Dan doktoranada 2024.

Sveučilište u Zagrebu

Tekstilno-tehnološki fakultet

Dan doktoranada 2024.

Doktorski studij

Tekstilna znanost i tehnologija

Zagreb, veljača 2024.

ISSN 2991-924X (Online)
ISSN 2584-6604 (Tisak)

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet
Doktorski studij Tekstilna znanost i tehnologija

DAN DOKTORANADA 2024.

Zbornik radova

Zagreb, 23. veljače 2024.

Naziv
Dan doktoranada 2024. – Zbornik radova

Nakladnik
Sveučilište u Zagrebu Tekstilno-tehnološki fakultet
Prilaz baruna Filipovića 28a, 10000 Zagreb

Grafička priprema
Ivana Špelić

Dizajn loga „Dan doktoranada“
Rajna Malinar

ISSN 2991 - 924X (Online)

ISSN 2584 - 6604 (Tisak)

Sadržaj

Uvod

Doktorski studij ***Tekstilna znanost i tehnologija*** nastavak je sveučilišnog diplomskog studija koji združuje teorijska znanja, istraživački rad i iskustvo u rješavanju problema temeljenih na poznavanju suvremenih proizvodnih sustava. Sveučilište u Zagrebu Tekstilno-tehnološki fakultet je nositelj ovog studija iz znanstvenog područja tehničkih znanosti, znanstvenog polja tekstilna tehnologija.

Doktorski studij Tekstilna znanost i tehnologija (*https://www.ttf.unizg.hr/tekstilna-znanost-i-tehnologija/226*) je jedini doktorski studij u području tekstilne znanosti i tehnologije u Republici Hrvatskoj te najznačajniji u regiji.

Osnovni cilj studija je osposobljavanje doktoranada za samostalni znanstvenoistraživački rad, poticanje inovativnosti i transfer rezultata znanstvenih istraživanja na unaprjeđenje suvremenih proizvodnih procesa u tekstilnoj i odjevnoj industriji. Svjetski napredak u području tehničkih znanosti posebno potencira istraživanje materijala i njihovih karakteristika, s naglaskom na primjenu biotehnologije i nanotehnologije. Veliki domet u tome predstavljaju zaštitni i kompozitni materijali, pametni tekstil, funkcionalna zaštitna i inteligentna odjeća i obuća. Međunarodni savjet akademija tehničkih znanosti (CAETS) svrstao je istraživanje materijala, pa tako i tekstilnih, na listu prioriteta.

Doktorski studij ***Tekstilna znanost i tehnologija*** omogućuje doktorandima nastavak rada u istraživačkim institucijama, institucijama s parcijalnim udjelom istraživačke djelatnosti, javnom i privatnom sektoru i gospodarstvu. Završetkom studija pristupnici su osposobljeni za timski rad te samostalno vođenje nacionalnih, bilateralnih i europskih znanstvenih i stručnih projekata iz područja istraživanja u okviru doktorskog studija. Stečena znanja i istraživački potencijal omogućuju im nastavak znanstveno-istraživačkog rada putem doktorskog usavršavanja.

Voditeljica doktorskog studija

prof. dr. sc. Sanja Ercegović Ražić

Dekanica Sveučilišta u Zagrebu
Tekstilno-tehnološkog fakulteta

prof. dr. sc. Anica Hursa Šajatović

Predgovor

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet kao nositelj doktorskog studija ***Tekstilna znanost i tehnologija*** već četvrti puta organizira znanstvenu konferenciju **Dan doktoranada**. Ova znanstvena manifestacija s ponosom predstavlja znanstveno-istraživački rad svojih doktorskih kandidata pod vodstvom njihovih cijenjenih mentora.

U Zborniku radova Dana doktoranada 2024. godine objavljeno je 29 proširenih sažetaka doktoranada pisanih hrvatskim i engleskim jezikom. Uz proširene sažetke doktoranada, objavljeni su cjeloviti radovi sedam doktora znanosti koji su doktorirali na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultet nakon 2022. godine, odnosno nakon prethodno održanog Dana doktoranada.

Zbornik radova pruža uvid u raznolikost i kvalitetu znanstveno-istraživačkih tema te uključenost naših doktoranada u razvoj novih, inovativnih metoda, materijala i tehnologija kroz implementaciju i primjenu novih ideja i inženjerskih rješenja.

Voditeljica doktorskog studija

prof. dr. sc. Sanja Ercegović Ražić

Martina Bobovčan Marcelić

Životopis	Martina Bobovčan Marcelić rođena je 1979. god. u Koprivnici. U veljači 2008. god. diplomirala je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Od 2006. god. bila je zaposlena u tvrtci Galko d.o.o., a od 2011. do 2021. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu u Zavodu za odjevnu tehnologiju. God. 2022. osnovala je vlastiti obrt koji se bavi dizajnom i izradom funkcionalne odjeće, izradom prototipova odjevnih predmeta specijalne namjene, kreativnim radionicama i dr.. Doktorski rad izradila je pod mentorstvom prof. dr. sc. Dubravka Rogalea, u području spajanja termoplastičnih polimernih materijala, procesnih parametara visokotehnoloških tehnika spajanja i svojstava spojeva na zaštitnoj i inteligentnoj odjeći.
Naslov teme doktorskog rada	Procesni parametri visokotehnoloških metoda spajanja i svojstva spojeva na zaštitnoj i inteligentnoj odjeći
Mentor	prof. dr. sc. Dubravko Rogale
Datum obrane doktorskog rada	10.5.2023. god.

PROCESNI PARAMETRI VISOKOTEHNOLOŠKIH TEHNIKA SPAJANJA I NJIHOV UTJECAJ NA SVOJSTVA SPOJEVA

Martina BOBOVČAN MARCELIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, mbobovcanm@gmail.com

Sažetak: *U radu je istražen utjecaj procesnih parametara primijenjenih visokotehnoloških tehnika spajanja na svojstva spojeva. Spojevi koji će se ispitivati nastali su spajanjem dijelova odjevnog predmeta upotrebom tehnike ultrazvučnog spajanja i visokofrekventnog (VF) spajanja. Upotrijebljene tehnike spajanja se koriste pri izradi zaštitne i inteligentne odjeće gdje spojevi moraju zadovoljavati određena svojstva, a neka od njih su zrakonepropusnost, vodonepropusnost, elastičnost, čvrstoća, debljina istisnutog ruba, kompresijska svojstva i dr.. U radu je istražen odnos utjecaja parametara spajanja na debljinu istisnutog ruba,na čvrstoću spojeva i gustoću energije po volumenu, te je dat prikaz međusobne povezanosti čvrstoće spajanja i gustoće energije po volumenu.*

1. Uvod

Dijelovi zaštitne i inteligentne odjeće mogu se spojiti konvencionalnim šivanjem, ali se nužno moraju koristiti i visokotehnološke tehnike spajanja materijala i elemenata budući da konvencionalne tehnike ne mogu polučiti zadovoljavajuće tehničke i tehnološke uvjete [1]. Tehnike spajanja koje su korištene za izradu spojeva razlikuju se s aspekta dovođenja i/ili iniciranja topline na mjestu spoja [2, 3]. Kod svih tehnika spajanja pravilna provedba procesa najčešće ovisi o vrijednostima tri procesna parametra spajanja, a to su temperatura/energija, pritisna sila i vrijeme spajanja kod stacionarnog spajanja tj, brzina kod kontinuiranog spajanja [4].

Na sve spojeve pri sastavljanju dijelova odjeće, a posebno kod odjeće zaštitne i inteligentne odjeće, postavljaju se određeni zahtjevi kao što su čvrstoća, elastičnost, trajnost, kvaliteta, estetika i drugi tehnički uvjeti, a posebno zrakonepropusnost i vodonepropusnost. Takvi odjevni predmeti izrađeni su od specifičnih tekstila. Da bi spojevi imali spomenuta svojstva potrebno je odrediti optimalne parametre spajanja ovisno o vrsti materijala i odabranoj tehnici spajanja. Na temelju iznesenih zahtjeva, kojima se definiraju značajke spoja, razmatra se o načinu na koji je potrebno projektirati spoj i tehnici spajanja pomoću koje će se spojiti dijelovi odjevnog predmeta [5].

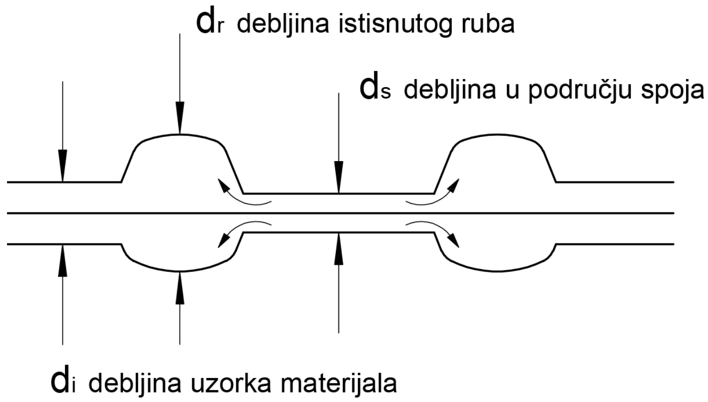
Istraživanja drugih autora ukazuju koliko je značajna upotreba optimalnih vrijednosti parametara spajanja i koliko značajan utjecaj imaju na kvalitetu spoja ali i na ostala svojstva spojeva koja su vrlo bitna kako bi odjevni predmet zadovoljio sve zahtjeve koji su definirani prema njegovoj namjeni [6].

2. Eksperimentalni dio

U radu su prikazana istraživanja utjecaja procesnih parametara spajanja na svojstva spojeva zaštitne i inteligentne odjeće. Spajana su dva različita uzoraka materijala M10 (PU 100 %) i M11 (PES 53 % i PU 47 %) pomoću tehnike ultrazvučnog i VF spajanja. Uzorci materijala su spajani na više načina rasporeda slojeva materijala, lice na lice, lice na naličje i naličje na naličje. Za istraživanja u radu korišten je izrazito velik raspon procesnih parametara, pa je za eksperimentalni dio izrađen veliki broj različitih uzoraka spojeva koji su mjereni, analizirani i ocjenjivani pri čemu su utvrđeni rasponi optimalnih vrijednosti procesnih parametara spajanja za obje tehnike spajanja.

Vrednovanje kvalitete spoja na temelju vizualnog izgleda spoja ocjenjivano u nekoliko faza. Na uzorcima spojeva koji su ocijenjeni dobrom ocjenom vizualne kvalitete, provedena su ispitivanja čvrstoće spojeva, debljine istisnutog ruba i dat je izračuni gustoće energije po volumenu.

Ocjenjivanje vizualnog izgleda spoja provedeno s obzirom na postignutu kvalitetu spoja, intenzitet debljine istisnutih rubova u području spoja, sl. 1, te nabora materijala uz područje spoja.



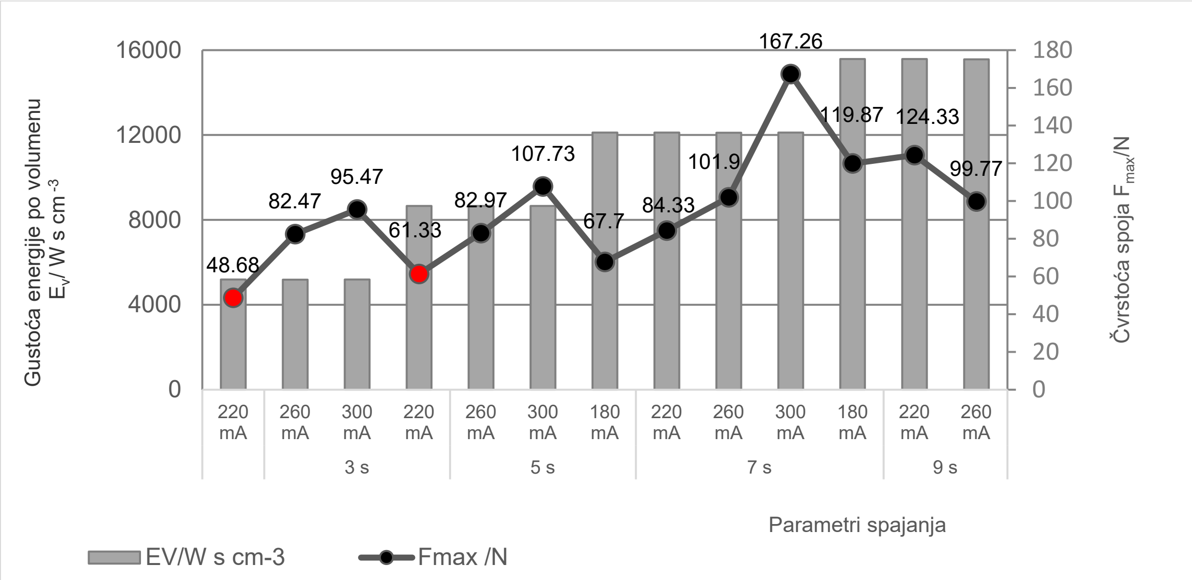
Slika 1: Shematski prikaz spoja s prikazom karakterističnih debljina spoja: debljina istisnutih rubova (d_r), debljina u području spoja (d_s) i debljina materijala izvan područja spajanja (d_i)

Za ispitivanje mehaničkih svojstva čvrstoće spoja korištena je kidalica proizvođača Mesdan S.p.A oznake TensoLab 3000, a za ispitivanje vrijednosti debljine istisnutog ruba korišten je mjerni uređaj za mjerenje karakteristika spojeva.
Analizom mjernih rezultata ispitivanih svojstava spojeva, čije vrijednosti se mijenjaju u ovisnosti o primijenjenim procesnim parametrima spajanja, utvrđen je odnos utjecaja procesnih parametara spajanja na čvrstoću spojeva i debljinu istisnutih rubova. Na temelju ulaznih parametara spajanja izračunate su i vrijednosti gustoće energije po volumenu za tehnike ultrazvučnog i VF spajanja, te je istražen njihov utjecaj na kvalitetu spojeva.

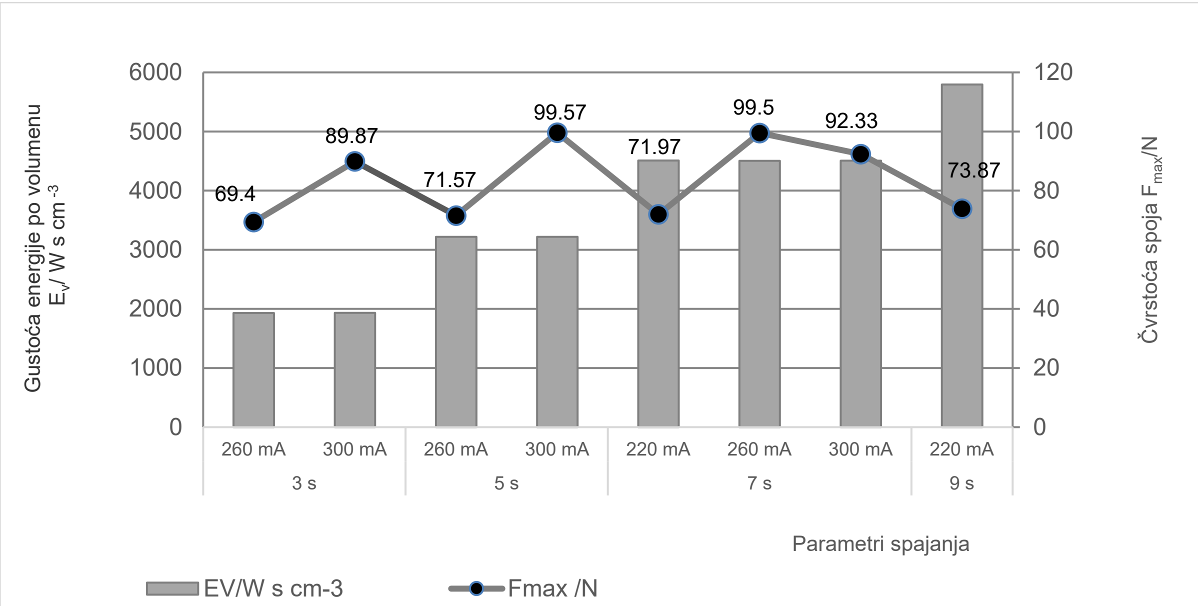
3. Rezultati i rasprava

Proučavanjem odnosa utjecaja parametara spajanja na vrijednosti izmjerenih čvrstoća spojeva, uočeno je da vrlo bitan faktor koji utječe na vrijednosti svih proučavanih svojstava spojeva je debljina istisnutih rubova. Manje vrijednosti debljine istisnutih rubova ukazuju da spoj ima blago istisnute rubove, a veće izmjerene vrijednosti upućuju na jači intenzitet istisnutih rubova. Vrlo naglašeni istisnuti rubovi su deformacije koje nastaju kod dovođenja i/ili iniciranja prevelike količine topline u zoni spajanja. Omekšani materijal se iz područja zahvaćenog djelovanju topline, djelovanjem pritisne sile, istiskuje u rubove spoja.
Iz rezultata ispitivanja čvrstoće spojeva i utjecaja različitih parametara spajanja može se zaključiti da na čvrstoću spojeva značajan utjecaj imaju parametri spajanja ali i raspored slojeva materijala. Najveće vrijednosti čvrstoće spojeva kod tehnike ultrazvučnog spajanja izmjerene su kod spojeva spajanih pri nižim brzinama spajanja i većim vrijednostima snage ultrazvučnog generatora. Kod tehnike VF spajanja najveće vrijednosti čvrstoće izmjerene su kod dužeg vremena spajanja i većim vrijednostima jakosti anodne struje.
Da bi se utvrdila količina energije kojom se djeluje na materijal prilikom spajanja, provedeni su izračuni te je na temelju ulaznih parametara spajanja izračunata vrijednosti gustoće energije po volumenu. Usporedbom vrijednosti dobiveni su podaci o količini energije koju je potrebno utrošiti za postizanje kvalitetnog spoja za uzorke materijala.

Na temelju izračuna podataka za gustoću energije po volumenu kod ultrazvučnog i visokofrekventnog spajanja na uzorcima materijala oznaka M10 i M11 spajanih na način lice na lice spajanog materijala, načinjena je analiza utjecaja na čvrstoću ispitanih uzoraka. Rezultati analize uzoraka spajanih ultrazvučnom i VF tehnikom prikazani su na sl. 2 i 3, te je dat prikaz utjecaja gustoće energije po kubnom centimetru na čvrstoću spojeve spajanih visokofrekventnom tehnikom spajanja.
Analizom je utvrđeno da spojevi kod kojih je izračunom dobiveno da iniciraju veću gustoću energije po volumenu imaju i veću čvrstoću i veću debljinu istisnutog ruba.



Slika 2: Prikaz utjecaja gustoće energije po volumenu E_v/W s cm^{-3} na čvrstoću spoj F_{max}/N kod visokofrekventnog spajanja uzorka materijala oznake M10



Slika 3: Prikaz utjecaja gustoće energije po volumenu E_v/W s cm^{-3} na čvrstoću spoj F_{max}/N kod visokofrekventnog spajanja uzorku materijala oznake M11

Analizom je utvrđeno da spojevi kod kojih je izračunom dobiveno da iniciraju veću gustoću energije po volumenu imaju i veću čvrstoću i veću debljinu istisnutog ruba.

4. Zaključak

Rezultati istraživanja jasno ukazuju da se pomoću mehaničkih parametara moguće egzaktno i znanstveno vrednovati svojstva spojeva na tekstilnim materijalima od kojih se izrađuje zaštitna i inteligentna odjeća. Istraživanjem se utvrdilo da upotreba optimalnih vrijednosti parametara spajanja ima značajan utjecaj ne samo na kvalitetu spoja već i na ostala svojstva spojeva (čvrstoća, debljina istisnutog ruba i gustoća energije po volumenu) koja su vrlo bitna kako bi određeni odjevni predmet zadovoljio sve zahtjeve koji su definirani prema njegovoj namjeni.
Utvrđeni rezultati ispitivanja čvrstoće spojeva, debljine istisnutog ruba i gustoće energije po volumenu za spojeve spajane ultrazvučnom i VF tehnikom spajanja daju tehnološku analizu najutjecajnijih procesnih parametara spajanja pri čemu su utvrđeni rasponi optimalnih vrijednosti procesnih parametara spajanja. Nove spoznaje prikazane u ovom radu pomoći će pri daljnjem razvoju suvremene zaštitne i inteligentne odjeće kao vrijednih uporabnih predmeta visoke dodane vrijednosti. Rezultati ovog rada omogućuju daljnji znanstveni, tehnički i tehnološki razvoj suvremenih visokotehnoloških spojeva na specifičnim odjevnim predmetima.

