammad, DAR, Saadat Hanif, HABIB, Usman, SHEHRYAR, Tehmina, MAHMOOD, Muhammad Tariq. Fabric defect detection using computer vision techniques: a comprehensive review. *Mathematical Problems in Engineering*, 2020, **2020**, 8189403, 1–24, doi: 10.1155/2020/8189403.
4. LI, Chao, LI, Jun, LI, Yafei, HE, Lingmin, FU, Xiaokang, CHEN, Jingjing. Fabric defect detection in textile manufacturing: a survey of the state of the art. *Security and Communication Networks*, 2021, **2021**, 9948808, doi: 10.1155/2021/9948808.
5. WIMALAWEERA, W. A., LAN, Tang Yee. A study of start-up marks of woven fabrics. *Research Journal of Textile and Apparel*, 1997, **1**(1), 71–83, doi: 10.1108/RJTA-01-01-1997-B009.
6. KARASAN, Ali, ERDOGAN, Melike. Creating proactive behavior for the risk assessment by considering expert evaluation: a case of textile manufacturing plant. *Complex & Intelligent Systems*, 2021, **7**(2), 941–959, doi: 10.1007/s40747-020-00246-0
7. PATIL, Tushar, CHAUDHARI, Bhushan, PATALE, Yatin, SHINDE, Tushar, PARSI, Rajendra, GULHANE, Sujit, RAICHURKAR, P. P. Development of techno-feasible mobile app for process optimization in textile industry. In *Advances in Systems Engineering. Lecture Notes in Mechanical Engineering.* Edited by V. H. Saran and R.K. Misra. Singapore : Springer, 2021, doi: 10.1007/978-981-15-8025-3_28.
8. AHMED, Suza, ALIMUZZAMAN, Sha, HAQUE, A. K. M. Monjurul. Effect of shed geometry on starting mark of woven fabric. *SN Applied Sciences*, 2020, **2**(4), 1–15, doi: 10.1007/s42452-020-2384-1.
9. AYALA, Andres Leal, GOVINDARAJ, Muthu. Detecting and quantifying set marks on woven fabrics. *Textile Research Journal*, 2001, **71**(7), 587–595, doi: 10.1177/004051750107100704.

10. MIHRIBAN, Kalkanci. Qualitative classification of woven fabrics produced from recycles threads of cotton and blends. *Industria Textila*, 2020, **71**(2), 118–123, doi: 10.35530/IT.071.02.1638.
11. VEIT, Dieter. Neural networks in textile engineering. In *Advances in Modeling and Simulation in Textile Engineering*. Edited by Nicholus Tayari Akankwasa and Dieter Veit. The Textile Institute Book Series. Woodhead Publishing, 2021, 39–98, doi: 10.1016/B978-0-12-822977-4.00017-0.
12. AU, K. F. Quality control in the knitting process and common knitting faults.In *Advances in Knitting Technology*. Edited by K.F. Au. Woodhead Publishing Series in Textiles. Woodhead Publishing, 2011, 213–232, doi: 10.1533/9780857090621.2.213.
13. WIJESINGHA, Dimuthu, JAYASEKARA, Buddhika. Detection of defects on warp-knit fabric surfaces using self organizing map. In *2018 Moratuwa Engineering Research Conference (MERCon)*. IEEE, 2018, pp. 601–606.
14. ORCHARD, G. A. J., BARKER, R. A. Application of high-speed photography to textile problems. *The Journal of Phtoographic Science*, 1957, **5**(5), 126–131, doi: 10.1080/00223638.1957.11736608.
15. NEUMANN, Florian, STRAUF AMABILE, Marion, GRIES, Thomas, ZEIDLER, Gert, KLEMM, Brigitte, HEINECKE, Thomas. Characteristics of stop marks in warp-knitted fabrics. *Proceedings of the 2nd Aachen-Dresden International Textile Conference, Dresden, December 04 - 05, 2008. Edited by Annett Dörfel*. Dresden : ITB, TU, 2008.
16. STRAUF AMABILE, Marion, GRIES, Thomas. Examination of stop marks: looking for the 'bad parkers' in the fabric; a new testing instrument for examining stop marks. *Kettenwirk-Praxis*, 2005, **39**(4), 28–29.
17. KALLIVRETAKI, Argyro, VASSILIADIS, Savvas, BLAGA, Mirela, PROVATIDIS, Christopher. Finite element modelling of the warp knitted structure. *RJTA*, 2007, **11**(4), 40–47, doi: 10.1108/RJTA-11-04-2007-B003.
18. ZHANG, Yuan, HU, Hong, KYOSEV, Yordan, LIU, Yanping. Finite element modeling of 3D spacer fabric: Effect of the geometric variation and amount of spacer yarns. *Composite Structures*, 2020, **236**, 111846, doi: 10.1016/j.compstruct.2019.111846.
19. ETTEHADI, Zahra, AJELI, Saeed, SOLTANI, Parham, ZARREBINI, Mohammad. Experimental and CFD analysis of air permeability of warp-knitted structures. *Fibers and Polymers*, 2020, **21**(6), 1362–1371, doi: 10.1007/s12221-020-9258-4.

Ümit Doğrul [1], Sena Tekeli [2]
[1] Mersin University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Çiftlikköy Campus, 33342, Yenişehir/Mersin, Turkey
[2] Toros University, School of Foreign Languages, English Translation and Interpreting, Mezitli Campus, 33340, Mezitli/Mersin, Turkey

Female Consumers' Clothing-related Attribute Expectations Differ According to Their Gender Identities

Vpliv spolne identitete na pričakovane lastnosti ženskih potrošniških oblačil

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 11-2021 • Accepted/*Sprejeto* 2-2022

Corresponding author/*Korespondenčna avtorica:*
Assist. Prof. Dr. Ümit Doğrul
E-mail: udogrul@mersin.edu.tr
Phone: +90 (324) 361 00 01/15295
ORCID ID: 0000-0002-4795-3170

Abstract

It is necessary to determine the factors that affect consumers' preferences in the ready-made clothing sector, where competition is intense. Gender is accepted as one of the most fundamental factors affecting purchasing decisions not only in the ready-made clothing industry, but also in many other sectors. However, rapidly changing environmental conditions require going beyond traditional patterns in explaining consumption behaviors. Accordingly, the concept of gender, which is socially constructed, has also been conceptualized from a psychological point of view. In this study, the concept of gender was based on psychological foundations and it was investigated whether female consumers' clothing-related attribute expectations differ according to their gender identities. Questionnaires created in line with the purpose of the study were applied to 393 people who were selected by convenience sampling. The data were collected through a face-to-face survey. Research hypotheses were tested with ANOVA analysis. As a result of the research, it was found that female consumers' clothing-related attribute expectations differ according to gender identities. In the literature, no study has been found that examines the changes in the clothing-related expectations of female consumers according to their gender identity roles. In this context, it is expected that the study will make significant contributions to both the managers in the clothing sector and academics.
Keywords: gender identity, clothing-related attribute expectations, cluster analysis

Izvleček

V sektorju konfekcijsko izdelanih oblačil, kjer vlada močna konkurenca, je treba ugotoviti, kateri dejavniki vplivajo na preference potrošnikov. Spol je eden najpomembnejših dejavnikov, ki vplivajo na odločitve o nakupu, ne samo pri konfekcijsko izdelanih oblačilih, temveč tudi marsikje drugod. Hitro spreminjajoče se okoljske razmere zahtevajo preseganje tradicionalnih vzorcev predvidevanja o vedenju potrošnikov. V skladu s tem je koncept spola, ki je na splošno razlagan kot biološki, v tej raziskavi obravnavan s psihološkega vidika. Raziskano je bilo, ali se pričakovanja potrošnikov o lastnostih oblačil razlikujejo glede na njihovo spolno identiteto. Za raziskavo so bili izdelani vprašalniki in z metodo priročnega vzorčenja je bilo izbranih 393 ljudi, ki so bili anketirani v živo. Raziskovalne hipoteze so bile preverjene s stati-

stično metodo ANOVA. Pokazalo se je, da se pričakovanja potrošnikov glede lastnosti oblačil razlikujejo glede na spolno identiteto. V literaturi ni bila najdena nobena raziskava o vplivu spolne identitete na spremenjena pričakovanja potrošnikov, povezanih z oblačili. S tega vidika je ta raziskava pomembna za menedžerje v sektorju oblačil kot raziskovalce.
Ključne besede: spolna identiteta, pričakovanja glede atributov v zvezi z oblačili, klasterska analiza

1 Introduction

Clothing indicates an individual's gender identity, ethnicity, and social class. Investigating clothing purchasing attitudes and behaviors is effective in understanding the consumption behaviors of both individuals and society [1]. Clothing, which is a necessity in the life of humans, is a buffer between individuals' sociological, psychological and economic structures and their physical structures. Features such as individuals' income, lifestyles and the way they express their own personalities, emotions, pleasures, dreams and wishes affective upon their clothing purchasing behavior [2]. One of the most important factors affecting consumers' clothing preferences is their gender. Çabuk and Köksal [3] argued that the concept of biological gender, which divides individuals into two different groups as male and female, does not provide sufficient data to explain consumer behavior.

When examining consumer behavior, it is necessary to determine gender identities that may cause women and men to behave in contrast to their traditional roles [4]. The concept of gender has evolved from biological gender (male and female) to gender identity that examines gender in many ways including biological, psychological and sociological gender roles. Today, changing perspectives and lifestyles depending on social and economic conditions have caused the differences between the roles of women and men to decrease gradually [5]. In other words, it causes women to try to gain a position in working life and men to share responsibilities such as housework and childcare [3]. These changes in social roles have led to the development of the gender identity concept [6]. In addition, it can be said that changes in this regard have effects on women's education, profession and clothing [5]. Recent studies indicate that gender identity is a changing concept and should be examined with dynamic groups in different contexts [7]. Clothing develops new identities, divides identities and displays identities. In other words, clothing is a concrete image of an individual's gender identity [8]. For this reason, it is expected that women's gender identity roles will have a significant impact on their clothing preferences. However, no study has been found in the literature that reveals the relationship between women's gender identities and their clothing preferences. In this respect, this study is important to reveal this relationship.

The aim of this study is to reveal how female consumers' clothing-related attribute expectations differ according to their gender identities. In this respect, first of all, the concepts constituting the conceptual framework of the study were discussed, the relevant literature was examined in accordance with the purpose of the study, and research hypotheses were developed associating them with the theoretical background. In the application part of the research, these hypotheses were tested, and the findings were evaluated.

1.1 Conceptual framework and research hypotheses

1.1.1 Gender identity

Gender identity refers to the behaviors an individual uses to communicate their gender identity to the social world apart from themselves. An individual can communicate their gender identity both consciously and unconsciously. These ways can include many micro-decisions such as clothing, hair, make-up or speaking style. Gender identity is an individual's way of expressing themselves. It is not determined by genotypes or phenotypes and cannot be verified or confirmed by another person, but rather depends on an individual's inner self. However, individuals' gender identity can be affected by the expectations of the society in which they live [9].

Gender identity is individuals' acceptance of their feminine or masculine characteristics and defining themselves according to these characteristics [10, 11]. Gender Schema Theory and Multi-Factor Gender Identity Theory, which are effective in the psychology literature, contribute to the development of studies on consumer behavior [12]. The Gender Schema Theory, developed by Bem [13], opposes traditional approaches to biological gender differences in information processing. Individuals' gender identities are effective in information processing processes. A woman may behave more masculinely than a man, and a man may behave more femininely than a woman. The difference between men and women constitutes a basic organizing principle in any culture [10]. According to Leinback et al. [14], every society has its specific roles, language, behaviors, occupations and characteristics that are considered appropriate for men and women. Behavior patterns defined as masculine and feminine in a society are coded into an individual's gender identity schemes [15]. The development of schemas related to gender identity continues throughout life [16].

Unlike the Gender Schema Theory, the Multifactorial Gender Identity Theory developed by Spence requires the measurement of many different variables to determine gender identity. According to this theory, individuals' gender identities are determined by measuring factors such as gender role behaviors, personal characteristics and gender attitudes. If a single variable is measured, the applicability of that variable is limited [13]. In other words, individuals' gender identity is multifactorial and each factor has a different developmental history that varies from individual to individual, because these factors are affected by many variables that are not gender-based [17].

The Bem Gender Identity Inventory, used most frequently since 1979, was created based on the idea that individuals with a differentiated gender identity exhibit the standard gender behaviors that a society expects from men and women. According to this inventory, individuals can be divided into four different gender identity role groups as masculine, feminine, androgynous and undifferentiated [14].

Masculine gender identity is mostly rational and externally oriented. Being competitive, self-confident, adventurous, independent, logical, having the characteristics of a leader and accordingly being able to make easy decisions and not getting excited during crisis, being competent in working life, hiding one's emotions, not being influenced easily and being scientific, aggressive and objective are masculine characteristics. Feminine gender identity, on the other hand, is emotional and internally oriented. Being aware of their feelings, expressing their feelings easily, being talkative and using polite language, being kind and understanding, having high moral values, enjoying art and literature, requiring high security and having regular habits are feminine characteristics [18]. The masculine personality structure is attributed to men, and the feminine personality structure is attributed to women. However, because gender identity is different from gender, there are women with masculine features as well as men with feminine features. While masculine women's purchasing decisions are similar to those of men, feminine men's decisions may be similar to feminine women's purchasing behavior. Therefore, the difference between gender and gender identity should be taken into account in consumption studies [1].

The concept of androgynous gender identity differs from the expressions reflecting traditional gender roles in a particular culture. Individuals with androgynous gender identity show both the most distinctive features considered masculine and the most typical features considered feminine[13]. Individuals with the fourth gender identity, expressed as undifferentiated, reflect both masculine and feminine characteristics at the lowest level [19]. In conclusion, individuals possessing high feminine features but low masculine features are 'feminine'; individuals possessing high masculine features but low feminine features are 'masculine'; those who have both masculine and feminine features at a high level close to each other are classified as 'androgynous' and those who have both masculine and feminine features at a low level are classified as 'undifferentiated' [13].

Similar to Bem [13], Yağcı and Ilarslan [4] found consumers are clustered into four different gender identity groups: masculine, feminine, androgynous and undifferentiated. In the study of Ye and Robertson [20], millennial consumers are clustered in two groups: feminine and masculine. Görmüş et al. [21] found that participants' gender identities were categorized as masculine, feminine, undifferentiated and androgynous. Unlike others, Neale et al. [11] found that consumers' gender identities are divided into three categories – masculine, feminine and androgynous. Kilicer et al. [1] found that consumers were divided into three groups: androgynous, undifferentiated and feminine in terms of gender identity, through the study conducted with an aim of examining consumers' gift purchase behavior. Yurttakalan and Gelibolu [22] examined generation Z consumers' online purchasing behaviors and determined participants' gender identities to be feminine, masculine and androgynous. Based

on this conceptual information in the literature, we predicted that female consumers' gender identities are different and hypothesis 1 was developed.
Hypothesis 1(H_1): Female consumers' gender identities differ from each other.

1.1.2 The relation between gender identity and clothing-related attribute expectations

Clothing, which is a necessity of human existence in society, is an important consumption tool that provides information about the individual's personal qualities, roles and socio-economic status [2, 23]. According to Morris [24], clothes carry non-verbal cues and a person's dress says a lot about that person. In other words, clothes often reflect a person's sense of self-confidence, personality, education, general character, past experiences, and socioeconomic status [25]. This indicates that clothing has a huge impact on social interaction and managing impression [26].

According to Crane [27], there is a significant relationship between clothing and an individual's identity, because clothing not only reflects an individual's own visual symbolic image but is also a way of expressing themselves in the social and cultural environment in which they live. Clothing reflects the conformity of an individual's identity to society, as well as their difference from others. According to Entwistle [28], clothing contributes to how societies and cultures develop and maintain what is typical, traditional and standard, or usual. In other words, clothing has historically been used in societies and cultures as a way to maintain existing norms as well as creating them. Clothing is not only a personal choice, but also a means to distinguish between the individual's identity and the socio-cultural world in which they live. One of the ways individuals socialize and develop identity is through clothing.

Guy and Banim [29] conducted qualitative research on how women feel about clothing, how clothing represents their identity, and which factors are effective in their clothing decisions. They argued that female consumers' identities are an affective factor on their clothing preferences and in eliminating their indecision. Goodman et al. [8] argued that clothing is an indicator of gender identity and they focused on the importance of clothing in the development of women's gender identity, revealing that clothing preferences contribute to the formation and preservation of identities. Aiken [30] found that there is a significant relationship between female consumers' gender identities and their clothing purchase decisions. It was also found that female consumers' reasons to buy clothes are design, comfort, interest, harmony and economy, and these reasons differ according to gender identity. Kaya [31] argued that clothing preferences, which are an important indicator of gender and social status, are effective in protecting or destroying symbolic boundaries, and differ according to consumers' gender identities [31].

Table 1: Clothing-related attribute expectations [23]

Attribute	Definition
Conformity	It refers to dressing similarly to others in social and business life.
Individuality	It refers to the clothing qualities that distinguish an individual from others.
Modesty	It refers to clothing qualities that are not noticed by others.
Exhibitionism	It refers to the clothing qualities that attract other individuals' attention.
Femininity	It refers to the use of clothes characterized by curvy lines, details in design and a soft appearance.
Masculinity	It refers to the use of clothes characterized by straight lines, a special effect and a tough appearance.
Aestheticism	It refers to clothes appealing to individuals' senses, especially visually.
Functionalism	It refers to the use of clothes that reflects practical benefit, protection, durability and ease of care.
Constancy	It refers to a high degree of consistency in individuals' clothing preferences.
Change	It refers to individuals' desire of change, excitement and trying different things in their clothing preferences.
Freedom	It refers to the individual's preference for clothes that do not tighten their body but make them feel free.
Restraint	It refers to the individual's preference of narrow and body-hugging clothes.

When the literature was examined, it was determined that although there are studies which try to explain the relationship between gender identity and clothing preferences, there has not been any study conducted to directly determine the relationship between consumers' gender identity and clothing-related attribute expectations. Attributes effective in choosing clothes express the ways of thinking and behaviors that reflect an individual's views on clothing tendencies [23]. Karhooff [23] divided the attributes effective in consumers' clothing preferences into 12 dimensions. Table 1 includes the descriptions of each dimension. Based on this conceptual information, it is predicted that the attributes that affect female consumers' clothing preferences may differ according to their gender identities and hypothesis 2 was developed.

Hypothesis 2 (H_2): In women's clothing preferences, clothing-related attribute expectations differ according to gender identity.

H_{2a}: In women's clothing preferences, conformity expectation differs according to gender identity.
H_{2b}: In women's clothing preferences, individuality expectation differs according to gender identity.
H_{2c}: In women's clothing preferences, femininity expectation differs according to gender identity.
H_{2d}: In women's clothing preferences, masculinity expectation differs according to gender identity.
H_{2e}: In women's clothing preferences, aestheticism expectation differs according to gender identity.
H_{2f}: In women's clothing preferences, functionalism expectation differs according to gender identity.
H_{2g}: In women's clothing preferences, constancy expectation differs according to gender identity.
H_{2h}: In women's clothing preferences, change expectation differs according to gender identity.
H_{2i}: In women's clothing preferences, freedom expectation differs according to gender identity.
H_{2j}: In women's clothing preferences, restraint expectation differs according to gender identity.

2 Methodology and results

2.1 Sample and data collection tool

The research population of the study consists of female consumers over the age of 17 in Turkey. Since it was not possible to reach the entire population, data were collected from 393 individuals using the convenience sampling method. Through face-to-face surveys, the data were collected in March and April 2021.

The questionnaire applied to collect the data consists of three parts. In the first part of the questionnaire, a 40-item (20 feminine-20 masculine) scale was provided to determine female consumers' gender identities. The scale was developed by Bem [32] and adapted to Turkish society by Dökmen [33]. In the second part of the questionnaire, the scale prepared by Karhooff [23] was provided to determine female consumers' clothing-related attribute expectations. A 5-point Likert scale was used in both scales. (1: Strongly disagree, 5: Strongly agree). In the third part of the questionnaire, questions were included to determine the participants' demographic characteristics.

2.2 Factor and cluster analysis to determine female consumers' gender identity roles

In the study, factor analysis with varimax rotation was applied to the Bem gender role inventory consisting of 40 statements in order to determine the factor structures related to gender identity. First, the results of the Kaiser-Meyer-Olkin (KMO) test were checked to evaluate the suitability of the variable set for factor analysis and the results of the Bartlett sphericity test was checked to test the suitability of the model. The KMO measurement value is 0.946 (Table 2). The Bartlett Sphericity test chi-square value (χ_2 = 11175,667; df = 780, $p < .001$) is statistically significant. Considering both results, the data set adequacy for exploratory factor analysis was determined [34]. In this study, considering the number of samples, it was ensured that the lower limit of item factor loads was 0.50 [35]. Two expressions (feminine, loyal) that did not meet this criterion were excluded from the scale. According to the results of the factor analysis, eight factors with an eigenvalue of at least 1 and explaining 69.477% of the variation in the items were determined. Each factor was evaluated to examine the compatibility of the resulting factor structures with the structures in the original scale and with the literature. Considering the dimensions of the original scale, the 5th, 6th and 7th factors, which consist of two expressions, consist of one masculine expression and one feminine expression. Therefore, these factors were considered to be insignificant. In addition, the 8th factor was not included in the study because it consisted of only one expression. Therefore, the statements in the 5th, 6th, 7th, and 8th factors were excluded from the study.

All the expressions in the 1st factor that emerged as a result of the analysis are included in the feminine characteristics in the original scale. In factor 4, only the expressions "generous" and "responsible to my family" are included in the masculinity dimension in the original scale. However, these two expressions can be considered related to the other expressions in the 4th factor. Therefore, the 1st and 4th factors have the characteristics of feminine identity and the 1st factor was named as "feminine_1" and the 4th factor as "feminine_2". All the expressions in the 2nd and 3rd factors are under the masculinity dimension in the original scale. The second factor was named "masculine_1", the third factor was named "masculine_2". Four factors to be used in determining gender identities explain 56.60% of the variance. When the cronbach's α values of the determined factors are examined, it is seen that it is between 0.837 and 0.912 (Table 2).

Confirmatory factor analysis was applied to test the construct validity of the four-factor structure obtained as a result of the explanatory factor analysis of the gender identity role scale. In order to test the acceptability of the model as a whole, the goodness of fit values were examined and it was determined that all goodness of fit criteria of the model were good and within acceptable limits ($\chi^2/df = 2.04$; RMSEA = 0.052; SRMR = 0.034; GFI = 0.87; NNFI = 0.99; NFI = 0.98; IFI = 0.99; CFI = 0.99). Therefore, when the confirmatory factor analysis results are considered, it is seen that all items in the measurement model are compatible with the model [36]. The construct validity of the confirmatory factor analysis alone is insufficient to show the validity of the scales in the measurement model. The construct validity of the measurement model should also be tested with confirmatory factor analysis. The construct validity was evaluated in this study by testing it with convergent validity and discriminant validity.

Table 3 shows that the composite reliability coefficients (CR) of the dimensions of the measurement model are above 0.70 and the average variance values explained (AVE) are above 0.50. Considering these values, it was determined that the scales used in the research had convergent validity and the first criterion of construct validity was met. To test the discriminant validity, which is another criterion to ensure construct validity, the square root of the mean variance explained by each factor and the correlation values between the factors were compared and it was determined that for each factor, the square root of the mean variance explained was higher than the correlation values between the dimensions. Construct validity was provided for all scales. After the construct validity of the measurement model was evaluated, the reliability of the scales was tested with the Cronbach's Alpha reliability coefficient. When the Cronbach's alpha values of each scale are examined, it is seen that it is between 0.912 and 0.948 (Table 3). Nunnally [37] stated that reliability coefficients above 0.7 are acceptable in social sciences. Accordingly, it can be said that the study scales have high reliability.

Cluster analysis was performed using four factors that Cluster analysis was performed using four factors that emerged as a result of factor analysis to determine the gender identities of the participants. The K-means algorithm is an algorithm that aims at collecting the observations with the closest values in the same cluster when the number of clusters is certain. Accordingly, hierarchical clustering and the K-means algorithm were used in this study because the number of clusters related to gender identity is certain [39]. As mentioned above, there are four clusters in the Bem Gender Identity Inventory: masculine, feminine, androgynous and undifferentiated.

The number of participants in each of the clusters determined as a result of the analysis and the cluster averages are shown in Table 4. Table 4 depicts that the averages of both the feminine and the masculine dimensions of the participants in the first Cluster are high. For this reason, this cluster was named androgynous. The second cluster is a cluster in which the averages of the feminine dimensions are low and the averages of the masculine dimensions are high. In the fourth group, the means of the feminine dimensions were high; the means of the masculine dimensions are low. Thus, the second cluster has masculine characteristics and the fourth cluster has feminine characteristics. Finally, the third cluster is a cluster with low means of both feminine and masculine dimensions. Therefore, the participants of this cluster do not clearly have feminine and masculine identity characteristics. For this reason, the third cluster was named as the indifferent.

As a result of the clustering analysis, 101 of the female consumers participating in the study were in the androgynous cluster, 110 were the masculine cluster, 59 were in the undifferentiated cluster and 123 were in the feminine cluster. In addition, it was

Table 2: Exploratory factor analysis (gender identity role scale)

Items	Components							
	1	2	3	4	5	6	7	8
Soft spoken	**0.865**							
Gentle	**0.824**							
Tender	**0.816**							
Loves children	**0.800**							
Warm	**0.798**							
Kind	**0.779**							
Understanding	**0.772**							
Emotional	**0.768**							
Does not use harsh language	**0.745**							
Ambitious		**0.783**						
Sociable		**0.769**						
Analytical		**0.756**						
Assertive		**0.754**						
Authoritarian		**0.753**						
Prescriptive		**0.747**						
Willing to take risks		**0.710**						
Act as a leader		**0.641**						
Willing to take a stand			**0.784**					
Keeping one's word			**0.769**					
Self-reliant			**0.768**					
Defends own belief			**0.765**					
Strong personality			**0.737**					
Dominant			**0.707**					
Forceful			**0.694**					
Sensitive to the needs of others				**0.768**				
Responsible to my family				**0.761**				
Devoted				**0.758**				
Eager to soothe hurt feelings				**0.745**				
Generous				**0.734**				
Compassionate				**0.726**				
Heartwarming				**0.706**				
Masculine					0.708			
Impassive					0.596			
Serious						0.674		
Yielding						0.580		
Aggressive							0.725	
Shy							0.700	
Honest								0.805
Feminine	0.382*							
Loyal	0.349*							
Eigenvalue	***12.522***	***7.304***	***1.712***	***1.658***	***1.297***	***1.223***	***1.063***	1.012
Variance explained	***18.741***	***14.084***	***12.048***	***11.727***	***3.471***	***3.208***	***3.138***	3.059
Total variance							***69.477***	
Keiser-Meyer-Olkin (KMO)							***0.946***	
Barlett's Test of Sphericity							***11175.667***	
df							***780***	
Sig. (value)							***0.000***	

* Factor loads below 0.5 [35] were excluded from the analysis.

Table 3: Reliability and validity analysis results (gender identity role scale)

	α	CR	VE	Corelation Between Structures			$(AVE)^{1/2}$
				(1)	(2)	(3)	
Feminine_1 **(1)**	0.948	0.952	0.689	1			0.830
Feminine_2 **(2)**	0.920	0.917	0.615	0.646	1		0.784
Masculine_1 **(3)**	0.912	0.922	0.598	−0.188	−0.240	1	0.773
Masculine_2 **(4)**	0.937	0.935	0.673	−0.216	−0.260	0.649	0.820

Table 4: The number of participants and the cluster averages

Gender identity dimensions	Cluster 1 (androgynous)	Cluster 2 (masculine)	Cluster 3 (undifferentiated)	Cluster 4 (feminine)	F	Sig.
Feminine_1	3.99	2.03	2.10	4.03	123.134	0.000
Feminine_2	4.03	1.88	1.69	4.25	176.653	0.000
Masculine_1	3.40	3.71	2.01	1.91	87.651	0.000
Masculine_2	3.82	4.21	1.77	1.76	168.951	0.000
Number of cases (N)	101	110	59	123		

determined by the ANOVA test that the four factors obtained through the factor analysis contributed to the differentiation of the four determined clusters ($p < 0.01$).

2.3 Construct validity of the scale of female consumers' clothing-related attribute expectations

Confirmatory factor analysis was conducted to test the construct validity of the scale of female consumers' clothing-related attribute expectations. In order to test the acceptability of the model as a whole, goodness of fit values were examined and it was determined that all goodness of fit criteria of the model were good and within acceptable limits ($\chi^2/df = 1.96$; RMSEA = 0.050; SRMR = 0.042; GFI = 90; AGFI = 0.85; NNFI = 0.92; NFI = 0.90; IFI = 0.94; CFI = 0.94). Therefore, when the confirmatory factor analysis results are taken into account, it can be concluded that all items in the measurement model are compatible with the model. Table 5 shows that the CR coefficients of the dimensions of the measurement model are above 0.70 and the AVE values are above 0.50. Considering these values, it was determined that the scales used in the research had convergent validity and the first criterion of construct validity was met [36].

In order to test the discriminant validity, which is another criterion for construct validity, the square root of the mean variance explained by each factor and the correlation values between the factors were compared, and it was determined that the square root of the mean variance explained for each factor was higher than the correlation values between the dimensions (Table 6). Construct validity was provided for all scales.

After the construct validity of the measurement model was evaluated, the reliability of the scales was tested with the Cronbach's Alpha reliability coefficient. When the alpha values of the scales of the dimensions in the study were examined, it was seen that the values were higher than the recommended value of 0.70 [37].

2.4 Female consumers' clothing-related attribute expectations according to their gender identities

A one-way analysis of variance (ANOVA) was applied to determine whether women's clothing-related attribute expectations differ according to their gender identities. According to one-way ANOVA analysis, in women's clothing preferences, change, functionalism, masculinity, femininity, restraint, aestheticism, conformity, and constancy attribute expectations of female consumers differ statistically according to their gender identities. It was determined that the expectation of individuality and the freedom attribute in women's clothing preferences did not show a statistically significant difference according to their gender identities. In line with these results, hypotheses H_{2a}, H_{2c}, H_{2d}, H_{2e}, H_{2f}, H_{2g}, H_{2h} and H_{2j} were supported. H_{2b} and H_{2i} hypotheses were not supported (Table 7).