Zahvala

Doktorski rad je izrađen u okviru projekta financiranog od Hrvatske zaklade za znanost pod nazivom Razvoj i toplinska svojstva inteligentne odjeće (IP-2018-01-6363), voditelj projekta prof. dr. sc. Dubravko Rogale.

5. Literatura

[1] Firšt Rogale, S. i sur.: *Inteligentna odjeća*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 978-953-7105-52-5, Zagreb, (2014)
[2] Grewell, D.; Benatar, A. i Park, J.: *Ultrasonic Welding in: Plastics and Composites Welding Handbook,* Grewell, Benatar, Park, (Ed.), Hanser, ISBN 1-56990-313-1 (2003), pp. 142-188
[3] Zhang, Z. et al: Study on Heating Process of Ultrasonic Welding for Thermoplastics, *Journal of Thermoplastic Composite Materials*, **23** (2010) 5, pp. 647-664
[4] Shi, W. and Littel, T.: Mechanisms of Ultrasonic Joining of Textile Materials, *International Journal of Clotinhg Science and Technology*, **12** (2000) 5, pp. 331-350
[5] Marcelić Bobovčan M. et al.: Study of Compression Properties of Welded Seams Formed Using Hot Wedge, Hot Air, Ultrasonic and High-Frequency Welding Techniques, *Textile Research Journal*, **92** (2022) 23-2, pp. 4736-4752
[6] Jakubčioniene, Ž. et al.: Investigation of the strength of textile bonded seams, *Materials Science,* **18** (2012) 2, pp. 172-176

Iva Brlek

Životopis	Dr. sc. Iva Brlek rođena je 1988. god. u Zagrebu, a 2013. god. završava diplomski studij pri Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu te 2014. god. upisuje poslijediplomski studij pri istom fakultetu. 2023. godine doktorirala je s temom „*Cosmetotextiles - carriers of active natural substances to the skin*“ pod mentorstvom prof. dr. sc. Sandre Bischof. Od 2015. do 2017. god. radila je kao stručni suradnik na projektu „Napredni tekstilni materijali dobiveni ciljanom modifikacijom površine, ADVANCETEX“, a od 2017. do danas kao asistent u Zavodu za Tekstilnu kemiju i ekologiju, Sveučilišta u Zagrebu Tekstilno-tehnološkog fakulteta. Nagrađena je za najbolji e-kolegij u ak. god. 2017./2018. i Dekanovom nagradom u kategoriji asistenti za objavu znanstvenog rada u časopisu s najvećim faktorom odjeka u ak. god. 2020./2021.
Naslov teme doktorskog rada	Kozmeto-tekstilije kao prijenosnici aktivnih tvari prirodnog porijekla na kožu
Mentor	prof. dr. sc. Sandra Bischof
Datum obrane doktorskog rada	17.2.2023. god.

KOZMETO-TEKSTILIJE KAO PRIJENOSNICI AKTIVNIH TVARI PRIRODNOG PORIJEKLA NA KOŽU

Iva BRLEK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, iva.brlek@ttf.hr

Sažetak: *Glavni cilj disertacije je bio utvrđivanje metodologije koja je najprimjerenija za kvantificiranje aktivnih tvari na kozmetotekstilijama, prije i nakon njihovog otpuštanja i pranja. Kako bi se mogla provesti istraživanja sintetizirane su mikrokapsule. Provedena su ispitivanja sintetiziranih mikrokapsula te su za aplikaciju na pamuk odabrane mikrokapsule s α-tokoferolom (α-toc) i mikrokapsule s eteričnim uljem smilja (EOI). Tekstilni materijali obrađeni mikrokapsulama su podvrgnuti ispitivanju postojanosti na pranje, trenje i svjetlost kako bi se utvrdilo vezivanje mikrokapsula, kao i njihovo otpuštanje tijekom upotrebe. Razvijen je prototip kozmetotekstilije koji se može koristiti za odjevne predmete koji su u bliskom kontaktu s kožom.*

1. Uvod

1.1. Kozmeto-tekstilije

Prema priručniku [1] koji se temelji na regulativi Europske komisije za kozmetičke proizvode [2], tekstil može biti "prijenosnik" koji na ljudsku kožu dostavlja aktivne tvari ili mješavine tvari. Djelatna(e) tvar(i) može(gu) se dostaviti u različite dijelove ljudskog tijela, posebno kožu. Imaju specifične funkcije, poput čišćenja kože, dodavanja mirisa, mijenjanja izgleda kože, ispravljanja mirisa ili, što je najvažnije, održavanja kože zdravom. Kozmetički pripravak, odnosno mješavina pripravaka, može biti prirodnog ili sintetskog porijetla. Da bi se aktivni pripravak ili smjesa nanesena na tekstilnu podlogu uopće smatrala djelatnom tvari, potrebno je imati sposobnost otpuštanja na kožu. Pripravci koji se ne oslobađaju na kožu ne smatraju se kozmetičkim proizvodima, niti se tkanine na koje su nanesene aktivne tvari koje se ne oslobađaju na kožu svrstavaju u kozmeto-tekstilije [1]. Različite literature [3, 4] klasificiraju kozmetičke tekstilije koristeći različite osnove i koncepte, najčešće koristeći utjecaje na ljudski organizam kao osnovu klasifikacije ili s obzirom na način nanošenja na tekstilne podloge.

1.2. Mikrokapsule

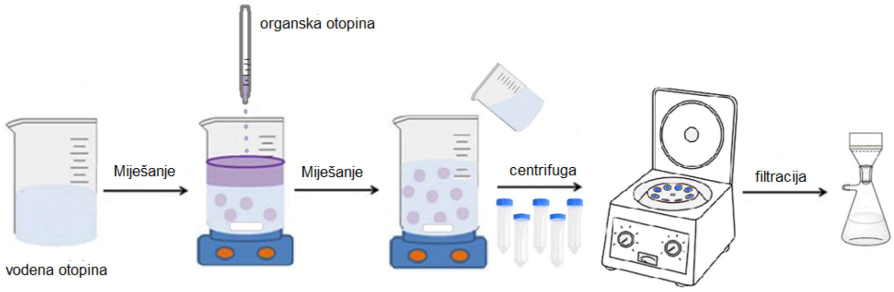
Mikrokapsule su čestice veličine od 1 do 1000 μm koje sadrže djelatnu tvar (u tekućem ili čvrstom stanju), okružene prirodnom, polusintetskom ili sintetskom polimernom membranom. Sastoje se od dva dijela, jezgre i membrane. Brojne aktivne tvari osjetljive su na toplinu, sklone su oksidaciji ili nekim drugim promjenama. Mikrokapsulacija ili vezanje u komplekse omogućuje zaštitu osjetljivih aktivnih tvari od štetnih utjecaja, kao što je razgradnja oksidacijom ili polimerizacijom tijekom sušenja i/ili termičke obrade i skladištenjem odjeće. Ovi procesi sprječavaju isparavanje hlapljivih spojeva i produljuju im životni vijek, što je od velike važnosti kod korištenja parfema i eteričnih ulja [5, 6].

1.3. Otpuštanje aktivnih tvari

Nakon što je aktivna tvar aplicirana na tekstilni materijal, važno je definirati i razumjeti mehanizam njezinog oslobađanja. Ponekad je primarni cilj potpuno otpuštanje djelatne tvari u određenom trenutku, a nekada je potrebno polagano otpuštanje, kako bi proizvod što duže zadržao svoju funkcionalnost. Aktivne tvari difundiraju kroz ovojnicu mikrokapsule određenom brzinom [7, 8].

2. Eksperimentalni dio

Odabrane su djelatne tvari, α-tokoferol i eterično ulje smilja te su sintetizirane etil-celulozne mikrokapsule metodom razdvajanja faza (Slika 1). Djelatne tvari α-tokoferol i eterično ulje smilja vrlo su osjetljive na vanjske utjecaje te je kapsulacija bila logičan izbor kako bi se spriječila njihova razgradnja, odnosno prerano isparavanje tijekom i nakon nanošenja na tekstil. Mikrokapsule su analizirane gravimetrijski i mikroskopski kako bi se odredila njihova morfologija i otkrila prisutnost ulja u mikrokapsulama.



Slika 1: Mikrokapsule etil celuloze sintetizirane metodom razdvajanja faza

Analiza antioksidansa provedena je i demonstrirana tehnikom elektronske spinske rezonancije (ESR). Mikrokapsule su nanesene na tekstil postupkom impregnacije, iscrpljivanja i elektropredenja. Tekstil tretiran mikrokapsulama (kozmeto-tekstil) podvrgnut je ispitivanju pranja, trenja i postojanosti na svjetlost kako bi se utvrdilo vezivanje mikrokapsula i njihovo otpuštanje tijekom uporabe. Za kvalitativne i kvantitativne analize aktivnih tvari prije i nakon testova postojanosti korištene su spektrofotometrija, kromatografija i mikroskopija. Remisijska spektrofotometrija je korištena, prije i nakon obrade, za analizu stupnja bjeline tekstila. Proveden je dermatološki test (Patch test) na 50 ispitanika kako bi se utvrdila mogućnost alergijske reakcije na kozmeto-tekstilije.

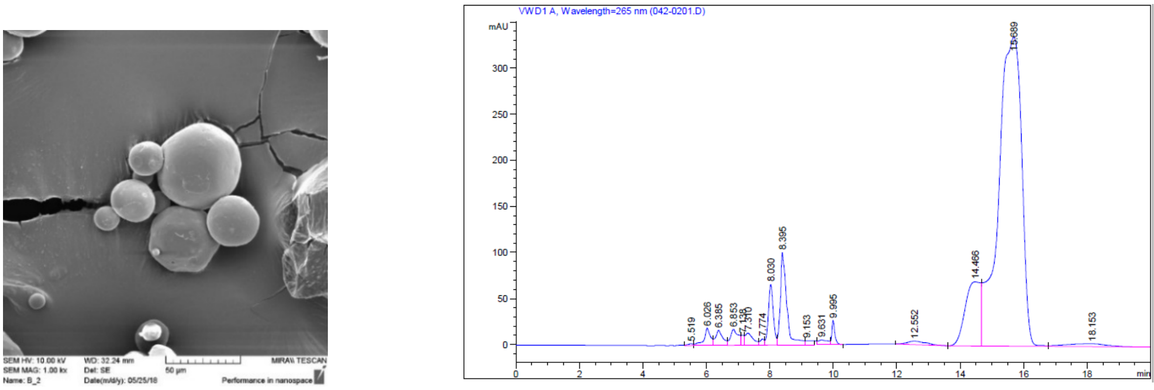
3. Rezultati i rasprava

U ovom istraživanju korišteno je nekoliko vrsta aktivnih tvari (α-toc, EOI i kombinacija α-toc i EOI), a za konačni prototip EOI je odabran kao najbolji. Optimizirana je sinteza mikrokapsula te je za daljnja istraživanja odabrana najbolja količina aktivne tvari i etil celuloze, koja ima ulogu membrane u sintetiziranim mikrokapsulama, u omjeru 1:3 (ulje: etil celuloza).
Pamučna tkanina odabrana je kao potencijalni kozmetički tekstil zbog svog prirodnog podrijetla, hidrofilnosti i ugodnih svojstava u dodiru s kožom. Studije su također provedene na drugim tekstilnim materijalima (npr. PES/pamuk, svila, modal i liocel). Metoda iscrpljenja pokazala se kao najprihvatljivija metoda primjene jer je omogućila ravnomjerno vezivanje mikrokapsula za tekstil u kontroliranim uvjetima temperature, vremena i koncentracije kemikalija, što nije bio slučaj kod impregnacije i elektroispredanja.

Tablica 1: Otpuštanje aktivnih tvari nakon ispitivanja postojanosti

Test postojanosti		**Kozmeto-tekstilije s EC mikrokapsulama koje sadrže α-toc**	**Kozmeto-tekstilije s EC mikrokapsulama koje sadrže EOI**
		otpuštanje aktivnih tvari (%)	
postojanost na trenje		5,54	73,77
postojanost na svjetlo		16,63	44,26
postojanost na pranje	1 ciklus	/	68,85
	10 ciklusa	/	88,11

Tekstil tretiran mikrokapsulama podvrgnut je ispitivanju postojanosti na pranje, trenje i na svjetlost kako bi se utvrdilo vezivanje mikrokapsula i njihovo otpuštanje tijekom uporabe. Kozmeto-tekstil koji je sadržavao mikrokapsule s eteričnim uljem pokazao je dobru postojanost na svjetlost (55,74 % aktivne tvari još uvijek je bilo prisutno na kozmetičkom tekstilu nakon testa), ali nije bio otporan na pranje jer se eterično ulje nije moglo otkriti na tekstilu nakon 10 ciklusa pranja. Dobiveni rezultati otpornosti na trenje pokazali su da se ulje trenjem o kožu postupno oslobađa, što je bio nužan preduvjet da se prototip kategorizira kao kozmeto- tekstilija. Postignuti učinci prikazani su testom postojanosti (Tablica 1).
Optimalni rezultati u sintezi dobiveni su u sljedećim uvjetima: sinteza po metodi isparavanja otapala, omjer ulje:EC 1:3, brzina miješanja u sintezi 400 okretaja u minuti. Prototip EC mikrokapsula koje sadrže EOI analiziran skenirajućim elektronskim mikroskopom (SEM) prikazan je na slici 2 a. Na slici 2 b prikazan je HPLC kromatogram EC-EOI mikrokapsula.

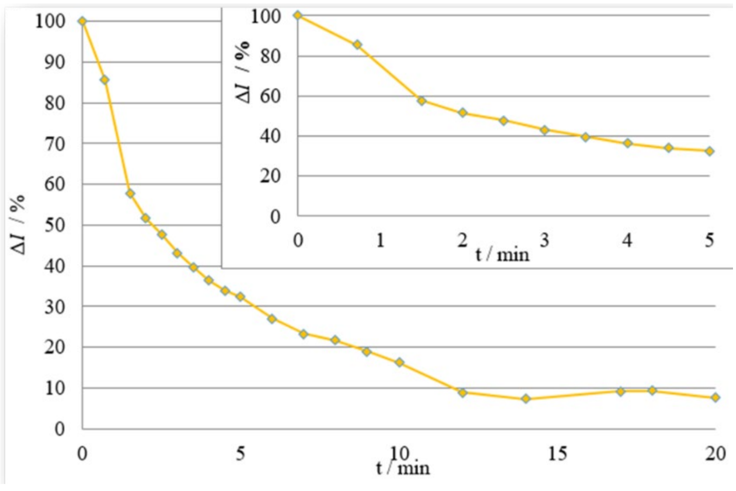


a b

Slika 2: Prototip EC mikrokapsula koje sadrže EOI: a) SEM slika EC mikrokapsula koje sadrže EOI, povećanje 1000x, b) HPLC kromatogram EC-EOI mikrokapsula

Optimalni rezultati u primjeni dobiveni su u sljedećim uvjetima: aplikacija na tekstil iscrpljenjem, vezivo Tubicoat WLI u koncentraciji 5,6 % na masu materijala, koncentracija mikrokapsula 8 % na masu materijala. Rezultati analize remisijskom spektrofotometrijom pokazali su neznačajnu promjenu bjeline materijala nakon obrade mikrokapsulama.

Nakon provedenog dermatološkog testa (Patch test) na 50 osoba, svi su pacijenti bili negativni na testirane uzorke tekstila. Budući da su testirani pacijenti najvjerojatnije imali senzibiliziranu kožu, može se zaključiti da su testirane kozmeto-tekstilije hipoalergene. Rezultati analize antioksidansa pomoću ESR tehnike prikazani su na slici 3. EOI kao aktivna tvar pokazala je značajan antioksidativni potencijal. Relativni intenzitet signala izmjeren 12 minuta nakon kontakta aktivne tvari s otopinom DPPH (slobodni radikal 2,2-difenil-pikrilhidrazil) bio je oko 8 % i ostao je relativno konstantan do kraja mjerenja.



Slika 3: Relativni intenzitet signala DPPH kao funkcija vremena reakcije t za aktivnu tvar EOI

4. Zaključci

Potvrđene su sve istraživačke hipoteze disertacije kako slijedi:
1. **Ciljanu učinkovitost kozmetičkih tekstila moguće je postići nanošenjem aktivnih, prirodnih proizvoda na bazi vitamina ili eteričnih ulja na tekstil.** *Ciljani učinci kozmetičkog tekstila bili su: dobro antioksidativno djelovanje i hipoalergenost kozmetičkog tekstila.*
2. **Sintetizirane mikrokapsule će se pričvrstiti na tekstilnu podlogu i postupno oslobađati od kozmetičkog tekstila.** *U tu svrhu provedena su sljedeća ispitivanja postojanosti na kozmetičkom tekstilu: ciklusi pranja, trljanje i svjetlosni test (Tablica 1).*
3. **Razvijena metodologija omogućit će kvantitativno određivanje količine aktivnih proizvoda u kozmetičkom tekstilu, što je u izravnoj vezi s učinkovitošću tretmana i postojanošću pranja.** *Za kvantitativno određivanje α-toc korištena je analiza visokotlačnom tekućinskom kromatografijom, a za kvantitativnu analizu EOI UV spektroskopija.*

Znanstveni doprinos doktorskog rada očituje se kroz:
1. Razvoj inovativnih, ekološki povoljnih i biorazgradivih kozmeto-tekstilija koje mogu imati i medicinski učinak.
2. Poboljšanje učinkovitosti kozmeto-tekstilija optimiranjem metoda i postupaka mikrokapsuliranja.
3. Doprinos klasifikaciji i standardizaciji metoda za ispitivanje kozmetičkih, aromaterapeutskih ili medicinskih učinaka kozmeto-tekstilija.
U radu su potvrđene sve postavljene hipoteze, kao i očekivani znanstveni doprinos istraživanja jer je disertacija rezultirala razvojem prototipa kozmetotekstilija, pamučnog materijala s etil celuloznim mikrokapsulama koje sadrže eterično ulje smilja, koji ima mogućnost široke primjenu u području wellness tekstilija, ali i u kozmetičkoj industriji i u području medicine.

Zahvala

Ovaj rad izrađen je u okviru projekta Hrvatske zaklade za znanost (HRZZ), br. 9967 Napredni tekstilni materijali dobiveni ciljanom modifikacijom površine, ADVANCETEX, voditeljice prof. dr. sc. Sandre Bischof.

5. Literatura

[1] Official website of the Europenian Union, *Dostupan na*: https://ec.europa.eu/docsroom/documents/42850 *Pristupljeno:* 2024-01-02
[2] The European Commission: Regulation (EC) No 1223/2009 of the european parliament and of the council of 30 November 2009 on cosmetic products, *Official Journal of the European Union* (2009) 1223, 342/59–209
[3] Singh, M. K. et al.: Cosmetotextiles: State of art, *Fibres & Textiles In Eastern Europe*, **19** (2011) 4, pp. 27–33, ISSN 1230-3666
[4] Rodrigues, S. N. et al.: Scentfashion®: Microencapsulated perfumes for textile application, *Chemical Engineering Journal*, **149** (2009) 1-3, pp. 463–472, ISSN 1873-3212
[5] Lam, P. L., Gambari, R.: Advanced progress of microencapsulation technologies: In vivo and in vitro models for studying oral and transdermal drug deliveries, *Journal of Controlled Release: Official Journal of the Controlled Release Society*, **178** (2014), pp. 25–45, ISSN 0168-3659
[6] Carvalho, I. T. et al.: Application of microencapsulated essential oils in cosmetic and personal health care products—A review, *International Journal of Cosmetic Science*, **38** (2016), pp. 109–119, ISSN 1468-2494
[7] Martins, I. M. et al.: Microencapsulation of essential oils with biodegradable polymeric carriers for cosmetic applications, *Chemical Engineering Journal*, 245 (2014), pp. 191–200, ISSN 1385-8947
[8] Nesterenko, A. et al.: Vegetable proteins in microencapsulation: A review of recent interventions and their effectiveness, *Industrial Crops and Products*, **42** (2013) 1, pp. 469–479, ISSN 0926-6690

Tea Bušac

Životopis	Rođena je 1992. god. u Zagrebu. Diplomirala je 2016. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, a 2023. god. doktorirala. Po završetku studija dodijeljena joj je Dekanova nagrada za uspješnost. God. 2018. radila je kao asistent na zamjeni u Zavodu za materijale, vlakna i ispitivanje tekstila, a 2019. god. počinje raditi kao asistent voditelja pogona u praonici rublja Salesianer Miettex Lotos d.o.o. Od 2020. god. zapošljava se na radno mjesto stručnog suradnika na projektu KK.01.2.1.02.0064, a 2023. god. zapošljava se kao administrator na projektu K.K.01.1.1.04.0091. Osim rada na europskim projektima uključena je i kao suradnik na nacionalnim istraživačkim projektima Hrvatske zaklade za znanost. Objavila je više znanstvenih i stručnih radova te sudjelovala na međunarodnim i domaćim konferencijama.
Naslov teme doktorskog rada	Modifikacije poliesterske tkanine radi poboljšanoga vezanja biopolimera kitozana i smanjenja sadržaja čestične tvari u otpadnoj vodi od procesa pranja
Mentori	prof. dr. sc. Sanja Ercegović Ražić prof. dr. sc. Mirjana Čurlin
Datum obrane doktorskog rada	13.12.2023. god.

MODIFIKACIJE POLIESTERSKE TKANINE RADI POBOLJŠANOGA VEZANJA BIOPOLIMERA KITOZANA I SMANJENJA SADRŽAJA ČESTIČNE TVARI U OTPADNOJ VODI OD PROCESA PRANJA

Tea BUŠAC

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
10000 Zagreb, tea.busac@ttf.unizg.hr

Sažetak: *U ovom istraživanju praćen je utjecaj konvencionalnih i naprednih procesa predobrade (plazmom i ozoniranjem) poliesterske tkanine s ciljem poboljšanoga vezanja biopolimera kitozana te smanjenja sadržaja čestične tvari u efluentima od pranja dobivenih poliester/kitozan struktura.*

1. Uvod

Proizvodnja i potrošnja tekstila kontinuirano raste zbog porasta broja stanovništva i kraće trajnosti odjevnih predmeta, što neminovno dovodi do globalnog povećanja tekstilnog otpada. Odjeća izrađena od sintetičkih vlakana tijekom uporabe, a posebice tijekom pranja, otpušta vlakna različite duljine i finoće.
U svrhu zaštite vodenih ekosustava od onečišćenja ove vrste upotrebljavaju se različiti preventivni i kurativni postupci. Osim preventivnog djelovanja tijekom procesa proizvodnje važno je istaknuti i ekološki povoljne modifikacije koje se nanose na tekstil (postojane, nepostojane i polupostojane), a imaju zadaću poboljšanja uporabnih svojstava tkanine kao i zaštitu od onečišćenja vodenih ekosustava potencijalno otpuštenim česticama [1-3]. Čestice otpuštene tijekom uporabnog ciklusa sintetičkih tekstilija spadaju u područje onečišćenja mikroplastikom koja prema literaturi predstavlja *bilo koju sintetičku čvrstu česticu ili polimernu matricu s pravilnim ili nepravilnim oblikom veličine od 1 µm do 5 mm, bilo primarnog ili sekundarnog podrijetla, koja je netopljiva u vodi* [4-5].
Istraživanja u području otpuštanja čestica/fragmenata s tekstilnih materijala, njihov utjecaj na vodeni ekosustav te doprinos identifikaciji i karakterizaciji otpuštenih čestica tema su brojnih znanstvenih istraživanja [6]. Primjenom normiranih i fizikalno-kemijskih metoda karakterizacije tekstilnog materijala istražen je utjecaj procesa pranja na postignuta funkcionalna svojstva te na potencijal otpuštanja fragmenata vlakana. U ovom radu prikazan je dio rezultata koji se odnosi na stabilnost strukture poliester/kitozan praćene tijekom izlaganja čimbenicima u procesu pranja. Za potvrdu prisutnosti kitozana primijenjena je metoda identifikacije bojilom Remazol® Red RB, a sadržaj otpuštenih čestica praćen je laserskom difrakcijom.

2. Eksperimentalni dio

Istraživanje je provedeno na standardnoj tkanini od poliesterskih vlakana, čije su značajke prikazane u tablici 1, koja je pripremljena ručnim ultrazvučnim rezačem, *Ultrasonic cutter TTS-400*, *Sonowave*.

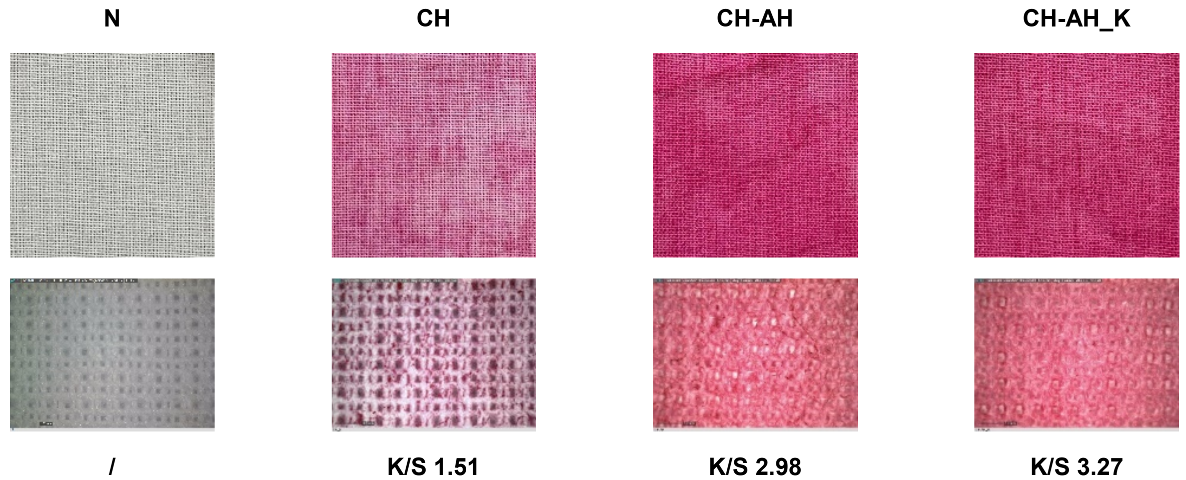
Tablica 1: Svojstva standardne poliesterske tkanine

Dobavljač (CFT)		Oznaka (PN-01)
Ton boje		bijeli
Plošna masa (g/m^2)		156,0
Gustoća (niti/cm)	osnova	27,7
	potka	20,0
Debljina (mm)		0,35
Finoća pređe (tex)	osnova	30,4
	potka	31,9
Vez		platneni

Alkalna hidroliza standardne poliesterske tkanine (AH) provedena je 2 % NaOH uz OK 1 : 5 pri temperaturi 98 °C u vremenu 30 minuta uz stupnjevito ispiranje vodom tijekom dva ciklusa vrućom i dva ciklusa hladnom vodom. Alkalna hidroliza dodatkom 3 g/L kationskog tenzida *Barquat BC50*, alkildimetilbenzalkonium klorid, *Quat-Chem Ltd*, (AH_K) provedena je pri istim uvjetima.
Funkcionalno naslojavanje biopolimera kitozana na neobrađenu poliestersku tkaninu te na odabrane predobrađene uzorke poliesterske tkanine provedeno je pomoću otopine kitozana (CH) koncentracije 0,5 % priređene otapanjem kitozana u destiliranoj vodi uz konstantno miješanje na magnetnoj miješalici (200 o/min) uz dodatak 0,1 mol/L klovodične kiseline ($HCl_{(aq)}$).
U cjelokupnom istraživanju praćen je utjecaj konvencionalnih i naprednih predobrada na stabilnost formirane strukture poliester/kitozan izložene čimbenicima u procesu pranja te na sadržaj čestične tvari u efluentima od pranja provedbom analize: i) svojstava i stabilnosti dobivenih polimernih struktura poliester/kitozan; ii) svojstava i stabilnosti dobivenih polimernih struktura poliester/kitozan nakon pranja; iii) efluenata od pranja s naglaskom na sadržaj čestične tvari; iv) filtarskog kolača dobivenog membranskom filtracijom efluenata od pranja.
U ovom radu prikazat će se samo dio rezultata koji se odnose na potvrdu modifikacije kitozanom konvencionalno predobrađenih poliesterskih tkanina i stabilnost strukture izložene čimbenicima u procesu pranja standardnim ECE A deterdžentom na 60 °C u vremenu 30 minuta.
Identifikacija prisutnosti kitozana na poliesterskoj tkanini provedena je bojilom antrakinonske strukture, Remazol® Red RB 133 % (C.I. Reactive Red 2). Uzorci su bojadisani sa 1 % bojila na masu materijala pri temperaturi 60 ºC u vremenu od 30 minuta uz brzinu okretaja 100 o/min s OK 1 : 50, u laboratorijskom uređaju *Polymat P 4502 (M), Mathis*. Ispiranje je provedeno tijekom četiri ciklusa u hladnoj vodi nakon čega je uslijedilo sapunanje sredstvom *Kempon 30, Kemo* sa 2 g/L, pri 90 ºC tijekom 10 minuta. Sadržaj čestične tvari određen je u efluentima od pranja kitozanom modificiranih struktura u kojima je uočen doprinos otpuštanju s pojedine komponente strukture određena je prema standardu HRN ISO 13320:2020 primjenom analizatora veličina čestica *PSA 1090 LD, Anton Paar*.

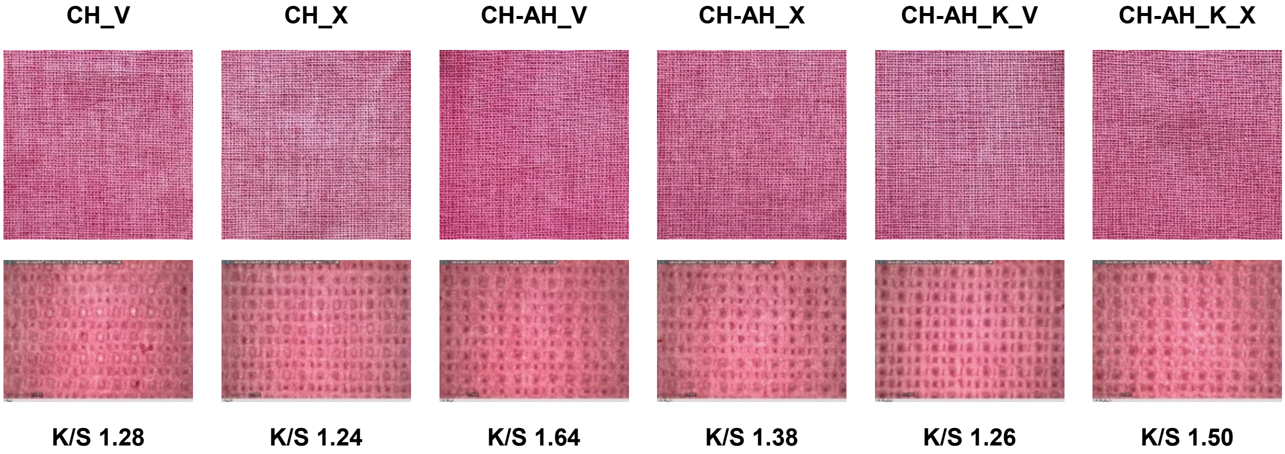
3. Rezultati i rasprava

Rezultati karakterizacije odnose se na svojstva i strukturalne značajke te ih je važno pratiti radi procjene pojedine predobrade i učinkovitosti modifikacije s kitozanom te stabilnosti strukture poliester/kitozan tijekom pranja. Pri tome se koriste brojne metode za identifikaciju kitozana na tekstilu, primjerice različita ionska bojila, te metoda potencijala strujanja. U ovom radu je za potvrdu prisutnosti kitozana primijenjena metoda bojadisanja bojilom Remazol® Red RB pri čemu se pomoću jakosti obojenja dokazuje njegova prisutnost.
Dobiveni rezultati, slika 1, prikazuju neobrađenu poliestersku tkaninu (N) te crveni ton boje s pripadajućim vrijednostima jakosti boje (K/S) za ostale uzorke predobrađene postupcima alkalne hidrolize (AH) i alkalne hidrolize uz dodatak promotora (AH_K) i modificirane kitozanom (CH) koji ukazuje na prisutnost kitozana za površini.



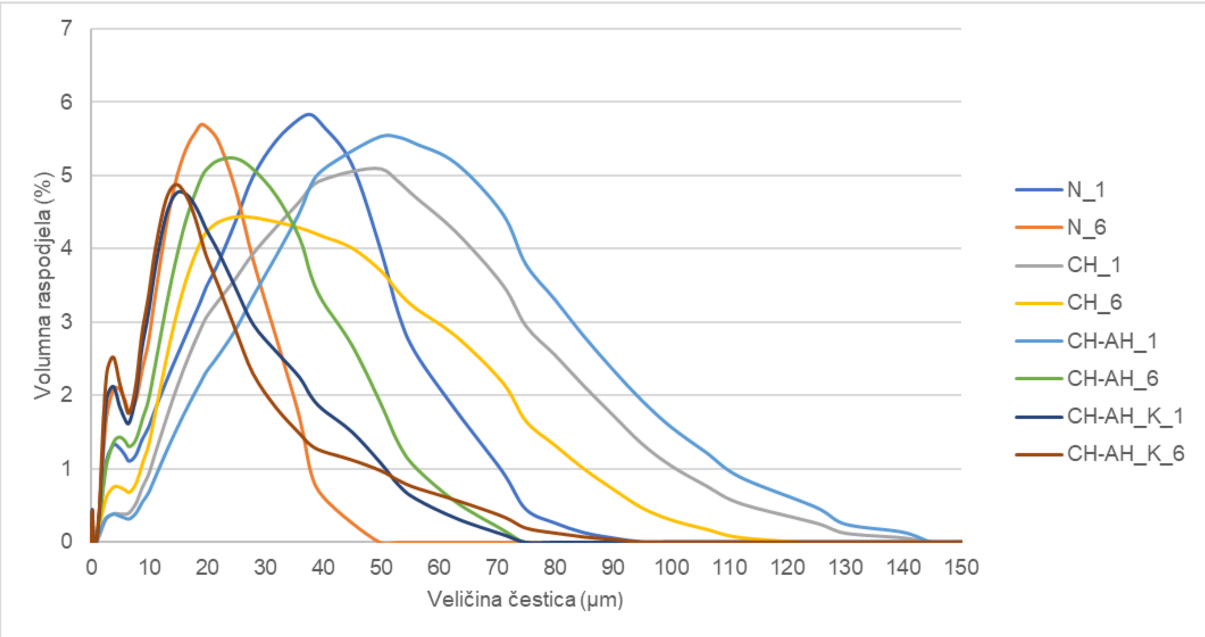
Slika 1: Mikrografi uzoraka poliesterske tkanine prije i nakon modifikacije bojadisanih bojilom Remazol® Red RB uz povećanja 50x i 230x i njihove K/S vrijednosti

Stabilnost struktura praćena je tijekom provedenih 5 (_V) i 10 (_X) ciklusa pranja, a rezultati bojadisanja prikazani su na slici 2. Smanjena jakost obojenja iskazane kao K/S vrijednosti, slika 2, pokazuje da kitozan nije potpuno stabilan u alkalnim uvjetima procesa pranja.



Slika 2: Mikrografi uzoraka opranih modificiranih poliesterskih tkanina bojadisanih bojilom Remazol® Red RB uz povećanja 50x i 230x i njihove K/S vrijednosti

Prikazane vrijednosti pokazuju najveći gubitak nakon 5 ciklusa pranja. Kitozanom obrađene alkalno hidrolizirane poliesterske tkanine nakon 5 i 10 ciklusa pranja (CH, CH-AH i CH-AH_K) i dalje su obojene, što potvrđuje prisutnost kitozana na površini i nakon 10 ciklusa pranja.
Čvrste tvari u efluentima od pranja mogu obuhvaćati čestice deterdženta, otpuštenih fibrilnih komponenata s poliesterske komponente u strukturi ili čestica otpuštenih s biopolimerne komponente u strukturi poliester/kitozan. Za karakterizaciju efluenata od procesa pranja s naglaskom na sadržaj čestične tvari primijenjena je analiza raspodjele veličina čestica, slika 3. Kompozitni uzorci efluenata od pranja i ispiranja prikupljeni su za analizu, pri čemu uzorci nakon 1 – 5 ciklusa pranja imaju oznaku _1, 6 – 10 ciklusa pranja oznaku _6.



Slika 3: Raspodjela veličina čestica u efluentima od 1 – 5 i 6 – 10 ciklusa pranja

Manji broj ciklusa pranja neobrađene poliesterske tkanine utječe na raspodjelu veličina čestica koja je pomaknuta prema većim česticama. Djelovanje kitozana na neobrađenoj poliesterskoj tkanini, pri izlaganju čimbenicima procesa pranja, vidljivo je iz rezultata raspodjele veličina čestica u efluentu koja je u ovom slučaju

za sve cikluse pranja pomaknuta prema većim česticama u odnosu na neobrađenu poliestersku tkaninu. Predobrada poliesterske tkanine alkalnom hidrolizom utječe na raspodjelu veličina čestica u efluentima od pranja pri čemu se može uočiti različita raspodjela za početne ciklusa pranja alkalno hidrolizirane poliesterske tkanine bez dodatka i s dodatkom promotora. Veći raspon veličina čestica dobiven je za početne cikluse pranja kod alkalno hidrolizirane poliesterske tkanine s dodatkom promotora.
Rezultati ukazuju da broj ciklusa pranja utječe na sadržaj čestične tvari koji podrijetlom pripada biopolimernoj i/ili polimernoj komponenti poliester/kitozan strukture.

4. Zaključci

Predobrada poliesterske tkanine alkalnom hidrolizom s i bez promotora ima utjecaj na stabilnost strukture poliester/kitozan, što potvrđuje metoda potvrde prisutnosti kitozana bojilom Remazol® Red RB. Određivanjem funkcije raspodjele veličina čestica u efluentima od pranja omogućena je detekcija veličinske kategorizacije potencijalno otpuštenih čestica u procesu pranja. Rezultati raspodjele u efluentima od pranja poliester/kitozan struktura ovise o strukturi polimera, interakciji kitozana sa strukturom, trajnosti modifikacije kroz uzastopne cikluse pranja, sadržaju i veličini suspendiranih čestica i djelovanju čimbenika u procesu pranja. Karakterizacija efluenata od pranja poliester/kitozan strukture metodom analize veličina čestica svrsishodna je te može dati značajan doprinos kurativnom djelovanju.

Zahvala

Ovaj rad sufinancirala je Hrvatska zaklada za znanost projektom HRZZ IP 2020 02 7575: Procjena otpuštanja čestica mikroplastike iz poliesterskih tekstilija u procesu pranja (2021. - 2025.) voditeljice prof. dr. sc. Tanje Pušić.