Table 5: Reliability and validity analysis results of the measurement model

Items	β
Change (CR: 0.908; AVE: 0.711; Cronbach's α: 0.907)	
I like to try new styles.	0.84
I follow fashion.	0.80
I think that various styles of clothing add excitement to my life.	0.86
I like to try different things about clothing.	0.87
Functualism (CR: 0.909; AVE: 0.71; Cronbach's α: 0.906)	
When buying a coat for cold winter days. keeping warm is important to me.	0.82
When purchasing clothes. the quality is important to me.	0.84
When buying clothes. I prefer healthy fabrics and products that will not harm me physically.	0.88
When buying clothes. it is important to me that they can be used for a long time.	0.84
Masculinity (CR: 0.861; AVE: 0.675; Cronbach's α: 0.859)	
I like to wear clothes made of sturdy. tightly woven materials.	0.76
I prefer hard fabrics over soft fabrics.	0.85
I prefer clothes that accentuate the shoulders.	0.85
Femininity (CR: 0.826; AVE: 0.616; Cronbach's α: 0.822)	
I love floral print clothes.	0.78
I like fancy dresses.	0.89
I prefer feminine clothes.	0.67
Restraint (CR: 0.836; AVE: 0.633; Cronbach's α: 0.834)	
I like that my clothes fit my body comfortably.	0.76
I like tight clothes. So I can feel them in my body.	0.92
I like tight-fitting clothes.	0.69
Aestheticism (CR: 0.724; AVE: 0.487; Cronbach's α: 0.705)	
I like to use various colors together when choosing clothes.	0.64
When I look at old paintings or photographs. I am fascinated by the beauty of the clothes of that period.	0.86
Local clothes catch my attention.	0.53
Individuality (CR: 0.838; AVE: 0.635; Cronbach's α: 0.835)	
I don't mind if my clothes are the same as what my friends wear.	0.69
I never dress alike with my friends.	0.84
It makes me uncomfortable to dress similarly to others in my group.	0.85
Conformity (CR: 0.835; AVE: 0.563; Cronbach's α: 0.833)	
My dressing style is similar to those around me.	0.62
To gain acceptance in a group. it is important to wear the right attire to comply with the group.	0.80
In a business setting. a person should dress similarly to other employees.	0.89
When a new fashion trend emerges. I and my friends try it.	0.66
Freedom (CR: 0.801; AVE: 0.573; Cronbach's α: 0.804)	
When buying a dress. it is important for me to be able to move freely in it.	0.72
I like comfortable clothes that I feel like I'm not wearing them.	0.79
I buy clothes that are comfortable and large enough to be able to move easily and freely.	0.76
Constancy (CR: 0.894; AVE: 0.679; Cronbach's α: 0.894)	
I don't like constantly changing my hairstyle and color.	0.76
I can buy different colors of the clothes. style of which I like.	0.87
Most of my clothes are in the same style.	0.86
Over the years, I think I have developed a style of dressing.	0.80

[a] Reverse code item

Table 6: Correlations between factors and discriminant validity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	$(AVE)^{1/2}$
Change **(1)**	1									0,843
Functionalism **(2)**	0.026	1								0.842
Masculinity **(3)**	−0.070	0.061	1							0.821
Femininity **(4)**	0.155	−0.173	−0.163	1						0.784
Restraint **(5)**	0.182	−0.008	−0.046	0.092	1					0.795
Aestheticism **(6)**	0.103	0.105	0.045	0.059	0.299	1				0.697
Individuality **(7)**	0.110	−0.085	0.089	0.069	0.084	0.077	1			0.796
Conformity **(8)**	−0.080	0.088	0.192	−0.017	−0.049	0.064	−0.066	1		0.750
Freedom **(9)**	0.123	0.194	−0.068	−0.024	0.084	0.137	−0.128	0.026	1	0.756
Constancy **(10)**	0.003	0.213	0.122	−0.106	0.007	0.076	0.022	0.197	−0.034	0.824

Table 7: Hypotheses testing (ANOVA analysis results)

Dependent variable	df	F-statistic	Sig.	Independent groups (Mean)	Mean difference	Sig.
Change	3	12.806*	.000	Androgynous (3.77) / Masculine (3.19)	0.579*	.001
				Androgynous (3.77) / Feminine (3.83)	−0.061	.974
				Androgynous (3.77) / Undifferentiated (3.03)	0.734*	.000
				Masculine (3.19) / Feminine (3.83)	−0.640*	.000
				Masculine (3.19) / Undifferentiated (3.03)	0.155	.806
				Feminine (3.83) / Undifferentiated (3.03)	0.795*	.000
Functionalism	3	12.807*	.000	Androgynous (3.79) / Masculine (3.96)	−0.169	.723
				Androgynous (3.79) / Feminine (3.15)	0.635*	.005
				Androgynous (3.79) / Undifferentiated (3.14)	0.643*	.005
				Masculine (3.96) / Feminine (3.15)	0.804*	.000
				Masculine (3.96) / Undifferentiated (3.14)	0.813*	.000
				Feminine (3.15) / Undifferentiated (3.14)	0.008	.999
Masculinity	3	37.062*	.000	Androgynous (3.43) / Masculine (3.97)	−0.540*	.003
				Androgynous (3.43) / Feminine (2.70)	0.728*	.000
				Androgynous (3.43) / Undifferentiated (2.96)	0.475**	.049
				Masculine (3.97) / Feminine (2.70)	1.268*	.000
				Masculine (3.97) / Undifferentiated (2.96)	1.015*	.000
				Feminine (2.70) / Undifferentiated (2.96)	−0.253	.484
Femininity	3	24.506*	.000	Androgynous (3.50) / Masculine (2.80)	0.695*	.000
				Androgynous (3.50) / Feminine (3.96)	−0.459**	.012
				Androgynous (3.50) / Undifferentiated (2.94)	0.555**	.013
				Masculine (2.80) / Feminine (3.96)	−1.155*	.000
				Masculine (2.80) / Undifferentiated (2.94)	−0.140	.862
				Feminine (3.96) / Undifferentiated (2.94)	1.015*	.000
Restraint	3	2.926**	.038	Androgynous (3.47) / Masculine (3.30)	0.166	.636
				Androgynous (3.47) / Feminine (3.68)	−0.213	.402
				Androgynous (3.47) / Undifferentiated (3.58)	−0.106	.919
				Masculine (3.30) / Feminine (3.68)	−0.379**	.024
				Masculine (3.30) / Undifferentiated (3.58)	−0.272	.345
				Feminine (3.68) / Undifferentiated (3.58)	0.106	.912
Aestheticism	3	5.708*	.001	Androgynous (3.97) / Masculine (3.58)	0.385*	.010
				Androgynous (3.97) / Feminine (3.52)	0.445*	.001
				Androgynous (3.97) / Undifferentiated (3.52)	0.448**	.013
				Masculine (3.58) / Feminine (3.52)	0.059	.958
				Masculine (3.58) /Undifferentiated (3.52)	0.062	.973
				Feminine (3.52) / Undifferentiated (3.52)	0.003	.999

Dependent variable	df	F-statistic	Sig.	Independent groups (Mean)	Mean difference	Sig.
Individuality	3	1.035$^{n.s.}$	.377	Androgynous (2.78) / Masculine (2.90)	−0.117	.889
				Androgynous (2.78) / Feminine (2.87)	−0.090	.941
				Androgynous (2.78) / Undifferentiated (2.58)	0.194	.748
				Masculine (2.90) / Feminine (2.87)	0.027	.998
				Masculine (2.90) / Undifferentiated (2.58)	0.312	.361
				Feminine (2.87) / Undifferentiated (2.58)	0.285	.427
Conformity	3	17.298*	.000	Androgynous (3.19) / Masculine (3.57)	−0.384**	.032
				Androgynous (3.19) / Feminine (2.63)	0.556*	.000
				Androgynous (3.19) / Undifferentiated (2.96)	0.231	.507
				Masculine (3.57) / Feminine (2.63)	0.941*	.000
				Masculine (3.57) / Undifferentiated (2.96)	0.615*	.001
				Feminine (2.63) / Undifferentiated (2.96)	−0.325	.180
Freedom	3	1.613 $^{n.s.}$	.186	Androgynous (3.73) / Masculine (3.79)	−0.0051	.978
				Androgynous (3.73) / Feminine (3.99)	−0.255	.180
				Androgynous (3.73) / Undifferentiated (3.81)	−0.074	.963
				Masculine (3.79) / Feminine (3.99)	−0.203	.350
				Masculine (3.79) / Undifferentiated (3.81)	−0.022	.999
				Feminine (3.99) / Undifferentiated (3.81)	0.181	.616
Constancy	3	17.448*	.000	Androgynous (3.54) / Masculine (4.02)	−0.482*	.010
				Androgynous (3.54) / Feminine (3.17)	0.370	.048
				Androgynous (3.54) / Undifferentiated (2.88)	0.661*	.002
				Masculine (4.02) /Feminine (3.17)	0.852*	.000
				Masculine (4.02) / Undifferentiated (2.88)	1.143*	.000
				Feminine (3.17) / Undifferentiated (2.88)	0.291	.357

*p < 0.01; ** p < 0.05; $^{n.s.}$ > 0.05 (not supported)

In addition, the Tukey test was used to determine which sub-groups differed among these groups. The Tukey test results have shown that in clothing preferences, androgynous and feminine identities, placed more importance on change and femininity in comparison to masculine and undifferentiated identities. Functionalism and masculinity in clothing preference is higher in androgynous and masculine groups than feminine and undifferentiated ones. Restraint expectation is higher in feminine than in masculine groups. Androgynous identities also prefer aesthetic clothing more than other gender identities. Masculine and androgynous groups care more about the conformity of the clothes than the feminine and undifferentiated groups. Finally, masculine identities prefer constancy in their clothing preferences more than other gender identities.

3 Discussion

The results of the study are discussed in terms of four basic issues; socio-demographic characteristics of the sample, scales, hypotheses and limitations of the study.

The analysis of the socio-demographic characteristics of the sample showed that 46.1% of the sample were 17–29 years old, 20.9% were 30–39 years old, 13.7% were 40–49 years old, 19.3% of the sample were 50 and over. In addition, 6.1% of the sample had completed primary school-secondary school education, 27.2% were high school graduates, 9.7% had obtained an associate degree, 45.5% had an undergraduate degree and 11.5% were postgraduate education graduates.

In terms of scales, it was determined that construct validity was provided for both the Clothing-related Attribute Expectations scale and Bem Gender Identity scale. In the present study, two dimensions – modesty and exhibitionism- were excluded from the original Clothing-related Attribute Expectations scale because items of these dimensions were supposed to be inappropriate in terms of cultural and social aspects. The original Bem Gender Identity scale has two dimensions- masculine and feminine-, but in this study both of these dimensions were divided into two different dimensions. In other words, the gender identity scale consisted of four dimensions. They were named as Feminine_1, Feminine_2, Masculine_1 and

Masculine_2. The results of the analysis showed that both scales are reliable and valid. Thus, it can be concluded that both scales had measured what structures they intended to measure.

When participants' gender identities were examined, it was found that four different types of gender identity- masculine, feminine, undifferentiated, androgynous- existed as stated in the original Bem Gender Identity Inventory. This finding supported the previous studies [4, 13, 21]. Women with different gender identities have different kinds of clothing-related attribute expectations. Women's individuality and freedom expectation do not differ regarding their gender identities, but the other clothing-related attribute expectations (change, functionalism, masculinity, femininity, restraint, aestheticism, conformity, constancy) change according to gender identities. As stated in the conceptual framework and research hypotheses, all of these four gender identities exhibit different characteristics and clothing is a way of showing one's characteristics to the world. Thus, it can be said that each of these four gender identities choose their clothes considering their own clothing-related attribute expectations.

When comparing clothing-related attribute expectations, it can be concluded that aestheticism is an attribute expected mostly by androgynous consumers. Constancy in clothing is mostly preferred by masculine consumers. In other words, they do not prefer to change the style they wear. Restraint is an attribute expected by feminine consumers. In other words, they like to wear tight clothing. Conformity is a preferred attribute in the clothing preference of masculine and androgynous groups compared with feminine and undifferentiated consumers. Compared to masculine and undifferentiated consumers, androgynous and feminine consumers expect change and femininity when choosing clothing. Functionalism and masculinity is important for masculine and androgenous consumers more than feminine and undifferentiated ones. These results support the conclusion that clothing preferences change according to gender identities obtained via the studies conducted by Aiken [30], Guy and Benim [29], Goodman et al. [8] and Kaya [31]. In short, 9 of the 11 research hypotheses developed to examine the direct relation between the variables were supported, but two were not supported.

The main limitation of this study is that sample only consisted of female consumers. Male consumers might have different gender identities than female consumers and their clothing preferences and clothing-related attribute expectations might change based on their gender identities. Thus, future studies could investigate their behaviour and also compare female and male customers in terms of their gender identities and clothing preferences. The current study focuses on abstract clothing-related attributes such as conformity, constancy and individuality. Future studies could investigate whether physical clothing-related attributes such as fabric, color, pattern, texture, styling, care and workmanship differ according to consumers' gender identities. To expand the scope of the relationship between fashion and gender identity, the value of incorporating feminine features into menswear and masculine features into womenswear for consumers who are androgenous or undifferentiated could be identified by examining such clothing styles as unisex clothing. The moderating effect of gender identity between clothing-related attributes and variables such as willingness to buy, brand loyalty, and attitude towards a brand could be investigated. Another research area would be the importance of gender identity in consumer segmentation. Validation of scales could be provided through studies conducted in different cultural settings. This study is in the context of ready-made clothing, but consumers' gender identities could be examined in terms of other contexts such as tourism, food and electronic preferences.

The other limitation is the sampling method. The convenience sampling method was used to form the sample of the study, but instead of this method, the quota sampling method might be used based on the other demographic factors such as income, age, gender, education, since these are also effective in consumers' behavior.

4 Conclusion

The direct relation between the clothing-related attribute expectations and gender identities was investigated. First, female consumers' gender identities were determined as masculine, feminine, undifferentiated, androgynous. Then, the question of whether female consumers' clothing-related attribute expectations differ according to their gender identities was examined. It was found that women's clothing-related attribute expectations differ according to their gender identities. Aside from individuality and freedom expectations, the other clothing-related attribute expectations (change, functionalism, masculinity, femininity, restraint, aestheticism, conformity, constancy) change in accordance to women's gender identities. Since no study has been found in this context, it is expected to contribute to the field both academically and managerially.

Firstly, the theoretical significance of this study lies in the variables examined. Although there are various studies in the ready-made clothing sector, they mostly investigate consumers' clothing preferences and their purchase decisions. The underlying clothing-related attribute expectations have not been investigated. The present study examined female consumers' clothing preferences in terms of clothing-related attribute expectations and gender identity. Since the main focus is whether clothing-related attribute expectations change in regards to gender identities, this study makes a major contribution to the marketing literature. Secondly, in the original Bem Gender Identity Inventory, there are two dimensions called masculine and feminine. But in this study both masculine and feminine characteristics are divided into two. Thus, gender-identity-items illustrate four dimensions. In this respect, the study contributes to the literature.

Biological gender is not the only a factor that affects people's attitudes, expectations and behavior, but gender identity is also effective in these aspects. Today, many clothing brands produce and sell clothing for men and women. In a life where there are so many differences, it is not enough to separate and define the concept of gender as male and female only. Clothing-related attribute expectations affecting clothing preferences vary according to gender identities. Thus, it can be said that unisex clothing, which emerged and became widespread in the 1960s, is a response to the individuals' clothing-related needs and wants arising from their differing gender identities. Today, although feminine style clothing maintains a secure place in women's clothing fashion as masculine style clothing does in men's clothing fashion, unisex clothing has become quite a fashion favorite. In this respect, understanding the importance of gender identity differences in clothing preferences will help clothing firms, brands and managers better understand consumers' gender identities and its effects on their behaviors. Understanding consumers' gender identities and its effects on their behaviors can lead managers to develop innovative strategies attracting the consumers and to design and produce specific clothing for each gender identity. It can be said that consumers might feel precious and unique. Thus, brands or companies can motivate consumers and gain profits through increased sales. In short, this study provides managerial evidence.

References

1. KILIÇER, T., BOYRAZ, E., TÜZEMEN, A. Kadın, erkek, ya da? Hediye satın alma davranışlarında cinsiyet kimliği rolünün etkisi. *Ege Akademik Bakış*, 2016, **16**(1), 121–133, https://hdl.handle.net/20.500.12881/10997.
2. ÇETIN, K. Satın alma davranışlarında kadınların giysi markası tercihlerini etkileyen faktörler. *Uluslararası Turizm, Işletme, Ekonomi Dergisi*, 2018, **2**(2), 354–366, https://dergipark.org.tr/en/download/article-file/619435.
3. ÇABUK, S., KÖKSAL A.S. Psikografik bir pazar bölümlendirme değişkeni olarak cinsiyet kimliği: Tüketim araştırmalarında cinsiyet kimliği kavramının incelenmesi. *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 2013, **22**(2), 27–40 https://dergipark.org.tr/en/pub/cusosbil/issue/4393/60444.
4. YAĞCI, M.I., ILARSLAN, N. Reklamların ve cinsiyet kimliği rolünün tüketicilerin satın alma davranışları üzerindeki etkisi. *Doğuş Üniversitesi Dergisi*, 2010, **11**(1), 138–155, doi: 10.31671/dogus.2019.183.
5. TOSUN, N.B. Reklam aracı olarak kadın. *Kadın Çalışmaları Dergisi*, 2006, **1**(1), 88–93.
6. YENIÇERI, T., ÖZAL, H. Tüketici karar verme tarzlarının cinsiyet kimliğine göre incelenmesi. *Pazarlama ve Pazarlama Araştırmaları Dergisi*, 2016, **9**(18), 135–168.
7. YE L., BOSE M., PELTON L.E. *How gender identity affects consumer behavior: Overview and future research: an abstract*. In *Finding New Ways to Engage and Satisfy Global Customers. AMSWMC 2018. Developments in Marketing Science: Proceedings of the Academy of Marketing Science*. Edited by P. Rossi and N. Krey. Springer, Cham, 2019, doi: 10.1007/978-3-030-02568-7_111.
8. GOODMAN, J., KNOTTS, G., JACKSON, J. Doing dress and the construction of wom-

en's gender identity. *Journal of Occupational Science*, 2007, **14**(2), 100–107, doi: 10.1080/14427591.2007.9686590.
9. PRICE, M., SKOLNIK, A. Gender identity. In *The SAGE encyclopedia of psychology and gender*. Edited by Kevin L. Nadal. SAGE Publications, 2017, doi: 10.4135/9781483384269.
10. BEM, S. L. Gender schema theory: a cognitive account of sex typing. *Psychological Review*, 1981, **88**(4), 354–364, doi: 10.1037/0033-295X.88.4.354.
11. NEALE, L., ROBBIE, R., MARTIN, B. Gender identity and brand incongruence: when in doubt, pursue masculinity. *Journal of Strategic Marketing*, 2016, **24**(5), 347–359, doi: 10.1080/0965254X.2015.1011203.
12. PALAN, K. M. Gender identity in consumer behaviour research: a literature review and research agenda. *Academy of Marketing Science*, 2001, **2001**(10), 1–24.
13. BEM, S. L. The measurement of psychological androgyny. *Journal of Consulting and Clinical Psychology*, 1974, **42**(2), 155–162, doi: 10.1037/h0036215.
14. LEINBACK, M. D., HORT, B. E., FAGOT, B. I. Bears are for boys: metaphorical associations in young children's gender stereotypes. *Cognitive Development*, 1997, **12**(1), 107–130, doi: 10.1016/S0885-2014(97)90032-0.
15. LEINBACK, M. D., FAGOT, B. I. Categorical habituation to male and female faces: Gender schematic processing in infancy. *Infant Behaviour and Development*, 1993, **16**(3), 317–332, doi: 10.1016/0163-6383(93)80038-A.
16. EYSENCK, M. W. *Psychology: an international perspective*. Sussex : Psychology Press, 2004.
17. SPENCE, J. T. Gender-related traits and gender ideology: evidence for a multifactorial theory. *Journal of Personality and Social Psychology*, 1993, **64**(4), 624–635, doi: 10.1037/0022-3514.64.4.624.
18. PIRA, A., ELGÜN A. Toplumsal cinsiyeti inşa eden bir kurum olarak medya: reklamla aracılığıyla ataerkil ideolojinin yeniden üretilmesi. In *2nd International symposium communication in the millennium: a dialogue between Turkish and American scolars,* 2004, https://docplayer.biz.tr/4280402-Toplumsal-cinsiyeti-insaa-eden-bir-kurum-olarak-medya-reklamlar-araciligiyla-ataerkil-ideolojinin-yeniden-uretilmesi.html.
19. MEYERS-LEVY, J. Influence of sex roles on judgement. *Journal of Consumer Research*, 1988, **14**(4), 522–530, doi: 10.1086/209133.
20. YE, L., ROBERTSON, T. M. A. Gender identity: does it matter for consumers' perceptions? *Journal of Business Diversity*, 2012, **12**(3), 81–92.
21. GÖRMÜŞ, A. Ş., AYDIN, S., ERGIN, G. Işletme bölümü öğrencilerinin iletişim becerilerinin cinsiyet rolleri bağlamında incelenmesi. *Sosyal Bilimler Dergisi*, 2013, **15**(1), 109–128, doi: 10.5578/JSS.6357.
22. YURTTAKALAN, D., GELIBOLU, L. Internetten satın alımlarda cinsiyet kimliğinin rolü: z kuşağı örneği. *KAÜIIBFD*, 2019, **10**(20), 858–880, doi: 10.36543/kauiibfd.2019.036.
23. KARLOOFF, N. I. *Clothing-related attitudes and the body image as perceive and expressed by business and professional women: dissertation.* Ohio State University, 1979.
24. MORRIS, D. *Man watching: a field guide to human behavior.* New York : Harry N. Abrams, 1977.
25. BROWN, H. D. *Principles of language learning and teaching.* White Plains, NY : Pearson Education, 2007.
26. ALIAKBARI, M., ABDOLLAHI, K. Does it matter what we wear? A socialinguistic study of clothing and human values. *International Journal of Linguistics*, 2013, **5**(2), 34–45, doi: 10.5296/ijl.v5i2.3051.
27. CRANE, D. *Fashion and its social agendas. Class, gender and identity in clothing.* Chicago : University of Chicago Press, 2000.
28. ENTWISTLE, J. *The fashioned body: fashion, dress and modern social theory.* Polity Press, 2000.
29. GUY, A., BANIM, M. Personal collections: Women's clothing use and identity. *Journal of Gender Studies*, 2000, **9**(3), 313–327, doi: 10.1080/713678000.
30. AIKEN, L. R. The relationships of dress to selected measures of personality in undergraduate women. *The Journal of Social Psychology*, 1963, **59**(1), 119–128, doi: 10.1080/00224545.1963.9919417.
31. KAYA, Ö. Moda ve giyinme yoluyla cinsiyetsiz moda. In *14. Uluslararası Türk Sanatı, Tarihi ve Folkloru Kongresi.* 2020, https://www.researchgate.net/publication/348013518_MODA_VE_GIYINME_YOLUYLA_CINSIYETSIZ_MODA.
32. BEM, S. L. Theory and measurement of androgyny: a reply to the Pedhazur-Tetenbaum and Locksley-Colten critiques. *Journal of Personality and Social Psychology*, 1979, **37**(6), 1047–1054, doi:10.1037/0022-3514.37.6.1047.
33. DÖKMEN, Z. Y. Bem cinsiyet rolü envanteri kadınsılık ve erkeksilik ölçekleri Türkçe for-

munun psikometrik özellikleri. *Kriz Dergisi*, 1999, **7**(1), 27–40, doi: 10.1501/Kriz_0000000139.
34. TABACHNICK, B. G., FIDELL, L. S. *Using multivariate statistics.* 4th Ed. Needham Heights : Allyn & Bacon, 2001.
35. HAIR, J.F., BLACK, W.C., BABIN, B.J., ANDERSON, R.E. *Multivariate data analysis*. 7th Ed. New York : Pearson, 2010.
36. SCHERMELLEH-ENGEL, K., MOOSBRUGGER, H., MÜLLER, H. Evaluating the fit of structural equation models: tests of significance and descriptive goodness-of-fit measures. *Methods of Psychological Research,* 2003, **8**(2), 23–74.
37. NUNNALLY, J.C., BERNSTEIN, I.H. The assessment of reliability. *Psychometric Theory*, 1994, **3**, 248–292.
38. ANDERBERG, M.R. *Cluster analysis for applications.* New York : Academic Press, 1973, 553-555.
39. ÖZDAMAR, K. *Paket programlar ile istatistiksel veri analizi.* Eskişehir: Kaan Kitabevi, 2004.

Pragati Bajpai[1], *Utpal Jana*[2], *Saminathan Ratnapandian*[3]
[1] *Uttar Pradesh Textile Technology Institute, Kanpur, 208001, India*
[2] *Indian Institute of Handloom Technology, Salem, Tamil Nadu, 636001, India*
[3] *Kumaraguru College of Technology, Department of Textile Technology, Coimbatore, 641049, India*

Assessment of Changes in Corn Husk Fibres after Acid Treatment

Ocena sprememb kislinsko obdelanih vlaken iz koruznega ličja

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 12-2021 • Accepted/*Sprejeto* 2-2022

Corresponding author/*Korespondenčni avtor:*
Assoc Prof. Saminathan Ratnapandian, PhD
E-mail: saminathan.r.txt@kct.ac.in
Phone: +91 7358242846
ORCID ID: 0000-0003-2905-2333

Abstract

Sustainability is desirable in any activity, including farming. Adding value to agricultural wastes such as stover (waste from corn cultivation) would provide financial benefits to farmers while reducing the environmental load of disposal. The literature identifies stover as being a raw material for bio-ethanol and a reinforcement for composites. Fibre from corn husks is generally extracted using an alkali digestion method followed optionally by enzymatic degradation. In this study, acid treatment was investigated for its feasibility to improve the desirable characteristics of alkali extracted corn husk fibres. The results revealed that increasing the acid concentration decreased fibre properties such as average fibre length, linear density and elongation at break. However, breaking tenacity achieved a maximum value, on treatment with 7.5 g/l sulfuric acid, before decreasing. These properties indicate the treatment's adequacy for use in textile products. Acid treatment did not significantly alter thermo-gravimetric analysis values, indicating that the fibre could withstand wet processing conditions.
Keywords: acid treatment, alkali digestion, corn husk, hemicelluloses, lignin, thermogravimetry, TGA

Izvleček

Trajnost je zaželena pri vseh dejavnostih, vključno s kmetijstvom. Dodana vrednost kmetijskih odpadkov, kot so rastlinski ostanki pri pridelavi koruze, bi kmetom zagotovila finančne koristi, hkrati pa zmanjšala obremenitev okolja zaradi odlaganja. Literatura navaja možnosti za uporabo rastlinskih ostankov kot surovino za bioetanol in ojačitev kompozitov. Vlakna iz koruznega ličja po navadi ekstrahirajo z alkalno obdelavo, ki ji lahko sledi še encimska obdelava. V tej študiji je bila raziskana primernost kislinske obdelave za izboljšanje želenih lastnosti alkalno ekstrahiranih vlaken iz koruznega ličja. Pokazalo se je, da so se s povečanjem koncentracije kisline poslabšale lastnosti vlaken, kot so povprečna dolžina, linearna gostota in pretržni raztezek. Najvišja trdnost vlaken je bila dosežena pri koncentraciji 7,5 g/l žveplove VI. kisline in se je z naraščanjem koncentracije začela zniževati. Vlakna so po lastnostih primerna za uporabo v tekstilnih izdelkih. Kislinska obdelava ni bistveno spremenila obstojnosti vlaken pri povišani temperaturi, kar kaže, da so obstojna v razmerah mokrih obdelav.
Ključne besede: kislinska obdelava, alkalna razgradnja, koruzno ličje, hemiceluloze, lignin, termična gravimetrija, TGA

1 Introduction

Nowadays, there is a significant global focus on sustainability, wherein conservation of non-renewable resources is of prime importance. This concept has urged governments, the academia and civil bodies to promote the utilization of renewable natural raw materials. Consequently, such products would be based on sustainable resources, be biodegradable or recyclable and not cause harmful emissions during production, service, or end-of-life disposal [1, 2].
Cotton is the single largest natural cellulosic fibre supplying the global demand of the textile and clothing sectors. The main reason for this is its superior wearer comfort properties. A growing world population needs both clothing and food for its survival. Hence, there is competition for agricultural land between these two basic requirements. This has resulted in intense research being conducted on alternative natural fibres such as flax, sisal, jute, kenaf and hemp [3]. It should be noted that the cultivation of these fibres also needs agricultural land. Hence, lignocellulosic agricultural by-products offer a desirable low-cost alternate source of cellulosic fibres [4].
During the last few decades, lignocellulosic fibres have been considered as substitutes for conventional man-made fibres and for application in fields such as transportation, construction and packaging, in both the academic and commercial arena. These short or long fibres can be used in the form of particulates for fillers, as they possess the properties, composition, structures and features necessary for reinforcements or fillers for polymer composites [5–8]. Utilizing agricultural residues as a fibre source would provide significant benefits for the environment by preventing incineration on the fields. Furthermore, the extra income would benefit the agricultural community [9–11]. The use of farming residues is promising in terms of cost and infrastructure. Production expenditures and land rent are generally covered by the costs of the primary crop. In terms of the infrastructure, farmers or crop processors already have the knowledge, experience, and technology to handle most of the agricultural residues, including corn husks [12–14].
Wheat and barley straw, corn husk, okra, sunflower, corn and nettle stalk and empty banana bunches are examples of agricultural residues that researchers have investigated as sources of fibres [15]. Corn husk has been the subject of limited research in terms of being a fibre source [9, 16]. This is contrary to the abundant availability of corn, the most widely grown grain in the world. Hence, corn husk offers excellent opportunities for research as a source of sustainable fibre [17–19].
The by-products of corn cultivation, namely stalk (50%); leaves (23%), cob (14%) and husk (13%), are commonly termed stover. Stover is usually fed to cattle or more often burnt in the field or used as fuel. Utilization of this by-product would benefit both farmers by providing additional value and the environment by reducing the pollution load of burning. Corn husks, also known as ears or shucks, are fibrous structures that can be up to 20 cm in length and are traditionally used for decoration, food wrapping, and other applications [20–22]. In order to utilize corn husks as a source of fibre, common extraction procedures used for lignocellulosic sources should be considered.
All natural cellulosic fibres other than cotton and kapok are multicellular, with a bundle of individual cells bound by natural polymers such as hemicellulose, cellulose and lignin [17, 20, 23]. The proportion of these components varies depending on age and growing conditions. Fibre characteristics are additionally affected by the extraction parameters employed. Corn husks are composed of about 42% cellulose, 13% lignin, 4% ash and 41% hemicellulose. Similar to bast fibres, the constituents other than ligno-cellulosic fibre can be removed by alkalization [24–26]. Cellulosic fibres are extracted from ligno-cellulosic by-products by using biological, mechanical and chemical methods. The traditional retting process uses bacteria (Bacillus and Clostridium) and fungi (Rhizomucor *pusillus* and Fusarium *lateritium*) found in the environment to remove lignin, pectin and other substances. This process is relatively time consuming and it is difficult to control fibre quality. Alternately, chemical retting uses alkali (sodium hydroxide), mild acids (oxalic acid) and enzymes for fibre extraction. Chemical concentration, temperature and duration of treatment are the main factors determining the quality of extracted fibres [27, 28]. Dilute sulfuric acid is used to hydrolyze hemi-celluloses [29]. Reddy et al. have reported on corn husk fibre extraction by combining alkali digestion and enzyme treatment [30].
The main objective of this study was to observe the effect of acid treatment on alkali extracted corn husk fibre. The extractable fibre content was measured.