5. Literatura

[1] Miraftab, M.; Horrocks, A. R.: *Ecotextiles: The way forward for sustainable development in textiles*, Elsevier, ISBN 978-1-84569-214-8, Engleska, (2007)

[2] Soljačić, I. & Pušić, T.: *Njega tekstila, knjiga 1.*, Sveučilište u Zagrebu, Zagreb, (2005), str 23-139

[3] Kaurin, T.; Pušić, T. & Čurlin, M.: Biopolymer textile structure of chitosan with polyester, *Polymers*, **14** (2022) 15, 3088, ISSN 2073-4360

[4] Frias, J. P. & Nash, R.: Microplastics: Finding a consensus on the definition, *Marine pollution bulletin*, **138** (2019), pp. 145-147, ISSN 1879-3363

[5] Kaurin, T. & Šaravanja, A.: Protokoli za analizu otpuštenih čestica u procesu kućanskog pranja, *15. Znanstveno-stručno savjetovanje Tekstilna znanost i gospodarstvo*, Zagreb (2023)

[6] Pušić, T. et al.: The Stability of the Chitosan Coating on Polyester Fabric in the Washing Process. *Tekstilec*, **66** (2023), pp. 1-20, ISSN 2350-3696

Katia Grgić

Životopis	Rođena u Dubrovniku 1978. god. Doktorirala je 2023. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu na temu "Adsorpcija cetilpiridinijevoga klorida na celulozne supstrate" pod mentorstvom prof. dr. sc. Tanje Pušić. Od 2009. god. do danas zaposlena je kao stručni suradnik na Sveučilištu u Zagrebu Tekstilnom-tehnološkom fakultetu. Osim stručnih poslova koji su vezani uz nastavu, bavi se stručnim i znanstvenim radom u okviru Znanstveno istraživačkog centra za tekstil, TSRC-a. Ostvarila je brojne suradnje s vanjskim dionicima iz akademskog, gospodarskog i javnog sektora. Aktivno sudjeluje na provedbi stručnih, razvojnih, istraživačkih projekata i organizaciji radionica vezanih za projekte. Sudjelovala je na međunarodnim i nacionalnim projektima, FP7, PoC 5, OPKK i HRZZ. Od 2021. god. s prof. dr. sc. Tanjom Pušić i izv. prof. dr. sc. Tihanom Dekanić sudjeluje na međunarodnim izložbama inovacija: INOVA, EUROINVENT/ICIR, KIDE, ICE-USV, na kojima dobivaju niz medalja i posebnih priznanja.
Naslov teme doktorskog rada	Adsorpcija cetilpiridinijevoga klorida na celulozne supstrate
Mentor	prof. dr. sc. Tanja Pušić
Datum obrane doktorskog rada	17.7.2023. god.

ADSORPCIJA CETILPIRIDINIJEVOGA KLORIDA NA CELULOZNE SUPSTRATE

Katia GRGIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
katia.grgic@ttf.unizg.hr

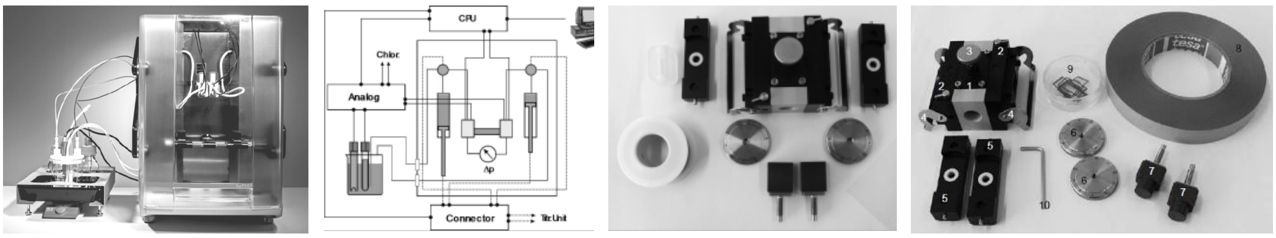
Sažetak: *Cetilpiridinijev klorid (CPC) je kationski tenzid koji pripada skupini kvaternih amonijevih spojeva. Koristi se u različitim područjima primjene, a najviše u kozmetici, farmakologiji i stomatologiji zbog baktericidne i antiseptičke aktivnosti. U ovom radu praćena je adsorpcija CPC-a na dva celulozna supstrata, pamučnu tkaninu i modelni celulozni film pri različitim vrijednostima pH primjenom metode potencijal strujanja u elektrokinetičkom analizatoru i mikrogravimetrijskom metodom, QCM-D.*

1. Uvod

Kationski tenzid zbog pozitivnog naboja površinski aktivnog iona reagira s negativno nabijenim površinama [1]. Povećanom koncentracijom kationskog tenzida u vodenim medijima pod utjecajem van der Waalsovih sila dolazi do procesa samoudruživanja u agregate, koji se nazivaju micele. Ove organske koloidne čestice imaju veličinu od jednog milimikrona do jednog mikrona [2]. Kritična micelarna koncentracija (CMC) ovisi o kemijskoj građi tenzida, otapalu, prisutnosti elektrolita i temperaturi [3]. Prema literaturi CMC cetilpiridinijeva klorida u otopini kalijevog klorida (0,0013 mol/kg) iznosi 0,000266 mol/kg pri temperaturi od 25 °C [4]. U ovom radu praćena je adsorpcija CPC-a iz micelarne otopine na celulozne supstrate pri 25 °C i različitim vrijednostima pH (pH 4, pH 6 i pH 9) elektrokinetičkom metodom potencijal strujanja i mikrogravimetrijskom metodom kvarc-kristalne mikrovage s praćenjem disipacije (eng. *Quartz Crystal Microbalance with Dissipation*, QCM-D). Dodatno je praćena i desorpcija CPC-a pri pH 6 pri 25 °C. Odabrani su celulozni supstrati, pamučna tkanina (PT) i modelni celulozni film (MCF), koji imaju višestruku primjeni u medicini i farmakologiji, zbog svoje velike površine i adsorpcijskih svojstava te su pogodni nosači različitih kozmetičkih i terapeutskih pripravaka [5-6].

2. Eksperimentalni dio

U radu su istraženi celulozni supstrati kao adsorbensi, standardna pamučna tkanina (PT) kao realni sustav i modelni celulozni film (MCF) kao modelni sustav. Primijenjen je cetilpiridinijev klorid (CPC) kao adsorbat, koncentracije 2,4 mmol/L.

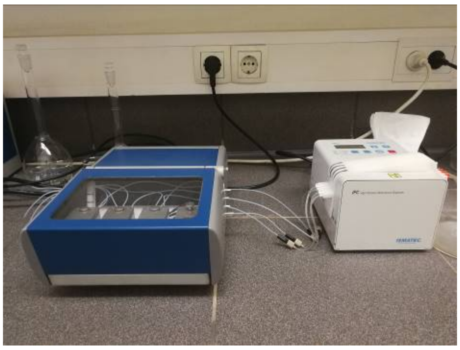


a b c d

Slika 1: Mjerni sustav: a. SurPASS elektrokinetički analizator, b) shematski prikaz instrumenta c) podesiva ćelija, AGC d) podesiva ćelija za diskove, AGCD [7].

Adsorpcija CPC-a iz otopina na standardnu pamučnu tkaninu i modelni celulozni film praćena je u elektrokinetičkom analizatoru SurPASS (A. Paar) sl.1 a i sl.1 b, metodom potencijal strujanja, pri čemu su korištene podesiva ćelija za plošne materijale (PT), sl.1 c i podesiva ćelija za diskove (MCF), sl.1 d. Koncentracija CPC-a iznosila je 2,4 mmol/L, a koncentracija elektrolita (KCl) u sustavu 1 mmol/L. Zeta potencijal (ζ) pamučne tkanine mjeren je u ovisnosti o vrijednosti pH otopine elektrolita.

Za praćenje adsorpcija CPC-a iz micelarne otopine na modelni celulozni film korištena je i mikrogravimetrijska metoda, QCM-D, sl.2, koja se temelji na piezoelektričnom učinku kvarcnog senzora i omogućuje praćenje adsorpcije koloidnih formulacija na čvrste površine, polimerne filmove [8].



a

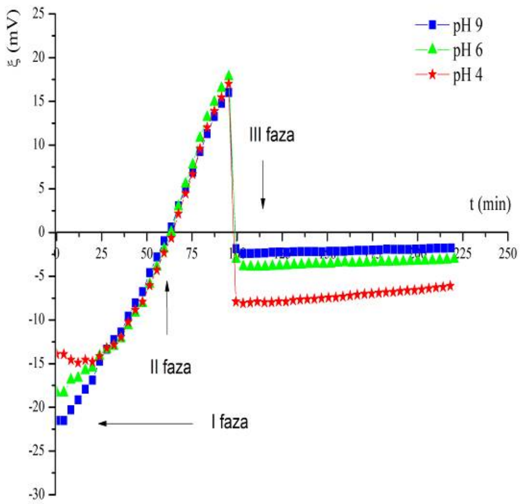
b

Slika 2: Mjerni sustav kvarc-kristalne mikrovage s praćenjem disipacije: a) QCM-D b) kućište za kvarcne senzore s celuloznim polimernim filmom (MCF).

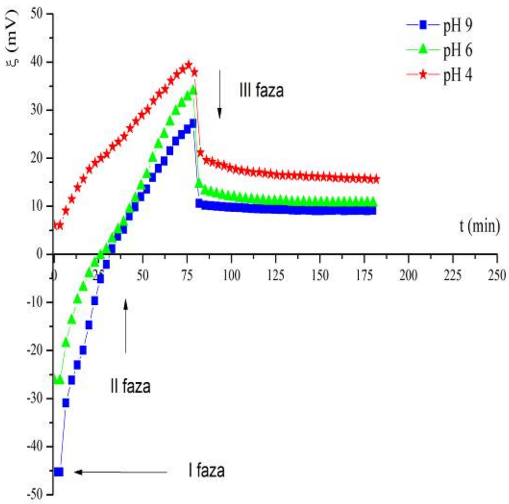
Adsorpcija CPC-a iz micelarne otopine (2,4 mmol/L) na MCF praćena je QCM-D metodom u otopini elektrolita 1 mmol/L KCl pri navedenim vrijednostima pH (pH 4, pH 6 i pH 9) uz promjenu rezonantne frekvencije kroz funkciju vremena.

3. Rezultati i rasprava

Adsorpcija CPC-a iz micelarne otopine pri varijaciji vrijednosti pH je istražena u tri faze, sl. 3. Prva faza (I.) odnosi se na određivanje zeta potencijala kod pH 4 (ζ = -13,9 mV), pH 6 (ζ = -18,3 mV) i pH 9 (ζ = -21,5 mV).



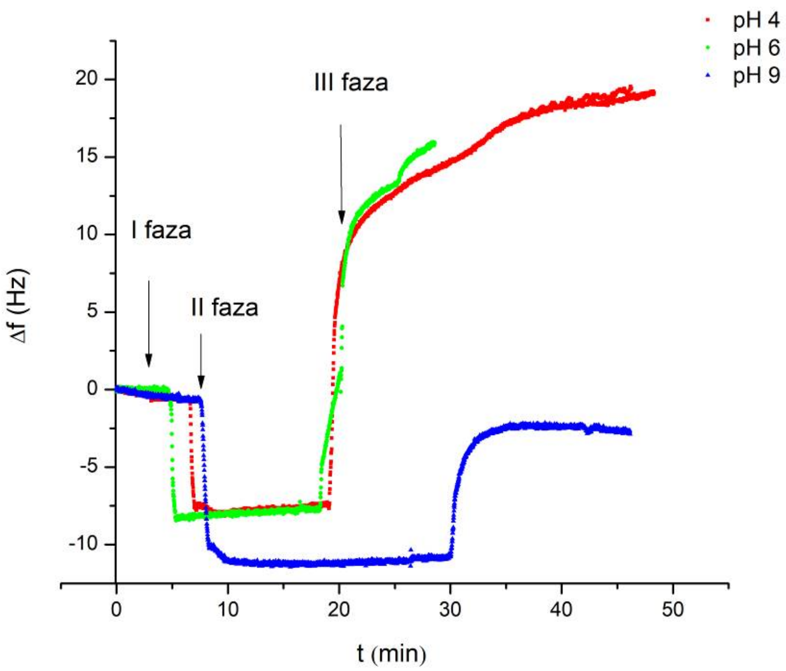
a



b

Slika 3: Adsorpcija CPC-a iz micelarne otopine: a) na PT i b) MCF pri različitim vrijednostima pH (pH 4, pH 6 i pH 9) i njegova desorpcija pri pH 6 u elektrokinetičkom analizatoru

U drugoj fazi (II.) praćena je brzina adsorpcije CPC-a dodanim u točno definiranim alikvotima na pamučnu tkaninu i MCF za sve tri vrijednosti pH. Na sl.3 a je vidljivo da se krivulje adsorpcije u fazi II. kod sve tri vrijednosti pH preklapaju, a utrošak adsorbata za postizanje točke nultog naboja pamučne tkanine iznosi oko 350 μg/g. Treća faza (III.) odnosi se na desorpciju CPC-a s pamučne tkanine u otopini elektrolita pri pH 6. Prema prikazanim rezultatima razvidne su razlike između pojedinih krivulja u ravnotežnom stanju. Najstabilnija krivulja desorpcije dobivena je za sustav CPC-pamučna tkanina (pH 9), koju ujedno karakterizira najmanje negativan zeta potencijal. Negativnije vrijednosti za sustave pri pH 6 i pH 4 pokazuju manju stabilnost ovih sustava u odnosu na pH 9.
Sl.3 b prikazuje adsorpciju CPC-a iz micelarne otopine na MCF gdje je vidljiv utjecaj vrijednosti pH na početnu vrijednost zeta potencijala MCF-a u prvoj fazi (I.). Vrijednost zeta potencijala MCF pri pH 4 je pozitivna (ζ = 6,0 mV), dok su kod pH 6 (ζ = -26,2 mV) i pH 9 (ζ =-45,2 mV) negativne. Početna vrijednost zeta potencijala MCF-a je ovisna o vrijednosti pH u sustavu i utječe na brzinu adsorpcije u drugoj fazi (II.) što je vidljivo iz sl.3 b. Desorpcija CPC-a s MCF u trećoj fazi (III.) u otopini elektrolita pri pH 6 u kratkom vremenu se stabilizira i vrijednosti zeta potencijala MCF-a su pozitivne što ukazuje na vezanje CPC micela na MCF.



Slika 4: Promjena u QCM-D frekvenciji u ovisnosti o vremenu - adsorpcija CPC-a iz micelarne otopine na MCF pri različitim vrijednostima pH (pH 4, pH 6 i pH 9) i njegova desorpcija pri pH 6

Procesi adsorpcije i desorpcije CPC-a iz micelarne otopine na MCF praćen metodom kvarcne mikrovage s praćenjem disipacije provedeni su u tri faze, sl. 4. U prvoj fazi (I.) dolazi do stabilizacije MCF u 1 mmol/L KCl pri pH 6. Druga faza (II.) prikazuje promjenu frekvencije u procesu adsorpcije CPC micelarne otopine pri različitim vrijednostima pH do postizanja konstantne frekvencije. Rezultati ukazuju da pri vrijednostima pH 4 i pH 6 nema značajne razlike u brzini adsorpcije CPC micela, dok pri pH 9 ima. U fazi (III.) dolazi do erozije modelnog celuloznog filma s 1 mmol/L KCl pri pH 6. Krivulje pri pH 4 i 6 ukazuju na brzu desorpciju CPC micela u odnosu na krivulju pri pH 9, gdje se može zaključiti da je površina MCF-a pri pH 9 najpogodnija za vezivanje CPC micela.

4. Zaključci

Rezultati procesa adsorpcije CPC iz micelarne otopine pri različitim vrijednostima pH (pH 4, pH 6 i pH 9), različitim metodama na različitim celuloznim supstratima ukazuju na utjecaj vrijednosti pH na brzinu procesa adsorpcije i desorpcije CPC micela s PT i MCF. Osim vrijednosti pH utjecaj ima i površina pamučne tkanine i modelnog celuloznog filma. Razlike su vidljive kod rezultata dobivenih metodom potencijal strujanja u prvoj fazi (I.) gdje MCF ima negativniju vrijednost zeta potencijala pri pH 9, a pozitivniju pri pH 4 u odnosu na pamučnu tkaninu. Razlike ukazuju na visoku amorfnost u makromolekulama celuloze MCF-a u odnosu na pamučnu tkaninu tj. veći broj dostupnih karboksilnih (-COOH) i hidroksilnih (-OH) skupina koje su odgovorne za vezivanje CPC micela. U procesu desorpcije CPC micela praćenom s obje metode i na oba supstrata najbolja stabilnost je dobivena pri pH 9 kod. Potencijal strujanja i kvarc-kristalna mikrovaga s praćenjem disipacije su se pokazale kao svrsishodne za istraživanje procesa adsorpcije i desorpcije CPC-a u sustavu s odabranim celuloznim supstratima i omogućavaju usporedbe realnog i modelnog sustava.

5. Literatura

[1] Soljačić, I. & Pušić, T.: *Čišćenje u vodenim medijima*, *Njega tekstila–I dio*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 953-7105-08-3, Zagreb, (2005), str. 56-68.

[2] Kallay, N. et al. Equilibrium of counterion association in micellar systems, Cetyltrimethylammonium bromide, *Annales Universitatis Mariae Curie - Sklodowska*, **63** (2008) 5, pp. 61-67., Lublin, Polonia, ISSN 2083 - 358X

[3] Bigler, N.: *Die Tenside CIBA Geigy Rundschau 2*, CIBA, ISSN 0366-5453, Zeitschrift / Print (1971)

[4] Mukhim, T. & Ismail, K.: Micellization of cetylpyridinium chloride in aqueous lithium chloride, sodium chloride and potassium chloride media, *Journal of Surface Science and Technology*, **21** (2005) 3/4., pp. 113-127, ISSN 0970 - 1893

[5] Lin, N., et al.: *Advanced Functional Materials from Nanopolysaccharides*, Springer, ISSN 2195-0644, Berlin, Njemačka, (2019), pp. 171-219

[6] Rehan, M., et al.: Design of multi-functional cotton gauze with antimicrobial and drug delivery properties. *Materials Science and Engineering: C*, **80** (2017), pp. 29-37.

[7] Instruction Manual SurPASS™ Electrokinetic Analyzer; Anton Paar GmbH, A48IB046en-B, Graz, Austria, (2013)

[8] NanoScience Instruments: Quartz Crystal Microbalance with Dissipation Monitoring; *Dostupno na* https://www.nanoscience.com/products/qsense-quartz-crystal-microbalance/, *Pristupljeno:* 2023-01-27

Nikolina Jukl

Životopis	Nikolina Jukl rođena je 1987. god. u Sv. Nedelji, Hrvatska. Diplomirala je 2013. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, a iste godine upisuje poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Od 2013. do 2022. god. radila je kao rukovoditeljica proizvodnje i konstruktorica u tvrtki Konfeks d.o.o. koja se bavi proizvodnjom radne i zaštitne odjeće. Od 2022. god. zaposlena je na Tekstilno-tehnološkom fakultetu kao asistentica. 2023. god. obranila je doktorski rad, pod mentorstvom prof. dr. sc. Snježane Firšt Rogale. Njezin znanstveno-istraživački, stručni i nastavni rad vezan je za znanstveno područje tehničkih znanosti, polje tekstilna tehnologija, usko vezan uz tehnološke procese proizvodnje odjeće te istraživanja termoizolacijskih svojstva odjeće.
Naslov teme doktorskog rada	Utjecaj vrste ugradbenih materijala i konstrukcije odjevnih kompozita na zbirna toplinska svojstva odjeće
Mentor	prof. dr. sc. Snježana Firšt Rogale
Datum obrane doktorskog rada	4.10.2023. god.

ODREĐIVANJE OTPORA PROLAZU VODENE PARE UGRADBENIH MATERIJALA I ODJEVNOG KOMPOZITA I NJEGOV ZNAČAJ PRI TEHNIČKOM PROJEKTIRANJU ODJEĆE

Nikolina JUKL

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, nikolina.jukl@ttf.unizg.hr

Sažetak: *Kao jedan od parametara koji utječu na zbirna toplinska svojstva odjeće otpor prolazu vodene pare može značajno utjecati na toplinsku ugodu nosioca odjevnog predmeta. U radu je istaknut dio rezultata doktorskog rada koji se odnosi na određivanje otpora prolazu vodene pare ugradbenih materijala i odjevnih kompozita kako bi se istaknuo njegov značaj pri tehničkom projektiranju odjeće. Prikazani su rezultati dobiveni mjerenjem na uređaju za nedestruktivna mjerenja Permetest, a mjerenja su provedena na tri ugradbena materijala i jednom odjevnom kompozitu sa ciljem jasnijeg definiranja protokola tehničkog projektiranja odjeće.*

1. Uvod

Ugradbeni materijali i odjevni kompoziti koji se koriste za proizvodnju namjenske odjeće moraju zadovoljiti određene kriterije koji se odnose na njihova toplinska svojstva. Toplinska ugoda nosioca mora biti ostvarena kako bi on bio u stanju obavljati svoju djelatnost, a to se prvenstveno odnosi na odjeću kojoj je predviđena namjena pri izloženosti atmosferskim uvjetima ili ekstremnim temperaturama. Za izradu namjenske odjeće koriste se ugradbeni materijali visokotehnoloških izvedbi i specifičnih svojstava prilagođenih potrebama korisnika, a svrha korištenja takvih materijala je osigurati toplinsku ugodu i vodonepropusnost vanjske školjke, a istovremeno i dišljivost odjevnog predmeta [1]. Najčešće se koriste laminirani materijali koji se uobičajeno sastoje od više slojeva tekstilnih materijala, te sloja membrane koji je najčešće na bazi politetrafluoretilena (PTFE) [2]. Također, često se primjenjuju i romboidno prošiveni materijali te fleece materijali od kojih se većinom izrađuju toplinski umeci. Postizanje optimalne slojevitosti također ima značajan utjecaj na toplinska svojstva i ugodu nosioca. Potrebno je postići postavljene zahtjeve uz što manju slojevitost jer više slojeva podrazumijeva i veću masu te voluminoznost odjevnog predmeta, što može rezultirati smanjenom pokretljivošću i ugodom nosioca. U sklopu doktorskog rada provedena su ispitivanja zrakopropusnosti, otpora prolazu vodene pare i topline, te kontaktnog kondukcijskog prijenosa topline u nestlačenom i stlačenom stanju za ugradbene materijale i odjevne kompozite, diferencijalnih gradijenata temperatura na odjevnim kompozitima i odjevnim sustavima, te toplinska svojstava odjevnih sustava u statičkom i dinamičkom modu. Jedna od postavljenih hipoteza doktorskog rada, vezana uz otpor prolazu vodene pare, glasi: ukupan otpor prolazu vodene pare jednak je zbroju serijskih otpora prolazu vodene pare pojedinačnih slojeva odjevnih kompozita u odjevnom sustavu. U ovome radu prikazani su djelomični rezultati određivanja debljine i otpora prolazu vodene pare na tri ugradbena materijala i odjevnom kompozitu koji je sačinjen od njih.

2. Eksperimentalni dio

Provedeno je određivanje debljine ugradbenih materijala pomoću Dino–Lite digitalnog USB mikroskopa kako bi se mogao proučiti njen utjecaj na otpor prolazu vodene pare. Za određivanje otpora prolazu vodene pare ugradbenih materijala i odjevnog kompozita korišten je mjerni uređaj za nedestruktivno određivanje otpora prolazu vodene pare Permetest, tvrtke Senzora, prema normi HRN EN ISO 20344:2012, sl. 1 [3]. Prednosti Permetesta ogledaju se u njegovim malim dimenzijama i težini, relativno kratkom vremenu trajanja mjerenja te u tome što su mjerenja nedestruktivna. Mjerenja su provedena na način da je Permetest smješten u klima komoru u kojoj je moguće točno odrediti uvjete okoliša, a prvo je potrebno kalibrirati uređaj prema referentnom materijalu poznatog otpora prolazu vodene pare od 4,62 m^2Pa/W. Permetest se sastoji od kučišta s elektroničkim elementima, te tzv. zračnog tunela. Mjerni uzorak postavlja se na okruglu mjernu glavu koja je učvršćena na zračni tunel i koja se sastoji od kružne i porozne vruće ploče promjera 8 cm. Mjerna glava može se okomito pomicati kako bi se umetnuo mjerni uzorak, sl. 1.

Otpor prolazu vodene pare definiran je izrazom [4]:

$$R_{et} = (P_m - P_a) \cdot (q_s^{-1} - q_0^{-1}) \tag{1}$$

gdje je:
R_{et} - otpor prolazu vodene pare [m^2Pa/W]
P_m - parcijalni tlak zasićene vodene pare za temperaturu ambijenta/prostorije u kojoj se provodi ispitivanje [Pa]
P_a - parcijalni tlak vodene pare ambijenta/laboratorija gdje se provodi ispitivanje [Pa]

Slika 1: Uređaj za nedestruktivno mjerenje otpora prolazu vodene pare, Permetest

Mjerenja su provedena na tri ugradbena materijala i reprezentativnom troslojnom odjevnom kompozitu koji se uobičajeno koriste za proizvodnju namjenske odjeće. Od ugradbenih materijala korišteni su dvoslojni laminirani materijal s ekspandirajućom politetrafluoretilen membranom (ePTFE) oznake MV1, romboidno prošivena podstava oznake MP2, te troslojni laminirani materijal, gdje su lice i naličje micro-fleece, a između njih je poliesterska membrana, oznake MP3. Odjevni kompozit oznake OK5 sačinjen je od navedenih ugradbenih materijala. Laboratorijske analize ugradbenih materijala dobivene su od proizvođača materijala, a osnovni podaci provedene analize su prikazani u tab. 1.

Tablica 1: Rezultati laboratorijske analize ugradbenih materijala

	Elementi ispitivanja	**Vrijednosti**	**Mjerna jedinica**
MV1	Sirovinski sastav		
	• Lice materijala: poliester	100	%
	• Membrana: ePTFE	100	%
	Plošna masa	169,8	g/m^2
MP2	Sirovinski sastav		
	• Lice/podstava: poliester	100	%
	• Membrana/punilo: polipropilen	100	%
	• Naličje/podstava: poliester	100	%
	Plošna masa	316,0	g/m^2
MP3	Sirovinski sastav		
	• Lice materijala: micro-fleece	100	%
	• Membrana: poliester	100	%
	• Naličje materijala: micro-fleece	100	%
	Plošna masa	304,0	g/m^2

3. Rezultati i rasprava

Rezultati određivanja debljine ugradbenih materijala i odjevnog kompozita prikazani su u tab. 2. Iz rezultata je vidljivo da dvoslojni laminirani materijal (MV1) ima najmanju izmjerenu debljinu, a zatim slijedi romboidno prošiveni materijal (MP2) te micro-fleece materijal (MP3). Rezultati su pokazali i da je debljina odjevnog kompozita, koja iznosi 4,74 mm, 1 mm manja od zbroja serijskih debljina pojedinačnih slojeva ugradbenih materijala od koji je sačinjen odjevni kompozit, što se može objasniti stlačivanjem slojeva materijala radi utjecaja mase pojedinačnih slojeva materijala.
Rezultati određivanja otpora prolazu vodene pare ugradbenih materijala i odjevnog kompozita prikazani su u tab. 3. Prvo je provedeno određivanje otpora prolazu vodene pare ugradbenih materijala, a zatim odjevnog kompozita. Ispitivanja su provedena pri prosječnoj temperaturi okoliša od 20 °C i prosječnoj relativnoj vlažnosti zraka od 52 %, što je u skladu s uputama proizvođača uređaja Permetest.

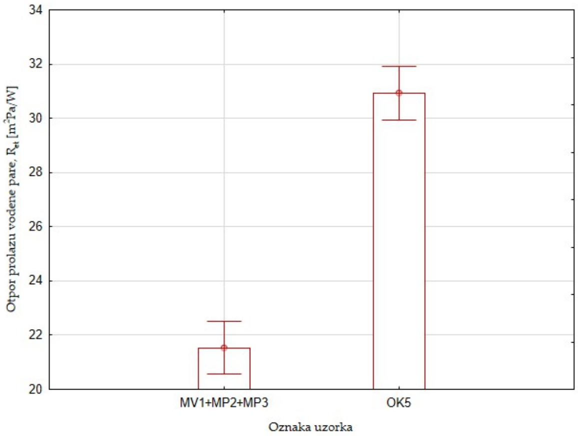
Tablica 2: Rezultati određivanja debljine ugradbenih materijala i odjevnog kompozita

	Debljina materijala, d_m [mm]					
Oznaka uzorka	**1**	**2**	**3**	**4**	**5**	$\bar{x}$
MV1	0,475	0,488	0,486	0,484	0,475	0,49
MP2	2,425	2,425	2,488	2,457	2,361	2,43
MP3	3,025	2,904	2,841	2,764	2,777	2,86
OK5	4,816	4,743	4,752	4,704	4,680	4,74

Tablica 3: Rezultati određivanja otpora prolazu vodene pare

	Broj mjerenja	**Otpor prolazu vodene pare referentnog materijala, R_{et} [m^{2}Pa/W]**	$\bar{x}$	**Otpor prolazu vodene pare uzorka, R_{et} [m^{2}Pa/W]**	$\bar{x}$
MV1	1	4,70	4,63	3,00	2,87
	2	4,60		2,80	
	3	4,60		2,80	
MP2	1	4,30	4,67	5,70	5,93
	2	4,90		6,00	
	3	4,80		6,10	
MP3	1	4,40	4,60	12,80	12,73
	2	4,80		12,60	
	3	4,60		12,80	
OK5	1	4,80	4,67	30,10	30,93
	2	4,90		30,90	
	3	4,30		31,80	

Otpor prolazu vodene pare dvoslojno laminiranog materijala oznake MV1 iznosi 2,87 m^{2}Pa/W, što je ujedno i najmanja izmjerena vrijednost od svih ispitivanih uzoraka. Općenito, laminirani materijali imaju mogućnost propusnosti znoja radi ugrađenih membrana čije su pore 20.000 puta manje od kapljica vode, ali 700 puta veće od molekula vodene pare. Stoga iako je otpor prolazu vodene pare mjernog uzorak oznake MV1 relativno mali, on je ipak dovoljan za ostvarivanje osjećaja ugode. Otpor prolazu vodene pare romboidno prošivene podstave (MP2) iznosi 5,93 m^{2}Pa/W. Od ugradbenih materijala najveći izmjereni otpor prolazu vodene pare pokazao je micro-fleece materijal (MP3), a on iznosi 12,73 m^{2}Pa/W. Razlog tome je debljina i struktura materijala čije je lice i naličje izrađeno od micro-fleecea, a srednji sloj je poliesterska membrana. Micro-fleece slojevi imaju veliku gustoću vlakana te veću debljinu u usporedbi s ostalim ugradbenim materijalima, te zajedno s slojem poliesterske membrane omogućavaju veći otpor prolazu vodene pare.
Rezultati su pokazali da se s povećanjem debljine materijala povećava i otpor prolazu vodene pare. Naime, dvoslojni laminirani materijal ima najmanju debljinu, zatim slijedi romboidno prošivena podstava, a zatim micro-fleece materijal. To ujedno objašnjava i značajno veću vrijednost ukupnog otpora prolazu vodene pare odjevnog kompozita u usporedbi s zbrojem serijskih vrijednosti pojedinih slojeva ugradbenih materijala od kojih je on sačinjen, što znači da nije moguće predvidjeti ukupan otpor prolazu vodene pare odjevnog kompozita na temelju zbroja serijskih otpora prolazu vodene pare pojedinačnih slojeva ugradbenih materijala od kojih je on sačinjen. Jasno je da je zbroj serijskih vrijednosti značajno manji od ukupnog otpora prolazu vodene pare odjevnog kompozita, što je potvrdila i statistička analiza, sl. 2.



Slika 2: Raspon srednjih vrijednosti rezultata zbroja serijskih otpora prolazu vodene pare pojedinačnih slojeva ugradbenih materijala i ukupnog otpora prolazu vodene pare reprezentativnog odjevnog kompozita OK5 s naznačenim varijacijama

Na temelju dobivenih rezultata i provedene statističke analize hipoteza koja je postavljena u ovome radu i prema kojoj je ukupan otpor prolazu vodene pare jednak zbroju serijskih otpora prolazu vodene pare pojedinačnih slojeva odjevnih kompozita u odjevnom sustavu se odbacuje.

4. Zaključci

Ispitivanjem otpora prolazu vodene pare pojedinih ugradbenih materijala i odjevnih kompozita utvrđeno je da laminirani materijali mogu imati relativno male vrijednosti otpora prolazu vodene pare, na što najviše utječe struktura samog materijala i slojeva od kojih je izrađen, ali i membrana koja se u njemu nalazi. Potrebno je naglasiti da čak i manje vrijednosti otpora prolazu vodene pare izmjerene u ovom radu omogućavaju toplinsku ugodu nosioca, čime korišteni materijali potvrđuju svoju svrhu i primjenu za izradu namjenske odjeće. Rezultati su dokazali i da debljina materijala utječe na otpor prolazu vodene pare jer se s povećanjem debljine povećava i otpor prolazu vodene pare. Također, utvrđeno je da je ukupan otpor prolazu vodene pare odjevnog kompozita veći od zbroja serijskih otpora prolazu vodene pare pojedinačnih slojeva ugradbenih materijala u odjevnom kompozitu, što ukazuje na to da nije moguće na temelju vrijednosti otpora prolazu vodene pare predvidjeti ukupan otpor prolazu vodene pare odjevnog kompozita koji je sačinjen od njih. Time se potvrdilo da su potrebna iscrpna ispitivanja otpora prolazu vodene pare ne samo ugradbenih materijala nego i odjevnih kompozita, s ciljem uspješnog tehničkog projektiranja namjenske odjeće.

Zahvala

HRZZ Hrvatska zaklada za znanost

Istraživanja su izvedena u okviru projekta HRZZ IP-2018-01-6363 Razvoj i toplinska svojstva inteligentne odjeće (ThermIC), financiranog od Hrvatske zaklade za znanost, voditelja prof. dr. sc. Dubravka Rogalea.

5. Literatura

[1] Firšt Rogale, S.; Rogale, D.: Advanced Materials for Clothing and Textile Engineering, *Materials*, **16** (2023), 9, 3407, eISSN 1996-1944
[2] Ebnesajjad, S.: *Expanded PTFE applications handbook: Technology, manufacturing and applications*, William Andrew: Elsevier, ISBN: 9781437778564, Amsterdam; Boston;. (2016)
[3] Hes, L.; Bernardo, C.; Queirós, M.: A new method for the determination of water vapour permeability of polymer films based on the evaluation of the heat of evaporation, *Polymer testing*, **15** (1996), pp. 189-201, ISSN 0142-9418
[4] Akalović, J. et al.: Water Vapor Permeability of Bovine Leather for Making Professional Footwear, *Leather and Footwear*, **67** (2018) 4, pp. 12-17, ISSN 0450-8726

Eva Magovac

Životopis

Eva Magovac je rođena u Karlovcu, a 1996. god. je upisala Sveučilište u Zagrebu Tekstilno-tehnološki fakultet gdje je diplomirala u veljači 2002. god., a doktorirala u srpnju 2023. god. Od 2002. do 2009. god. radila je za nekoliko privatnih tekstilnih/kožarskih tvrtki, a 2009. se zaposlila na Tekstilno-tehnološkom fakultetu kao suradnik na EU projektu FP7 T-Pot: Unlocking the Croatian Textile Research Potentials. 2011. god. se zaposlila u Hrvatskoj gospodarskoj komori kao stručni suradnik. Od 2014. god. do danas radi na Sveučilište u Zagrebu Tekstilno-tehnološki fakultet kao stručni suradnik. Tijekom karijere pohađala je brojne edukacije u organizaciji HUP-a, HMD-a, Visokog učilišta Algebra kao i kratkotrajne znanstvene-istraživačke boravke u tvrtci Toray Textiles Europe Ltd., UK; na Prirodoslovno-tehničkom fakultetu Sveučilišta u Ljubljani, te na Texas A & M sveučilištu u SAD-u.

Naslov teme doktorskog rada

Površinska modifikacija pamučnih tekstilija usporivačima gorenja metodom nanosa sloj-po-sloj

Mentori

prof. dr. sc. Sandra Bischof   prof. dr. sc. Bojana Vončina

Datum obrane doktorskog rada

5. 7.2023. god.

POVRŠINSKA MODIFIKACIJA PAMUČNIH TEKSTILIJA USPORIVAČIMA GORENJA METODOM NANOSA SLOJ-PO-SLOJ

Eva MAGOVAC

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
eva.magovac@ttf.unizg.hr

Sažetak: *Glavni cilj rada bio je razviti ekološku obradu protiv gorenja (FR) pamuka, kao i višenamjensku FR/antimikrobnu obradu pomoću inovativne metode nanosa sloj-po-sloj kao odgovor na tehnološke nedostatke trenutnih komercijalnih postupaka završnih obrada pamučnih tekstilija, a to su upotreba velikih količina toksičnih kemikalija, gubitak vlačne čvrstoće obrađenih tkanina, te velik broj postupaka u proizvodnji na visokim temperaturama uz veliku potrošnju vode i električne energije. U ovom radu konvencionalna obrada koja zahtijeva dodavanje vrlo velikih količina različitih organofosfornih kemikalija zamijenjena je ekološkom obradom upotrebom kemikalija iz obnovljivih izvora u vrlo niskim koncentracijama. Dobivena obrada smanjila je zapaljivost pamuka, kao i rast bakterija.*

1. Uvod

Pamuk kao biljno celulozno vlakno bogato je -O- i -OH funkcionalnim skupinama koje su odgovorne za visoku zapaljivost, ali i visoku propusnost vlage i vode, što je ujedno i dobra podloga za rast bakterija. Zbog toga je pamučne tkanine namijenjene za radnu i zaštitnu odjeću potrebno obraditi usporivačima gorenja, a one koje se upotrebljavaju u ugostiteljskim objektima ili ustanovama za medicinsku skrb i njegu, poželjno je i dodatno obraditi antimikrobnim sredstvima. Na tržištu postoje postojane i nepostojane obrade protiv gorenja (FR). Postojane se temelje na organofosfornim spojevima kod kojih je prisutan sinergizam dušika i fosfora, a vežu se na celulozu čvrstim kovalentnim vezama (Pyrovatex, Proban) [1]. Postojane obrade je moguće kombinirati s antimikrobnim spojevima, no oni istovremeno ne smiju biti vezani za celulozu čvrstim kovalentnim vezama jer se na taj način ne mogu kontrolirano otpuštati u prisutnosti vlage, te time reducirati ili eliminirati rast bakterija. Antimikrobna sredstva (AM) koja se koriste u komercijalnim postupcima mokre obrade pamuka najčešće su kvaterni amonijevi spojevi.

Glavni nedostatak komercijalnih postupaka obrade protiv gorenja i multifinkcionalnih FR/AM obrada je upotreba velikih količina kemikalija, emisija toksičnog i kancerogenog formaldehida tijekom proizvodnje ili životnog ciklusa proizvoda, gubitak vlačne čvrstoće obrađenih pamučnih tkanina, te velik broj postupaka u proizvodnji na visokim temperaturama. Kako bi se prevladali gore navedeni tehnološki nedostaci obrada protiv gorenja, javila se potreba za uvođenjem novih ekološki povoljnijih sredstava, ali i metoda kao što su npr. sol-gel, UV obrade, obrade plazmom, te LbL naslojavanje.

LbL naslojavanje je postupak uranjanja pamučne tkanine naizmjenično u otopine pozitivno i negativno nabijenih polielektrolita do postizanje željenog slojeva. Između svakog uranjanja u suprotno nabijene polielektrolite tkanina se ispire u deioniziranoj vodi (DI). Ove strukture mogu se dalje podvrgnuti postkemijskim reakcijama, kao što su UV ili toplinsko umrežavanje [2].