Essential physical properties and thermal stability of the fibres were determined according to relevant standards and by using appropriate instruments.

2 Materials and methods

2.1 Materials

Corn husks were collected from farms in the Salem district, Tamilnadu, India. Both outer (matured) and inner (younger) husk leaves were collected after field drying. These husks were grey in color. Sodium hydroxide (100%), acetic acid (98%) and sulfuric acid (98%) were of LR grade and sourced from Sigma Aldrich.

2.2 Methods

2.2.1 Alkaline fibre extraction

10 grams of husk were treated with 10 grams per liter (g/l) of sodium hydroxide at a material to liquor ratio (mlr) of 1:20. The alkali solution was heated to 90 °C before adding the bundle of husks. Treatment was carried out for 30 minutes at boiling temperature. This was followed by rinsing with water at 60 °C and then with water at room temperature. The alkalized samples were neutralized with 2.5 g/l acetic acid at 50 °C and finally washed. The sample was combed using fingers to loosen the fibres and dislodge very short fibres. Subsequent washing removed the impurities. The resultant fibres were dried under ambient conditions and weighed to determine fibre realization. The experiment was conducted in triplicate and the average result is reported.

2.2.2 Acid treatment

Fibres extracted in the previous step were treated, in triplicate, with sulfuric acid to remove residual lignin and hemicellulose. Individual samples weighing 10 grams were treated with sulfuric acid at concentrations of 5, 7.5 and 10 g/l. Consistent treatment parameters of mlr 1:20, temperature 60 °C and time 30 minutes were employed for all three concentrations. The treated fibres were washed twice with water followed by room temperature drying. The weight of fibres before and after treatment was compared to determine the degree of removal of impurities.

2.2.3 Characterization

All samples were conditioned under standard atmosphere of 21 °C and 65% RH for 24 hours prior to characterization. Physical properties such as length, linear density, breaking strength, elongation and moisture content of the extracted fibres were determined in accordance with ASTM standard methods listed in Table 1.

Breaking tenacity was measured using a Tinius Olsen H1KS tester. A crosshead speed of 15 mm/min, gauge length of 2.54 cm. and a 10 N load cell were used. The moisture regain in the fibres was measured using an ETARDY Model 82 & 82/R10 machine. Thermo gravimetric analyses were carried out using a Perkin Elmer TGA analyzer under flowing nitrogen atmosphere (20 ml/min). The samples were scanned from 50 °C to 450 °C at a heating rate of 30 °C/min. The analyses were performed with about 4 mg of air-dried samples.

Table 1: Test methods employed for fibre characterization

Sample no.	Property	Test method
1	Linear density	ASTM D1577-07
2	Breaking tenacity	ASTM D 3822-07
3	Moisture regain	ASTM D 2495-07

3 Results and discussion

3.1 Husk to fibre ratio by alkalization

Alkali treatment yielded 26–28% fibres on the initial weight of corn husks. This is consistent with the work reported by Sari et al [31].

3.2 Weight loss by acid treatment

Table 2 presents the weight loss percentage after treatment at evaluated acid concentrations. The weight loss indicates the removal of impurities such as hemicellulose and lignin and is viewed to be directly related to acid concentration. It may be assumed that the cellulose content was not affected since cellulose is not dissolved by sulfuric acid below 50% (W:W) concentration.

Table 2: Weight loss after acid treatment

Sample no.	H_2SO_4 (g/l)	Weight loss (%)
1	5	9.33
2	7.5	12.53
3	10	13.33

3.3 Fibre length

Length is an important property of textile fibres. In general, a longer fibre is preferred because it confers a number of advantages in the spinning process. Acid treatment reduces fibre length as reported by other researchers [32, 33]. This is commonly attributed to the removal of a large portion of non-cellulosic constituents that glue the fibres together. Average fibre length at different treatment stages shown in Table 3 reveals the inverse relationship between acid concentration and average fibre length. Milder treatment results in longer fibres. Table 4 confirms that corn husk fibre length falls between that of cotton and other vegetable fibres. It should be noted that both alkali and acid-treated fibres have sufficient length to be converted into spun yarns.

Table 3: Fibre length after different treatments

Treatment	Average length (cm)
Alkalized (control)	25.7
H_2SO_4, 5 g/l	24.2
H_2SO_4, 7.5 g/l	19.1
H_2SO_4, 10 g/l	19.9

Table 4: Fibre length comparison

Fibre type	Length (cm)
Cotton	1.6–6.96
Husk fibre	9.5–35.5
Flax	up to 90
Jute	100–400
Hemp	up to 400
Sisal	up to 100

3.4 Linear density

Fineness or linear density is commonly measured in mass per unit length. It influences yarn properties and the resultant fabric properties. Table 5 shows that acid treatment reduced the linear density of corn husk fibres. The degree of reduction is proportional to the concentration of sulfuric acid (H_2SO_4) used. The initial average linear density of 61.7 tex of alkali extracted fibres was reduced to 30.5 tex by acid treatment. A probable reason is the removal of non-cellulosic constituents.

Table 5: Linear density of alkalized and acid treated fibres

Treatment	Linear density (tex)
Alkalized	61.7
H_2SO_4, 5 g/l	43.8
H_2SO_4, 7.5 g/l	38.6
H_2SO_4, 10 g/l	30.5

3.5 Moisture regain

Similar to fineness, moisture regain was reduced after acid treatment in direct proportion to acid concentration. As shown in Table 6, the value is more than that of cotton and less than those of other bast fibres. Table 6 clearly indicates that increasing acid concentration significantly affects the moisture regain values.

Table 6: Comparison of moisture regain of plant fibres

Type of fibre	Moisture regain (%)
Alkalized corn husk	13.5
Acid (H_2SO_4) treated corn husk, 5 g/l	9.7
Acid (H_2SO_4) treated corn husk, 7.5 g/l	10.2
Acid (H_2SO_4) treated corn husk, 10 g/l	11.8
Jute	13.0
Flax	12.0
Cotton	8.5

3.6 Breaking strength and elongation

A fibre must possess sufficient strength to be processed into a textile material. It is widely accepted that a single fibre strength of 5 grams per denier is necessary for a textile fibre although, in exceptional cases, fibre strength around 1.0 gram per denier have been employed [17, 34].

The changes in tenacity and elongation-at-break shown in Table 7 reveal that with an increase in acid concentration, the tensile strength reaches its maximum at the concentration of 7.5 g/l. This may be due to the removal of weak cross-linking material and increased constituent fibre attenuation. The strength became less at higher concentration (10 g/l), probably caused by damage of critical gluing components. Elongation at break reduces at higher acid concentrations.

Table 7: Breaking tenacity and elongation of corn husk fibre

Treatment	Breaking tenacity (cN/tex)	Elongation at break (%)
Alkalized	16.09	7.84
H_2SO_4, 5g/l	16.15	6.91
H_2SO_4, 7.5 g/l	17.98	6.08
H_2SO_4, 10 g/l	13.34	4.16

3.7 Thermal stability

Fibres used in textiles must withstand wet and dry heat, resist ignition on exposure to a flame and preferably self-extinguish when the flame is removed. Heat stability is essential during the manufacturing processes of dyeing and finishing and during cleaning and general maintenance by the consumer. Thermo-gravimetric analysis assesses the change in mass as temperature is increased. Figure 1 indicates that the alkalized and acid treated fibre samples show similar trends of thermal degradation. The initial weight loss observed up to 110 °C is due to moisture evaporation. The degradation of hemicelluloses and other impurities occurred from 250–300 °C whereas cellulose decomposed between 300 and 355 °C. The more thermally stable lignin decomposed at elevated temperatures between 350 °C and 410 °C. Acid treatments did not affect the thermal degradation behavior of the fibres. The observed thermal stability is sufficient for use in textile processes and applications.

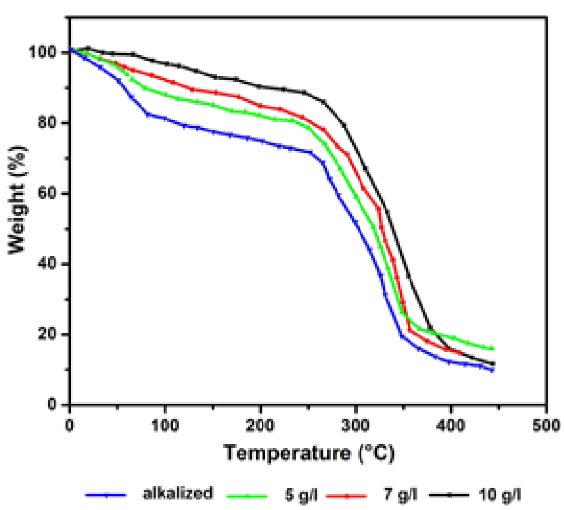


Figure 1: TGA curves of alkalized and acid-treated corn husk fibres

4 Conclusion

Corn husk is a viable source of non-cotton cellulosic fibre. This is of significant importance because husk is a non-avoidable low-value by-product of corn cultivation. The utilization of such a product increases commercial benefits to farmers. In addition, the ecological detriment of burning such waste is avoided. This study is unique in exploring the process sequence of alkaline digestion followed by acid treatment. This approach yielded fibres with characteristics compatible with textile production processes. Work on coloration, blending with other fibres and producing usable commodities is in progress.

Acknowledgements

The authors express their gratitude to the management of their respective institutes for supporting and encouraging this collaborative work.

Conflict of interests

The authors declare that there are no conflicts of interest in the publication of this research.

References

1. ZABANIOTOU, A., ANDREOU, K. Development of alternative energy sources for GHG emissions reduction in the textile industry by energy recovery from cotton ginning waste. *Journal of Cleaner Production*, 2010, **18**(8), 784–790, doi: 10.1016/j.jclepro.2010.01.006.
2. MOHANTY, B.C., CHANDRAMOULI, K.V., NAIK, H.D. *Natural dyeing processes of India*. Ahmedabad : Calico Museum of Textile, 1987.
3. PANTHAPULAKKAL, S., ZERESHKIAN, A., SAIN, M. Preparation and characterization of wheat straw fibres for reinforcing application in injection molded thermoplastic composites. *Bioresource technology*, 2006, **97**(2), 265–272, doi: 10.1016/j.biortech.2005.02.043.
4. MALHERBE, S., CLOTE, T. E. Lignocellulose biodegradation: fundamentals and applications. *Reviews in Environmental Science and Biotechnology*, 2002, **1**, 105–114, doi: 10.1023/A:1020858910646.

5. *Natural fibres, biopolymers, and biocomposites*. Edited by Amar K. Mohanty, Manjusri Misra and Lawrence T. Drzal. Boca Raton : CRC Press , 2005.
6. MONTEIRO, S.N., LOPES, F.P., BARBOSA, A.P., BEVITORI, A.B., SILVA, I.L., COSTA, L.L. Natural lignocellulosic fibers as engineering materials - an overview. *Metallurgical and Materials Transactions A*, 2011, **42**(10), 2963–2974, doi: 10.1007/s11661-011-0789-6.
7. SATYANARAYANA K.G., ARIZAGA, G.G., WYPYCH, F. Biodegradable composites based on lignocellulosic fibers - an overview. *Progress in Polymer Science*, 2009, **34**(9), 982–1021, doi: 10.1016/j.progpolymsci.2008.12.002.
8. TSERKI, V., MATZINOS, P., ZAFEIROPOULOS, N.E., PANAYIOTOU, C. Development of biodegradable composites with treated and compatibilized lignocellulosic fibers. *Journal of applied polymer science*, 2006, **100**(6), 4703−4710, doi: 10.1002/app.23240.
9. YILMAZ, N.D. Effects of enzymatic treatments on the mechanical properties of corn husk fibers. *Journal of the Textile Institute*, 2013, **104**(4), 396−406, doi: 10.1080/00405000.2012.736707.
10. VÄISÄNEN, T., HAAPALA, A., LAPPALAINEN, R., TOMPPO, L. Utilization of agricultural and forest industry waste and residues in natural fiber-polymer composites: a review. *Waste Management*, 2016,**54**, 62–73, doi: 10.1016/j.wasman.2016.04.037.
11. JARABO, R., MONTE, M.C., FUENTE, E., SANTOS, S.F., NEGRO, C. Corn stalk from agricultural residue used as reinforcement fiber in fiber-cement production. *Industrial Crops and Products*, 2013, **43**, 832–839, doi: 10.1016/j.indcrop.2012.08.034.
12. DUNGANI, R., KARINA, M., SULAEMAN, A., HERMAWAN, D., HADIYANE, A. Agricultural waste fibers towards sustainability and advanced utilization: a review. *Asian Journal of Plant Sciences*, 2016, **15**(1/2), 42–55.
13. MENGQI, Z., SHI, A., AJMAL, M., YE, L., AWAIS, M. Comprehensive review on agricultural waste utilization and high-temperature fermentation and composting. *Biomass Conversion and Biorefinery*, 2021, 1–24, doi: 10.1007/s13399-021-01438-5.
14. SADH, P.K., S. DUHAN, DUHAN, J.S. Agro-industrial wastes and their utilization using solid state fermentation: a review. *Bioresources and Bioprocessing*, 2018, **5**(1), 1–15, doi: 10.1186/s40643-017-0187-z.
15. BAJPAI, P.K., MEENA, D., VATSA, S., SINGH, I. Tensile behavior of nettle fiber composites exposed to various environments. *Journal of Natural Fibers*, 2013, **10**(3), 244−256, doi: 10.1080/15440478.2013.791912.
16. YILMAZ, N. D., CALISKAN, E., YILMAZ, K. Effect of xylanase enzyme on mechanical properties of fibres extracted from undried and dried corn husks. *Indian Journal of Fibre & Textile Research*, 2014, **39**(1), 60−64, http://hdl.handle.net/123456789/27370.
17. REDDY, N., YANG, Y. Properties and potential applications of natural cellulose fibres from corn husks. *Green Chemistry*, 2005, **7**(4), 190−195, doi: 10.1039/B415102J.
18. REDDY, N., YANG, Y. Biofibers from agricultural byproducts for industrial applications. *Trends in Biotechnology*, 2005, **23**(1), 22–27, doi: 10.1016/j.tibtech.2004.11.002.
19. ROUF SHAH, T., K. PRASAD, KUMAR, P. Maize - a potential source of human nutrition and health: a review. *Cogent Food & Agriculture*, 2016, **2**(1), 1–10, doi: 10.1080/23311932.2016.1166995.
20. KIRBY, R. H. *Vegetable fibres, botany, cultivation and utilization*. London : World Crops Books , 1963, 464.
21. LI, C.Y., KIM, H.W., WON, S.R., MIN, H.K., PARK, K.J., PARK, J.Y., AHN, M.S., RHEE, H.I. Corn husk as a potential source of anthocyanins. *Journal of agricultural and food chemistry,* 2008, **56**(23), 11413–11416, doi: 10.1021/jf802201c.
22. FAGBEMIGUN, T.K., FAGBEMI, O.D., OTITOJU, O., MGBACHIUZOR, E., IGME, C.C. Pulp and paper-making potential of corn husk. *International Journal of AgriScience*, 2014, **4**(4), 209–213.
23. KOPANIA, E., J. WIETECHA, CIECHANSKA, D. Studies on isolation of cellulose fibres from waste plant biomass. *Fibres & Textiles in Eastern Europe*, 2012 (6B (96)), 167–172.
24. LEWIN, M., PEARCE, ELI M. *Handbook of fibre science and technology*. Vol. 4. New York : Marcel Dekker, 1985, 727–808.
25. YILMAZ, N.D., POWELL, B.N., LEE, B.P., MICHIELSEN, S. Hemp-fiber based nonwoven composites: effects of alkalization on sound absorption performance. *Fibres and Polymers*, 2012, **13**(7), 915–922, doi: 10.1007/s12221-012-0915-0.

26. WAKELYN, P.J. *Cotton fiber chemistry and technology*. Boca Raton : CRC Press, 2006.
27. AMADUCCI, S., ZATTA, A., PELATTI, F., VENTURI, G. Influence of agronomic factors on yield and quality of hemp (Cannabis sativa L.) fibre and implication for an innovative production system. *Field crops research*, 2008, **107**(2), 161–169, doi: 10.1016/j.fcr.2008.02.002.
28. MUTHU, S.S., LI, Y., HU, J.Y., MOK, P.Y. Quantification of environmental impact and ecological sustainability for textile fibres. *Ecological Indicators*, 2012, **13**(1), 66–74, doi: 10.1016/j.ecolind.2011.05.008.
29. CHEN, Y., SHARMA-SHIVAPPA, R.R., KESHWANI, D., CHEN, C. Potential of agricultural residues and hay for bioethanol production. *Applied biochemistry and biotechnology*, 2007, **42**(3), 276–290, doi: 10.1007/s12010-007-0026-3.
30. REDDY, N., SALAM, A., YANG, Y. Effect of lignin on the heat and light resistance of lignocellulosic fibers. *Macromolecular Materials and Engineering*, 2007, **292**(4), 458–466, doi: 10.1002/mame.200600446.
31. SARI, N. H., WARDANA, I. N. G., IRAWAN, Y. S., SISWANTO, E. The effect of sodium hydroxide on chemical and mechanical properties of corn husk fiber. *Oriental Journal of Chemistry*, 2017, **33**(6), 3037–3042.
32. PALME, A., THELIANDER, H., BRELID, H. Acid hydrolysis of cellulosic fibres: comparison of bleached kraft pulp, dissolving pulps and cotton textile cellulose. *Carbohydrate polymers*, 2016, **136**, 1281–1287, doi: 10.1016/j.carbpol.2015.10.015.
33. JOHAR, N., AHMAD, I., DUERESNE, A. Extraction, preparation and characterization of cellulose fibres and nanocrystals from rice husk. *Industrial Crops and Products*, 2012, **37**(1), 93–99, doi: 10.1016/j.indcrop.2011.12.016.
34. NEEDLES, H.L. *Textile fibers, dyes, finishes, and processes: a concise guide*. Park Ridge : Noyes Publication, 1986, 131.

Renjini Girija, Sudhakar Rajagopal
Bangalore University, Department of Apparel Technology and Management, Bangalore Karnataka 560056, India

Predicting Drape of Fused Collar using Design of Experiment

Napovedovanje drapiranja fiksiranega srajčnega ovratnika z uporabo sistematične zasnove poskusa

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 7-2021 • Accepted/*Sprejeto* 2-2022

Corresponding author/*Korespondenčna avtorica:*
Dr. Sudhakar Rajagopal, Assist. Prof.
E-mail: sudhakar@bub.ernet.in
ORCID ID: 0000-0001-6349-1052
Phone: +91 9845804755

Abstract

The fused collar components used in shirt manufacturing requires a specific fall and drape that depends on the type of used interlining. The interlining selection is primarily based on the subjective evaluation of fused composites. There is a need to predict the behaviour of fused shirt collars objectively. The drape of fused composites can be indicative of the shape and fall of the shirt collar. The aim of this paper was to propose a set of polynomial equations using DOE that can predict the drape behaviour of fused shirt collars before and after the washing. The Plackett-Burman design was used to screen the influential factors and the full factorial design was used to derive the polynomial equation explaining the effect of factors on the drape behaviour of fused shirting samples. The prediction was attempted with easily measurable parameters of component materials and the fusing process. The study found that the fabric weave, cover factor, raw material, interlining weight and pressure applied during the fusing process have a significant effect on the drape of fused collars. This information can be used in the 3D sampling of fused shirt components.
Keywords: design of experiment, drape coefficient, fused fabric components, shirt collar

Izvleček

Fiksirane komponente ovratnika, ki se uporabljajo pri izdelavi srajc, zahtevajo poseben pad in sposobnost oblikovanja, ki je odvisna od vrste uporabljene medvloge. Izbira medvloge temelji predvsem na subjektivnem ocenjevanju fiksiranca, zato je toliko pomembnejše objektivno napovedovanje obnašanja fiksiranih srajčnih ovratnikov. Parametri drapiranja fiksiranca lahko pokažejo, kakšna sta oblika in pad srajčnega ovratnika. S sistematično zasnovo poskusa (DOE) so bile razvite polinomske enačbe za napovedovanje drapiranja fiksiranih srajčnih ovratnikov pred pranjem in po njem. Za spremljanje vplivnih dejavnikov je bil uporabljen Plackett-Burmanov delni faktorski načrt, popolni faktorski načrt pa je bil uporabljen za izpeljavo polinomske enačbe, ki pojasnjuje vpliv dejavnikov na drapiranje fiksiranih srajčnih vzorcev. Napovedovanje je bilo preizkušeno z uporabo vrednosti preprosto merljivih parametrov sestavnih materialov in postopka fiksiranja. Študija je pokazala, da med parametre, ki pomembno vplivajo na drapiranje fiksiranih ovratnikov, spadajo: vezava, faktor kritja, surovina, površinska masa medvloge in pritisk pri fiksiranju. Pridobljena spoznanja je mogoče uporabiti pri 3-D vzorčenju fiksiranih srajčnih komponent.
Ključne besede: sistematično načrtovanje eksperimenta, koeficient drapiranja, komponente fiksiranca, srajčni ovratnik

1 Introduction

Formal shirts are constructed with a collar fused with an interlining. The drape of the collar is an important aesthetic and functional feature in a shirt. The drape of the collar explains its ability to fall or hang due to its weight, anchored from the points of its joining seam with the shirt stand or neckline. It contributes to the wearing comfort [1]. The way the collar drapes or falls is an important determinant in classifying it as a formal, semi-formal or casual category wear. The drape of the collar is a complex three-dimensional double curvature form. The specific form or shape of the collar is achieved with the application of a fusible or non-fusible interlining [2]. The collar cut fabric parts are fused with two interlining layers, i.e. the skin and patch in formal shirts (cf. Figure 1).

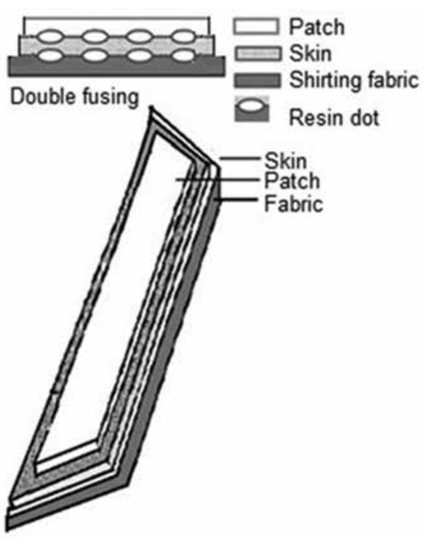


Figure 1: Schematic diagram of collar component with skin and patch interlining

The drape of the fabric is measured using a drape meter. The drape coefficient (DC) is the ratio of the projected area of the draped specimen to the original area of the specimen. The fabrics that easily deform and have lower stiffness have low DC [3, 4]. Shirt collars are normally fused with interlinings to make them stiff. Due to higher stiffness, the formability of the component reduces significantly [5, 6]. High stiffness along with low formability in garment parts can pose problems in sewing operations and lead to reduced wearing comfort [7]. Studies on the changes in DC in different fabrics before and after fusing the interlining have shown that it increases to similar levels after the fusing, irrespective of the original DC of the fabric [8]. The presence of resin in the fused components restricts the movement of yarns within the fabric structure, which contributes to higher bending stiffness and higher DC. Furthermore, the fabric grain direction in the fused fabrics that have the least bending rigidity deforms more readily.

There have been previous studies on predicting drape in fused fabrics. The image analysis of nodes formed by draped fused fabric composites showed that parallel nodes are formed in the fabric direction with the least bending stiffness [9]. The draped fused panel was simulated using the finite element method and similarities were reported between the simulated model and the drape of the actual fused fabric [10]. In suiting and jacket, the properties of the component fabrics of fused composites and the fusing parameters of time, temperature and pressure have a significant effect on the fused composite properties [11–16]. The effect of these parameters on the fused shirt components needs further study. The literature indicates that the drape of the fused fabric is a good indicator of its ability to conform to required collar shape and fall. The understanding of the drape behaviour of the fused composites and predicting the same can be used in the 3D sampling process. It will also aid in ensuring the desired appearance in product development. This study aims to understand the relationship between various properties of the fabric, interlining, fusing process conditions and drape of fused collar composites.

2 Materials and methods

2.1 Materials

Shirting fabrics of medium weight used for formal men's shirts were selected for this study. The properties of selected fabrics were established using the standard test method for thread density (warp and weft) (ASTM D 3775-17e1), yarn number (ASTM D 1059-17), and type of weave and fabric weight (ASTM D 3776-20). The fabric physical properties are listed in Table 1. 100% cotton woven interlinings with high-density polyethylene adhesive resin were used in the fusing of samples. The patch interlinings used are of two different areal weights (135 g/m^2 and 160 g/m^2). The selected interlining finish was the flat and raised finish. Fabrics were cut to the length of two metres and kept in standard atmosphere for conditioning. The fusing was done on a full-width

Table 1: Shirting fabrics used in experimental design

Fabric code	Fabric weave	Fibre blend	Mass per unit area (g/m²)	Yarn linear density of warp × weft	Threads in fabric length × width ends × picks	Fabric cover factor
				(tex)	(1/cm)	
F1	Plain	PES/CO [a)]	130	15 × 15	57 × 35	25
F2	1/1 and 3/1 twill	PES/CO	132	10 × 10	44 × 37	20
F3	2/2 matt	CO [b)]	118	12 × 12	54 × 36	24
F4	Plain	PES/CO	107	8 × 11	52 × 41	22
F5	Plain	PC	130	24 × 25	31 × 22	21
F6	2/2 matt and 3/1 twill	CO	145	10 × 10	51 × 35	21
F7	1/1 & 2/1 twill	CO	136	11 × 12	59 × 41	24
F8	2/1 twill	PES/CO	145	20 × 20	51 × 38	26
F9	7/7 matt & plain	PES/CO	114	9 × 10	72 × 41	25
F10	Plain	PES/CO	132	11 × 12	67 × 31	25
F11	1/1 and 3/1 twill	PES/CO	101	8 × 8	59 × 35	21
F12	Plain	CO	134	11 × 13	64 × 35	25
F13	2/1 herringbone	PES/CO	115	8 × 8	51 × 43	21
F14	Plain	CO	109	12 × 12	55 ×51	25
F15	Plain	PES/CO	124	19 × 25	28 × 22	19
F16	Plain	CO	116	20 × 20	25 ×21	17
F17	Plain	CO	135	7 × 7	61 × 28	20
F18	1/1 & 2/1 twill	CO	133	8 × 8	61 × 29	21
F19	2/2 matt	CO	109	12 × 11	67 × 31	25
F20	Plain	CO	111	12 × 11	48 × 30	21

[a)] 50% polyester/50% cotton

[b)] 100% cotton

fabric with the interlining following the experimental design on a continuous fusing machine (Hashima model HP-600LFS). The fusing was conducted at two different temperature settings (150 °C and 170 °C), time settings (15 s and 20 s) and pressure settings (0.1471 MPa and 0.2941 MPa), following the experimental design. The samples were double fused with skin interlining (90 g/m²) according to the fusing procedure followed for collar fusing in shirt manufacturing (cf. Figure 1).

2.2 Methods

The experiments were designed to initially filter the most relevant factors and build a predictive regression model using the identified factors. The factors considered for the screening design of the experiment were the physical properties of the fabric, interlining physical properties and fusing parameters. The physical properties of the fabric are mass per unit area (g/m²), fibre blend, weave structure, fabric cover factor and finish. The interlining properties included weight per unit area and finish. The fusing process factors included time, temperature and pressure applied during fusing. The ends per inch and picks per inch of the fabric were determined using a pick glass as per ASTM D3775. The warp and weft yarn linear density were measured using a Beesley balance (ASTM D 1907). The cover factor of the fabric was calculated using Peirce's formula [17]. Each of the ten factors were considered in two levels as shown in Table 2.

The initial fusing was carried out in line with the screening design matrix of the Plackett-Burman design with ten factors and twenty runs (cf. Table 3). The DC evaluated on fused samples before and after the washing was analysed. The factors that showed a statistically significant impact on drape coefficient

(P-value < 0.05) were selected for the forming of the full factorial design. The designs were replicated twice and the adequacy of the model was checked using its adjusted squared coefficient of determination (adj. R^2) [18].

After the fusing, the samples for drape evaluation were prepared by cutting four circular samples with 25 centimetres in diameter. The samples were mounted on the face as well as the backside and the average of eight readings was noted. The drape

Table 2: Factors and levels used in screening design of experiment

S. no.	Factor	Code	Level (–1)	Level (+1)
1	Fabric weight (g/m^2)	Fgsm	100–125	130–150
2	Fabric weave	FW	Plain	Combination
3	Fabric cover factor	FC	17–21	23–26
4	Fabric fibre content	FFC	Cotton	50% polyester/50% cotton
5	Fabric finish	FF	Silicon finish	None
6	Interlining weight (g/m^2)	Igsm	225	250
7	Interlining finish	IF	Raised	Flat
8	Time (s)	t	15	20
9	Temperature (°C)	T	150	170
10	Pressure (MPa)	P	0.1471	0.2941

Table 3: Plackett-Burman design of experiment and drape coefficient (DC) of fused samples

S. no.	Fgsm	F W	FC	FFC	FF	Igsm	IF	*t*	*T*	P	Fabric code	DC before washing (%)		DC after washing (%)	
												Replicate I	Replicate II	Replicate I	Replicate II
1	+1	–1	+1	+1	–1	–1	–1	+1	+1	–1	F1	86.09	91.51	87.78	88.46
2	+1	+1	–1	+1	+1	–1	–1	+1	–1	+1	F2	93.20	94.89	86.43	88.12
3	–1	+1	+1	–1	+1	+1	–1	+1	–1	–1	F3	92.05	91.51	85.75	84.91
4	–1	–1	+1	+1	–1	+1	+1	+1	–1	–1	F4	86.09	85.92	80.34	80.17
5	+1	–1	–1	+1	+1	–1	+1	+1	–1	–1	F5	97.26	96.58	87.11	87.11
6	+1	+1	–1	–1	+1	+1	–1	+1	+1	–1	F6	88.80	86.77	86.43	86.43
7	+1	+1	+1	–1	–1	+1	+1	+1	+1	+1	F7	84.40	83.72	87.95	87.78
8	+1	+1	+1	+1	–1	–1	+1	+1	–1	+1	F8	89.48	88.80	84.57	84.40
9	–1	+1	+1	+1	+1	–1	–1	+1	+1	–1	F9	89.58	89.44	85.41	85.41
10	+1	–1	+1	+1	+1	+1	–1	+1	+1	+1	F10	84.99	85.28	80.68	80.17
11	–1	+1	–1	+1	+1	+1	+1	+1	–1	+1	F11	86.94	89.14	83.05	82.54
12	+1	–1	+1	–1	+1	+1	+1	+1	–1	–1	F12	90.73	88.46	81.18	81.35
13	–1	+1	–1	+1	–1	+1	+1	+1	+1	–1	F13	94.89	91.51	87.45	87.11
14	–1	–1	+1	–1	+1	–1	+1	+1	+1	+1	F14	70.86	81.35	84.23	84.91
15	–1	–1	–1	+1	–1	+1	–1	+1	+1	+1	F15	87.28	89.71	84.74	84.40
16	–1	–1	–1	–1	+1	–1	+1	+1	+1	+1	F16	87.45	87.11	83.05	82.88
17	+1	–1	–1	–1	–1	+1	–1	+1	–1	+1	F17	78.44	82.03	84.23	84.40
18	+1	+1	–1	–1	–1	–1	+1	+1	+1	–1	F18	85.41	88.80	84.74	86.09
19	–1	+1	+1	–1	–1	–1	–1	+1	–1	+1	F19	79.56	81.69	91.17	92.52
20	–1	–1	–1	–1	–1	–1	–1	+1	–1	–1	F20	87.45	91.51	85.75	85.25

coefficient (DC) of the fused samples was calculated as given in Equation 1.

$$Drape\ coefficient\ = \frac{\frac{w}{W} - a}{A - a} \times 100\ (\%) \qquad (1),$$

where w is the mass of draped pattern, W is the mass/unit area of the paper, A is the area of the circle with a diameter of 25 cm and a is the area of the circle with a diameter of 12.5 cm (ASTM D 3691-19). The samples were washed following the standard ASTM D 2724-19. The DC of each fused sample was evaluated before and after the washing.

3 Results and discussion

The drape coefficient of the fabric gives a partial measurement of its hand and can be used to predict fabric deformation [19]. The fused fabric drape is more complex than fabric drape due to the effect of component fabric properties, interlining properties and their combined properties [6]. The drape in stiff composites such as the shirt collar gives an indication to the formability along the neckline and fall of the collar. The average DC of the fabric samples before the fusing is 36.21%. After the fusing, the average DC increased to 89%, and after washing the fused samples, the average DC reduced to 85%. DC increased significantly after the fusing to the interlining and reduced slightly after the washing (cf. Figure 2).

3.1 Drape coefficient of collar samples before washing

The screening design analysis shows that DC (before washing) is influenced by four significant factors: fabric weave (FW), fabric cover factor (FC), fabric fibre content (FFC) and pressure (P). After the washing, there is a change in factors that have a significant effect on the drape. These are fabric weave, fabric fibre content and interlining areal weight. The full factorial design with four factors and thirty-two runs was used to analyse the results before the washing (cf. Table 4), and the Adj. R^2 for this model with all the terms was 74%. The model, factors and interactions (FW × P, FC × P, FC × FFC × P) are statistically significant (P-value < 0.05).

The terms FW × FC, FW × FFC, FCC × P, FW × FC × FFC, FW × FC × P, FC × FFC × P and FW × FC × FFC × P are insignificant (P-value > 0.05) and removed to form the final model (cf. Table 5). The Adj. R^2 for this reduced model after removing insignificant terms is 68.30%. The lack of fit has

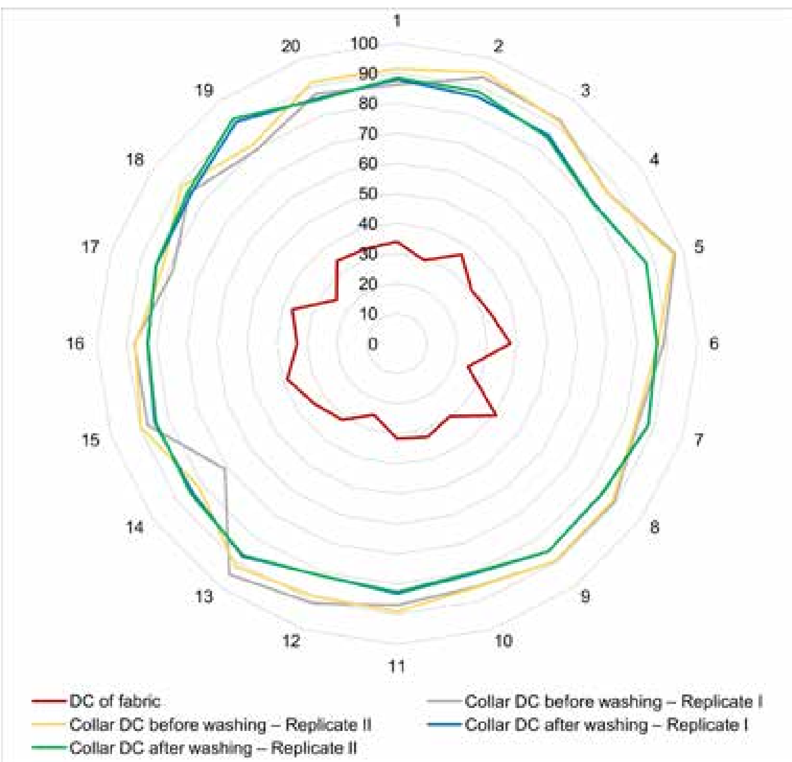


Figure 2: Drape coefficient (DC) of fabric and fused collar samples

the P-value of 0.185 (more than 0.05). The highest contribution to the total effect in the model by individual factors is by fabric cover factor (16.65%), followed by pressure (12.96%), fabric fibre content (9.75%) and fabric weave (4.25%). The contribution of the interaction between fabric weave and pressure is 13.71%, fabric cover factor and pressure is 9.21%, and fabric cover factor, fabric fibre content and pressure is 8.93%. The regression equation for the model after removing insignificant terms predicting the DC of collar samples before the washing is given in Equation 2.

$$Drape\ coefficient\ of\ collar\ samples\ before\ washing = 88.705 + 0.980\,FW - 1.940\,FC + 1.485\,FFC - 1.712\,P + 1.760\,FS \times P - 1.443\,FC \times P + 1.421\,FC \times FFC \times P \quad (2)$$

Fabric weave affects the drape of the fused samples [8]. The DC of fused samples of the plain fabric is lower than the samples with the combination weave fabrics (cf. Figure 3a). Interestingly, the fused samples with a lower cover factor show higher DC than the fabrics with a higher cover factor. The fused fabric with a low cover factor forms a compact composite as the lower cover factor allows a better and even penetration of the resin between yarn interstices. The interaction between the fabric weave and cover factor (cf. Figure 3b) implies that the samples with plain fabrics of a low cover factor have higher DC than the samples with a high cover factor and plain weave. Drape instability is reported in fabrics with a higher cover factor [20] and this instability can cause the results seen in the fused collars of the fabrics with a high cover factor. The fabrics with polyester-cotton content have registered higher DC than 100% cotton fabrics. Both 100% cotton and PC blend fabrics with a low cover factor have higher DC than other samples (cf. Figure 3a). The polyester content in the PC blend fabrics is prone to crystallisation and shrinkage when exposed to high temperature (150 °C to 170 °C) [21] and this led to higher DC. The fabric with a lower cover factor allows higher resin penetration into the interstices, making the fused collar gain higher stiffness. This leads to higher DC due to the effect of higher bending stiffness in the fused samples. The results imply that at lower pressure, the DC of fused samples of both fibre content types has higher DC (cf. Figure 3a). The interaction of pressure with fabric weave and fabric cover factor is significant (cf. Table 5). The lower pressure of 0.1471 MPa has a relatively smaller effect on DC between two fabric weave levels and the fabric cover factor. However, when the pressure is increased to 0.2941 MPa, DC is higher for the combination weave fabrics with low cover factors (cf. Figure 3c).

Table 4: Full factorial design for drape coefficient (DC) of samples before washing

S. no.	FW	FC	FFC	P	Fabric code	DC (%)	S. no.	FW	FC	FFC	P	Fabric code	DC (%)
1	–1	–1	–1	–1	F20	87.45	17	–1	–1	–1	–1	F20	91.51
2	+1	–1	–1	–1	F6	88.80	18	+1	–1	–1	–1	F6	86.77
3	–1	+1	–1	–1	F12	90.73	19	–1	+1	–1	–1	F12	88.46
4	+1	+1	–1	–1	F3	92.05	20	+1	+1	–1	–1	F3	91.51
5	–1	–1	+1	–1	F5	97.26	21	–1	–1	+1	–1	F5	96.58
6	+1	–1	+1	–1	F13	87.45	22	+1	–1	+1	–1	F13	91.51
7	–1	+1	+1	–1	F1	86.09	23	–1	+1	+1	–1	F1	91.51
8	+1	+1	+1	–1	F9	89.58	24	+1	+1	+1	–1	F9	89.44
9	–1	–1	–1	+1	F16	87.45	25	–1	–1	–1	+1	F16	87.11
10	+1	–1	–1	+1	F18	91.02	26	+1	–1	–1	+1	F18	92.36
11	–1	+1	–1	+1	F14	70.86	27	–1	+1	–1	+1	F14	81.35
12	+1	+1	–1	+1	F7	84.40	28	+1	+1	–1	+1	F7	83.72
13	–1	–1	+1	+1	F15	87.28	29	–1	–1	+1	+1	F15	89.71
14	+1	–1	+1	+1	F2	93.20	30	+1	–1	+1	+1	F2	94.89
15	–1	+1	+1	+1	F10	84.99	31	–1	+1	+1	+1	F10	85.28
16	+1	+1	+1	+1	F8	89.48	32	+1	+1	+1	+1	F8	88.80

Table 5: Analysis of variance for drape coefficient of collar samples before washing

Source	Master model		Predictive model				
	DF	P-value	DF	Cr (%)	Adj. SS	Adj. MS	P-value
Model	15	0.000	7	75.46	545.89	77.984	0.000
Linear	4	0.000	4	43.61	315.49	78.873	0.000
FW	1	0.039	1	4.25	30.71	30.713	0.053
FC	1	0.000	1	16.65	120.45	120.446	0.000
FFC	1	0.004	1	9.75	70.55	70.546	0.005
P	1	0.001	1	12.96	93.79	93.788	0.002
2-way interaction	6	0.002	2	22.92	165.78	82.891	0.000
FW × FC	1	0.061	–	–	–	–	–
FW × FFC	1	0.169	–	–	–	–	–
FW × P	1	0.001	1	13.71	99.15	99.154	0.001
FC × FFC	1	0.814	–	–	–	–	–
FC × P	1	0.004	1	9.21	66.63	66.629	0.006
FFC × P	1	0.115	–	–	–	–	–
3-way interaction	4	0.038	1	8.93	64.61	64.612	0.007
FW × FC × FFC	1	0.909	–	–	–	–	–
FW × FC × P	1	0.169	–	–	–	–	–
FW × FFC × P	1	0.536	–	–	–	–	–
FC × FFC × P	1	0.005	1	8.93	64.61	64.612	0.007
4-way interaction	1	0.197	–	–	–	–	–
FW × FC × FFC × P	1	0.197	–	–	–	–	–
Error	16	–	24	24.54	177.55	7.398	
Lack of fit	–	–	8	11.12	80.47	10.058	0.185
Pure error	–	–	16	13.42	97.08	6.067	
Total	31	–	31	100.00			

3.2 Drape coefficient of collar samples after washing

The screening design analysis shows that DC (after washing) is influenced by three significant factors: fabric weave, fabric fibre content and interlining areal weight. The full factorial design formed with the three factors for a further analysis is presented in Table 6. The model, the factors and their interactions except for FW × FFC and FW × Igsm are statistically significant (P-value < 0.05) (cf. Table 7). After removing the insignificant terms, the regression equation (cf. Equation 3) that explains the effect of fabric weave, fabric fibre content and interlining areal weight is as follows:

$$\begin{aligned} &Drape\ coefficient\ of\ collar\ samples\ after\ washing \\ &= 87.022 + 2.073\,FW - 0.508\,FFC - 3.004\,Igsm \\ &- 1.988\,FFC \times Igsm + 1.100\,FW \times FFC \times Igsm \end{aligned} \quad (3)$$

Fabric weave (22.63%) and interlining areal weight (47.50%) contribute significantly to the effect, whereas the fabric fibre content has only 1.36% contribution to the effect on DC (cf. Table 7). The significant interactions are FFC × Igsm and FFC × FW × Igsm. The lack of fit in the model has the P-value of 0.181 (more than 0.05). As noted earlier, DC reduced after the washing. Figure 4a shows the main effects of the drape of the collar sample before the washing. The washed samples with plain fabrics have lower DC than the samples with the combination weave fabrics (cf. Figure 4b). The fused plain fabrics have a lower DC than the fused fabrics with combination weaves [22]. The same result is seen in the fused samples before and after the washing. As discussed earlier, this is due to the resin evenly spreading in the plain weave. The resin integrates into the woven structure interstices making the fused composite

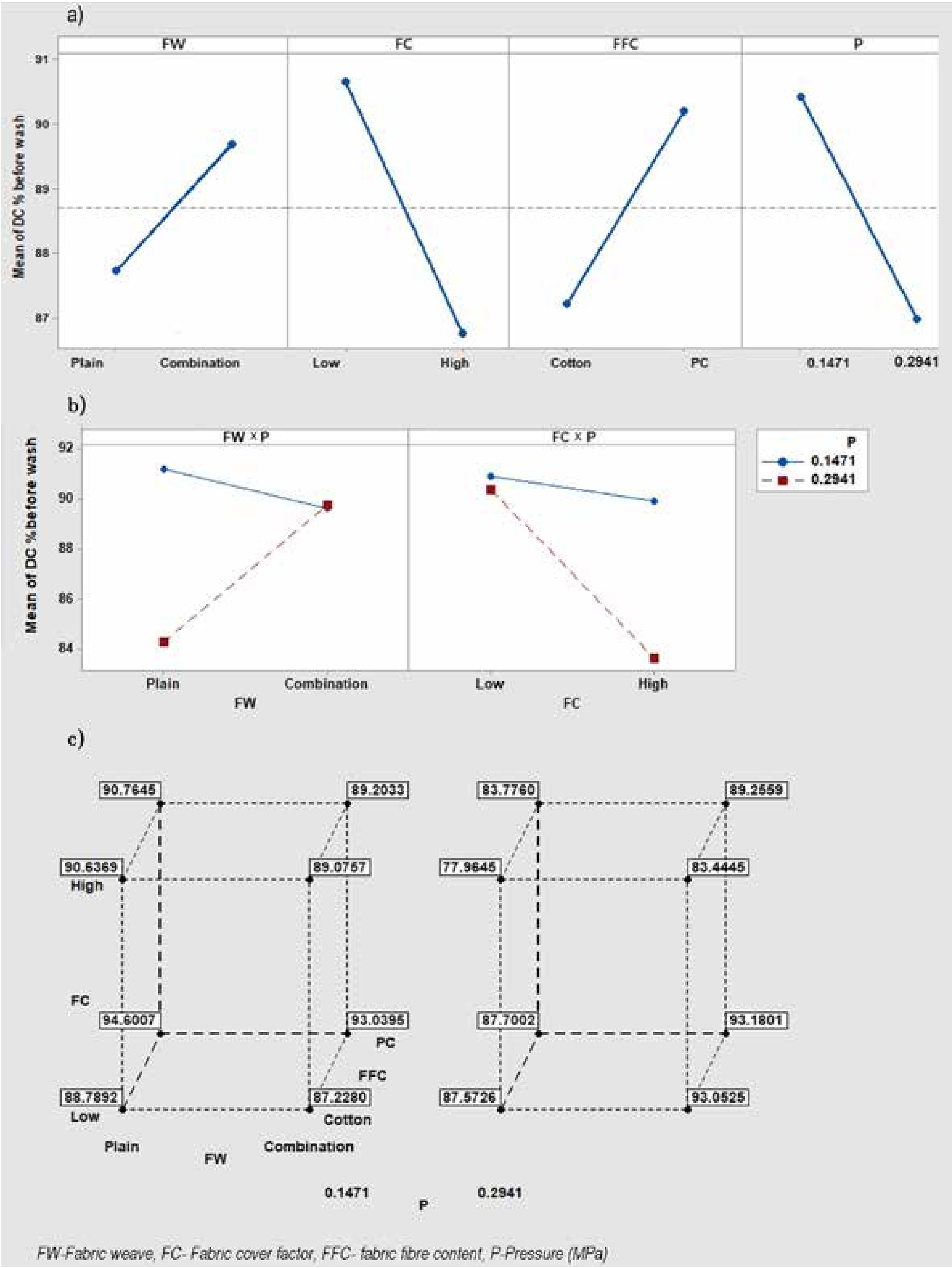


Figure 3: Effect plots for drape coefficient of fused collar samples before washing

Table 6: Full factorial design for drape coefficient (DC) of collar samples after washing

S. no.	FW	FFC	Igsm	Fabric code	DC (%)	S.no	FW	FFC	Igsm	Fabric code	DC (%)
1	–1	–1	–1	F14	84.74	9	–1	–1	–1	F14	85.41
2	+1	–1	–1	F18	91.51	10	+1	–1	–1	F18	92.52
3	–1	+1	–1	F1	90.83	11	–1	+1	–1	F1	90.83
4	+1	+1	–1	F2	91.51	12	+1	+1	–1	F2	92.86
5	–1	–1	+1	F12	84.74	13	–1	–1	+1	F12	85.75
6	+1	–1	+1	F3	88.12	14	+1	–1	+1	F3	87.45
7	–1	+1	+1	F4	78.64	15	–1	+1	+1	F4	78.64
8	+1	+1	+1	F11	84.74	16	+1	+1	+1	F11	84.06

Table 7: Analysis of variance for drape coefficient of collar samples after wash

Source	Master Model		Predictive Model				
	DF	P-Value	DF	Cr (%)	Adj. SS	Adj. MS	P-Value
Model	7	0.000	5	98.67	299.89	59.98	0.000
Linear	3	0.000	3	71.49	217.26	72.42	0.000
FW	1	0.000	1	22.63	68.76	68.76	0.000
FFC	1	0.008	1	1.36	4.12	4.12	0.010
Igsm	1	0.000	1	47.50	144.37	144.37	0.000
2-way interactions	3	0.000	1	20.82	63.27	63.27	0.000
FW × FFC	1	0.073	–	–	–	–	–
FW × Igsm	1	1.000	–	–	–	–	–
FFC × Igsm	1	0.000	1	20.82	63.27	63.27	0.000
3-way interactions	1	0.000	1	6.37	19.36	19.36	0.000
FW × FFC × Igsm	1	0.000	1	6.37	19.36	19.36	0.000
Error	8	–	10	1.33	4.04	0.40	–
Lack of fit		–	2	0.46	1.40	0.70	0.181
Pure error		–	8	0.87	2.63	0.33	–
Total	15		15	100.00	303.93		

compact. This compactness improved the drapability of the fused fabrics.

The collar samples made of 100% cotton fabrics had lower DC than the PC blend fabrics before the washing. However, after the washing, the cotton fabric samples maintained DC at a similar level, whereas the collar samples made of PC blends showed a reduction in DC. This means that the collars made of PC blend fabrics may lose their shape after the washing. The fused samples with lower interlining areal weight (225 g/m^2) exhibited a higher DC than those fused with a higher weight interlining (250 g/m^2), as seen in Figure 4a. The loss of the sizing material in interlining after the washing made the fused samples softer. This led to lower DC in the fused collars with higher weight interlining. For cotton fabrics, DC is similar for both levels of interlining areal weight; however, for PC blend fabrics, there is a significant difference between the two levels of interlining areal weight (cf. Figure 4b). The reduction of DC is greater in the samples of PC blended fabrics and higher weight interlining (250 g/m^2). Moreover, the influence of the interlining areal weight is significant only in the washed samples and not before the washing. The highest DC is achieved in the samples with PC fabrics with a combination weave fused with the interlining areal weight of 225 g/m^2. The lowest DC is achieved in the samples with PC blend fabrics of plain weave fused with the interlining areal weight of 250 g/m^2 (cf. Figure 4c).

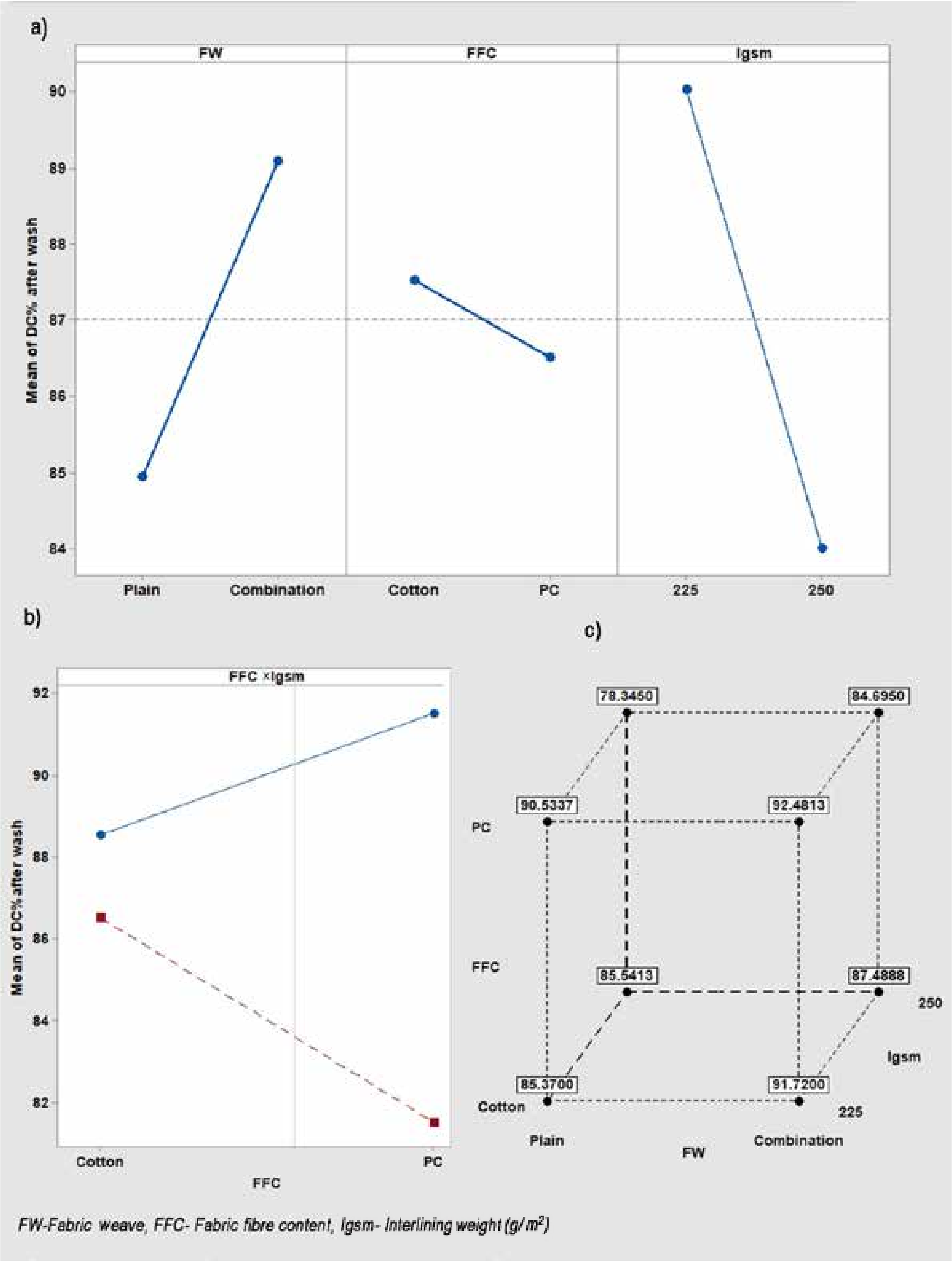


Figure 4: Effect plots for drape coefficient of collar samples after washing

4 Conclusion

The shirt collars are designed to possess a very high level of drape coefficient. In most cases, the collars are double fused to enhance this property. Since collars should conform to the desired shape and form after being sewn to the shirt neckline, it is important to understand the effect of various factors that lead to increased drape coefficient in the fused collar components. A very high drape coefficient was found in the samples with polyester/cotton blend fabrics of a low cover factor. A lower cover factor in fabrics is due to higher interstices between yarns – it is a function of yarn density and count. These spaces allow higher penetration of resin causing higher drape coefficient. Furthermore, lower pressure of 0.1471 MPa was found insufficient for the penetration of the adhesive resin, which also led to higher drape coefficient of most fused samples. The washed samples consisting of 100% cotton fabric were found to have lower drape coefficient than the corresponding unwashed samples. Additionally, the effect of the interlining weight is observed only after the samples are washed. This study shows the effect of various factors that contribute to the drape property of fused composites. The factors chosen to explain the fused collar behaviour are easily measurable without the need for complex methods or expensive testing instruments. This facilitates commercial applications in the 3D sampling of shirts. The regression equation was derived to predict the value of drape coefficient of fused collars given the type of fabric and interlining property. The information is useful in the objective selection of the right materials for the required aesthetic and functional property of the fused collar.

References

1. SANAD, REHAM ABDELBASET, CASSIDY, TOM. Fabric objective measurement and drape. *Textile Progress*, 2015, **47**(4), 317–406, doi: 10.1080/00405167.2015.1117243.
2. MAHAR, T.J., AJIKI, I., DHINGRA, R.C. AND POSTLE, R. Fabric mechanical and physical properties relevant to clothing manufacturing. Part 3: shape formation in tailoring. *International Journal of Clothing Science Technology*, 1989, **1**(3), 6–13, doi: 10.1108/eb002950.
3. KAWABATA, S., NIWA, M. Fabric performance in clothing and clothing manufacturing. *Journal of the Textile Institute,* 1989, **80**(1), 19–50, doi: 10.1080/00405008908659184.
4. HAMDI, T., GHITH, A., AND FAYALA, F. Fuzzy logic method for predicting the effect of main fabric parameters influencing drape phenomenon. *AUTEX Research Journal*, 2020, **20**(3), 220–227, doi: 10.2478/aut-2019-0034.
5. BEHERA, B.K., MISHRA, R. Effect of crease behaviour, drape and formability on appearance of light weight worsted suiting fabrics. *Indian Journal of Fibre & Textile Research*, 2007, **32**(3), 319–325, http://nopr.niscair.res.in/handle/123456789/340.
6. JEVŠNIK, S., GERŠAK, J., GUBENŠEK, I. The advance engineering methods to plan the behaviour of fused panel. *International Journal of Clothing Science and Technology*, 2005, **17**(3/4), 161–170, doi: 10.1108/09556220510590858.
7. MASTEIKAITE, V., SACEVICIENE, V., CIRONIENE, V. Compressed loop method for the bending behaviour of coated and laminated fabrics analysis. *Textile Research Journal,* 2014, **43**(3), 350–365, doi: 10.1177/1528083712454154.
8. SHARMA, K.R., BEHERA, B.K., ROEDEL, H., SCHENK, A. Effect of sewing and fusing on drape behaviour of suiting fabrics. *International Journal of Clothing Science and Technology*, 2005, **17**(2), 75–90, doi: 10.1108/09556220510581227.
9. KOEING, S.K., KADOLPH, S.J. Comparison of performance characteristics of seven fusible interfacing. *Textile Research Journal*, 1983, **53**(6), 341–346, doi: 10.1177/004051758305300603.
10. JEVŠNIK, S., GERŠAK, J. Modelling the fused panel for a numerical simulation of drape. *Fibres & Textiles in Eastern Europe,* 2004, **12**(1), 47–52.
11. TYLER, D.J. Alternative method of joining materials. In *Carr and Latham's technology of clothing manufacture*. Edited by David J. Tyler. John Wiley & Sons, 2009, 221–246.
12. VILUMSONE-NEMES, I. Automation in spreading and cutting, In *Automation in garment manufacturing.* Edited by Rajkishore Nayak and Rajiv Padhye. Woodhead Publishing, 2018, 139–164.
13. FAN, J., LEEUWNER, W., HUNTER, L. Compatibility of outer and fusible interlining fabric in tailored garments Part I: Desirable range of mechanical properties of fused composites. *Textile Research Journal*, 1997, **67**(2), 137–142, doi: 10.1177/004051759706700210.
14. GERŠAK, J., ŠARIĆ, A. Objective evaluation of a stabilized garment parts. *International Journal*

of Clothing Science and Technology, 1995, **7**(2/3), 102–110, doi: 10.1108/09556229510087218.

15. SHISHOO, R., KLEVMAR, P.H., CEDNAS, M., OLOFSSON, B. Multilayer textile structures - relationship between the properties of a textile composite and its components. *Textile Research Journal*, 1971, **41**(8), 669–679, doi: 10.1177/004051757104100807.
16. YOON, S.Y., PARK, C.K., KIM, H.S., KIM, S. Optimization of fusing process conditions using taguchi method. *Textile Research Journal*, 2010, **80**(11), 1016–1026, doi: 10.1177/0040517509349784.
17. PEIRCE, F.T. 26—The "handle" of cloth as a measurable quantity. *Journal of the Textile*
18. *Institute Transactions,* 1930, 21(9), T377–T416, doi: 10.1080/19447023008661529.
19. MONTGOMERY, D.C. *Design and analysis of experiments.* John Wiley & Sons, 2013.
20. CUSICK, G.E. 46—The dependence of fabric drape on bending and shear stiffness. *Journal of the Textile Institute Transactions,* 1965, **56**(11), T596–T606, doi: 10.1080/19447026508662319.
21. JEONG, Y.J., PHILLIPS, D.G. A study of fabric-drape behaviour with image analysis. Part II: the effects of fabric structure and mechanical properties on fabric drape. *Journal of the Textile Institute,* 1998, **89**(1), 70–79, doi: 10.1080/00405009808658598.
22. MILITKÝ, JIŘÍ. Tensile failure of polyester fibers. In *Handbook of properties of textile and technical fibres*. Edited by Anthony R Bunsel. Woodhead Publishing, 2018, 421–514, https://doi.org/10.1016/B978-0-08-101272-7.00013-4.
23. HUNTER, L., FAN, J., CHAU, D. Fabric and garment drape. In *Engineering Apparel Fabrics and Garments*. Edited by J. Fan and L. Hunter. Woodhead Publishing, 2009, 102-125.