Cilj ove doktorske disertacije bio je razviti alternativnu FR i/ili multifunkcionalnu FR/AM obradu namijenjenu pamučnim tkaninama uz pomoć nove tehnike koja se naziva sloj-po-sloj (LbL) naslojavanje uz korištenje sredstava iz obnovljivih izvora (biljni i životinjski otpad), te minerala od kojih su neki poznati od davnina, odnosno:

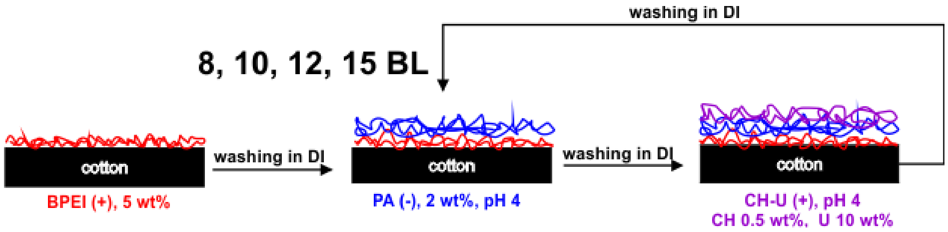
- zamijeniti konvencionalne kemikalije onima iz obnovljivih izvora
- razviti inovativnu nehalogenu FR i multifunkcionalnu FR/AM obradu pamučnih tkanina pomoću LbL naslojavanja
- smanjiti količinu kemikalija potrebnih za učinkovito smanjenje gorivosti pamuka
- smanjiti utrošak energije u postupku
- utvrditi mehanizme gorenja FR pamuka naslojenog pomoću LbL metode

2. Eksperimentalni dio

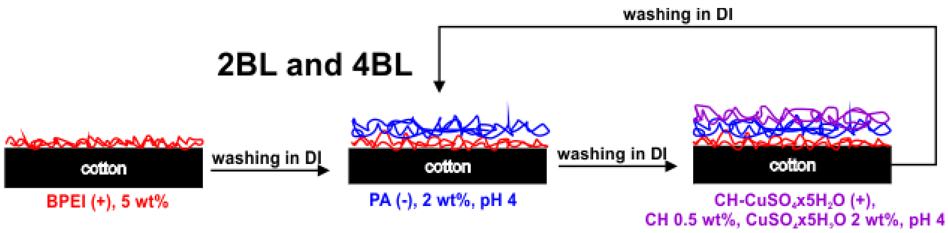
Materijali: Kemijski bijeljeni pamuk (119 g/m^2), fitinska kiselina (*eng. phytic acid* - PA, 2 %, pH 4), kitozan (*eng. chitosan* - CH, 0,5 %, pH 4), razgranati polietilenimin (*eng. branched polyethylenimine* - BPEI, 5 %), urea (U, 10 %, pH 4) i bakrov (II) sulfat pentahidrat ($CuSO_4$ x $5H_2O$, 2 %), deionizirana voda (DI).

LbL naslojavanje:
Pamuk je prvo uronjen u kationsku otopinu BPEI kako bi se formirao temeljni sloj za bolje prianjanje sredstava na pamuk. Pamučna tkanina je zatim naizmjenično uronjena u anionsku PA i kationsku otopinu CH-U dok se ne postigne željeni broj dislojeva (*engl bilayer*-BL). Nakon svakog koraka naslojavanja slijedilo je ispiranje u DI kako bi se uklonili svi nevezani polielektroliti. Na kraju LbL naslojavanja pamučna tkanina je uronjena u otopinu $CuSO_4$ x $5H_2O$. Masa svih uzoraka izmjerena je nakon sušenja na 80 °C tijekom 24 sata, prije i nakon LbL naslojavanja:

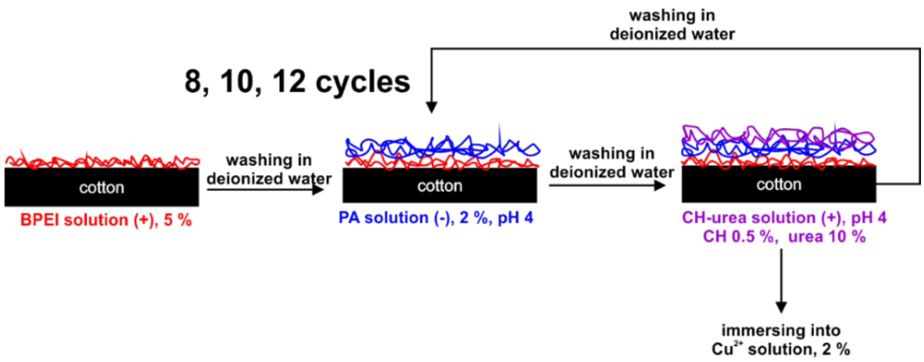
1. 8, 10, 12, 15 BL: $PA^-/(CH\text{-}U)^+$, BPEI – primarni sloj (slika 1) [3]
2. 4, 8 BL: PA^-/CH^+ and $PA^-/(CH\text{-}CuSO_4 \times 5H_2O)^+$, BPEI – primarni sloj (slika 2) [4]
3. 8, 10, 12 BL: $PA^-/(CH\text{-}U)^+$ + impregnacija $CuSO_4$ x $5H_2O$ (slika 3) [5].



Slika 1: Shema LbL naslojavanja 8, 10, 12, 15 BL: $PA^-/(CH\text{-}U)^+$ [3]



Slika 2: Shema LbL naslojavanja 4, 8 BL: $PA^-/(CH\text{-}CuSO_4 \times 5H_2O)^+$ [4]



Slika 3: Shema LbL naslojavanja 8, 10, 12 BL: $PA^-/(CH\text{-}U)^+$ + impregnacija u $CuSO_4$ x $5H_2O$ [5]

Karakterizacija: Maseni prirast (%), indeks granične vrijednosti kisika prema ISO 4589-2:2017 (Concept Equipment, *eng. limiting oxygen index* - LOI), vertikalni test gorenja prema ASTM D6413/D6413M-15 (Govmark, *eng. vertical flammability testing* - VFT), mikrokalorimetrija sagorijevanja prema ASTM D6413/D6413M-15 (Govmark, *eng. microscale combustion calorimetry* - MCC), termogravimetrijska analiza s FTIR spektrofotometrijom (Perkin Elmer, *eng. termogravimetric analyzator with FTIR* - TG-IR), skenirajuća elektronska mikroskopija s EDS detekcijom (Tescan – Oxford Instruments, *eng. scanning electron microscopy* - SEM-EDS), postotak redukcije bakterija (%) prema AATCC Test Method 100-2019.

3. Rezultati i rasprava

Pamučna tkanina obrađena LbL naslojavanjem se sama ugasila tijekom VFT ispitivanja, a vrijednosti LOI-a kretale su se u rasponu od 24,5 – 28,0 % sa 17,3 – 19,0 % prinosa mase u usporedbi s tipičnim Pyrovatex® postupkom, gdje je prinos 20 – 25 %, a vrijednosti LOI-a su oko 28 %. Za usporedbu prinos mase nepostojanih sredstava protiv gorenja npr. borne kiseline/boraks je oko 10 %, a diamonijevog fosfata/amonijevog sulfamata je oko 15 %.
Nadalje u ovoj doktorskoj dizertaciji Pyrovatex® postupak koji zahtijeva oko 350 g/l različitih sredstava zamijenjen je ekološki prihvatljivijim obradom (LbL naslojavenjem) korištenjem sredstava u koncentraciji obično ≤ 100 g/l s neznatnim utjecajem na mehanička svojstva obrađene pamučne tkanine (do ± 14 % prekidne sile) na temperaturama ispod 100 °C. Za usporedbu, Pyrovatex® postupak smanjuje prekidnu silu za 20 – 25 %, dok nepostojana sredstva općenito smanjuju prekidnu silu [6-8].
MCC kalorimetrijske vrijednosti LbL naslojenog pamuka pokazale su smanjenje najveće brzine otpuštanja topline (pHRR) u rasponu 50,9 – 61,8 % u odnosu na neobrađeni pamuk i smanjenje ukupne brzine oslobađanja topline (THR) u rasponu 54,3 – 70,3 % u odnosu na neobrađeni pamuk što znači da se povećava količina pepela zaostalog nakon gorenja, a smanjuje stvaranje hlapivih plinova [3-5].
TG analiza je pokazala smanjenje maksimalne temperature dekompozicije (T_1) obrađene pamučne tkanine za 57 – 66 °C u odnosu na neobrađenu i povećanje pougljenjenog ostatka (%) na T_1 u rasponu 43 – 46 % za neobrađenu na 56 – 63 % za obrađenu pamučnu tkaninu.
Na FT-IR spektrima hlapljivih plinova nastali zagrijavanjem pamučne tkanine obrađene LbL naslojavanjem (CH/PA-U) sadrže vodu; metan/metanol; ugljikov dioksid; ugljikovog monoksid; formaldehid, eter/ester mravlje kiseline, cikloalkane; N-H, kao i PH i NH spojeve. Levoglukozan koji je odgovoran za visoku zapaljivost celuloze nije pronađen. Naknadnom obradom u otopini $CuSO_4$ x $5H_2O$ hlapljivi plinove nastali zagrijavanjem obrađene pamučne tkanine još dodatno sadrže spojeve sumpora (S-S), bakrov monosulfid i bakrov (II) oksid. N-P plinski međuprodukti mogu djelovati u plinskoj fazi kao hvatači slobodnih radikala [9].
EDS analiza pokazala je da ostatak nakon gorenja obrađenih tkanina uglavnom sadrži ugljik, kisik, fosfor, dušik u slučaju PA/CH-U obrade, a u slučaju naknadne obrade sa $CuSO_4$ x $5H_2O$ ostatak nakon gorenja dodatno sadržava i bakar. PA i CH-U kod zagrijavanja proizvode N-P međuprodukte, koji fosforiliraju celulozu na temperaturi ispod 350 – 400 °C proizvodeći pougljenjeni ostatak, koji djeluje kao fizička barijera blokirajući dovod topline i kisika na površinu polimera djelujući isto tako i u kondenzirajućoj fazi. Cu^{2+} ioni dodatno kataliziraju fosforilaciju celuloze djelujući u kondenzirajućoj fazi, no istovremeno nanočestice CuO ili CuS prisutne u hlapljivim plinovima mogu djelovati kao inertna prašina koja apsorbira i raspršuje toplinu uzrokujući snižavanje temperature [10].
FR/AM nanosloj pokazao je smanjenje Gram-negativne *K. pneumoniae* i Gram-pozitivne *S. aureus* za gotovo 100 % zahvaljujući Cu^{2+} ionima i kitozanu te se ovakva obrada preporučuje za dekorativne tekstilije.

Predloženi mehanizmi djelovanja:

1. Spojevi bogati fosforom i dušikom, te bakrom (PA, CH-U i $CuSO_4$ x $5H_2O$) međusobno kemijski djeluju tvoreći kisele N-P-Cu međuprodukte, koji fosforiliraju i dehidriraju celulozu na temperaturama nižim od onih termalne dekompozicije celuloze i stvaraju toplinski stabilne umreženi ostatak nakon gorenja. Taj ostatak oblaže površinu polimera, djelujući kao štit, koji sprječava daljnje gorenje i tinjanje polimera
2. Nije pronađen levoglukozan, što potvrđuje da su kiseli međuprodukti N-P-Cu iz FR obrade uspješno fosforilirali celulozu i inhibirali stvaranje visoko zapaljivog levoglukozana.
3. PH i NH spojevi nađeni u IR spektru plinovitih produkata gorenja, mogu djelovati u plinovitoj fazi kao hvatači slobodnih radikala ili njihovi međuproizvodi djeluju fizički smanjujući koncentraciju O u okolnoj atmosferi
4. Nanočestice CuO ili CuS prisutne u hlapljivim plinovitim produktima nastalim zagrijavanjem mogu djelovati kao inertna prašina koja apsorbira i raspršuje toplinu uzrokujući snižavanje temperature
5. Ostatak nakon gorenja pamuka obrađenog PA/CH-U (i $CuSO_4$ x $5H_2O$) sastoji se od C, O, P i N (i Cu), što znači da su P i N uhvatili C i spriječili njegovu potpunu oksidaciju stvaranjem štita na površini polimera u obliku mjehurića tipičnog za bubreću FR i kondenziranu fazu
6. TG-IR analiza plinovitih produkata i EDS analiza ostatka nakon gorenja dokazuju da alternativni usporivači gorenja djeluju u plinovitoj kao i u kondenziranoj fazi, gdje CH i celuloza djeluju kao donori ugljika, PA kao kiseli donor, a U kao sredstvo za ekspandiranje koje ispušta dušikove plinske produkte u obliku mjehurića.

4. Zaključci

U radu je dokazano da je LbL naslojavanjem pamuka moguće postići učinkovitu kombiniranu FR i AM obradu korištenjem alternativnih sredstava u koncentracijama ≤ 100 g/l. To je znatno manje u odnosu na klasične komercijalne obrade protiv gorenja primjenom tzv. Pyrovatex® postupka, no obrada nije postojana. Također je dokazano da je moguće proizvesti multifunkcionalnu obrađenu pamučnu tkaninu koja zadovoljava komercijalne zahtjeve FR/AM obrada: zahtjev negorivosti (LOI ≥ 28 %) i smanjenje razvoja gram-negativnih i gram-pozitivnih bakterija za 100 %. Uz veću dostupnost biorazgradivih kemikalija iz obnovljivih izvora po nižim troškovima i poboljšanjem postojanosti na pranje, LbL naslojavanje ima potencijal postati industrijski primjenjivo rješenje za FR ili višenamjensku FR/AM funkcionalizaciju pamuka. Buduća istraživanja proširit će se na poboljšanje postojanosti na pranje kao i kompatibilnost s konvencionalnim procesima bojenja/tiskanja.

Zahvala

Prof. Sandra Bischof, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, projekt Hrvatske zaklade za znanost 2013-11 9967 ADVANCETEX Advanced textile materials by targeted surface; prof. dr. sc. Bojana Vončina, Sveučilište u Mariboru Fakultet strojarstva, Slovenija; prof. dr. sc. Jaime C. Grunlan, Odjel za strojarstvo, Texas A&M, College Station, SAD za sufinanciranje 2-mjesečnog boravka; prof. dr. sc. Igor Jordanov, Odjel za tekstil, Sveučilište Sv. Ćirila i Metodije Fakultet tehnologije i metalurgije iz Skopja, Sjeverna Makedonija; prof. dr.sc. Ana Budimir, Zavod za tipizaciju i praćenje uzročnika bolničkih infekcija, Klinički bolnički centar Zagreb; prof. dr. sc. Sandra Flinčec Grgac i prof. dr. sc. Karlo Lelas, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet; prof. dr. sc. Olivera Šauperl, Sveučilište u Mariboru Fakultet strojarstva, Slovenija.

5. Literatura

[1] Magovac, E.; Bischof, S.: Non-Halogen FR Treatment of Cellulosic Textiles, *Tekstil*, **64** (2015) 9, pp. 298–309, ISSN 0492-5882
[2] Magovac, E. et al.: Layer-by-Layer Deposition: A Promising Environmentally Benign Flame-Retardant Treatment for Cotton, Polyester, Polyamide and Blended Textiles, *Materials*, **15** (2022). 2, pp. 1-30, ISSN 1996-1944
[3] Magovac, E. et al.: Environmentally-Benign Phytic Acid-Based Multilayer Coating for Flame Retardant Cotton, *Materials*, **13** (2020) Br. 23, pp.1-10, ISSN 1996-1944
[4] Magovac, E. et al.: Antibacterial Cotton from Novel Phytic Acid-Based Multilayer Nanocoating, *Green Materials*, **10** (2022) 1, pp. 35-40, ISSN 2049-1220
[5] Magovac, E. et al.: Environmentally Benign Phytic Acid-Based Nanocoating for Multifunctional Flame-Retardant/Antibacterial Cotton, *Fibers*, **9** (2021) 69, pp. 1-13, ISSN 2079-6439
[6] Ginter, A. E. et al.: The Effects of a Borax-Boric Acid Solution on Cotton and Rayon Fabrics, *Research Bulletin*, (1954) 547, pp. 1–23
[7] Veerappagounder, S. et al.: Study on Properties of Cotton Fabric Incorporated with Diammonium Phosphate Flame Retardant through Cyclodextrin and 1,2,3,4-Butane Tetracarboxylic Acid Binding System, *Journal of Industrial Textiles*, **45** (2016) 6, pp. 1204–1220 , ISSN 1528-0837
[8] Pal, A. et al.: Eco-friendly fire-retardant finishing of cotton fabric with mixture of ammonium sulfamate and sodium Stannate with and without zinc acetate as external reagent, *Cellulose,* **30** (2023), pp. 11813–11828, ISSN 0969-0239
[9] Scharte, B.: Phosphorus-Based Flame Retardancy Mechanisms—Old Hat or a Starting Point for Future Development?, *Materials,* **3** (2010) 10, pp. 4710–4745, ISSN 1996-1944
[10]Mitani, T.: A Flame Inhibition Theory by Inert Dust and Spray, *Combustion and Flame*, **43** (1981), pp. 243–253, ISSN 0010-2180

Ksenija Višić

Životopis	Rođena 1983. god., u Varaždinu. Diplomirala je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu (TTF) 2009. god. Krajem iste godine zapošljava se na TTF-u kao stručni suradnik/asistent na FP7 projektu, FP7-SME-2007-2-217809. Početkom 2013. god. zapošljava se kao suradnik na Eureka projektu, E! 5785 Flameblend. Od 2013. do 2015. god. zaposlena je u tvrtki Info Novitas d.o.o. kao voditelj prodaje. Od 2015. do 2016. zaposlena je na TTF-u kao asistent u Zavodu za tekstilnu kemiju i ekologiju. U razdoblju od 2016. do 2018. god. uposlena je kao direktor marketinga u tvrtki Info Novitas d.o.o. Od 2018. do 2019. god. ponovo je angažirana kao asistent na TTF-u, gdje je od 2020. do 2023. god. kao doktorand na projektu K.K.01.1.1.04.0091 Biokompoziti. Objavila je 2 izvorna znanstvena rada u citatnoj bazi WoSCC, 3 radova u drugim časopisima, 3 sažetka i 14 radova u zbornicima skupova.
Naslov teme doktorskog rada	Utjecaj fizikalno-kemijskih svojstava inhibitora posivljenja na zeta potencijal opranih pamučnih materijala
Mentor	prof. dr. sc. Tanja Pušić
Datum obrane doktorskog rada	10.6.2022. god.

UTJECAJ FIZIKALNO-KEMIJSKIH SVOJSTAVA INHIBITORA POSIVLJENJA NA ZETA POTENCIJAL OPRANIH PAMUČNIH MATERIJALA

Ksenija VIŠIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz barunaFilipovića 28a, Zagreb, ksenija.visic@ttf.unizg.hr

Sažetak: *Istraživanja u doktorskom radu obuhvaćaju specijalne dodatke, inhibitore posivljenja, u formulaciji praškastog deterdženta. Odabrani inhibitori posivljenja su karboksimetil celuloza (CMC), karboksimetil škrob (CMS) i njihova kombinacija (CMC+CMS) čija je koncentracija prilagođena pranju celuloznih materijala na 40 °C, 60 °C i 90 °C u tvrdoj i mekoj vodi. Karakterizacija svojstava pamučnih tkanina nakon 10 ciklusa pranja u odnosu na neopranu načinjena je analizom rezidualnih tvari i zeta potencijalom pamučnih tkanina prije i nakon 10 ciklusa pranja u navedenim uvjetima.*

1. Uvod

Razvoj sredstava za pranje uvjetovan je tehnološkim smjernicama, pri čemu je neophodno načiniti formulaciju u kojoj sve komponente djeluju sinergijski s preostalim čimbenicima Sinnerovog kruga, temperatura, mehaničko djelovanje i vrijeme [1]. U posljednje vrijeme se promiču ekološki prihvatljivi niskotemperaturni procesi u malim omjerima kupelji, koji zahtijevaju visokoučinkovite tenzide, bildere, bjelila i njihove aktivatore, enzime i specijalne polimere u deterdžentima [2]. Inhibitori posivljenja (ARA-antiredeposition agents) imaju bitnu ulogu u primarnim i sekundarnim učincima pranja jer uz anionske tenzide i bildere dodatno elektronegativno nabijaju prljavštine i vlakno te fizički sprečavaju taloženje nečistoća na vlakno [3]. Kako bi inhibitor posivljenja kao polimer bio efikasan mora biti srodan sirovinskom sastavu tekstilije koje se peru, kako bi se privremeno vezao na vlakno, povećao negativan naboj površine vlakna te odbijao negativno nabijenu česticu prljavštine i spriječio redepoziciju. Obzirom da je njihovo djelovanje povezano s površinom materijala, važno je poznavati njeno stanje i stupanj opterećenja određenim tvarima. U ovom radu je istražen utjecaj tvrde i meke vode na zeta potencijal pamučne tkanine i sadržaj rezidualnih tvari na pamučnim tkaninama nakon procesa pranja deterdžentom uz dodatak inhibitora posivljenja (CMC, CMS i njihova kombinacija, CMC+CMS) na 40 °C, 60 °C i 90 °C kroz 10 ciklusa u odnosu na neopranu pamučnu tkaninu.