Muralidhar B. A.
Anna University, A. C. Tech. Campus, Department of Textile Technology, Chennai 600 025, India

Effect of Workwear Fabric Fluorocarbon Coating on Changes in Tensile Properties of Sewing Threads

Vpliv fluorokarbonskega premaza delovnih oblačil na spremembe nateznih lastnosti sukancev

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 03-2022 • Accepted/*Sprejeto* 04-2022

Corresponding author/*Korespondenčni avtor:*
Dr. Muralidhar B. A., Assist Prof
E-mail: muralidharba@annauniv.edu; muralidharba@yahoo.co.in
ORCID ID: 0000-0002-9648-8578

Abstract

This paper presents the findings of changes in the tensile behaviour of sewing threads in two-seam configuration on three different workwear fabrics, i.e. drill, duck and rip-stop structures, before and after the coating. For this research, commercially available workwear fabrics were obtained from the domestic industry and the sewing was carried out using a 40 tex core-spun polyester sewing thread. High-speed heavy-duty lockstitch sewing machines were used to construct both the superimposed (SSa) and lapped seams (LSd). The strength of sewing threads sewn in the two-seam configuration were carefully unravelled and compared with the unsewn sewing thread (UST). The effect of coating on the changes in tenacity, breaking elongation and initial modulus of the needle thread was reported. It was found that there was a significant effect of weave structure on the tenacity of the sewing thread.
Keywords: breaking elongation, tenacity, fabric coating, initial modulus, sewing threads

Izvleček

V članku so predstavljene ugotovitve o spremembah nateznih lastnosti sukancev, izločenih iz dveh različnih tipov šivov, sešitih na tkaninah za delovna oblačila, ki so se razlikovala v vezavi (platno, keper, rips). Za raziskavo so bile uporabljene tržno dostopne tkanine domače proizvodnje, namenjene za izdelavo delovnih oblačil. Za šivanje je bil uporabljen oplaščen poliestrski sukanec finoče 40 tex. Šivanje s ploskim (SSa) in zapognjenim šivom (LSd) je bilo izvedeno na visokohitrostnem šivalnem stroju za težke tkanine s prešivnim vbodom. Igelni šivalni sukanci so bili skrbno izločeni iz sešitih šivov, da bi se primerjale natezne lastnosti sukancev pred obremenjevanjem med šivanjem (UST) in po njem. Proučen je bil vpliv premaza tkanin na spremembe natezne trdnosti, pretržnega raztezka in začetnega modula šivalnega sukanca. Pokazalo se je, da vezava tkanin pomembno vpliva na natezno trdnost šivalnega sukanca in da so abrazivne poškodbe pri tkanini v vezavi rips največje, pri čemer se je po impregniranju začetni modul vseh preskusnih vzorcev bistveno izboljšal.
Ključne besede: pretržni raztezek, natezna trdnost, premaz tkanine, začetni modul elastičnosti, šivalni sukanci

1 Introduction

Garment manufacturing is a process of transforming a two-dimensional fabric into three-dimensional apparel by bringing together dissimilar pattern pieces along with the functional and aesthetic styling to enhance the desirable features and to cover up the undesirable features of human beings. Garments' performance fundamentally depends on the fabric and sewing thread characteristics. Sewing threads are special categories of yarn engineered to pass through the sewing machine swiftly without distortion and breaking to deliver the aesthetics and performance of stitches and seams. Various sewing threads are made from cotton and polyesters fibres, e.g. staple spun, multifilament, monofilament, textured, continuous filament or core-spun yarns. Each has distinct properties and is a prime contributor to seam quality [1–2]. The sewing thread, which is about 1% of the mass of the garment, plays a key role in sewing operations. Readymade garment industries widely use either domestic or high-speed industrial sewing machines in sewing operations. During the conversion in cut and sewn garments, seams are introduced to mould, shape and transform the fabric into garments [3]. A seam comprises two or more plies of a material or materials held together by a series of stitches. Seams are used for assembling materials in the manufacture of apparel/garments. In garment construction, seam failure is considered a major problem, their occurrence generally results from poor seam selection, non-compatible sewing thread selection for the given seam type etc. The seam line affects the overall appeal of a garment. Even, straight, neat, smooth seams that are not puckered contribute to aesthetics. According to the British Standard 3870, there are eight types of seams, i.e. Class 1 (superimposed seam), Class 2 (lapped seam), Class 3 (bound seam), Class 4 (flat seam), Class 5 (decorative seam), Class 6 (edge neatening Seam), Class 7 and Class 8 [4].

A sewing thread is a smooth, strong, elastic, evenly spun ply or cabled yarn with a special finish to reduce friction and resist abrasion as it passes through the needle eye and the material in the stitching and seaming process [5]. A stitch is the formation of the interlacing of the sewing thread in a precise repeated unit. The term *stitches* denote both the thread interlocking (lock-stitch) or interlooping (chain-stitch) used to make joints between two pieces of a fabric that are sewn together. Seam parameters – seam allowance and stitch density together are known to affect the bending length and flexural rigidity of seams [6]. It is understood that during the sewing, generally two series of sewing threads are used, i.e. the needle thread and the bobbin thread. The needle thread passes through several guides, pre-tensioners, take-up lever, tension regulator, tension spring, needle eye etc. before being stitched into a seam [7]. Throughout the passageway, the needle thread is subjected to needle heating, wearing, repeated tensile stresses, torsional forces and pressure [8]. The sewing thread is repeatedly abraded against the material being sewn and the metal surfaces of the take-up lever, guides and needle eye roughly 50–80 times [9]. The degree of influence gets further enhanced with bobbin thread interlacement, fabric weight, number of plies in the seam configuration, and the surface characteristics of a sewing needle and sewing thread. Several investigators have detected that there could be around 30% to 40% strength loss in the needle sewing thread once sewn [10–11]. Moreover, with heavyweight, bulky fabrics with a higher cover factor, the damage could be even more severe. The extent of the sewing thread strength reduction is related to the magnitude of stresses acting and their ability to endure without degradation. Regarding the stitch type, lockstitch is widely used and more secure [12–15].

Poor sewing threads can seriously increase production costs by causing numerous stoppages of sewing machines, in addition to rendering the garment unusable. To accomplish good sewing performance, a sewing thread that possesses requisite physical and mechanical characteristics must be selected according to fabric characteristics and its end-use application. A core-spun sewing thread is the most preferred sewing thread, which is due to its higher strength and abrasion resistance used for sewing workwear fabrics. Among different varieties of core-spun sewing threads commercially available, a polyester-cotton core-spun sewing thread shows better performance as the polyester core gives the required strength, abrasion resistance and cotton fibres on the surface give them good heat resistance. Workwear apparel is a specialised category of clothes that serve as lifesavers and is used in applications such as military wear, hospital drapes, survival suits, firefighter clothing, chemical protective clothing etc. The workwear clothing combines a fabric of higher mass per unit area woven in a specific construction, e.g. duck, drill, rib-stop, sateen etc., followed by one or more functional finishes such as UV protection, waterproofness, air permeability, flame retardancy etc. to enhance their performance and wear comfort [16]. The widely used waterproof breathable finish given to fabrics is fluorocarbon coating [17].

Naeem et al. [18] stated in their work on the effect of the sewing speed on seam strength that seam strength decreases at different rates in superimposed and lapped seams. Furthermore, the lightweight fabric category showed maximum destruction due to the sewing speed. Akter et al. [19] reported in their investigation that sewing threads with the polyester filament core show better seam efficiency and seam strength. Rengasamy et al. [20] established in their study on dynamic sewing tension that the needle thread undergoes four major tension peaks during one sewing cycle, i.e. bobbin thread withdrawal, needle piercing the fabric, tightening of the needle thread around the shuttle and stitch tightening. They also reported that spun polyester threads and polyester filament displayed the lowest and the highest tightening tension. Rudolf [21] considered the properties of 100% PES core-spun sewing threads at different stitching speeds and reported that the loading in the sewing process causes structural changes in thread-twisted fibres. Nayak [22] investigated the effect of Lycra percentage, type of sewing thread and silicon finish on denim fabric sewability, and reported that with an increase in Lycra percentage, the seam efficiency improves as well, whereas the needle damage and seam pucker are affected by fabric weight. Rudolf et al. [23] observed in their study that the tensile and frictional loading of the sewing threads increased with increasing sewing machine stitching speed. It was further reported that the sewing threads with a lower twist intensity show better mechanical properties. In another work, Rudolf [24] investigated and reported that the structural changes in the sewing threads are a result of the deformation of built-in fibres across the cross-section, which in turn influences breaking tenacity, breaking extension, sewing thread fineness and the initial modulus of fibres.

A good quality sewing thread with high breaking tenacity, initial modulus and good breaking elongation must be selected to achieve high efficiency from the sewing threads during the sewing operation. From the literature, it can be observed that quite a few researchers have carried out studies on sewing thread strength loss after the sewing; however, the effect of fabric physical characteristics and finishing remains unfamiliar. Since workwear fabrics are functionally finished, a requirement before being made into a garment, this research assumes the significance of finishing. As such, in this study, the effect of different weight workwear fabrics structure on the change in the tensile properties of sewing threads concerning functional finishing in superimposed seam (SSa) and lapped seam (LSd) were studied.

2 Experimental

2.1 Materials

The fabrics used in this study were 100% cotton undyed workwear fabrics, namely drill, rip-stop and duck, varying in weave structure and weight, were taken into consideration. The workwear fabrics were obtained from three different mills in India, i.e. Loyal textile mills Ltd., M/s Vaibhav Textile Mills and Balavigna Pvt. Ltd. Commercially available polyester-cotton core-spun sewing threads of 40 tex linear density were purchased from Vardhman Threads Pvt. Ltd. The sewing thread was made up of two single yarns plied together with about 40 twists/inch in Z-direction. In the study, the sewing thread was used without any modification for both the needle and bobbin thread. A Juki industrial lockstitch sewing machine – DDL 8300N model, was used for producing a balanced seam with 10 stitches/inch in the superimposed (SSa) and lapped seam (LSd) configuration. The sewing machine specifications are tabulated in Table 1. Ballpoint sewing needles of size 100 Nm manufactured by Groz-Beckert were used in this investigation.

Table 1: Heavy-duty industrial sewing machine specification

Application	Heavy duty (DDL8300N)
Maximum sewing speed	4000 rpm
Maximum stitch length	5 mm
Needle bar stroke	35 mm
Lubrication	Automatic
Lubricating oil	JUKI New defrix oil no. 1
Feed dog	3 row
Hook	Automatic-lubricating full-rotary hook

2.2 Chemicals

The undyed workwear fabrics procured were subjected to the desizing and scouring process before the sewing. Following this, the workwear fabrics were separated into two halves, one half was coated with a fluorocarbon coating using padding mangles, in line with the methods specified by the manufacturer.

2.3 Methods

2.3.1 Physical characterisation of workwear fabrics

The workwear fabrics were characterised for thickness, weight, thread count and thread density (cf. Table 2). The weight of fabrics was calculated using a GSM cutter and an electronic balance. The thickness of the fabric was measured in a thickness tester under constant compressive load of 2 kPa. The warp and weft yarn counts were measured by using a Beesley's balance and the fabric construction was measured using counting glass. All these physical characterisations were performed according to the ASTM standards. The workwear fabric thread interlacement pattern is shown in Figure 1 and the symbols used to represent the test specimens are included in Table 3. The desized, scoured and uncoated drill, rip-stop and duck fabrics in superimposed seam (SSa) and lapped seam (LSd) were

Table 2: Physical characteristics of workwear fabrics

S. No.	Fabric composition	Weave pattern	Thickness (mm)	Mass per unit area (g/m^2)	Fabric construction properties			
					Thread count (tex)		Threads in fabric (cm^{-1})	
					Warp	Weft	Warp	Weft
1	100% cotton	Duck (2/2)	0.49	256	37	49	32	13
2	100% cotton	Rip-stop (1/1)	0.52	238	30	37	37	21
3	100% cotton	Drill (3/1)	0.71	309	37	49	36	22

	X		X
X		X	
	X		X
X		X	

a)

			X
		X	
	X		
X			

b)

		X	X
X	X		
		X	X
X	X		

c)

Figure 1: a) Plain weave (rip-stop), b) drill weave and c) duck weave

Table 3: Nomenclature of test specimens

S. No.	Symbol	Specimen description	S. no.	Symbol	Specimen description
1	UST	Unsewn sewing thread	8.	FRS-BC-LSd	Uncoated rip-stop fabric sewn in lapped seam
2.	FDR-BC-SSa	Uncoated drill fabric sewn in superimposed seam	9.	FRS-AC-LSd	Coated rip-stop fabric sewn in lapped seam
3.	FDR-AC-SSa	Coated drill fabric sewn in superimposed seam	10.	FDK-BC-SSa	Uncoated duck fabric sewn in superimposed seam
4.	FDR-BC-LSd	Uncoated drill fabric sewn in lapped seam	11.	FDK-AC-SSa	Coated duck fabric sewn in superimposed seam
5.	FDR-AC-LSd	Coated drill fabric sewn in lapped seam	12.	FDK-BC-LSd	Uncoated duck fabric sewn in lapped seam
6.	FRS-BC-SSa	Uncoated rip-stop fabric sewn in superimposed seam	13.	FDK-AC-LSd	Coated duck fabric sewn in lapped seam
7.	FRS-AC-SSa	Coated rip-stop fabric sewn in superimposed seam			

symbolically represented as FDR-BC-SSa, FRS-BC-SSa, FDK-BC-SSa and FDR-BC-LSd, FRS-BC-LSd, FDK-BC-LSd, while the desized, scoured and fluorocarbon coated drill, rip-stop and duck fabrics in superimposed seam (SSa) and lapped seam (LSd) were symbolically represented as FDR-AC-SSa, FRS-AC-SSa, FDK-AC-SSa and FDR-AC-LSd, FRS-AC-LSd, FDK-AC-LSd.

2.3.2 Desizing and scouring process

To remove the starch applied during the weaving process, the workwear fabrics were desized using the acid steeping method. In this method, the material is padded with mineral acid (sulphuric acid) 2 cm^3/L and stored in large vats at about 60 °C for about 45 minutes to allow the acid to hydrolyse the starch. After this, the material is thoroughly rinsed to remove the hydrolysed starch and then dried. The material to liquor ratio was maintained at 1 : 20, and laboratory-grade reagent sulphuric acid was used in this study. The scouring process is carried out to remove natural impurities such as fats, oils, pectins, pectos, ash, wax and other minerals from a greige cotton fabric for better bleaching and dyeing properties. Scouring is done by boiling the cotton material in strong sodium hydroxide (alkali) solutions for a few hours. Other reagents used to enable thorough scouring include surfactants to reduce the surface tension and an emulsifying agent to remove non-saponifiable fats and waxes held in the suspension in the liquor. In the scouring in this study, the material to liquor ratio was maintained at 1 : 20, and the chemicals used were 10% caustic soda, 15% soda ash, 15% wetting agent and 5% sequestering agent. The scouring bath temperature was maintained at 90–100 °C for 8 hours. Afterwards, the scouring bath was allowed to cool down for about 2 hours; then, the materials were removed, thoroughly rinsed and flat dried in shade.

2.3.3 Padding process

The fluorocarbon solution (Nuva HPU), procured from Clariant Chemicals Pvt. Ltd., was used for coating the workwear fabrics without any modifications. The coating recipe was made up of 60% fluorocarbon solution (Nuva HPU), 10% Printofix Thickener ECS and 30% water. The pretreated fabrics were then padded in continuous padding mangle range, followed by curing at 150 °C for 5 minutes.

2.3.4 Seam preparation

The three workwear fabrics were sewn on an industrial heavy-duty lockstitch machine with the stitch density of 2.5 mm stitch length at a constant speed of 3000 rpm to produce a balanced seam. Five replicates were sewn in each seam type in each workwear fabric, measuring about 2 meters in length. The static tension for bobbin threads was adjusted manually by trial runs to obtain a balanced stitch and maintained constant. The same sewing thread was used for needle and bobbin threads to prepare the seams. After the sewing, the needle threads were taken out for characterisation. The superimposed seam is one of the most familiar means of seaming. The most basic superimposed seam (SSa) is where one ply of a fabric is stacked upon another with thread stitching through all plies of fabric. The superimposed seam is used on many garment side seams. A lapped seam (LSd) is achieved with two or more pieces of a fabric overlapping each other. A lapped seam has commonly, yet not always, one ply of a fabric fold under itself for a finished edge. Lapped seams are common when working with leather and sewing side seams on jeans and dress shirts. The diagram of both seams is shown in Figure 2. After the sewing in the two-seam configuration above, the sewing threads in superimposed seams were removed by unravelling warp and weft yarns of the fabric and then the needle threads were separated from the seam. In lapped seams, bobbin threads were cut out and the needle thread was carefully removed for further characterisation. The mean values of the experiment results were statistically evaluated with Student's *t*-test at 95% confidence level.

a) b)

Figure 2: Seam configuratzion: a) superimposed seam (SSa) and b) lapped seam (LSd)

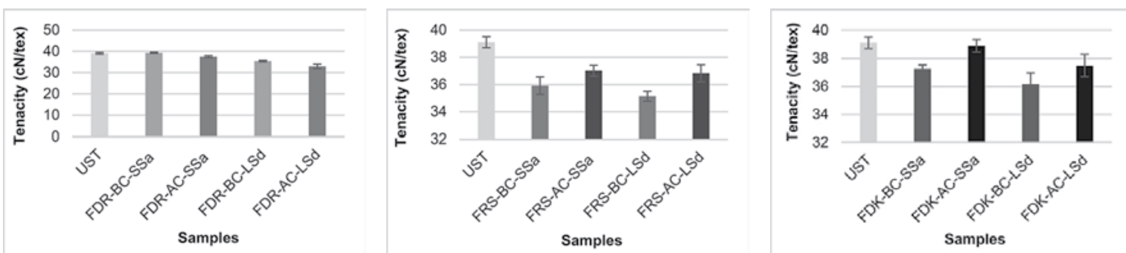
2.4 Characterisation

2.4.1 Tenacity, breaking elongation and initial modulus

The axial strength and elongation of the sewing thread determine the effectiveness of the tensile force acting on the sewing thread. Highly extensible threads are generally preferred for garments. These parameters are necessary for good seam quality. The tensile testing of the needle thread before and after the sewing was performed at a gauge length of 100 mm with a traverse speed of 500 mm/min on an Instron 3369 tensile testing machine as per ASTM standard D2256. An average of thirty tests were carried out for each sample and the mean values were reported (Figures 3–8). The threads extracted from the seams before and after the coating were tested, and compared with the unsewn sewing thread.

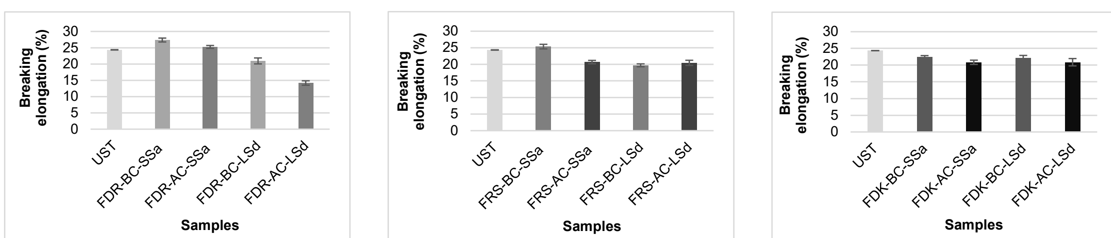
3 Results and discussion

The tensile properties of the polyester-cotton core-spun sewing thread, in superimposed and lapped seams, before and after the sewing of coated and uncoated workwear fabrics are shown in Figures 3–8. It can be observed that there is a considerable change in tenacity, breaking elongation and initial modulus of the sewing threads after the sewing of workwear fabrics.



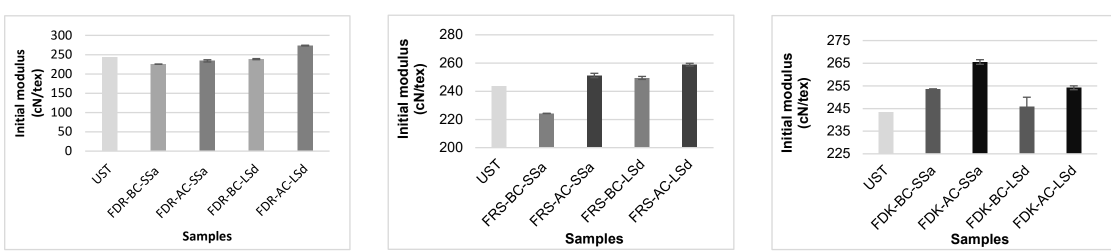
a) b) c)

Figure 3: Effect of coating and seam configuration on tenacity of (a) drill, (b) rip-stop and (c) duck fabrics



a) b) c)

Figure 4: Effect of coating and seam configuration on breaking elongation of (a) drill, (b) rip-stop and (c) duck fabrics



a) b) c)

Figure 5: Effect of coating and seam configuration on initial modulus of (a) drill, (b) rip-stop and (c) duck fabrics

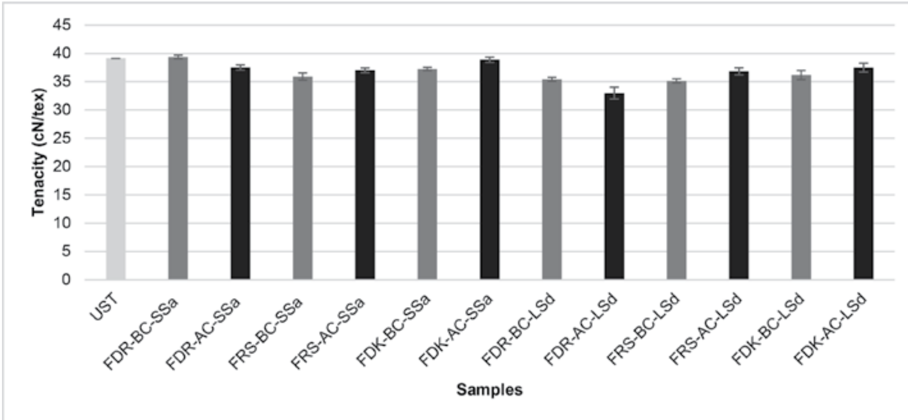


Figure 6: Comparison of tenacity changes between sewing threads from bobbins and sewing threads extracted from workwear fabrics

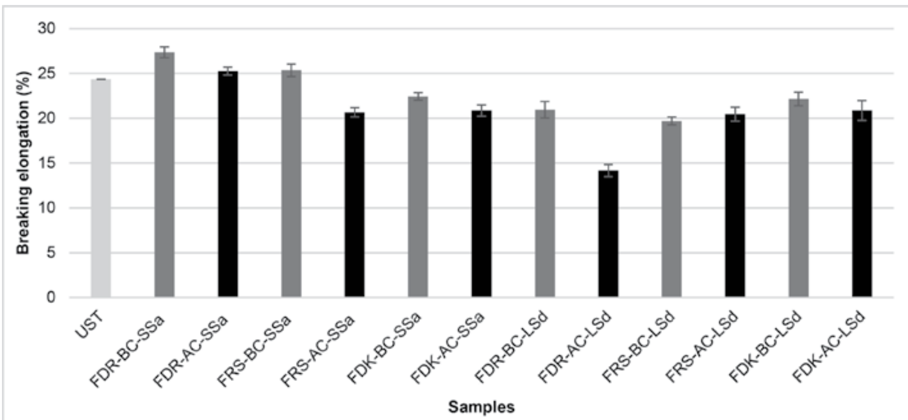


Figure 7: Comparison of breaking elongation changes between sewing threads from bobbins and sewing threads extracted from workwear fabrics

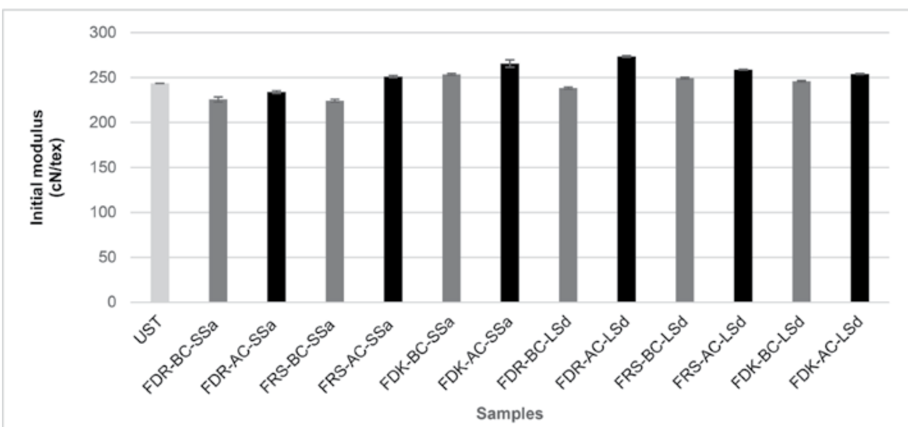


Figure 8: Comparison of initial modulus changes between sewing threads from bobbins and sewing threads extracted from workwear fabrics

3.1 Effect of tenacity

The tenacity changes in the sewing threads before and after the sewing of uncoated and coated workwear fabrics (drill, rip-stop and duck fabrics) are shown in Figures 3a, 3b and 3c. From the results, it is clear that the sewing threads lost their strength after the sewing. The highest strength reduction was observed in rip-stop workwear fabrics and the smallest strength reduction was observed in drill workwear fabrics. The strength reduction in drill workwear fabric was about 4.7% in the test specimen FDR-AC-SSa and 6.89% in the specimen FDR-AC-LSd, both being significant at 95% confidence level. An exact opposite trend was observed with rip-stop workwear fabrics. The coated fabric sewing thread strength increased by 3.06% in the test specimen FRS-AC-SSa and 4.81% in the specimen FRS-AC-LSd. However, the strength increase was significant for the specimen FRS-AC-LSd and insignificant for the FRS-AC-SSa test specimen. An almost similar trend was observed with duck workwear fabrics with strength improvements of 4.40% in the specimen FDK-AC-SSa and 3.62% in the specimen FDK-AC-LSd. The strength improvement was statistically significant for the former and insignificant for the latter specimen.

The tenacity loss percentage observed among workwear fabrics (Figure 6) was 8.16%, 4.76% and 0.6%, respectively, for the specimens FRS-BC-SSa, FDK-BC-SSa and FDR-BC-SSa with respect to the UST specimens. With the test specimens FRS-BC-SSa and FDK-BC-SSa, the abrasive damage was much higher compared to FDR-BC-SSa. This behaviour could be attributed to the weave structure. Rip-stop being a plain-woven structure with threads interlacing alternately, the core-spun polyester sewing thread is subjected to higher abrasive damage as it enters the fabric. Similarly, the duck weave is a plain structure with two yarns working together in the warp direction, meaning that the abrasive damage is intermediate compared to rip-stop fabrics. Nevertheless, drill fabrics with one interlacement for every four repeating threads underwent the least abrasive damage. A significant increase in tenacity in the specimen FDR-BC-SSa could result from variations in the sewing thread. Furthermore, all the specimens considered showed a significant tenacity loss in lapped seams. The specimens FDR-BC-LSd, FRS-BC-LSd and FDK-BC-LSd showed 9.43%, 10.15% and 7.52% tenacity loss compared to UST. This behaviour could be attributed to the higher number of layers in the seam configuration leading to higher abrasion. The tenacity loss of sewing threads removed from the coated workwear fabric amounted to 6.89% and 4.7% for the specimens FDR-AC-SSa and FDR-AC-LSd., whereas all other specimens showed an improvement in tenacity after the coating, which could be a consequence of inherent lubricity characteristics of fluorocarbon [17]. For the specimens FRS-AC-LSd, FDK-AC-LSd, FRS-AC-SSa and FDK-AC-SSa, the percentage increase was 4.81%, 3.62%, 3.06% and 4.40%, respectively.

3.2 Effect of breaking elongation

The changes in the breaking elongation of the sewing threads before and after sewing the uncoated and coated workwear fabrics (drill, rip-stop and duck fabrics) are shown in Figures 4a, 4b and 4c. The results did not show any clear trend, though in most specimens, the sewing threads lost their breaking elongation after the sewing. The highest breaking elongation reduction was observed in rip-stop workwear fabrics and the smallest breaking elongation reduction was observed in duck workwear fabrics. The breaking elongation reduction in drill workwear fabrics was about 7.68% in the test specimen FDR-AC-SSa and 32.36% in the specimen FDR-AC-LSd, both being significant at 95% confidence level. With rip-stop workwear fabrics, the loss in breaking elongation was 18.46% for the test specimen FRS-AC-SSa. However, for the specimen FRS-AC-LSd, the breaking extension increased by 3.81%. While the loss of breaking extension was significant for the former specimen, the increase in breaking extension for the latter specimen was insignificant. Duck workwear fabrics showed a reduction in breaking elongation across all specimens considered. The breaking elongation loss percentage after sewing coated duck fabrics was 7.04% and 5.78%, respectively, in the specimens FDK-AC-SSa and FDK-AC-LSd. The reduction in breaking elongation was statistically significant for the former and insignificant for the latter specimen at 95% confidence level.

The breaking elongation loss percentage observed at the workwear fabric specimen (cf. Figure 7) FDK-BC-SSa was 7.81%, which could be attributed to the thermal damage of the core-spun polyester sewing thread. For the specimens FDR-BC-SSa and FRP-BC-SSa, there was an increase in breaking elongation by 12.41% and 4.15%, respectively, which can be attributed to the high extensibility of core-spun sewing threads. The breaking elongation loss percentage for the specimens FDR-BC-LSd, FRS-BC-LSd and FDK-BC-LSd were 13.93%, 19.06% and 8.99%, respectively, indicating higher mechanical restraint due to the presence of three layers of a fabric in the seam construction, which deteriorated the amorphous region of the polyester sewing thread [21].

A significant loss in breaking extension was observed in all test specimens after the coating except at the specimens FRS-AC-LSd and FDK-AC-LSd, which showed an improvement of 3.81% and 5.78% compared to their uncoated counterparts. Conversely, the breaking extension loss percentage was 7.68%, 18.46%, 7.04% and 32.36% for the specimens FDR-AC-SSa, FRS-AC-SSa, FDK-AC-SSa and FDR-AC-LSd. This can be attributed to the reduced mobility of threads and the increase in the coefficient of friction between the fabric and sewing thread leading to lower breaking extensibility.

3.3 Effect of initial modulus

The changes in the initial modulus of sewing threads before and after sewing the uncoated and coated workwear fabrics (drill, rip-stop and duck fabrics) are shown in Figures 5a, 5b and 5c. From the results, it is clear that the initial modulus of sewing threads sewn on coated fabrics across all three workwear fabrics improved after the sewing. The highest initial modules improvement was observed in drill workwear fabrics and the smallest improvement was observed in rip-stop workwear fabrics. The initial modulus in drill workwear fabric increased by about 3.7% in the test specimen FDR-AC-SSa and 14.70% in the specimen FDR-AC-LSd, both being significant at 95% confidence level. In rip-stop workwear fabrics, the initial modulus increase was 12.01% in the test specimen FRS-AC-SSa and 3.76% in the specimen FRS-AC-LSd. The initial modulus increase was significant for both specimens. Furthermore, in duck workwear fabrics, the initial modulus increase was 4.71% in the specimen FDK-AC-SSa and 3.36% in the specimen FDK-AC-LSd. The improvements were statistically significant for both specimens.

The initial modulus loss percentages among workwear fabrics (cf. Figure 8) were 7.37% and 7.93%, respectively, for the specimens FDR-BC-SSa and FRS-BC-SSa. The specimen FDK-BC-SSa showed an improvement by 4.13% compared to UST. Further, the loss percentage of 2.10 % was observed for the specimen FDR-BC-LSd, whereas the specimens FRS-BC-LSd and FDK-BC-LSd showed an improvement of 2.41% and 0.96% compared to UST. This behaviour could be attributed to the change in the viscoelastic properties of the sewing thread during dynamic loading as observed by Rudolf [21] in the study of polyester core-spun sewing threads.