2. Eksperimentalni dio

Standardna pamučna tkanina bez optičkih bjelila i aperture (F) čije su tehničke značajke propisane normom ISO 2267:2001 odabrana je kao celulozni supstrat. U istraživanju je primijenjena raspršena smjesa deterdženta (5 g/L), proizvođača Labud Zagreb, tablica 1 kojoj su dodani analizirani inhibitori posivljenja, tablica 2 u masenom udjelu 0,4 %. Ciklusi pranja (10) standardne pamučne tkanine deterdžentom kojem su dodani odabrani inhibitori posivljenja provedeni su u tvrdoj (TW) i mekoj (SW) vodi na 40 °C, 60 °C i 90 °C.

Tablica 1: Sastav baznog deterdženta

Sastojak	w, %
Anionski tenzid	3,0
Sapun	0,42 - 0,50
Natrijev perkarbonat	6,0
Zeolit	5,6 - 6,3
Silikati	5,1 - 5,7
Natrijev karbonat	35,0 - 40,0
Voda	do 100

Tablica 2: Značajke inhibitora posivljenja (ARA)

ARA	DS	pH (1 %)	Viskozitet (1 %, 25 °C) mPas
CMC	0,57	8,5 – 10,5	20-100
CMS	0,75	9,0 – 11,5	20 – 100

DS- stupanj supstitucije

Proces pranja u laboratorijskoj perilici karakterizira kontinuiran rad, nizak omjer kupelji (1:5), visok omjer punjenja (1:12), reverzibilno okretanje, brzina od 40 do 50 o/min, a ispiranje uz rotiranje bubnja istom brzinom i cikličko centrifugiranje brzinom 1400 o/min. Stupanj opterećenja pamučne tkanine rezidualnim tvarima prije i nakon procesa pranja analiziran je žarenjem pamučne tkanine kako bi se odredio sadržaj pepela prema HRN ISO 4312 [4]. Utjecaj inhibitora posivljenja (CMC, CMS, CMC+CMS) na svojstva pamučne tkanine (F) oprane baznim deterdžentom u tvrdoj (TW) i mekoj vodi (SW) na temperaturama 40 °C, 60 °C i 90 °C analiziran je preko naboja površine. Karakterizacija naboja površine pamučne tkanine prije (F) i nakon 10 ciklusa pranja (MF) provedena je metodom potencijala strujanja u elektrokinetičkom analizatoru, EKA, A. Paar, Austria, pri čemu su pamučne tkanine čvrsta stacionirana faza, a otopina elektrolita KCl (1 mmol/L) pokretna faza. Iz vrijednosti potencijala strujanja pamučne tkanine uložene u adjustable gap cell (AGC) i parametara u sustavu ovisno o pH vrijednosti 1 mmol/l KCl izračunat je zeta potencijal (ζ) prema izrazu Helmoltz-Smoluchowski [5].

3. Rezultati i rasprava

Primijenjeni deterdžent sadrži bildere, zeolit i natrijev karbonat, čija je uloga omekšati vodu tijekom pranja i onemogućiti taloženje anorganskih taloga na površinu pamučnog materijala. Neovisno o tome, obzirom na varijaciju temperatura pranja, analiza rezidualnih tvari na standardnoj pamučnoj tkanini (MF) pokazala je opterećenost površine inkrustacijama. U tablici 3 prikazane su vrijednosti sadržaja pepela (P) na pamučnoj tkanini (PT) prije i nakon pranja deterdžentom različitog sastava u tvrdoj i mekoj vodi na 40 °C, 60 °C i 90 °C u laboratorijskoj perilici.

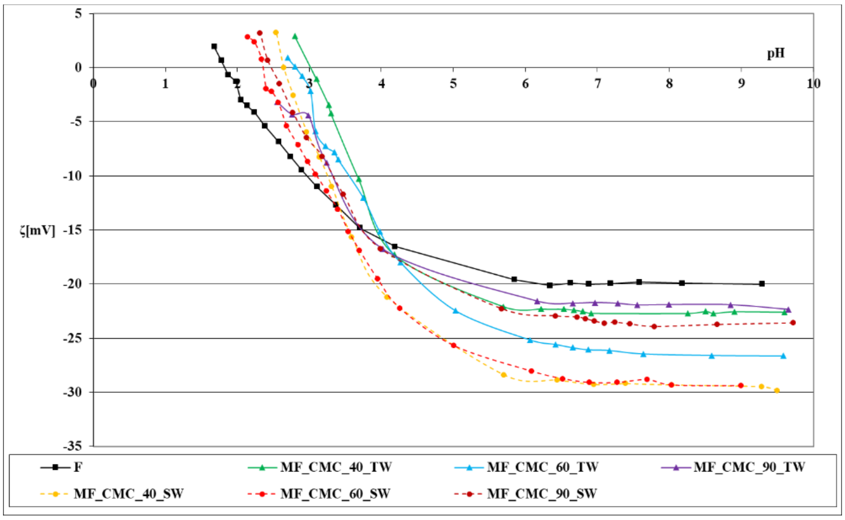
Tablica 3: Sadržaj pepela (P) nakon žarenja pamučnih tkanina prije i nakon 10 ciklusa pranja

uzorak	voda	P (%)		
		40 °C	60 °C	90 °C
F	-	0,2		
MF_CMC	TW	0,8	1,0	1,5
MF_CMS		1,0	1,1	1,5
MF_CMC+CMS		0,9	1,1	1,5
MF_CMC	SW	0,2	0,2	0,3
MF_CMS		0,2	0,2	0,3
MF_CMC+CMS		0,2	0,2	0,3

Neoprana tkanina (F) sadrži 0,2 % pepela što je uobičajena vrijednost za kontrolnu pamučnu tkaninu. Iz rezultata prikazanih u tablici 3 razvidno je da tvrdoća vode i temperatura pranja utječu na vrijednosti pepela opranih pamučnih tkanina. Pranje pamučne tkanine deterdžentom uz inhibitore posivljenja u mekoj vodi tvrdoće 44,5 ppm nije povećalo sadržaj rezidualnih tvari.

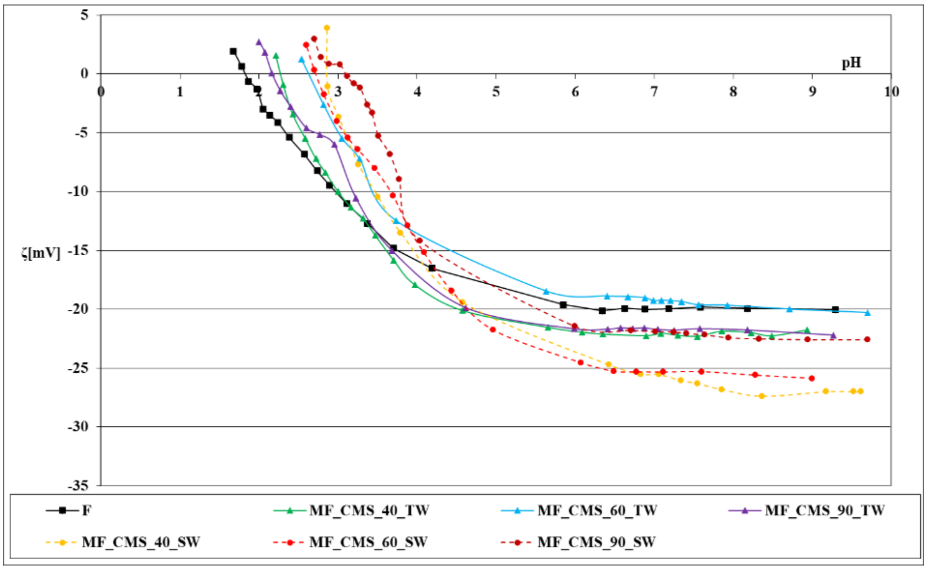
Visoki stupanj tvrdoće vode (404,1 ppm) utječe na vrijednosti sadržaja pepela na opranim pamučnim tkaninama, a u pravilu su veće od 6 do 10 puta u odnosu na vrijednosti pepela pamučnih tkanina opranih u mekoj vodi. Generiranje taloga na površinu pamučnih tkanina u pranju tvrdom vodom na 60 °C i 90 °C je veće u odnosu na 40 °C, čime se može zaključiti da ugrađeni bilderi nisu dostatni za vezanje iona zemnoalkalijskih elemenata u tvrdoj vodi pri višim temperaturama. Sastojci deterdženta za pranje standardne pamučne tkanine (bez zaprljanja) kroz 10 ciklusa nisu se fenomenološki orijentirali na uklanjanje prljavština. Moguće je da su i neke organske komponente u deterdžentu, npr. sapun i anionski tenzidi, interakcijom s kalcijevim i magnezijevim ionima generirale teško topive i/ili netopive taloge, koji su dodatno opteretili površinu pamučne tkanine i povećali sadržaj rezidualnih tvari (ukupan pepeo).

Utjecaj inhibitora posivljenja CMC, CMS i njihove mješavine na naboj površine standardne pamučne tkanine (F) nakon 10 ciklusa pranja (MF) baznim deterdžentom analiziran je titracijskim krivuljama zeta potencijala u ovisnosti o pH 1 mmol/L KCl.



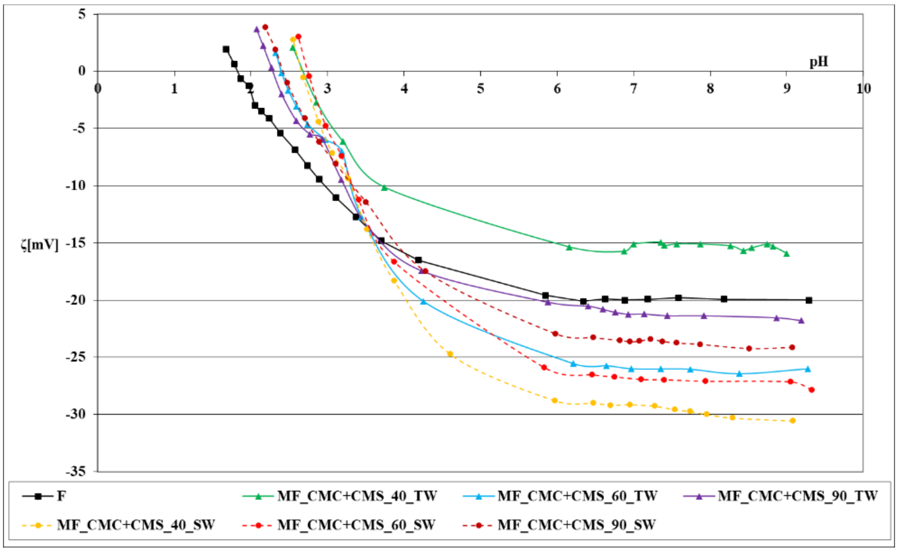
Slika 1: Zeta potencijal pamučnih tkanina prije i nakon 10 ciklusa modifikacije deterdžentom s CMC u tvrdoj i mekoj vodi na 40 °C, 60 °C i 90 °C u ovisnosti o pH 1 mmol/L KCl

Vrijednosti zeta potencijala opranih pamučnih tkanina (MF) u svim variranim uvjetima u području pH 9 do pH 4 su negativnije u odnosu na vrijednosti zeta potencijala standardne pamučne tkanine (F). Prateći razlike između krivulja i vrijednosti ne može se postaviti jednoznačan model ponašanja, ali u pravilu, pamučne tkanine polimerom modificirane u mekoj vodi imaju negativniji naboj površine u odnosu na tkanine modificirane polimerom u tvrdoj vodi. Na temelju dobivenih odnosa, CMC kao polimer utječe na povećanje negativnog naboja površine pamučne tkanine oprane u mekoj vodi na 40 °C i 60 °C. Manje negativan naboj površine imaju pamučne tkanine oprane deterdžentom s CMC na 90 °C u tvrdoj i mekoj vodi u odnosu na gotovo sve preostale polimerom modificirane pamučne tkanine. To se povezuje s utjecajem povišene temperature (90 °C) na slabiji potencijal CMC, a ne sa stupnjem opterećenja površine depozitima, obzirom da je njihov sadržaj na površini tkanina opranih deterdžentom uz CMC na 40 °C, 60 °C i 90 °C u tvrdoj vodi gotovo podjednak, a u mekoj nizak.



Slika 2: Zeta potencijal pamučnih tkanina prije i nakon 10 ciklusa modifikacije deterdžentom s CMS u tvrdoj i mekoj vodi na 40 °C, 60 °C i 90 °C u ovisnosti o pH 1 mmol/LKCl

Vrijednosti zeta potencijala svih pamučnih tkanina opranih deterdžentom s CMS manje su negativne u odnosu na vrijednosti pamučnih tkanina s CMC. Krivulje zeta potencijala karakterizira grupiranost: prvi par – najniži naboj površine pamučnih tkanina opranih s CMS u mekoj vodi na 40 °C i 60 °C; drugi - manje negativan triplet su tkanine oprane s CMS u tvrdoj vodi na 40 °C i 90 °C, te na 90 °C u mekoj vodi. Naboj površine tkanine oprane s CMS u tvrdoj vodi na 60 °C je sličan naboju površine standardne pamučne tkanine (F) u visoko alkalnom području. Na temelju dobivenih odnosa, može se zaključiti da CMC kao ARA u deterdžentu djeluje na povećanje negativnog naboja površine pamučne tkanine u mekoj vodi na 40 °C i 60 °C.



Slika 3: Zeta potencijal pamučnih tkanina prije i nakon 10 ciklusa modifikacije deterdžentom s CMC+CMS u tvrdoj i mekoj vodi na 40 °C, 60 °C i 90 °C u ovisnosti o pH 1 mmol/L KCl

Krivulje zeta potencijala nisu grupirane, te su slične krivuljama tkanina opranim deterdžentom s CMC, čime se ukazuje na dominantan utjecaj CMC u mješavini CMC+CMS u odnosu na CMS, koji je specifičan po grupiranosti i nižem naboju površine oprane pamučne tkanine.

4. Zaključci

Svi dobiveni rezultati ukazuju na značajan utjecaj temperature i tvrdoće vode kao medija za proces pranja. Vrijednosti sadržaja pepela koje upućuju na sadržaj rezidualnih tvari na opranim pamučnim tkaninama u mekoj vodi gotovo su podjednake vrijednostima neoprane pamučne tkanine, što potvrđuje da sastav deterdženta variran kroz inhibitore posivljenja i temperaturu pranja u mekoj vodi nemaju utjecaj na te vrijednosti. Iz pregleda prikazanih rezultata vidljivo je da visoki stupanj tvrdoće vode i temperatura pranja imaju dominantan utjecaj na sadržaj ukupnog pepela na opranim pamučnim tkaninama.
Rezultati analize površine iskazani preko zeta potencijala pokazuju značajan CMC potencijal u smjesi primjenjenih inhibitora posivljenja, CMC+CMS.

5. Literatura

[1] Sinner, H.: Über das Waschen mit Haushaltwaschmaschinen : in welchem Umfange erleichtern Haushaltwaschmaschinen und -geräte das Wäschehaben im Haushalt?, Hamburg: Haus und Heim Verlag, (1960)
[2] Smulders, E. et al.: Recent developments in the field of laundry detergents and cleaners, *Tenside Surfactants Detergents,* **34** (1997) 6, pp. 386-392, ISSN 0932-3414
[3] Soljačić, I., Pušić, T.: *Njega tekstila: Čišćenje u vodenom mediju*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN: 9537105091, Zagreb, (2005)
[4] HRN ISO 4312:2001 Površinski aktivne tvari - Procjena određenih učinaka pranja - Metode analize i ispitivanja za čistu kontrolnu pamučnu tkaninu (ISO 4312:1989)
[5] Luxbacher, T.: 6-Electrokinetic properties of natural fibres, U *Handbook of Natural Fibres: Volume 2: Processing and Applications*, Woodhead Publishing, ISBN 9781845696986, Manchester, UK (2012), pp. 185-215

Darinka Cvetković

Životopis	Rođena u Zagrebu 1962. god. 1981. god. zapošljava se u Radio industriji Zagreb u IETA (istraživanje u elektrotehnici i telekomunikaciji) u laboratoriju na poslovima snimanja i izrade tehničkih filmova (fotolakovi, suhi film, kemijsko bakrenje dvostranih pločica, na galvanskim kupkama i njihovim analizama), te administrativnim poslovima. 1984. upisuje Fakultet kemijskog inženjerstva uz rad. 1991. upisuje Kemijsko-tehnološki fakultet, smjer obuća na kojem diplomira. 2009. upisuje razlikovni studij na Tekstilno-tehnološkom fakultetu, a 2011. god. na istom upisuje diplomski studij, smjer tekstilna kemija, materijali i ekologija. Doktorski studij upisuje 2017. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, s ciljem unapređenja istraživačkih kompetencija.
Naslov teme doktorskog rada	
Studijski savjetnik	izv. prof. dr. sc. Maja Somogyi Škoc
Datum obrane doktorskog rada	

PRIMJENA PROPOLISA I LJEKOVITIH BILJAKA U RAZVOJU JASTUČIĆA ZA LIJEČENJE UPALE DOJKI

Darinka CVETKOVIĆ

Gračansko Dolje 44, Zagreb, cvetkovicdarinka@gmail.com

Sažetak: *Obloge za dojke ne mogu zamijeniti antibiotik, ali mogu pomoći bržem rješavanju simptoma. Na tragu tog razmišljanja doktorski rad se usmjerio prema prirodnim lijekovima koji mogu ubrzati proces cijeljenja. Upotreba ljekovitog bilja stara je koliko i ljudska civilizacija. Biljke su oduvijek bile neizostavan dio čovjekove svakodnevice, bilo kao hrana ili kao lijek. Među mnogim narodima širom svijeta i do danas se zadržala tradicija uporabe ljekovitih biljaka. Osim tradicionalne uporabe, ljekovite biljke postale su izvor bioaktivnih tvari za proizvodnju farmaceutskih pripravaka koji se mogu koristiti u medicini, ali i na tekstilu.*

1. Uvod

Do upale dojke kod zdravih žena koje ne doje dolazi rijetko, a rizična skupina su žene i muškarci koji imaju oslabljeni imunitet, dijabetes ili kronične bolesti. Upala dojke se kod žena ili muškaraca može pojaviti zbog oštećenja bradavice, pušenja, a može se pojaviti i kod žena koje imaju implantate [1]. Kod žena koje doje do upale dojke dolazi kada bakterija iz usta dojenčeta ili kože uđe u mliječni kanal kroz pukotinu na bradavici. Drugi razlog koji uzrokuje upalu dojke je mlijeko koje ostaje u dojkama, odnosno koje nije izdojeno do kraja, a to onda vodi do začepljenosti mliječnog kanala [2]. U slučaju infekcije koriste se antibiotici, a kod bolova mogu pomoći lijekovi protiv bolova kao što je ibuprofen. Kako bi se smanjili bolovi, mogu pomoći i topli ili hladni oblozi prije i nakon dojenja [3]. Jedan od najpoznatijih obloga je onaj od listova zelja, ali pri tome postoji rizik od infekcije bakterijom lisetrije (lat. *Listeria monocytogenes*). Osim tradicionalne uporabe, ljekovite biljke postale su izvor bioaktivnih tvari za proizvodnju farmaceutskih pripravaka koji se mogu koristiti u medicini, farmaceutskoj industriji, u prehrambenoj industriji itd., u drugim prerađivačkim sektorima (kozmetička industrija, proizvodnja biljnih zaštitnih sredstava i sl.) [4]. Ne postoji stroga granica između ljekovitih, začinskih i aromatičnih vrsta, jer se često ista biljka može koristiti za sve tri namjene (npr. nana se koristi u medicini, od nje se proizvodi eterično ulje, ali služi i za dobivanje aroma) [5]. Zbog svega navedenog ljekovite i aromatične biljke često se nazivaju jednim zajedničkim imenom - ljekovito bilje.

2. Eksperimentalni dio

U polazišnoj osnovi istraživanja postaviti će se hipoteza da se korištenjem dosadašnjih znanstvenih saznanja i dostignuća u području razvoja materijala može ostvariti novi doprinos u razvoju jastučića za dojilje kao obloga za liječenje upale dojki.