After the coating, the initial modulus of all test specimens considered improved significantly. The improvements were 3.71%, 12.01%, 4.71%, 14.71%, 3.76 and 3.36%, respectively, for the specimens FDR-AC-SSa, FRS-AC-SSa, FDK-AC-SSa, FDR-AC-LSd, FRS-AC-LSd and FDK-AC-LSd, the specimen FDR-AC-LSd showing the highest increase and the specimen FDK-AC-LSd the smallest improvement. The latter can be attributed to the high flexibility of core-spun sewing threads, which remain flexible even after coating.

4 Conclusion

In this study, the effects of fabric structure, seam configuration and coating on tenacity, breaking elongation and initial modulus were investigated. During high-speed sewing, the tensile characteristics of needle threads were influenced by the fabric structure. The sewing process brought about elastic deformation in sewing threads. Tenacity and breaking elongation were significantly affected by the fabric weave structure. Moreover, drill fabric structures with longer floats in the weave structure imparted the least abrasive damage to polyester sewing threads among all structures considered. A higher mechanical restraint was observed in the lapped seam configuration due to the presence of three layers in the seam compared to the superimposed seam construction. After the coating, the initial modulus of all test specimens considered improved significantly, suggesting the flexibility of core-spun sewing threads.

Declaration of conflict of interest

The authors declared no potential conflicts of interest concerning the research, authorship and/or publication of this article.

Funding

T*he authors received no financial support for the research, authorship and/or publication of this article.*

References

1. MANDAL, S., ABRAHAM, N. An overview of sewing threads mechanical properties on seam quality. *Pakistan Textile Journal*, 2010, **1**, 40–43.
2. MERIÇ, B., DURMAZ, A. Effect of thread structure and lubrication ratio on seam properties. *Indian Journal of Fibre & Textile Research*, 2005, **30**(3), 273–277.
3. ABOU NASSIF, N. A. Investigation of the effects of sewing machine parameters on the seam quality. *Life Science Journal*, 2013, **10**(2), 1427–1435.

4. FARHANA, K., SYDUZZAMAN, M., YEASMIN, D. Effect of sewing thread linear density on apparel seam strength: a research on lapped & superimposed seam. *Journal of Advancements and Engineering and Technology*, 2015, **3**(3), 1–7.
5. CHOUDHARY, A. K., GOEL, A. Effect of some fabric and sewing conditions on apparel seam characteristics. *Journal of Textiles*, 2013, **2013**, 1–7, doi: 10.1155/2013/157034.
6. MURALIDHAR, B. A. Sewing needle temperature and fabric bending property correlation. *Journal of Textile and Clothing Science*, 2021, **4**(3), 21–30.
7. MIDHA, V. K., KOTHARI, V. K., CHATTOPADHYAY, R., MUKHOPADHYAY, A. Effect of workwear fabric characteristics on the changes in tensile properties of sewing threads after sewing. *Journal of Engineered Fibers and Fabrics*, 2010, **5**(1), 31–38, doi: 10.1177/155892501000500104.
8. ŽUNIČ-LOJEN, D., GERŠAK, J. Thread loadings in different measuring positions on the sewing machine. *Textile Research Journal*, 2005, **75**(6), 498–506.
9. MIDHA, V.K., MUKHOPADHYAY, A., CHATOPADHYAY, R., KOTHARI, V.K. Studies on the changes in tensile properties of sewing thread at different sewing stages. *Textile Research Journal*, 2009, **79**(13), 1155–1167, doi: 10.1177/0040517508101456.
10. SUNDARESAN, G., HARI, P. K., SALHOTRA, K. R. Strength reduction of sewing threads during high speed sewing in an industrial lockstitch machine. Part I: mechanism of thread strength reduction. *International Journal of Clothing Science and Technology*, 1997, **9**(5), 334–345, doi: 10.1108/09556229710185460.
11. SUNDARESAN, G., SALHOTRA, K. R., HARI, P. K. Strength reduction in sewing threads during high speed sewing in industrial lockstitch machine: Part II: effect of thread and fabric properties. *International Journal of Clothing Science and Technology*, 1998, **10**(1), 64–79, doi: 10.1108/09556229810205303.
12. KHANNA, S. Interactions of sewing variables: effect on the tensile properties of sewing threads during sewing process. *Journal of Textile and Apparel, Technology and Management*, 2015, **9**(3), 1–13.
13. MUKHOPADHYAY, A. Relative performance of lockstitch and chainstitch at the seat seam of military trouser. *Journal of Engineered Fibers and Fabrics*, 2008, **3**(1), 1–4, doi: 10.1177/155892500800300103.
14. BARBULOV–POPOV, D., CIRKOVIC, N., STEPANOVIĆ, J. The influence of stitch density and of the type of sewing thread on seam strength. *TEM Journal*, 2012, **1**(2), 104–110.
15. KONCER, P., GÜRARDA, A., KAPLANGIRAY, B., KANIK, M. The effects of sewing thread properties on the needle thread tension in an industrial sewing machine. *Textile and Apparel*, 2014, **24**(1), 118–123.
16. KORDOGHLI, B., CHEIKHROUHOU, M., SAIDENE, C.K. Mechanical behaviour of seams on treated fabrics. *AUTEX Research Journal*, 2009, **9**(3), 87–93.
17. PRUITT, L. A. Fluorocarbon polymers in biomedical engineering. In *Encyclopedia of Materials: Science and Technology*. Edited by K. H. Jürgen Buschow, Robert W. Cahn, Merton C. Flemings, Bernhard Ilschner, Edward J. Kramer, Subhash Mahajan, Patrick Veyssière. Elsevier, 2001, 3216–3221, doi: 10.1016/B0-08-043152-6/00572-6.
18. NAEEM, M. S., MAZARI, A., KHAN, I. A., IFTIKHAR, F. Effect of sewing speed on seam strength. *Vlákna a Textile*, 2014, **2**, 24–29.
19. AKTER, M., KHAN, M.R. The effect of stitch types and sewing thread types on seam strength for cotton apparel. *International Journal of Scientific & Engineering Research*, 2015, **6**(7),198–205.
20. RENGASAMY, R.S., WESLEY, D.S. Effect of thread structure on tension peaks during lock stitch sewing. *AUTEX Research Journal*, 2011, **11**(1), 1–5.
21. RUDOLF, A., GERŠAK, J., UJHELYIOVA, A., SMOLE, M.S. Study of PES sewing thread properties. *Fibers and Polymers*, 2007, **8**(2), 212–217, doi: 10.1007/BF02875794.
22. NAYAK, R., PADHYE, R., GON, D.P. Sewing performance of stretch denim. *Journal of Textile and Apparel, Technology and Management*, 2010, **6**(3), 1–9.
23. RUDOLF, A., GREŠAK, J. Influence of sewing speed on the changes of mechanical properties of differently twisted and lubricated threads during the process of sewing. *Tekstil: časopis za tekstilnu i odjevnu tehnologiju*, 2007, **56**(5), 278–285.
24. RUDOLF, A., GERŠAK, J. Study of the relationship between deformation of the thread and built-in fibres. *International Journal of Clothing Science and Technology*, **13**(3/4), 289–300, doi: 10.1108/EUM0000000005783.

Mazyar Ahrari[1], Mehmet Karahan[2], Muzzamal Hussain[3], Yasir Nawab[3], Asfandyar Khan[3], Amir Abbas Shirazi[4]
[1] Bursa Uludag University, Faculty of Engineering, Textile Engineering Department,
Gorukle Campus, 16059, Nilufer, Bursa, Turkey
[2] Bursa Uludag University, Vocational School of technical Sciences, 16059, Nilufer, Bursa, Turkey
[3] National Textile University, School of Engineering & Technology, Faisalabad, 37610, Punjab, Pakistan
[4] Bahauddin Zakariya University, College of Textile Engineering, Multan, 60000, Punjab, Pakistan

Development of Anti-Bacterial and Anti-Viral Nonwoven Surgical Masks for Medical Applications

Razvoj protibakterijskih in protivirusnih netkanih kirurških mask za medicinske namene

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 04-2022 • Accepted/*Sprejeto* 05-2022

Corresponding author/*Korespondenčni avtor:*
Dr. Muzzamal Hussain, Assist Prof
E-mail: muzzamal313@gmail.com
ORCID ID: 0000-0002-8021-1347

Abstract

This article aims to investigate the development of surgical masks for medical applications by incorporating biocidal silver nanoparticles. Medical masks were developed in three layers of a nonwoven fabric, where the outer and inner layers were made of a spun-bond polypropylene nonwoven fabric and the middle layer consisted of a melt-blown nonwoven polypropylene fabric. In this study, silver nanoparticles in the concentrations of 1–5% were applied to masks with the pad-dry-cure method. The samples were cured at room temperature and subsequently examined for antimicrobial properties. Scanning electron microscopy, energy dispersive spectroscopy and Fourier transform infrared spectroscopy were used to investigate the morphological characteristics and chemical composition of the samples. Microbial cleanliness, bacterial filtration efficiency, antiviral effect and breathability tests were performed according to standard test protocols. The results revealed that the application of silver nanoparticles to a three-layer mask rendered the end product with outstanding antimicrobial and antiviral properties with poor breathability (air permeability) results.
Keywords: polypropylene, nonwoven fabric, antimicrobial, silver nanoparticles

Izvleček

V članku je predstavljen razvoj kirurških mask za medicinske namene z vgradnjo biocidnih nanodelcev srebra. Medicinske maske so bile izdelane iz treh slojev vlaknovin, pri čemer sta bila zunanja in notranja plast izdelani iz spunbond polipropilenske vlaknovine, srednji sloj pa iz polipropilenske vlaknovine meltblown. Na masko so bili z metodo impregniranja in zamreževanja naneseni srebrovi nanodelci v koncentraciji 1–5 % pri sobni temperaturi ter nato analizirani glede protimikrobnih lastnosti. Za raziskovanje morfoloških značilnosti in kemične sestave vzorcev so bile uporabljene metode rastrske elektronske mikroskopije, energijske disperzivne rentgenske spektroskopije in infrardeče spektroskopije s Fourierjevo transformacijo. Testi mikrobne čistosti, učinkovitosti bakterijske filtracije, protivirusnega učinka in zračne prepustnosti so bili opravljeni po standardnih testnih protokolih. Rezultati so pokazali, da je nanos srebrovih nanodelcev na triplastno masko dal končni izdelek izjemnih protimikrobnih in protivirusnih lastnosti s slabo zračno prepustnostjo.
Ključne besede: polipropilen, netkana tekstilija, protimikrobno sredstvo, srebrovi nanodelci

1 Introduction

Medical masks have long been used in hospitals by medical staff and nurses to protect themselves and patients from infectious microorganisms [1, 2]. Today, with the outbreak of the COVID-19 pandemic caused by the novel coronavirus (SARS-CoV-2), the use of medical masks in daily life has become inevitable according to the World Health Organization recommendations [3].

In general, a virus is an infectious genetic unit that has the smallest structure of all bacteria. The specific characteristics of viruses place them on the border between the animate and inanimate nature. They can infect both eukaryotic cells (e.g. animals, insects and plants) and prokaryotes (e.g. bacteria) [4–8]. An epidemic is a disease that affects a large number of people within a community, population or region at a particular time, while a pandemic is the spread of a new disease around the world affecting many people [9–11]. Numerous epidemics and pandemics have occurred throughout human history. Some respiratory viral diseases which turned into an epidemic and global pandemic include the Russian Flu (1889–1890), Spanish Flu (1918–1919), Asian Flu (1957–1958), Hong Kong Flu (1968–1970), Severe Acute Respiratory Syndrome (SARS) (2002–2003), Swine Flu (2009–2010), Middle East Respiratory Syndrome (MERS) (2012–Present), Coronavirus Disease 2019 (COVID-19) (2019–Ongoing) [12–21].

Doctors, nurses and medical staff working in hospitals and health centres have been applying face masks since the late nineteenth century to prevent the entry of various bacteria, viruses and microorganisms into their bodies and that of patients [22]. Face masks can be introduced as part of effective personal care equipment (PCE) when confronting infectious viruses [23]. Nevertheless, several studies revealed that face masks, when contaminated, could be a major source of transmission, especially in case of the SARS-CoV-2 virus [24, 25]. According to the latest information, the risk of transmission of the SARS-CoV-2 virus through surfaces is low; however, the virus can survive on the surface for several days. In contrast, the transmission of the virus through surface is high at the medical masks and gowns used during the treatment of COVID-19 patients in the intensive care unit (ICU) [26].

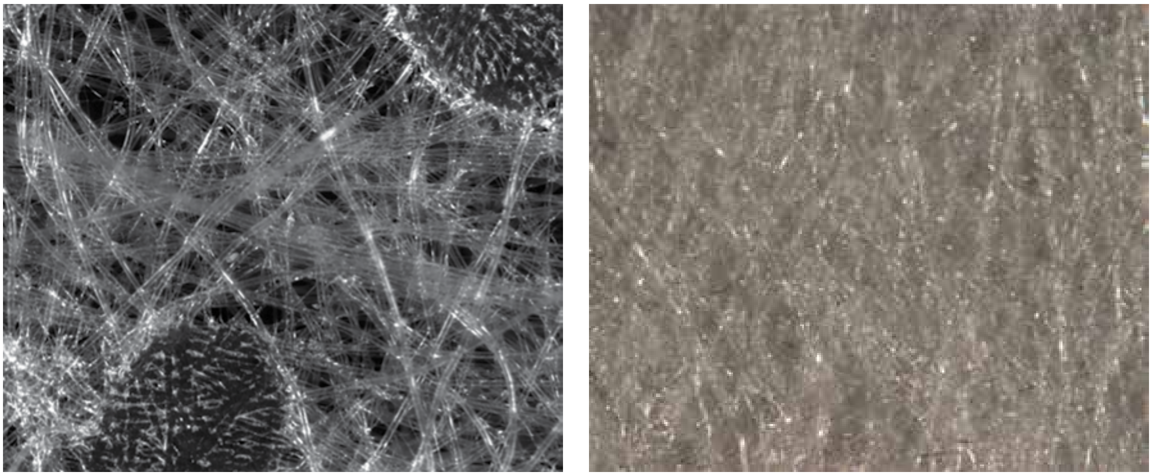
Silver (Ag) nanoparticles (NPs) were first identified as an antibacterial agent and subsequently, their antiviral effect was reported [27, 28]. Ag salts have been known to have antibacterial properties since ancient ages [29], and they are still used to monitor bacterial growth in a number of uses, incl. dental work, catheters and burn wounds [30, 31]. Indeed, Ag ions and Ag-based compounds are considered to be extremely toxic to microorganisms, with significant biocidal effects on bacteria species, incl. *Escherichia coli* [32]. Ag NPs are the most commonly used metal nanoparticles in nanotechnology for several medical applications. Silver molecules, individually or in the presence of antibiotics, have antimicrobial activity against a wide range of pathogens, incl. *Escherichia coli*, *Acinetobacter baumannii*, *Staphylococcus aureus*, *Micrococcus luteus*, *Enterococcus faecium*, *Salmonella typhi*, *Klebsiella pneumoniae*, *Listeria monocytogenes* and *Staphylococcus epidermidis* [33–35].

This paper reports for the first time on a novel approach towards the application of silver nanoparticles onto nonwoven three-layer masks with the pad-dry-cure method. The effect of various concentrations of silver nanoparticles on the antimicrobial and antiviral activity, and breathability were established. The surface morphology of treated and non-treated nonwoven masks were analysed with SEM and the chemical composition with FT-IR.

2 Experimental

Three-layer disposable face masks were developed from 100% polypropylene (PP) melt-blown and spun-bond nonwoven fabrics (cf. Figure 1) purchased from Akinal Textile, Turkey and Gulsan Synthetics, Turkey. Rudolf's RUCO-BAC AGP product, which is the reaction mass of titanium dioxide and silver chloride, was applied in the face-mask treatments as a biocidal finish.

Figure 1: Three-layer nonwoven mask showing spun-bond and melt-blown polypropylene sheets



a) b)

Figure 2: Original polypropylene fabric stereo microscope micrograph (100×): a) spun-bond, b) melt-blown

A stereo microscope micrograph (100×) of a spun-bond nonwoven fabric prepared for the fabrication of surgical masks is shown in Figure 2.

Technical specifications of three-layer nonwoven fabrics are summarised in Table 1. Face-mask wires and elastic string bands (stretchable earloops) were purchased from Serhat Lastik, Turkey. Biocidal silver nanoparticles were supplied by Rudolf Chemicals Co., Turkey and were used as received without further purification. A PROWHITE vertical foulard machine (Model Y001, Turkey) was used in the finishing process to apply the finish onto the fabrics.

Table 1: Technical specifications of nonwoven fabrics used in mask development

Substrate type	Fabric type	Density (g/m^2)
Outer layer	PP spun-bond nonwoven	30
Middle layer	PP melt-blown nonwoven	25
Inner layer	PP spun-bond nonwoven	20

2.1 Production of masks

A fully automatic surgical mask production line (cf. Figure 3) was used for the manufacturing of the masks with the dimensions of 170 mm × 95 mm. The main production process flow was coil material feeding, nose bridge tendon feeding, folding and pressing, mask cutting and shaping, ear band feeding, welding and unloading of the finished product. Nose wires and ear bands of the masks were automatically cut and welded by ultrasonic welding.

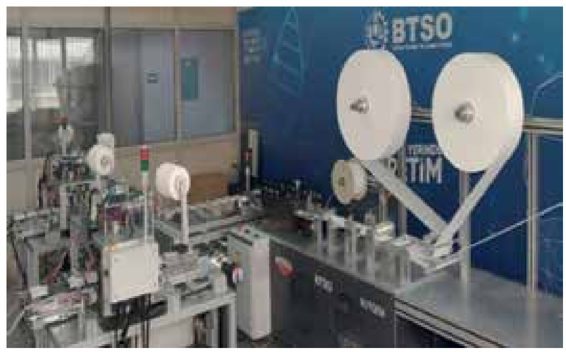


Figure 3: Surgical mask production line collected from Otima, Turkey

2.2 Application of biocidal antiviral chemical finishing onto fabrics

The application of biocidal properties to nonwoven fabrics with a biocidal finish was carried out in a vertical Foulard machine (PROWHITE Y001). The wet pick-up was 100% using liquor ratio of 1:10, and the dry add-on was 1% and 5% on the weight of an untreated sample. During the padding process, the Foulard pressure was 2.95 bar at 3.5 m/min speed under ambient temperature. PP nonwoven fabrics were padded with biocidal nanoparticles of different concentrations and coded M-1, M-2, M-3, M-4, M-5, M-6, M-7 and M-8, as shown in Table 2. No chemical treatment was applied on the middle layer in all cases.

The padded nonwoven fabrics were air-dried at room temperature. Treated PP nonwoven fabrics were utilised to fabricate disposable face masks by means of a fully automatic surgical face mask production line as shown in Figure 3.

Table 2: Configuration of masks used in study

Sample no.	Outer layer – treated with silver nanoparticles (g/l)	Inner layer – treated with silver nanoparticles (g/l)
M-1	1	no treatment
M-2	1	1
M-3	2	no treatment
M-4	2	2
M-5	3	no treatment
M-6	3	3
M-7	4	no treatment
M-8	5	no treatment
Reference	no treatment	no treatment

2.3 Characterisation

The surface morphologies of the untreated and treated PP nonwoven fabric in different concentrations of biocidal silver nanoparticles were analysed with scanning electron microscopy (SEM) (HITACHI TM3030 Plus, Japan). In addition, the distribution of nanoparticles on face masks was investigated by using SEM. A small piece of a mask (1 × 1 mm) was cut from the outermost layer of the nanoparticle-coated mask. The sample was mounted onto a coverslip, coated with gold alloy and analysed with scanning electron microscopy. An EDAX AMETEK spectrometer equipped with an octane detector using TEAM™ software was used to record the spectra and for a subsequent EDS spectral analysis of uncoated samples.

Fourier transform infrared spectroscopy (FT-IR) was performed using a Shimadzu FT-IR (Japan) spectrophotometer operated in % transmittance mode at room temperature in the range 600–4000 cm^{-1} and the resolution of 8 cm^{-1}. FTIR works by measuring how much light is absorbed by the bonds of vibrating molecules to create a molecular fingerprint in the infrared region of the electromagnetic spectrum. The infrared spectrum is divided into three parts, i.e. near IR, mid-IR and far IR. Near infrared has the most energy and can penetrate a sample considerably deeper than mid or far infrared; however, it is also less sensitive. When infrared light is absorbed, molecules vibrate and bonds stretch and bend, according to IR principles. It operates by delivering an IR beam across a sample and the sample molecules must experience a dipole moment shift during the vibration in order for an IR observable transition to occur. Absorption happens when the IR frequency matches the vibrational frequency of the bonds, allowing the spectrum to be recorded. Different functional groups absorb heat at different frequencies when using infrared. It is determined by their structure and the functional groups contained in a sample can be determined using a vibrational spectrum. The results of an IR spectrometer analysis are compared to a frequency table to determine which functional groups are present.

2.4 Assessment of microbiological tests on mask

The antibacterial activity of masks was checked according to the standard test protocol, i.e. EN 14683:2019+AC:2019 [36]. The bacterial filtration efficiency (BFE) of the face mask material as a barrier to bacterial penetration was measured using the BFE test method based on EN 14683:2019+AC:2019 Annex B [37]. The test area was 4.9 cm^2 and the tests were repeated 5 times for accuracy. The test samples were conditioned at 21 °C ± 5 °C and (85 ± 5) % relative humidity for 4 hours. *Staphylococcus aureus* (ATCC 6538) was used for the BFE tests. The bacterial concentration was 5×10^5 CFU/ml and incubated for 24 h at 35 °C ± 2 °C. The specimen of the mask material was clamped between an impactor in an aerosol chamber and aerosol of *Staphylococcus aureus* was introduced into the aerosol chamber. The BFE of the mask was given by the number of CFU (colony forming unit) passing through the medical face-mask material and expressed as the percentage of the number of CFU in the aerosol. The test flow rate and the time were 28.3 l/min and 2 minutes, respectively. The mean particle size of samples was 3.0 µm.

For the microbial cleanliness (bioburden) analysis, EN 14683:2019+AC:2019 Annex D [37] standard test method was used and five repetitions were performed for each type of test. The samples were weighed and put in extraction liquid after being shaken for 5 min at 250 rpm and then inoculated on suitable agar plates. The plates were incubated for 3 days at 30 °C ± 1 °C for 72 hours, and 7 days at 20–25 °C for Tryptic Soy Agar (TSA) and Sabouraud Dextrose Agar (SDA) plates, respectively. After the incubation, total microorganism counts were calculated as CFU/g.

2.5 Assessment of antiviral activity on fabric

Antiviral tests were applied to samples with the highest antibacterial activity (M-3, M-5, M-6, M-7 and M-8). For the antiviral activity tests, control fabric samples, which were sterilised and dried in autoclave at 121 °C for 15 minutes, and six test fabric samples at the mass of 0.4 grams were used. Three control fabric samples were used to measure the virus titre immediately after the inoculation, three control fabric samples and three test fabric samples were used for the control test of the effect of the virus-free test sample. 400 μl of the Bovine coronavirus ATCC's reference strain VR-874 was inoculated on the remaining three control fabric samples and three test fabric samples for the main test. At the end of the contact period of 2 hours, 20 ml of Casein Digest-Soy Lecithin Polysorbate (SCDLP) medium was added to the samples. After the virus recovery procedures in the ISO 18184 standard, they were cultivated in MDBK (NBL-1) ATCC (CCL-22) cells with serial dilutions. All recovery and logarithmic reduction calculations were conducted using the Spearman-Karber method, taking into consideration the virus dilutions that create visible cytopathic effects on the control and test samples that were studied simultaneously on an inverted microscope.

2.6 Determination of physical properties (breathability) on mask

Air permeability tests were carried out on untreated and treated PP nonwoven fabrics to investigate their breathability. The differential pressure required to draw air through the face mask was measured at a constant airflow rate using a differential manometer according to the EN 14683:2019+AC:2019 Annex C. The samples were conditioned at 21 °C ± 5 °C temperature and 85% ± 5% humidity for 4 hours. The area of tests was 25 mm in diameter and the airflow was adjusted to 8 l/min.

2.7 Performance of medical face masks

The TS EN 14683:2014 standard defines the features and performance requirements of the product. The performance levels are determined by testing the products according to these requirements. Table 3 shows the test and performance limits used in the classification of the product.

3 Results and discussion

3.1 Characterisation of reference and silver oxide-doped samples

The FT-IR spectra of samples are presented in Figure 4, the aliphatic C-H stretching vibration of spun bond PP is associated with multiple absorption peaks at 2840–3000 cm^{-1}. The in-plane rocking vibration of the CH_2 group is associated with the absorption peak at 840 cm^{-1} and the C-H bending vibrations in the CH_2 group are observed at 1454 and 1377 cm^{-1}.

3.2 Morphological observations

In the scanning electron microscope and stereo microscope micrographs, the presence of silver and titanium nanoparticles on nonwoven fabrics is evident. The morphological results (cf. Figures 5

Table 3: Performance requirements for medical face masks

Test	Type I[a)]	Type II	Type IIR
Bacterial filtration efficiency (BFE), (%)	≥ 95	≥ 98	≥ 98
Differential pressure (Pa/cm^2)	< 40	< 40	< 60
Splash resistance pressure (kPa)	Not required	Not required	≥ 16
Microbial cleanliness (CFU/g)	≤ 30	≤ 30	≤ 30

[a] Type I medical face masks should only be used for patients and other persons to reduce the risk of spreading infections particularly in epidemic or pandemic situations. Type I masks are not intended for use by healthcare professionals in an operating room or in other medical settings with similar requirements.

and 6) illustrate the clogged pores and corroborate the worse differential pressure (breathability) test results (cf. section 3.6 Determination of physical properties (breathability) on mask).

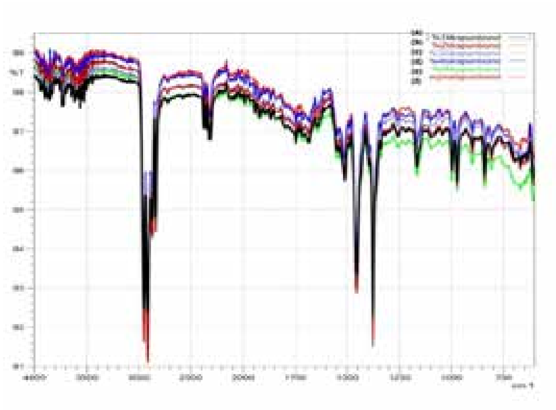


Figure 4: FT-IR spectra of PP fabrics treated with silver nanoparticles: a) 1 g/l, b) 2 g/l, c) 3 g/l, d) 4 g/l, e) 5 g/l and f) untreated

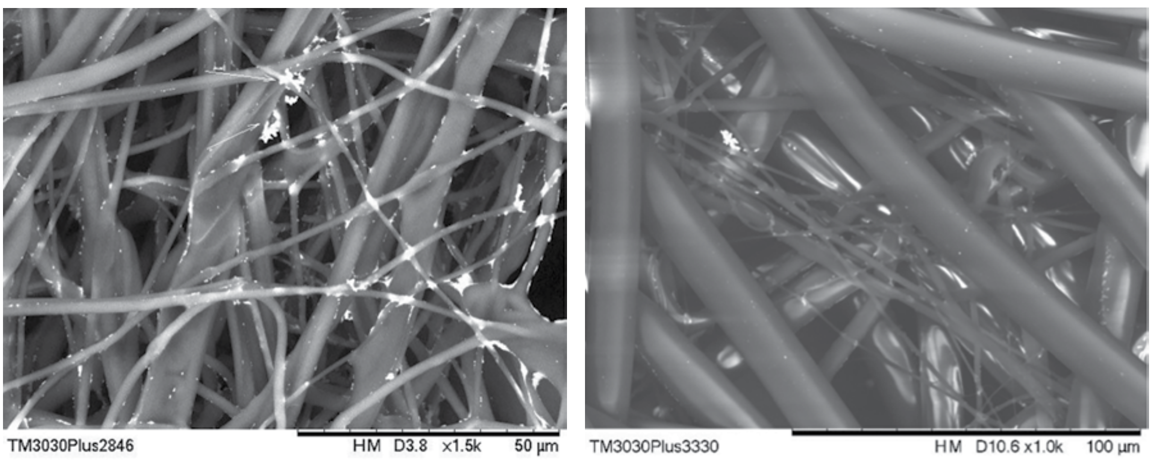
The presence of Ti and Ag in the finishing masks were confirmed by the EDS investigations as mentioned in Figure 7. The weight % of each element observed in the EDS analysis of PP treated with 5% add-on is given in Table 4.

Table 4: EDS investigation of finished masks with 5% dry add-on

Element	Weight (%)	Error (σ) (%)
C	74.3	1.1
O	15.0	1.0
Ti	6.8	0.6
Ag	3.1	0.6
Cl	0.9	0.2

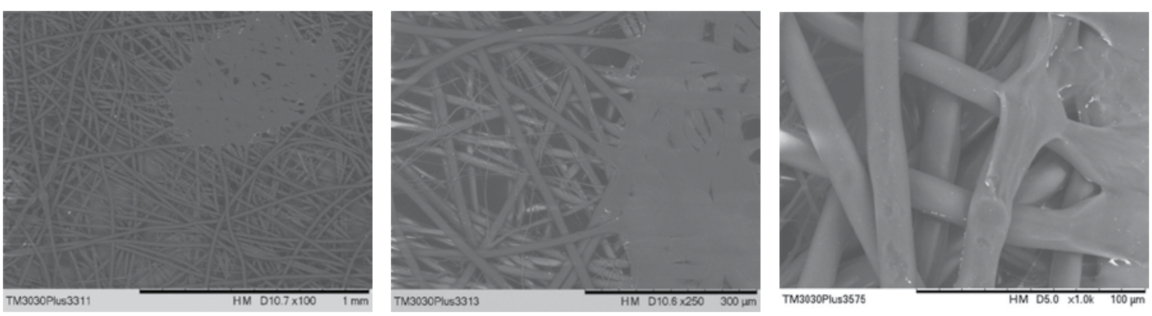
3.3 Bacterial filtration efficiency test (BFE)

Bacteria filtration efficiency is a standard that prevents the release of small particles from mouth while speaking and prevents bacteria from entering our respiratory tract. The rise of the bacteria



a) b)

Figure 5: Scanning electron micrographs of silver nanoparticles on nonwoven mask. After treatment with nanoparticles, white agglomerations are seen in three layers of mask; melt-blown (a), spun-bond (b); magnification of (a) is 1,500×, magnification of (b) is 1,000×



a) b) c)

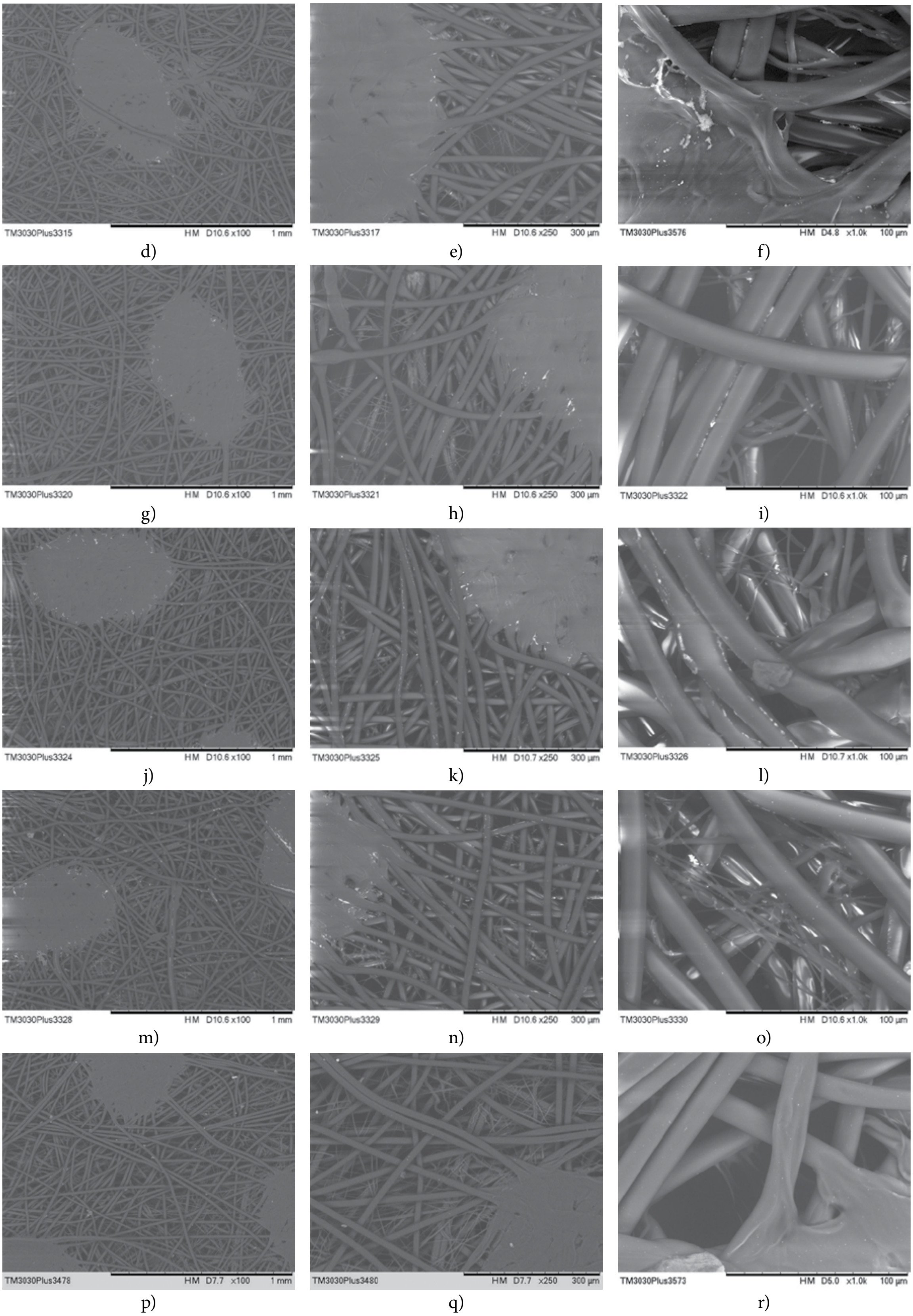


Figure 6: Scanning electron micrographs of silver nanoparticles on nonwoven mask (a–c: 1 g/l; d–f: 2 g/l; g–i: 3 g/l; j–l: 4 g/l; m–o: 5 g/l; p–r: untreated). Magnifications are 100×, 250× and 1000×, respectively.

a) b) c)

Figure 7: SEM (a) and EDS (b and c) investigations of finished samples (5% add-on), confirming presence of Ti and Ag in masks

filtration efficiency rate means that the protection of masks increases. According to this information, when surgical masks are classified, Type II and Type IIR provide the same amount of protection, while Type I shows less protection than the previous two. Due to the BFE results, all samples are categorised as Type IIR, except for the samples 9 and Reference, which is categorised as Type I (cf. Figure 8).

3.4 Microbial cleanliness (bioburden) (CFU/g)

Regarding microbial cleaning, the biological load of a mask should be evaluated according to Annex D of the ISO 14683 standard or according to the EN ISO 11737-1 standard. This value should be at most 30 CFU/g for Type I, Type II and Type IIR. Due to the obtained results, all samples passed the microbial cleanliness test successfully.

3.5 Antiviral efficiency test

Figure 9 shows a comparison of viral reduction percentage results of samples M-3, M-5, M-6, M-7 and M-8. Comparing the M-3 test fabric virus titres with the control fabric virus titres, it was found that at 25 °C, 5-minute contact time caused at least 0.17 log10 (32.39%) reduction against the Bovine coronavirus in all experimental conditions.

In the case of the test fabric M-5, it was observed that the log10 reduction factor was 0.25 log10 with a 43.76% reduction against the Bovine coronavirus. Regarding the M-7 test fabric, it was determined that it caused at least a 0.08 log10 (16.82%) reduction against the same virus. By comparing the M-6 test fabric virus titres with the control virus titres, it was found that at 25 °C, 5-minute contact time caused at least a 0.33 log10 (53.22%) reduction against the Bovine coronavirus in all experimental conditions. In the case of the M-8 test fabric, it was found that at 25 °C, 5-minute contact time caused at least a 0.17 log10 (32.39%) reduction against the Bovine coronavirus in all experimental conditions. Table 5 shows a detailed comparison of all results of the antiviral efficiency tests.

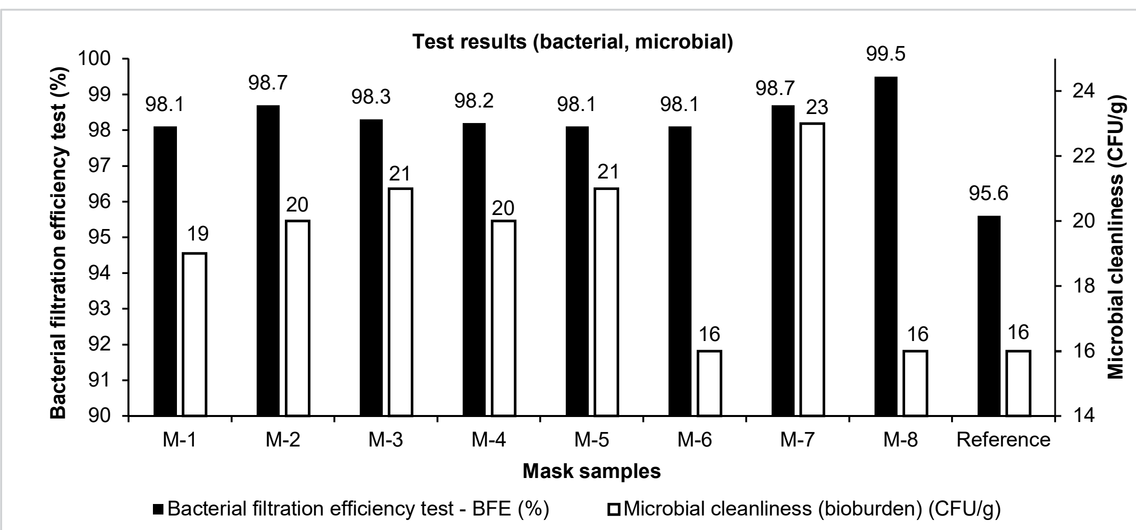


Figure 8: Bacterial filtration efficiency, microbial cleanliness and differential pressure results of treated and untreated nonwoven masks

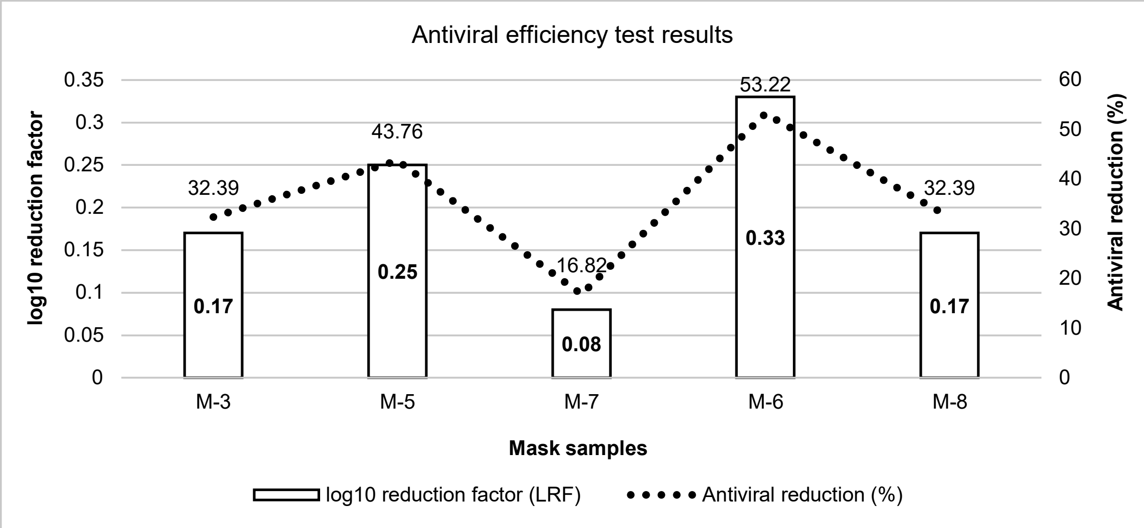


Figure 9: Comparison of log10 reduction factor and antiviral reduction percentage of different samples at 25 °C and 5-minute contact time

3.6 Determination of physical properties (breathability) on mask

A face mask should protect the wearer's nose, mouth and chin. It should be worn tightly that the sides of the mask fit to the face. At the same time, it should allow the user to breathe comfortably during a long-term use. Since the mouth and nose part are closed during the use of the mask, the exhaled carbon dioxide gas cannot go out and is inhaled back. The breathability rate shows how much of the exhaled carbon dioxide goes outside through the mask. Due to differential pressure (breathability) test results based on the EN 14683:2019+AC:2019 Annex C standard, none of the treated samples passed the limit defined by the standard, i.e. below 40 Pa/cm^2, apart from the reference (untreated) sample (cf. Figure 10). The uneven distribution of silver nanoparticles probably led to pore clogging in spun-bond nonwoven fabric breathability zones, which can also be confirmed by SEM observations.

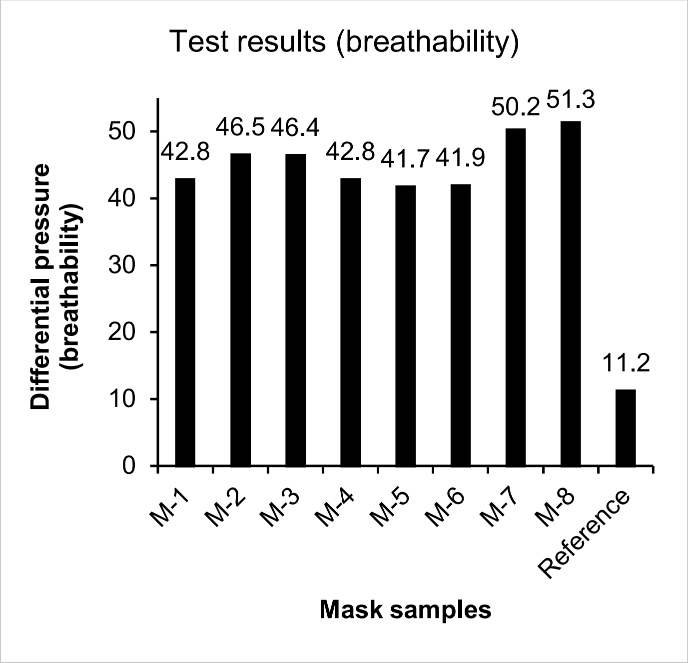


Figure 10: Differential pressure (breathability) results of treated and untreated nonwoven masks

Table 5: Antiviral efficiency test results of different samples against Bovine coronavirus

Sample No.	Sample specifications	Contact time (min)	Log10 reduction factor	Antiviral reduction (%)
M-3	Control fabric 1	0	–	–
	Control fabric 1	5	0.08	16.8
	Test fabric 1	5	0.17	32.39
	Control fabric 1	30	–	–
	Test fabric 1	30	0.2 ≤ 0.5 log10	–
M-5	Control fabric 1	0	–	–
	Control fabric 1	5	0.41	61.09
	Test fabric 2	5	0.25	43.76
	Control fabric 2	30	–	–
	Test fabric 2	30	0.2 ≤ 0.5 log10	–
M-7	Control fabric 1	0	–	–
	Control fabric 1	5	0.33	53.22
	Test fabric 2	5	0.08	16.82
	Control fabric 2	30	–	–
	Test fabric 2	30	0.2 ≤ 0.5 log10	–
M-6	Control fabric 1	0	–	–
	Control fabric 1	5	0.5	68.37
	Test fabric 3	5	0.33	53.22
	Control fabric 3	30	–	–
	Test fabric 3	30	0.2 ≤ 0.5 log10	–
M-8	Control fabric 1	0	–	–
	Control fabric 1	5	0.33	53.22
	Test fabric 4	5	0.17	32.39
	Control fabric 4	30	–	–
	Test fabric 4	30	0.2 ≤ 0.5 log10	–

4 Conclusion

This study successfully developed antibacterial and antiviral surgical masks for medical applications. The fabrication method (pad-dry-cure) was proven feasible and scalable for a large-scale production. The biocidal silver nanoparticles, which have the potential to be applied to surgical face masks, delivered better resistance against bacterial and viral transmission as well as penetration. The adhesion of silver and titanium nanoparticles to nonwoven polypropylene was confirmed by SEM and EDS results. However, the addition of silver nanoparticles resulted in pore clogging of the spun-bond nonwoven polypropylene fabric, which finally resulted in poor differential pressure (breathability) results. The bacterial filtration efficiency, microbial cleanliness and antiviral efficiency test results were satisfactory. The increasing amount of biocidal agent in the formulation led to an increase in the antiviral activity, meaning that the developed surgical masks provided better resistance against microbes and viruses; however, for better breathability, lower concentrations of silver nanoparticles are recommended.

Acknowledgments

This work was based on the research project TR41/20/COVID/0019, which was funded by the Bursa Eskişehir Bilecik Development Agency of Turkey (BEBKA). We would like to thank Bursa Technology Coordination and R&D Center (BUTEKOM) for their valuable support.

Conflict of interests

All authors listed in the manuscript declare no conflict of interests related to this research. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, nor in the decision to publish the results.

References

1. HO, K.F., LIN, L.Y., WENG, S.P., CHUANG, K.J. Medical mask versus cotton mask for preventing respiratory droplet transmission in micro environments. *Science of the Total Environment*, 2020, **735**, doi: 10.1016/j.scitotenv.2020.139510.
2. MONTANÕ-LUNA, Victoria Eugenia, MIRANDA-NOVALES, María Guadalupe. Face masks use as a preventive measure in the context of the SARS-CoV-2 pandemic. *Revista Mexicana de Pediatría*, 2020, **87**(5), 163–169, doi: 10.35366/97169.
3. UNG, Carolina Oi Lam. Community pharmacist in public health emergencies: quick to action against the coronavirus 2019-nCoV outbreak. *Research in Social and Administrative Pharmacy*, 2020, **16**(4), 583–586, doi: 10.1016/j.sapharm.2020.02.003.
4. ZABEL, R.A., MORRELL, J.J. *Wood microbiology: decay and its prevention*. San Diego: Academic Press, 1992, pp. 52–89.
5. XIN, Xiaying, HUANG, Gordon, ZHANG, Baiyu. Review of aquatic toxicity of pharmaceuticals and personal care products to algae. *Journal of Hazardous Materials*, 2021, **410**, doi: 10.1016/j.jhazmat.2020.124619.
6. MELBY, P.C., ANSTEAD, G.M. Immune responses to protozoans. In *Clinical immunology: principles and practice*. Edited by Robert R. Rich, Thomas A. Fleisher, William T. Shearer, Harry W. Schroeder, Anthony J. Frew, Cornelia M. Weyand. Elsevier, 2008, pp. 433–445.
7. PANDEY, K. D., PATEL, A. K., SINGH, M., KUMARI, A. Secondary metabolites from bacteria and viruses. In *Natural bioactive compounds*. Edited by Rajeshwar P. Sinha and Donat-P. Häder. Academic Press, 2021, pp. 19–40, doi: 10.1016/B978-0-12-820655-3.00002-1.
8. KIRTI, A., SHARMA, M., RANI, K., BANSAL, A. CRISPRing protozoan parasites to better understand the biology of diseases. *Progress in Molecular Biology and Translational Science*, 180, 21–68, doi: 10.1016/bs.pmbts.2021.01.004
9. MORENS, D.M., FOLKERS, G.K., FAUCI, A.S. What is a pandemic? *Journal of Infectious Disease*, 2009, **200**(7), 1018–1021, doi: 10.1086/644537.
10. SNOWDEN, Frank M. *Epidemics and society: from the black death to the present*. New Haven: Yale University Press, 2019, 512 p., doi: 10.2307/j.ctvqc6gg5.
11. HAYS, J.N. *Epidemics and pandemics: their impacts on human history*. Santa Barbara: ABC-CLIO, 2005.
12. COBURN, B.J., WAGNER, B.G., BLOWER, S. Modeling influenza epidemics and pandemics: insights into the future of swine flu (H1N1). *BMC Medicine*, 2009, **7**, 1–8, doi: 10.1186/1741-7015-7-30.
13. SAMAL, J. A historical exploration of pandemics of some selected diseases in the world. *International Journal of Healing Science and Research*, 2014, **4**(2), 165–169.
14. POTTER, C.W. A history of influenza. *Journal of Applied Microbiology*, 2001, **91**, 572–579.
15. De GRAAF, J. Affluenza: the all-consuming epidemic. *Environmental Management and Healing*, 2002, **13**(2), 224, doi: 10.1108/emh.2002.13.2.224.3.
16. WIJDICKS, E.F.M. Historical lessons from twentieth-century pandemics due to respiratory viruses. *Neurocritical Care*, 2020, **33**, 591–596, doi: 10.1007/s12028-020-00983-7.
17. KELLY, B.D. Plagues, pandemics and epidemics in Irish history prior to COVID-19 (coronavirus): what can we learn? *Irish Journal of Psychological Medicine*, 2020, **37**(4), 269–274, doi: 10.1017/ipm.2020.25.
18. PIRET, J., BOIVIN, G. Pandemics throughout history. *Frontiers in Microbiology*, 2021, **11**, doi: 10.3389/fmicb.2020.631736.
19. CUNHA, B.A. Influenza: historical aspects of epidemics and pandemics. *Infectious Disease Clinic of North America*, 2004, **18**(1), 141–155, doi: 10.1016/S0891-5520(03)00095-3.
20. LINA, B. History of influenza pandemics. In *Paleomicrobiology: past human infections*. Edited by Didier Raoult and Michel Drancourt. Berlin, Heidelberg: Springer, 2008, pp. 199–211.
21. GHENDON, Y. Introduction to pandemic influenza through history. *European Journal of Epidemiology*, 1994, **10**, 451–453, doi: 10.1007/BF01719673.

22. RAHMAN, M.S., MONDAL, M.I.H., HASAN, M.S., ALOM, J., AHMED, M.B., AHMED, F. Microorganisms, infection and the role of medical textiles. In *Antimicrobial textiles from natural resources*. Edited by Md. Ibrahim H. Mondal. Woodhead Publishing, 2021, pp. 45–85, doi: 10.1016/B978-0-12-821485-5.00004-4.
23. KÄHLER, C.J., HAIN, R. Fundamental protective mechanisms of face masks against droplet infections. *Journal of Aerosol Science*, 2020, **148**, doi: 10.1016/j.jaerosci.2020.105617.
24. HOWARD, J., HUANG, A., LI, Z., TUFEKCI, Z., ZDIMAL, V., VAN DER WESTHUIZEN, H. M., ... & RIMOIN, A. W. An evidence review of face masks against COVID-19. *Proceedings of the National Academy of Sciences*, 2021, **118**, doi: 10.1073/pnas.2014564118.
25. CHUGHTAI, A.A., STELZER-BRAID, S., RAWLINSON, W., PONTIVIVO, G., WANG, Q., PAN, Y., ... & MACINTYRE, C.R. Contamination by respiratory viruses on outer surface of medical masks used by hospital healthcare workers. *BMC Infectious Disease*, 2019, **19**, doi: 10.1186/s12879-019-4109-x.
26. HAMMETT, E. How long does Coronavirus survive on different surfaces? *BDJ Team*, 2020, **7**, 14–15, doi: 10.1038/s41407-020-0313-1.
27. RAI, M., YADAV, A., GADE, A. Silver nanoparticles as a new generation of antimicrobials. *Biotechnology Advances*, 2009, **27**(1), 76–83, doi: 10.1016/j.biotechadv.2008.09.002.
28. MURPHY, M., TING, K., ZHANG, X., SOO, C., ZHENG, Z. Current development of silver nanoparticle preparation, investigation, and application in the field of medicine. *Journal of Nanomaterials*, 2015, **2015**, doi: 10.1155/2015/696918.
29. SILVER, S., PHUNG, L.T. Bacterial heavy metal resistance: new surprises. *Annual Review in Microbiology*, 1996, **50**, 753–789, doi: 10.1146/annurev.micro.50.1.753.
30. CATAURO, M., RAUCCI, M.G., DE GAETANO, F., MAROTTA, A. Antibacterial and bioactive silver-containing $Na_2O{\cdot}CaO{\cdot}2SiO_2$ glass prepared by sol–gel method. *Journal of Materials Science: Materials in Medicine*, 2004, 15, 831–837, doi: 10.1023/B:JMSM.0000032825.51052.00.
31. CRABTREE, J. H., BURCHETTE, R. J., SIDDIQI, R. A., HUEN, I. T., HADNOTT, L. L., FISHMAN, A. The efficacy of silver-ion implanted catheters in reducing peritoneal dialysis-related infections. Peritoneal Dialysis International, 2003, **23**(4), 368–374, doi: 10.1177/089686080302300410.
32. ZHAO, G., STEVENS, S.E. Multiple parameters for the comprehensive evaluation of the susceptibility of Escherichia coli to the silver ion. *Biometals*, 1998, **11**, 27–32, doi: 10.1023/A:1009253223055.
33. SALUNKE, G. R., GHOSH, S., KUMAR, R. S., KHADE, S., VASHISTH, P., KALE, T., CHOPADE, B. A. Rapid efficient synthesis and characterization of silver, gold, and bimetallic nanoparticles from the medicinal plant *Plumbago zeylanica* and their application in biofilm control. *International Journal of Nanomedicine*, 2014, **9**, 2635–2653, doi: 10.2147/IJN.S59834.
34. WANG, C., HUANG, X., DENG, W., CHANG, C., HANG, R., TANG, B. A nano-silver composite based on the ion-exchange response for the intelligent antibacterial applications. *Material Science Engineering C*, 2014, **41**, 134–141, doi: 10.1016/j.msec.2014.04.044.
35. TAMAYO, L.A., ZAPATA, P.A., VEJAR, N.D., AZÓCAR, M.I., GULPPI, M.A., ZHOU, X., ... PÁEZ, M.A. Release of silver and copper nanoparticles from polyethylene nanocomposites and their penetration into *Listeria monocytogenes*. *Material Science Engineering C,* 2014, **40**, 24–31, doi: 10.1016/j.msec.2014.03.037.
36. RUBIO-ROMERO, J.C., DEL CARMEN PARDO-FERREIRA, M., TORRECILLA-GARCÍA, J.A., CALERO-CASTRO, S. Disposable masks: disinfection and sterilization for reuse, and non-certified manufacturing, in the face of shortages during the COVID-19 pandemic. *Safe Science*, 2020, **129**, doi: 10.1016/j.ssci.2020.104830.
37. REYCHLER, G., VANDER STRAETEN, C., SCHALKWIJK, A., PONCIN, W. Effects of surgical and cloth facemasks during a submaximal exercise test in healthy adults. *Respiratory Medicine*, 2021, **186**, doi: 10.1016/j.rmed.2021.106530.

Vishal Trivedi[1], Pradeep Joshi[1], K. N. Chatterjee[2], Girendra Pal Singh[3]
[1] Amity University, ASFT, Sector 125, Noida, Uttar Pradesh, India
[2] The Technological Institute of Textile & Sciences, Bhiwani, Haryana, India
[3] Govt. Art Girls College, Kota, Rajasthan, India

Impact of Store Ambience on Impulse Purchasing of Apparel Consumers

Vpliv ambienta trgovine na potrošnikovo impulzivno nakupovanje oblačil

Original scientific article/*Izvirni znanstveni članek*
Received/*Prispelo* 03-2022 • Accepted/*Sprejeto* 05-2022

Corresponding author/*Korespondenčni avtor:*
Vishal Trivedi, Assist Prof (Grade-I)
E-mail: vishal.trivedi22@gmail.com
Mobile: +918006473336
ORCID ID: 0000-0001-6180-5572

Abstract

The aim of this research was to identify the impact of store ambience on apparel consumer impulse purchase behaviour. In this paper, the influence of window display (WD), promotional offers (PO), store layout (SL), background music (BM) and fragrance of store (FOS) on consumer impulsive buying behaviour (IBB) for apparel was evaluated. The study was performed among 210 consumers in Delhi (NCR), at the DLF Mall of India, using a questionnaire developed based on existing literature. The research data was analysed using the factor analysis, and correlation and linear regression tests. According to the research findings, store features such as window display, promotional offers and fragrance have a significant effect on impulse purchase behaviour. The current study makes some suggestions for retailers to improve the ambience of their stores in order to boost impulse buying among apparel buyers.
Keywords: apparel consumer, impulse buying, store ambience, factor analysis, regression test

Izvleček

Namen raziskave je bil ugotoviti vpliv ambienta trgovine na impulzivno nakupovalno vedenje potrošnikov oblačil. V tem članku je bil ovrednoten vpliv izložb, promocijskih ponudb, postavitve trgovine, glasbe v ozadju in dišav v trgovinah na impulzivno nakupovalno vedenje potrošnikov oblačil. Raziskava je bila izvedena med 210 potrošniki v regiji Delhi, v nakupovalnem središču DLF, z uporabo vprašalnika, razvitega na podlagi obstoječe literature. Rezultati raziskave so bili analizirani s faktorsko analizo, korelacijskimi in linearnimi regresijskimi testi. V raziskavi je bilo ugotovljeno, da imajo funkcije trgovine, kot so izložbe, promocijske ponudbe in dišave, pomemben vpliv na impulzivno nakupovalno vedenje potrošnikov. Ta raziskava podaja nekaj predlogov za trgovce na drobno za izboljšanje ambienta svojih trgovin, da bi med kupci oblačil spodbudili impulzivno nakupovanje.
Ključne besede: potrošnik oblačil, impulzivno nakupovanje, trgovinski ambient, faktorska analiza, regresijski test

1 Introduction

The Indian retail sector has evolved as one of the most efficient and rapidly evolving industries due to the entry of several new significant enterprises into retail operations. It contributes more than 10% to the GDP of the country and employs around 8% of the labour force. India is the fifth-largest retail destination in the world, in terms of retail space [1].
According to the Kearney report [2], India's retail business is expected to develop at a slower rate of 9% between 2019 and 2030, going from $779 billion in 2019 to $1,407 billion by 2026 (F) and more than US $1.8 trillion by 2030 (F). Brick and mortar (B&M) stores, an offline retailer, predicted to increase their revenue by about 1.39–2.77 billion (USD) in FY22. By the end of 2022, India's direct selling business would be worth $2.54 billion USD, which is huge, and this has resulted in strong market competition. According to the report of Wazir advisor [3], the Indian apparel and accessories market is predicted to increase at a rate of approximately 7.6% by 2025 (F), reaching USD 1605 billion; hence, the competition among apparel retailer will be high.
Marketing researchers have revealed an encouraging phenomenon of impulse shopping and have employed a range of tactics to stimulate impulsive buying of apparel consumers [7]. The researchers explained how the display of a product in a retail store makes it pleasant and enticing to customers. The exterior and interiors of the apparel store, the pricing, promotion strategy, service orientation, shop-floor help, variety of items, product quality, navigation in store and operational execution are critical elements to attract customers for impulse buying [13]. Retailers need to understand the importance of having an effective strategy to improve the abmience of their stores as competition in the retail area has intensified in recent years [4]. A previous study observed that merchandising has an impact on consumer purchase behaviour [5]. According to Park [6], it has been demonstrated that an in-store display and promotional signs can affect college students' clothing impulse buying behaviour. There is no specific data that has been found between the retail atmosphere (incl. window display, promotional offers, store layout, store fragrance and background music) and apparel consumer IBB in the Indian (Delhi-NCR) context, nor how a retail display can influence the impulse buying (IB) decisions of apparel consumers in the Delhi (NCR) context. Therefore, the aim of this study was to identify the effect of in-store qualities on customer impulse buying behaviour in Delhi (NCR) markets and to provide recommendations for the most effective way to improve store attributes based on study results. Therefore, this research had five main objectives:

a) To identify the impact of window display on the impulse purchase behaviour of apparel shoppers.
b) To evaluate the impact of promotional offers on the impulse purchase behaviour of apparel shoppers.
c) To evaluate the effect of store layout on the impulse purchase behaviour of apparel shoppers.
d) To identify the effects of background music on the impulse purchase behaviour of apparel consumers.
e) To examine the impact of store fragrance on the impulse purchase behaviour of apparel consumers.

1.1 Impulse buying (IB)

For the past many years, numerous researchers have shown a keen interest in impulsive purchasing [7]. In the case of clothes shopping, impulse purchasing plays an important role. Apparel shoppers may profit more from impulse purchases when retailers provide promotional offers, which is significant for the apparel retail business. According to Abratt [8], IB at a retail store may be of great interest to both the manufacturer and the retailer. Impulse shopping implies instant buying, which is an advance shopping intention either to buy a particular product category or to satisfy a desire [9]. Rook [10] suggested that impulse purchasing is an unplanned, cognitive process that comes from affective reactions, which happen after the exposure to retail environment cues inside a physical store. Thus, store attributes play a critical role during apparel impulse buying.
Kim [11] introduced a model that represents the impulsive purchase process. This model was adopted from Churchill and Peter [12] consumer buying process model that identifies internal and external stimuli of impulse purchasing that influence consumer buying behaviour.

1.2 Factors influencing impulse purchase decisions

To gain better understanding of impulsive purchasing, we need to evaluate the internal and external

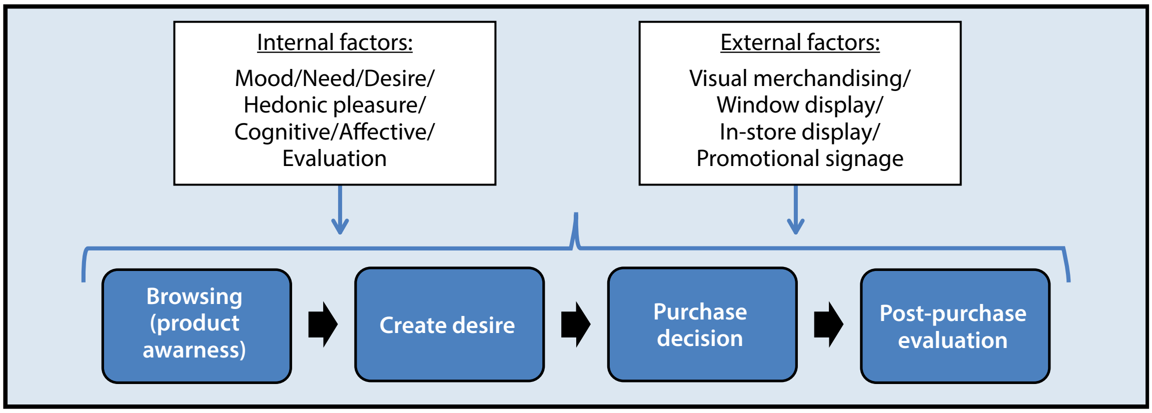


Figure 1: Model of impulse purchase process [12]

elements that inspire an impulse consumer. Two basic types of factors that can cause IB decisions are internal and external factors.

1.2.1 Internal factors

Internal variables of impulse purchasing examine the internal cues and traits of an individual that cause them to indulge in impulsive buying. Internal factors relate to an individual's internal emotions and qualities, e.g. emotional state, mood, self-feelings. Many authors have examined conceptual approaches to investigate impulse buying in the context of psychological elements (e.g. personality, self-regulation), hedonic experiences (e.g. shopping delight, emotional state, mood) and situational factors (e.g. available time, money) [13, 14].

A person's affective state can be identified by their emotional state, mood and self-feelings [15]. Internal stimuli are processed affectively and/or intellectually by the consumer, resulting in impulsive or non-impulsive conduct. As a result, sentiments such as "irresistible, want to buy, pleasant buying, feelings, and mood management" may occur [16].

1.2.2 External factors

External elements of impulsive buying are marketing strategies that are managed and controlled by retailers in an attempt to encourage customers to impulse buy [17]. When consumers see visual cues such as promotional signage, they may want to buy apparel impulsively [5]. External marketing stimuli not only bring in new consumers, but also encourage up- and cross-selling to existing (and new) customers by promoting spontaneous purchases of complementary or better products [18].

Situational factors and store display affect both in-store responses and the choice of store due to the changing and adopting nature of preferences and buying behaviour [19]. According to the findings by Rhee [20], consumers' perceptions regarding a store's visual appeal showed a stronger link with the store selection than apparel product quality, overall price level and variety. This gives credibility to the view that the store atmosphere influences the consumers' choice of a store, with window display of apparel store playing an important part. This shows that the retail setting of apparel stores influences consumer buying behaviour.

Previous research on store features has revealed that the atmosphere of a retail store is closely related to individual purchase behaviour. Beatty [9] and Donovan [21] developed the concept of retail environment and characterised it as an attempt to design the atmosphere of a store to produce specific emotional and motivational impacts in the consumer's mind that eventually enhance purchasing possibilities. The tangible variables of a retail environment, according to Faber [22], include equipment, colour scheme, store cleanliness, layout of store, display of apparel products and interior décor. On the other hand, the intangible variables include aroma, temperature, lighting and background sound [23].

Direct sensory stimuli in a retail ambience include visual components and physical amenities, while general design aspects include colour, shelf space and store layout [24]. A window display is a presentation of items that impacts individual's purchasing intentions and merchants want to provide consumers with an appropriate product at the right moment through a correct product display [25]. Retail layout may stimulate a customer's interest in

the store's ambience, resulting in increased shopper attention [26]. Impulsive buying tendency (IBT) is defined as the proclivity to make unexpected purchases and to buy immediately, with little or no thought to the implications. Shoppers with a higher IBT score are more likely to have impulsive cravings and make impulsive purchases at retail outlets [9].
Consumers and salespeople present in the store are examples of social factors in a store. The behaviour of salespeople at a retail establishment has a significant impact on individual's purchasing decisions [24]. Another important aspect is crowding, which is both challenging and necessary in retail setting [27]. Crowding, along with retail atmosphere, design and social aspects, is a more significant component that is expected to impact consumer purchase behaviour. Crowding at a retail outlet is a result of social, personal and physical elements that sensitise individuals to possible difficulties that arise due to restricted space [28].
To fulfil the objectives of this research, apparel consumer's IBB is a dependent variable and five external factors, i.e. window display, store layout, promotional offers, background music and fragrance of store, are considered as independent variables. The following hypotheses were formulated to explore the relationships between IBB of apparel consumer and these external factors.

H1: Window display influences the apparel consumer impulse purchase decision.
H2: Promotional offers influence the apparel consumer impulse purchase decision.
H3: Store layout influences the apparel consumer impulse purchase decision.
H4: Background music influences the apparel consumer impulse purchase decision.
H5: Fragrance of store influences the apparel consumer impulse purchase decision.

2 Experimental

2.1 Methodology

For this research, a sample group was selected while shopping for apparel at the DLF mall located in Delhi (NCR) to participate in the survey. The survey format was used for this study as an instrument. In order to obtain a precise measurement of impulse buying tendency (IBT), window display (WD), promotional offers (PO), store layout (SL), background music (BM) and fragrance of store (FOS), this research formulated and used a scale on which items were examined and tested. To prove research hypothesis, 25 questions were formulated. Impulse buying tendency (IBT) and window display (WD) were the key variables, measured using a scale developed by Mehta [5] and Parsad et al. [29]. Promotional offers (PO), background music (BM) and fragrance of store (FOS) were measured using a scale developed and modified by Mohan et al. [30] and Vinish et al. [17]. The questionnaire was divided into seven major sections to evaluate the respondents' impulse buying behaviour for apparel, and the factors that influence this behaviour and demographics (Demographically). The first section of the questionnaire assessed the respondents' tendency towards impulsive purchase. The second section was used to evaluate the effect of an in-store window display, the third section was used to measure the impact of a store layout. The fourth section evaluated the effect of promotional offers, the fifth section measured the impact of background music, the sixth section examined the influence of store fragrance, while the last segment included questions to determine the demographic profile of respondents, i.e. gender, age, qualification level, occupation and income level. Each variable was measured using a five-point Likert scale ranging from strongly disagree = 1 to strongly agree = 5.
This research included 210 Delhi (NCR) apparel store customers. In this survey, a convenience sample approach of non-probability sampling was used. Only 210 out of 265 questionnaires completed by respondents were correctly filled out and used for data analysis. Further, Cronbach Alpha was used to identify the reliability of the scale [31].

2.2 Data analysis method

SPSS 23 (Statistical Package for the Social Sciences) software was used for data analysis. It generates descriptive statistics and frequency tables to check for data mistakes and do demographic research. The Kolmogorov-Smirnov test demonstrates the precision of utilising parametric statistics. It was followed by a factor analysis based on the principal component analysis with a reliability test (Cronbach's alpha). The Pearson correlation test was used to determine the relationship between apparel consumer impulsive purchase behaviour and each of the five store attributes. The hypotheses were tested using regression analysis to determine the relationship between apparel consumers impulsive purchase behaviour (dependent variable) and the five categories of store features (independent variable). In the questionnaire, different variables were developed to measure each item under study. Further, we used the principal component analysis (PCA) with Varimax Rotation to reduce these measurements to single variables. Table 1 summarises the descriptive statistics for each variable, while Table 2 represents the results of the principal component analysis with a reliability test. The PCA findings showed that all of the items had a factor loading of 0.5 or above, indicating that each item belonged to only one group (cf. Table 2). The Cronbach's alpha scores for all proposed variables were above the minimal criterion of 0.70 [31], ranging from 0.7011 to 0.798, showing that the data was statistically consistent and suitable for further study.

Table 1: Descriptive statistics for variables

Variables	No. of samples	Mean	Standard deviation
Impulse buying tendency (IBT)	210	3.065	0.8539
Influence of window display (WD)	210	3.178	0.9245
Influence of promotional offers (PO)	210	3.256	1.0235
Influence of store layout (SL)	210	3.012	1.0321
Influence of background music (BM)	210	2.985	0.9857
Influence of fragrance of store (FOS)	210	3.312	1.2758

Table 2: Results of principal component analysis with reliability test

Factor	Item	Factor loading	Eigen value	Variance (%)	Cronbach Alpha
Impulse buying tendency (IBT)	IBT1	0.634	1.688	43.42	0.7011
	IBT2	0.678			
	IBT3	0.698			
	IBT4	0.707			
	IBT5	0.818			
Influence of window display (WD)	WD1	0.741	1.942	64.768	0.7242
	WD2	0.853			
	WD3	0.679			
	WD4	0.747			
Influence of promotional offers (PO)	PO1	0.746	2.235	55.606	0.798
	PO2	0.714			
	PO3	0.833			
	PO4	0.635			
Influence of store layout (SL)	SL1	0.781	1.876	52.314	0.714
	SL2	0.878			
	SL3	0.886			
	SL4	0.72			
Influence of background music (BM)	BM1	0.826	2.717	56.921	0.709
	BM2	0.834			
	BM3	0.744			
	BM4	0.628			
Influence of fragrance of store (FOS)	FOS1	0.889	2.139	71.313	0.7671
	FOS2	0.814			
	FOS3	0.754			
	FOS4	0.717			

3 Results and discussion

3.1 Descriptive statistics for demographics

Demographic characteristics of 210 apparel consumers represent 55.71% of females and 44.29% of males. The majority of respondents are in the age group of 18–25 (45.23%), then 25–35 years (29.52%), 35–45 years (15.24%) and above 45 years (10.01%). This shows that most respondents are aged 18–35. 74% respondents reported monthly family income from 100,000 to 200,000 Indian rupees.

3.2 Hypothesis testing

H1: Window Display influences the apparel consumer impulse purchase decision. The correlation test (cf. Table 3) revealed a significant association between IB and window display, with the p-value lower than 0.05 and r-value of 0.383. Furthermore, the regression analysis revealed that window display has a substantial effect on apparel consumer impulse buying behaviour. The hypothesis is supported by the p-value being lower than the alpha level (cf. Table 4).

H2: Promotional offers influence the apparel consumer impulse purchase decision. The Pearson correlation test confirmed a substantial association with a modest p-value lower than 0.05 & ($r = 0.405$) (cf. Table 3). The regression analysis revealed that promotional offers influenced consumer impulsive buying behaviour. The p-value was lower than the alpha level, confirming the validation of the hypothesis (cf. Table 4).

H3: Store layout influences the apparel consumer impulse purchase decision. The correlation test ($r = 0.280$) and ($p < 0.05$) revealed a significant weak relationship between IBB and store layout (cf. Table 3). Even though the Pearson correlation test revealed a substantial relationship between impulse buying behaviour and store layout, the regression analysis indicated that store layout had no significant impact on apparel consumer impulse buying behaviour (p value is greater than 0.05) (cf. Table 4).

H4: The p-value being lower than 0.05 and r-value of 0.252 (cf. Table 3) confirmed that background music slightly influences the apparel consumer impulse purchase decision. The Pearson correlation test discovered a positive weak relationship between IBB and background music. As a result, it can be concluded that background music is not highly associated with customer impulse purchase behaviour. The regression analysis discovered that there is no significant association between background music and customer impulsive buying behaviour. The fact that the p-value was greater than the alpha level (cf. Table 4) demonstrated that the data presented inadequate evidence for a significant association between apparel shopper impulsive buying behaviour and background music.

H5: Fragrance of store influences the apparel consumer impulse purchase decision. The Pearson correlation test (cf. Table 3) demonstrated a substantial association between IB and store fragrance, with the p-value lower than 0.05 and r-value of 0.372. The regression analysis demonstrated that store fragrance had a significant impact on the IBB of apparel consumers. The p-value being lower than the alpha level supports the hypothesis (cf. Table 4). As a result, the final multiple regression equation was developed using unstandardised coefficients (B):

$$\begin{aligned} IBB = 1.166 + (0.180)\ WD + (0.171)\ PO + \\ (0.171)\ FOS + (0.099)\ BM + (-0.006)\ SL \end{aligned} \tag{1}$$

Further, the beta coefficient (β) from the regression analysis can be utilised to discover dependent variables with a higher influence on impulse purchase behaviour for apparel consumers [32]. According to the beta coefficient results (β), window display contributed the most to explaining the apparel impulsive purchase behaviour, followed by promotional offers and store fragrance (BETA = 0.231, 0.189 and 0.172, respectively) (cf. Table 4). Figure 2 represents the effect of store attributes (variables) related to the impulse purchase behaviour for apparel consumers.

Table 3: Result of correlation with IBB

Variables	Coefficient (r)	Significance (p)
Influence of window display (WD)	0.383	0.001
Influence of promotional offers (PO)	0.405	0.001
Influence of store layout (SL)	0.28	0.002
Influence of background music (BM)	0.252	0.003
Influence of fragrance of store (FOS)	0.372	0.001

Table 4: Result of regression analysis

Hypothesis	B (unstandardised coefficients)	p-value	β (standardised coefficients)	t-statistics
H1: Window display influences apparel consumer impulse purchase decision.	0.18	0.004	0.231	2.954
H2: Promotional offers influence apparel consumer impulse purchase decision.	0.171	0.029	0.189	2.207
H3: Store layout influences apparel consumer impulse purchase decision.	−0.006	0.132	−0.007	−0.085
H4: Background music influences apparel consumer impulse purchase decision.	0.099	0.079	0.133	1.772
H5: Fragrance of store influences apparel consumer impulse purchase decision.	0.171	0.007	0.172	2.748

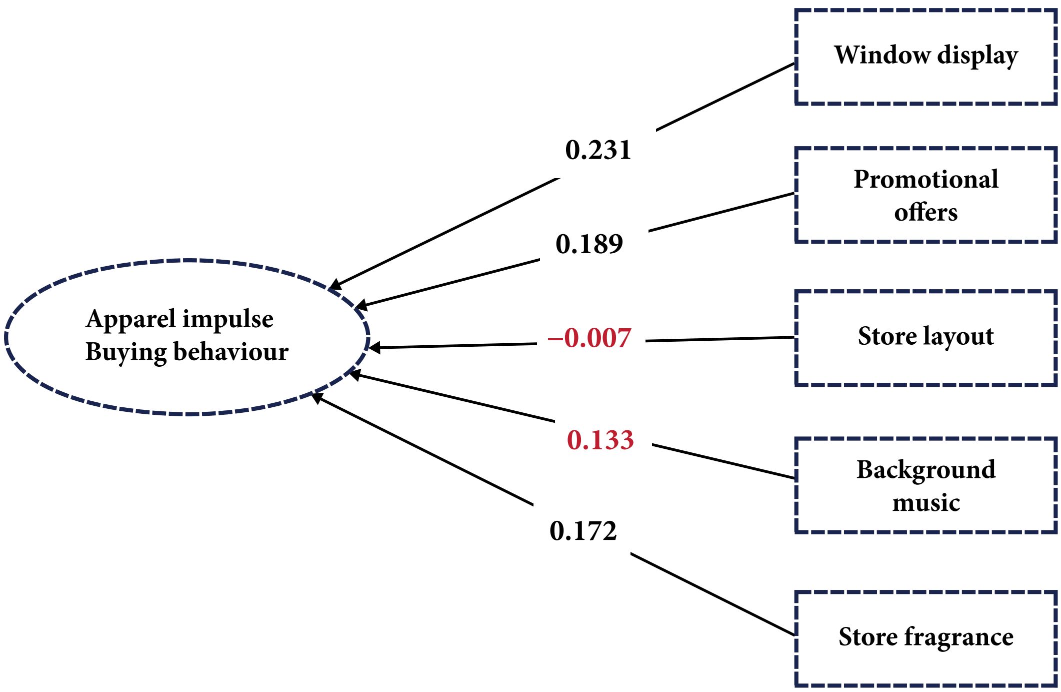


Figure 2: Structural model between store variables and impulse purchase behaviour for apparel

4 Conclusion and implications

This research evaluated a structural model to establish the relationships between various store variables and apparel shopper impulse purchase behaviour. The model helps retailers and researchers investigate the structural links between apparel store attributes and impulse buying behaviour of consumers. According to the findings, window display, promotional offers and store fragrance all have a direct significant impact on impulsive apparel purchase. Although retail store layout and background music do not significantly influence customer impulsive buying behaviour, the findings indicated that these three characteristics (incl. window display, promotional offers and store fragrance) and consumer impulse buying behaviour are highly associated. This suggests that these store attributes, acting as motivators that arouse a desire, eventually persuade a customer to make a spontaneous purchase decision upon entering the store, i.e. they have a significant impact on consumer impulse purchase behaviour for apparel.

Apparel retailers should pay attention to visual display and marketing stimuli since they might increase the impulse buying of clothing. The current study offers sufficient evidence that stores may use visual tactics, interactive promotional offers and fragrance to increase the attractiveness of merchandise and assist customers in becoming aware of apparel products. As apparel impulse buying is more common in younger shoppers than in elder, this tenet may be vital for store managers to be aware of young people's requirements, which may enhance their earnings. Furthermore, the research suggested that an increase in personal income has made impulse buying ubiquitous. The availability of money boosts the shopper's purchasing capability, while limited money reduces the chances of impulse purchasing. Retailers need to pay more focus on numerous promotional offers as these promotional activities meet the consumers' psychological requirements. Offering bonus packs, discount prices and cashback offers motivate consumers to do more buying impulsively. This study reveals that store layout and background music do not have a significant impact on IBB for apparel. Nevertheless, retailers must enhance the chance of impulse purchases by developing favourable emotions in customers through store layout, window displays, promotional offers, background music and store aroma.

The data was aprroved stastically and revealed critical links between store atmosphere and impulse purchasing of apparel customers. These findings may be used by senior managers, esp. retail store managers, to improve ambience of the store and to provide a more convenient shopping experience to attract apparel customers.

Despite its valuable findings, this study does have some drawbacks. The data was obtained to test the model at the DLF Mall in Delhi (NCR), India. Another possible limiting issue is the use of broadly generalised apparel products regardless of brands. As Indian consumers have different emotional values, lifestyles, cultural backgrounds and purchase behaviours, future research on the topic might be expanded in the following ways: a) gathering data from more representative samples with a broader variety of demographic attributes; b) including other store characteristics, situation factors, e.g. salesperson behaviour, crowd in stores, perceived enjoyment, availability of time/money and availability of product varieties; c) broadening the emphasis to branding, fashionable products (e.g. apparel, home furnishings, cosmetics, accessories); e) evaluating impulse buying in online shopping; and f) making comparisons inside and across other nations.

Acknowledgements

We would like to thank ASFT, Amity University, Noida, Uttar Pradesh, for allowing us to assist with the composition of this research paper.

References

1. Retail industry in India [online]. IBEF [accessed 23. 5. 2022]. Available on World Wide Web: <https://www.ibef.org/industry/retail-india>.
2. Value e-commerce: the next big leap in India's retail market [online]. Kearney [accessed 23. 5. 2022]. Available on World Wide Web: <https://www.kearney.com/consAumer-retail/article/?/a/value-ecommerce-the-next-big-leap-in-india-retail-market>.
3. Indian fashion market report. Gurugram : Wazir advisors, 2020.
4. HAN, Y.K., MORGAN, G.A., KOTSIOPULOS, A., KANG-PARK, J. Impulse buying behavior of apparel purchasers. *Clothing and Textiles Research Journal*, 1991, **9**(3), 15–21, doi: 10.1177/0887302X9100900303.
5. MEHTA, N., CHUGAN, P. K. Visual merchandising: impact on consumer behavior (An exploratory study of apparel segment in Ahmedabad). In *Mapping the global future: evolution through innovation, and excellence*. Edited by Nejdet Delener, Leonora Fuxman, F. Victor Lu and Susana Rodrigues. New York : Global Business and Technology Association (GBATA), 2012, 607–614.
6. PARK, E.J., FORNEY, J.C. Assessing and predicting apparel impulse buying. *Journal of Global Fashion Marketing*, 2011, **2**(1), 28–35, doi: 10.1080/20932685.2011.10593080.
7. AMOS, C., HOLMES, G. R., KENESON, W.C. A meta-analysis of consumer impulse buying. *Journal of Retailing and Consumer Services*, 2014, **21**(2), 86–97, doi: 10.1016/j.jretconser.2013.11.004.
8. ABRATT, R., GOODEY, S.D. Unplanned buying and in-store stimuli in supermarkets. *Managerial And Decision Economics*, 1990, **2**(1), 1–12, doi: 10.1002/mde.4090110204.
9. BEATTY, S.E., FERRELL, M.E. Impulse buying: modeling its precursors. *Journal of Retailing*, 1998, **74**(2), 169–191, doi: 10.1016/S0022-4359(99)80092-X.
10. ROOK, D. W. The buying impulse. *Journal of Consumer Research*, 1987, **14**(2), 188–189, doi: 10.1086/209105.

11. KIM, J. *College students' apparel impulse buying behaviors in relation to visual merchandising*: *Master Thesis.* University of Georgia Graduate School, Athens, 2003.
12. CHURCHILL, G.A., PETER, J.P. *Marketing: creating value for customers*. Boston : Irwin/McGraw-Hill, 1998.
13. MANDOLFO, M., LAMBERTI, L. Past, present, and future of impulse buying research methods: a systematic literature review. *Frontiers in Psychology*, 2021, **12**(7), 1–11, doi: 10.3389/fpsyg.2021.687404.
14. PALLIKKARA, V., PINTO, P., HAWALDAR, I.T., PINTO, S. Impulse buying behaviour at the retail checkout: an investigation of select antecedents. *Business: Theory and Practice*, 2021 **22**(1), 69–79, doi: 10.3846/btp.2021.12711.
15. YOUN, S., FABER, R.J. Impulse buying: its relation to personality traits and cues. In *NA - Advances in Consumer Research. Volume 27.* Edited by Stephen J. Hoch and Robert J. Meyer. Provo, UT : Association for Consumer Research, 179–185.
16. COLEY, A., BURGESS, B. Gender differences in cognitive and affective impulse buying. *Journal of Fashion Marketing and Management*, 2003, **7**(3), 282–295, doi: 10.1108/13612020310484834.
17. VINISH, P., PINTO, P., HAWALDAR, I. T., PINTO, S. Impulse buying behavior among female shoppers: exploring the effects of selected store environment elements. *Innovative Marketing*, 2020, **16**(2), 54–70, doi: 10.21511/im.16(2).2020.05.
18. DAWSON, S., KIM, M. External and internal trigger cues of impulse buying online. *Direct Marketing*, 2009, **3**(1), 20–34, doi: 10.1108/17505930910945714.
19. HAUSMAN, A. A multi-method investigation of consumer motivations in impulse buying behavior. *Journal of Consumer Marketing*, 2000, **17**(5), 403–419, doi: . 10.1108/07363760010341045.
20. RHEE, Y.J. A study on relationship between risk dimension of apparel involvement and online impulse buying behavior. *Journal of the Korean Society of Clothing and Textiles*, 2007, **31**(12), 1733–1741, doi: 10.5850/JKSCT.2007.31.12.1733.
21. DONOVAN, Robert. J., ROSSITER, J.R. Store atmosphere: an environmental psychology approach. *Journal of Retailing*, 1982, **58**(1), 34–57.
22. FABER, R.J., CHRISTENSON, G.A. Can you buy happiness? A comparison of the antecedent and concurrent moods associated with the shopping of comulsive and non-compulsive buyer. *AMA Winter Educators' Conference Proceedings*, 1995, 378–379.
23. DONOVAN, R.J., ROSSITER, J.R., MARCOOLYN, G., NESDALE, A. Store atmosphere and purchasing behavior. *Journal of Retailing*, 1994, **70**(3), 283–294, doi: 10.1016/0022-4359(94)90037-X.
24. BAKER, J., PARASURAMAN, A., GREWAL, D., VOSS, G.B. The influence of multiple store enviornment cues on perceived merchandise value and patronage intensions. *Journal of Marketing*, 2002, **66**(2), 120–141, doi: 10.1509/jmkg.66.2.120.18470.
25. BAKER, J., LEVY, M., GREWAL, D. An experimental approach to making retail store environment decisions. *Journal of Retailing*, 1992, **68**(4), 445–460.
26. BLOCH, P. H., RIDGWAY, N.M., SHERRELL, D.L. Extending the concept of shopping: an investigation of browsing activity. *Journal of the Academy of Marketing Science*, 1989, **17**(1), 13–21, doi: 10.1007/BF02726349.
27. MICHON, R., CHEBAT, J.C., TURLEY, L.W. Mall atmospherics: the interaction effects of the mall environment on shopping behavior. *Journal of Business Research*, 2005, **58**, 576–583, doi: 10.1016/j.jbusres.2003.07.004.
28. EROGLU, S.A., MACHLEIT, K.A. An empirical study of retail crowding: antecedents and consequences. *Journal of Retailing,* 1990, **66**(2), 201–221.
29. PARSAD, C., PRASHAR, S., VIJAY, T.S. Comparing between product-specific and general impulse buying tendency: does shoppers' personality influence their impulse buying tendency? *Asian Academy of Management Journal*, 2019, **24**(2), 41–61, doi: 10.21315/aamj2019.24.2.3.
30. MOHAN, G., SIVAKUMARAN, B., SHARMA, P. Impact of store environment on impulse buying behavior. *European Journal of Marketing*, 2013, **47**(10), 1711–1732, doi: 10.1108/EJM-03-2011-0110.
31. NUNNALLY, J.C. *Psychometric theory 3E*. Tata McGraw-Hill Education, 1994.
32. SCHROEDER, L.D., SJOQUIST, D.L., STEPHAN, P.E. *Understanding regression analysis*. Newbury Park : Sage Publication, 1986.

Appendix

Table 5: Measurement items and content

Variable	Measurement	Content
Impulse buying tendency (IBT)	IBT1	“When I see new style of apparel products, I buy it immediately,” describes me.
	IBT2	“Buy now, think about it later” describes me.
	IBT3	When I go for apparel shopping, I buy apparels that I had not intended to buy.
	IBT4	I can’t suppress the desire of wanting to buy new style of apparel spontaneously.
	IBT5	I often buy apparel products without thinking.
Influence of window display (WD)	WD1	I am more likely to enter retail store if it has an eye-catching window display.
	WD2	I get an idea of what I want to buy after looking through in-store displays.
	WD3	Attractive display draws my attention and induce my impulsive buying.
	WD4	I feel compelled to visit retail store if it has an interesting window display.
Influence of promotional offers (PO)	PO1	I am more likely to make unplanned buying if the apparel product has a sale sign.
	PO2	When I see a special promotional signage in store, I go to look at the products.
	PO3	If there is a discount on apparel products, I am more likely to make an impulse purchase.
	PO4	Promotional activities (Such as buy one get one and so on) encourages me to make me to do impulse purchases during apparel shopping.
Influence of store layout (SL)	SL1	When I enter a store, I tend to follow the store layout while browsing the store.
	SL2	If the layout of the store is well structured, I am more likely to make an impulse purchase.
	SL3	If the store has eye catching arrangements, I tend to spend more time in the store.
	SL4	If it is easy to find out the apparel products that encourages me to do more purchases.
Influence of background music (BM)	BM1	Pleasant and calm background music makes me spend more time in a store.
	BM2	If I like the music inside retail store, my chances of unplanned buying become greater.
	BM3	The music playing in the store influences my impulse buying behaviour.
	BM4	I spend more time in the retail store browsing it if I like the background music.
Influence of fragrance of store (FOS)	FOS1	If retail store smells good, I tend to stay longer and look at the merchandise.
	FOS2	The fragrance used in the store affects my buying intentions.
	FOS3	I am more likely to make unplanned buying if the store smells good.
	FOS4	If fragrance of retail store is pleasant, I intend to go back to the store in future.

SHORT INSTRUCTIONS FOR AUTHORS OF SCIENTIFIC ARTICLES

Scientific articles categories:

- **Original scientific article** is the first publication of original research results in such a form that the research can be repeated and conclusions verified. Scientific information must be demonstrated in such a way that the results are obtained with the same accuracy or within the limits of experimental errors as stated by the author, and that the accuracy of analyses the results are based on can be verified. An original scientific article is designed according to the IMRAD scheme (Introduction, Methods, Results and Discussion) for experimental research or in a descriptive way for descriptive scientific fields, where observations are given in a simple chronological order.
- **Review article** presents an overview of most recent works in a specific field with the purpose of summarizing, analysing, evaluating or synthesizing information that has already been published. This type of article brings new syntheses, new ideas and theories, and even new scientific examples. No scheme is prescribed for review article.
- **Short scientific article** is original scientific article where some elements of the IMRAD scheme have been omitted. It is a short report about finished original scientific work or work which is still in progress. Letters to the editor of scientific journals and short scientific notes are included in this category as well.

Language: The manuscript of submitted articles should be written in UK English and it is the authors responsibility to ensure the quality of the language.

Manuscript length: The manuscript should not exceed 30,000 characters without spacing.

Article submission: The texts should be submitted only in their electronic form in the format *.doc (or *docx) and in the format *.pdf (made in the computer program Adobe Acrobat) to the address: tekstilec@a.ntf.uni-lj.si. The name of the document should contain the date (year-month-day) and the surname of the corresponding author, e.g. 20140125Novak.docx. The articles proposed for a review need to have their figures and tables included in the text. The article can also be submitted through a cloud-based file transfer service, e.g. "WeTransfer" (www.wetransfer.com).

Publication requirements: All submitted articles are professionally, terminologically and editorially reviewed in accordance with the general professional and journalistic standards of the journal Tekstilec. Articles are reviewed by one or more reviewers and are accepted for publication on the basis of a positive review. If reviewers are not unanimous, the editorial board decides on further proceedings. The authors can propose to the editorial board the names of reviewers, whereas the editorial board then accepts or rejects the proposal. The reviewers' comments are sent to authors for them to complete and correct their manuscripts. The author is held fully responsible for the content of their work. Before the author sends their work for publication, they need to settle the issue on the content publication in line with the rules of the business or institution, respectively, they work at. When submitting the article, the authors have to fill in and sign the Copyright Statement (www.tekstilec.si), and send a copy to the editors by e-mail. They should keep the original for their own personal reference. The author commits themselves in the Copyright Statement that the manuscript they are submitting for publication in Tekstilec was not sent to any other journal for publication. When the work is going to be published depends on whether the manuscript meets the publication requirements and on the time reference the author is going to return the required changes or corrections to the editors.

Copyright corrections: The editors are going to send computer printouts for proofreading and correcting. It is the author's responsibility to proofread the article and send corrections as soon as possible. However, no greater changes or amendments to the text are allowed at this point.

Colour print: Colour print is performed only when this is necessary from the viewpoint of information comprehension, and upon agreement with the author and the editorial board.

More information on: www.tekstilec.si