Slika 1: Troslojni jastučići za dojilje [6]

U planiranju i izvođenju istraživanja koristiti će se opća znanja iz područja metodologije znanstvenog rada – priprema istraživanih materijala, provedba istraživanja i obrada dobivenih rezultata s ciljem ostvarivanja i potvrđivanja hipoteze. Koristiti će se metode i postupci koji omogućuju ponovljivost obrada i morfoloških značajki istraživanih materijala uz primjenu pouzdanih standardiziranih i razvijenih mjernih tehnika (FTIR-ATR, SEM-EDS, AFM, DSC/TGA, raznim mikrobiološkim testovima, ispitivanjima neškodljivosti za in vivo primjenu, itd.), ali i u tom trenutku novim mjernim tehnikama na globalnom nivou.

Istraživanje će obuhvatiti sljedeće cjeline, koje će se tijekom rada dopunjavati i po potrebi mijenjati, a u ovisnosti o dobivenim spoznajama:

1. Odabir biljaka na području Republike Hrvatske i pčelinjeg proizvoda
2. Konzultacije i suradnja s potencijalnim članovima povjerenstva
3. Razvoj vlastitih tinktura, izračun potrebnih količina ekstrakata/bioaktivnih komponenti odabranih biljaka i pčelinjeg proizvoda
4. Optimiranje i priprema tinktura
5. Nanašanje optimiranih tinktura na odabrane tekstilne obloge postupkom uranjanja
6. Ispitivanje i vrednovanje preliminarnih uzoraka.
7. Prijava obrasca DR.SC.01. i dr. Pisanje i objava znanstvenog rada.
8. Primjena statističke metode Dizajna eksperimenta (engl. Design of Experiments, DOE).
9. Nanašanje optimiranih tinktura na odabrane tekstilne obloge postupkom uranjanja.
10. Ispitivanje i vrednovanje uzoraka.
11. Konzultacije i suradnja s članovima povjerenstva i drugim institucijama
12. Primjenjivost obloga za liječenje upala dojki i mogućnost komercijalne proizvodnje.


sasušeno sjeme piskavice [7]


gavez [8]


matičnjak [9]


propolis [10]

Slika 2: Neke od odabranih biljaka i propolis

3. Zaključak

Očekivani rezultati doktorskoga rada su razvoj prototipova jastučića za dojilje kao obloga za liječenje upale dojki, te razvoj metodologije za vrjednovanje njihove uporabne i funkcionalne kvalitete.

Zahvala

Rad doktorandice Darinke Cvetković sufinanciran je sredstvima istraživačkog projekta „Antibakterijska prevlaka za biorazgradive medicinske materijale" - ABBAMEDICA" Hrvatske zaklade za znanost (HRZZ- IP-2019-04-1381), voditeljice prof. dr. dr. sc. Ive Rezić.

4. Literatura

[1] *Dostupan na* https://krenizdravo.dnevnik.hr/zdravlje/bolesti-zdravlje/upala-dojke-kod-zena-koje-ne-doje-mastitis-uzroci-simptomi-lijecenje-i-obloge, *Pristupljeno:* 14.12.2023.
[2] Boakes, E. et al.: Breast Infection: A Review of Diagnosis and Management Practices. *European Journal Of Breast Health*, **14** (2018), pp. 136-143
[3] *Dostupan na* https://poliklinika-mazalin.hr/blog/njega-dojki-nakon-poroda/, *Pristupljeno:* 14.12.2023.
[4] *Dostupan na* https://www.info-ks.net/lifestyle/zdravlje/77415/oblozi-od-kupusa-su-lijek-evo-sta-ce-da-se-desi-ako-ih-stavite-na-grudi-noge-ruke-ili-vrat, Pristupljeno: 14.12.2023.
[5] Jovović, Z. i sur.: *Tehnologija proizvodnje ljekovitog, aromatičnog i začinskog bilja*, Univerzitet Crne Gore, ISBN COBISS.CG-ID, Podgorica, (2020.)
[6] *Dostupan na* https://lansinoh.hr/product/jastucici-za-prsa/, *Pristupljeno:* 14.12.2023.
[7] *Dostupan na* https://ba.underextract.com/dietary-supplement/fenugreek-powder.html, *Pristupljeno:* 14.12.2023.
[8] *Dostupan na* https://encian.hr/hr/novosti/gavez-mast-najbolji-lijek-protiv-bolova-21028, *Pristupljeno:* 14.12.2023.
[9] *Dostupan na* https://hr.underextract.com/dietary-supplement/organic-lemon-balm-powder.html, Pristupljeno: 14.12.2023.
[10] *Dostupan na* https://www.uppula.hr/proizvodi/propolis, *Pristupljeno:* 14.12.2023.

Ivana Čorak

Životopis

Diplomirala je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu 2015. god. Radila je kao stručnjak za kvalitetu u Boxmark Leather d.o.o. Na TTF-u je radila kao asistentica na projektu HRZZ-DOK-2018-09-4254 „*Bio-inovirani poliesterski materijal za ciljanu primjenu u bolničkom okruženju*“. Bila je suradnica na HRZZ UIP-05-2019-8780 HPROTEX te bilateralnom znanstveno-istraživačkom projektu Bio-inovirani poliesteri između Hrvatske i Srbije. Dobila je nagradu o.d. Dekanice za izvrsnost na poslijediplomskom sveučilišnom studiju TZT 2019./2020. god. te Nagradu TSRC 2021. god. za najuspješniji znanstveno-istraživački rad iz područja tekstila u kategoriji I: za mlade istraživače TTF-a. Od 2023. god. je zaposlena kao asistentica na matičnom Fakultetu. Znanstveni rad joj je vezan uz površinsku modifikaciju poliestera i razvoj antimikrobnih tekstilija, a nastavni uz tisak i bojadisanje.

Naslov teme doktorskog rada

Bio-inovirani poliesterski materijal za ciljanu primjenu u bolničkom okružju

Mentor

prof. dr. sc. Anita Tarbuk

Datum obrane doktorskog rada

BIO-INOVIRANI POLIESTERSKI MATERIJAL ZA CILJANU PRIMJENU U BOLNIČKOM OKRUŽJU

Ivana ČORAK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, ivana.corak@ttf.unizg.hr

Sažetak: *Istraživanja u okviru doktorskog rada obuhvaćaju razvoj bio-inoviranih poliesterskih materijala za ciljanu primjenu u bolničkom okružju. Aktivacija površine poliesterske tkanine provedena je hidrolizom lužinom pri sniženoj temperaturi uz dodatak akceleratora te ekološki prihvatljivim enzimima amano lipazama. Provedena je funkcionalizacija kitozanom homogeniziranim u vodenoj otopini octene kiseline metodom impregnacija-sušenje-kondenzacija. Istražena elektrokinetička svojstva i antimikrobna učinkovitost funkcionaliziranih tkanina nakon 10 ciklusa prilagođenog pranja potvrđuju postojanost obrade.*

1. Uvod

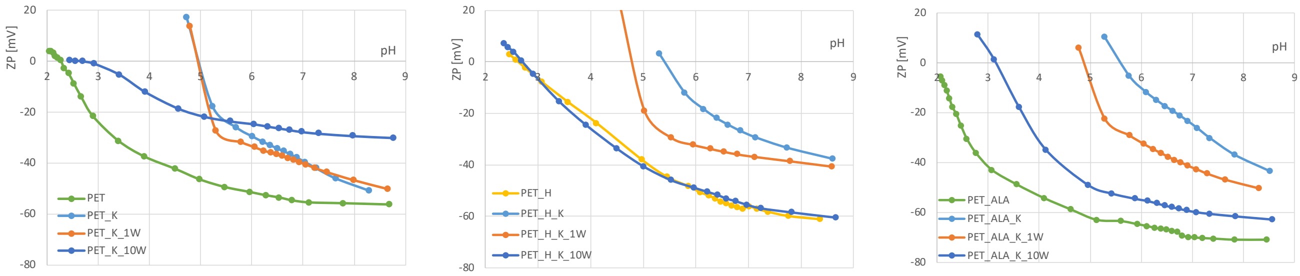
Poliester čini gotovo 80 % ukupne proizvodnje sintetskih vlakana, od kojih je najzastupljeniji poli(etilen-tereftalat), PET. PET je hidrofoban zbog velike kristaliničnosti što za posljedicu ima nisku adsorptivnost, nakupljanje statičkog elektriciteta, sklonosti prljanju, neudobnost pri nošenju i stvaranje pilinga [1-3] te se provode površinske modifikacije. Hidroliza uzrokuje cijepanje na esterskim vezama i rezultira povećanim brojem hidroksilnih i karboksilnih skupina, a tkanine imaju bolju adsorptivnost, izgled i sjaj poput svile. Alkalna hidroliza nije ekološki ni energetski povoljna, a može doći do pada čvrstoće tkanine radi smanjenja poprečnog presjeka. Kao alternativa, istražuju se enzimi, prirodne i potpuno biorazgradive proteinske strukture koje omogućuju selektivnu obradu polimernih materijala pri niskoj temperaturi. Zbog veličine enzima djeluju isključivo na površini vlakna pa ne dovode do oštećenja. Za enzimatsku hidrolizu PET-a koriste se različiti enzimi, no najbolji učinci postižu se lipazama i kutinazama [2, 3].
Kitozan je prirodni biopolimer pretežno građen iz 2-amino-2-deoksi-D-glukopiranoznih jedinica, povezanih β-1,4-vezama. Unatoč brojnim postojećim antimikrobnim sredstvima, svijest javnosti i politike EU-a istaknuli su potrebu za novim bio-sredstvima u razvoju bolničkih materijala. Velik interes za primjenu kitozana u bolničkom okružju proizlazi iz njegovih svojstava: biokompatibilnosti, biorazgradivosti, netoksičnosti, antimikrobne, hemostatske i hidratantne učinkovitosti [4].

2. Eksperimentalni dio

Za istraživanja je korištena komercijalna poliesterska tkanina iz 100 % poli(etilen-tereftalata) površinske mase 60 g/m^2 (Belira) – oznaka PET. Hidroliza je provedena u 1,5 M NaOH na 80 °C u vremenu od 10 min uz dodatak 2 g/l akceleratora, kationskog tenzida heksadeciltrimetil amonijeva klorida (HDTMAC, 25 % vodena otopina, Fluka) – oznaka PET-H. Enzimatska hidroliza je provedena s 0,2 g/l Amano Lipase A (Aspergillus niger) tvrtke Sigma-Aldrich pri vrijednosti pH 9 na 60 °C u vremenu 60 min – oznaka PET-ALA. Za funkcionalizaciju je korišten kitozan dobiven iz micelija gljive bukovače tvrtke Chibio BioTECH – oznaka K. Tkanine su impregnirane u homogeniziranoj otopini kitozana u octenoj kiselini (3 g/l), sušene na 110 °C u vremenu 2 min i termokondenzirane na temperaturi 170 °C u vremenu 90 sekundi.
Kako bi se utvrdila postojanost obrade, istražena su elektrokinetička svojstva (Surpass, Anton Paar) i antimikrobna učinkovitost (HRN EN ISO 20645:2008 na *Staphylococcus aureus* (ATCC 6538), *Escherichia coli* (ATCC 8739) i *Candida albicans* (ATCC 10231)) funkcionaliziranih tkanina nakon 1 i 10 ciklusa prilagođenog pranja u perilici rublja Wascator FOM71 CLS (Electrolux). Pranje je provedeno u mekanoj vodi uz dodatak deterdženta s optičkim bjelilom (ISO 15797:2002) uz naknadno dodavanje PAP-a, ε-(ftalimido) peroksi heksanske kiseline, na 50 °C po posebno izrađenom programu. Sušenje je provedeno u sušilici T5130-LAB – Type A1 (Electrolux) u trajanju od 30 min u programu NORMAL LAB.

3. Rezultati i rasprava

Prisutnost kitozana na tkanini potvrđena je vrijednostima zeta potencijala i izoelektrične točke (sl.1).



a b c

Slika 1: Zeta potencijal poliesterskih tkanina: a) nehidrolizirana, b) alkalno hidrolizirana, c) enzimatski hidrolizirana nakon funkcionalizacije i pranja

Vidljivo je da su hidrolizirane tkanine negativnije radi većeg broja aktivnih skupina. Nakon funkcionalizacije su pozitivnije radi amino skupina vezanoga kitozana. Pranjem dolazi do djelomičnog skidanja kitozana, ali učinci ostaju što potvrđuje i istraživanje antimikrobne učinkovitosti (tab.1). Najbolji učinci uočeni su na enzimatski hidroliziranom poli(etilen-tereftalatu).

Tablica 1: Antimikrobna učinkovitost poliesterskih tkanina prije i nakon funkcionalizacije te pranja

Uzorak	PET			PET-H			PET-ALA		
	Sa	*Ec*	*Ca*	*Sa*	*Ec*	*Ca*	*Sa*	*Ec*	*Ca*
_	-	-	-	+	+/-	-	+/-	+/-	-
_K	+/-	+/-	+/-	+	+/-	+/-	+/-	+/-	+/-
_K_1W	+/-	+/-	-	+/-	+/-	-	+/-	+/-	+/-
_K_10W	+/-	+/-	-	+/-	+/-	-	+/-	+/-	-

Sa - Staphylococcus aureus, Ec - Escherichia coli, Ca - Candida albicans; + ima zonu inhibicije, učinkovit; - nema zone, rast mikroorganizama, neučinkovit; +/- nema zone, nema rasta mikroorganizama na površini tkanine niti ispod nje, učinkovit

4. Zaključci

Dobiveni rezultati ukazuju na ekološki, energetski i ekonomski prihvatljiviju provedbu alkalne i enzimatske hidrolize poliestera i funkcionalizaciju kitozanom. Rezultati zeta potencijala ukazuju na prisutnost kitozana na obje tkanine čak i nakon višestrukih ciklusa prilagođenog procesa pranja.

Zahvala

Rad doktorandice Ivane Čorak sufinanciran je iz „Projekta razvoja karijera mladih istraživača – izobrazba novih doktora znanosti“ Hrvatske zaklade za znanost (HRZZ-DOK-2018-09-4254). Mišljenja, nalazi i zaključci ili preporuke navedene u ovom materijalu isključiva su odgovornost autora i ne odražavaju nužno stajališta Hrvatske zaklade za znanost. Rad je sufinancirala HRZZ projektom UIP-2017-05-8780 “Bolničke zaštitne tekstilije”.

5. Literatura

[1] Grancarić, A.M., Pušić, T., Kallay, N.: Modifikacija poliesterskog vlakna alkalnom hidrolizom, *Polimeri*, 12 (1991), str. 141–145

[2] Guebitz, G.M., Cavaco-Paulo, A.: Enzymes go big: Surface hydrolysis and functionalization of synthetic polymers, *Trends Biotechnol*, **26** (2008), pp. 32–38

[3] Kardas, I. et al.: The influence of PET fibres surface enzymatic modification on the selected properties, *AUTEX Research Journal*, **14** (2014) 3, pp. 179-186

[4] Flinčec Grgac, S. et al.: The Chitosan Implementation into Cotton and Polyester/Cotton Blend Fabrics, *Materials*, **13** (2020) 7, 1616

Selma Imamagić

Životopis	Selma Imamagić rođena je 1998. god. u Zagrebu. 2022. god. diplomirala je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, smjer: odjevno inženjerstvo. Nakon završetka diplomskog studija, iste godine upisuje doktorski sveučilišni studij Tekstilna znanost i tehnologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Od 3.7.2023. god. zaposlena je u Zavodu za odjevnu tehnologiju Sveučilišta u Zagrebu Tekstilno-tehnološkog fakulteta na suradničkom radnom mjestu asistenta.
Naslov teme doktorskog rada	
Studijski savjetnik	prof. dr. sc. Anica Hursa Šajatović
Datum obrane doktorskog rada	

RAZVOJ I PRIMJENA PROGRAMA ZA TERMINIRANJE PROCESA PROIZVODNJE ODJEĆE

Selma IMAMAGIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, selma.imamagic@ttf.unizg.hr

Sažetak: *Terminiranje proizvodnje je postupak usklađivanja termina u kojem određeni radni nalozi trebaju biti proizvedeni. Pritom se teži pronaći najbolji mogući raspored strojeva i uređaja kao i izvođenja tehnoloških operacija po radnim mjestima. Doktorski rad temeljit će se na razvoju programa za terminiranje procesa proizvodnje odjeće i testiranju njegovog rada na primjeru iz realnog sektora.*

1. Uvod

Današnja težnja za individualizacijom životnog stila zajedno s brzim promjenama dizajna modela odjevnih predmeta zahtijevaju prilagodljivost odjevne industrije te brz i prikladan odgovor na spomenute zahtjeve. Male proizvodne serije, veliki asortiman odjevnih predmeta različitih boja, dezena i odjevnih veličina, velika kakvoća izrade, kratki rokovi isporuke kao i stalna tendencija smanjenja vremena izrade odjevnog predmeta, odnosno njegove cijene predstavljaju globalne čimbenike razvoja odjevne industrije [1]. S tim u vezi zahtijevaju se nova rješenja u procesu proizvodnje odjeće. Jedno od rješenja pronalazi se u poboljšanju planiranja proizvodnje, raspoređivanja dostupnih resursa (ljudi i strojeva) te kontrole procesa proizvodnje koji predstavljaju ključne elemente za uspješnost poslovanja poduzeća u području odjevne industrije. U tom smislu razvijaju se matematički modeli i računalni programi u području terminiranja proizvodnje kojima se teži odrediti optimalni redoslijed izvođenja tehnoloških operacija po radnim mjestima, odnosno proizvodnje radnih naloga kao i rasporeda strojeva i opreme za postizanje željenog rezultata proizvodnje (kvaliteta i kvantiteta gotovih odjevnih predmeta) unutar definiranih rokova isporuke [2].

S tim u vezi kao glavni ciljevi terminiranja proizvodnog procesa ističu se:
- skraćenje ciklusa proizvodnje,
- pridržavanje planiranih termina isporuke (uklanjanje mogućih kašnjenja ili preuranjenosti),
- optimalno opterećenje strojeva i opreme,
- skraćenje vremena protoka materijala kroz proizvodni proces te
- smanjenje troškova proizvodnje [3].

Temelj ovog doktorskog rada bit će razvoj programa za terminiranje proizvodnje namijenjen primjeni u odjevnoj industriji kojim bi se ostvarila većina gore navedenih ciljeva. Noviteti u odnosu na postojeće programe očitovao bi se u dodavanju parametra složenosti izvođenja tehnološke operacija, odnosno sposobnosti radnika da ju izvede prilikom automatske raspodjele tehnoloških operacija po radnim mjestima te automatskom izračunu potrebnog broja radnika za proizvodnju određenog radnog naloga.

2. Eksperimentalni dio

Eksperimentalni dio doktorskog rada obuhvatit će razvoj programa za terminiranje procesa proizvodnje odjeće. Njegov razvoj provest će se u programskom jeziku C++, a ideja vodilja razvoja bit će primjena jednog od pravila za definiranje prioriteta prilikom izvođenja tehnoloških operacija na radnim mjestima (tab. 1).

Tablica 1: Primjeri prioritetnih pravila za raspoređivanje tehnoloških operacija po radnim mjestima [4]

Prioritetna pravila za raspoređivanja tehnoloških operacija po radnim mjestima	**Opis pravila**
LTT (eng. *Longest Task Time*)	prioritet izvođenja ima tehnološka operacija s najduljim vremenom izvođenja
STT (eng. *Shortest Task Time*)	prioritet izvođenja ima tehnološka operacija s najkraćim vremenom izvođenja
MFT (eng. *Most Following Tasks*)	prioritet izvođenja ima tehnološka operacija s najvećim brojem „sljedbenika“ (tehnoloških operacija koje joj slijede)
LNFT (eng. *Least Number of Following Tasks*)	prioritet izvođenja ima tehnološka operacija s najmanjim brojem „sljedbenika“ (tehnoloških operacija koje joj slijede)
RPW (eng. *Ranked Positional Weight*)	prioritet izvođenja ima tehnološka operacija kojoj slijedi tehnološka operacija s najduljim vremenom izvođenja

3. Rezultati i rasprava

Rezultati razvijenog programa za terminiranje proizvodnje odjeće imaju cilj utvrditi skraćenje ciklusa proizvodnje određenog odjevnog predmeta kao i postizanje najboljeg mogućeg rasporeda strojeva i opreme te tehnoloških operacija izrade odjevnog predmeta po radnim mjestima prilikom proizvodnje određenog radnog naloga.
Postizanje spomenutih ciljeva želi se ispitati na primjeru iz realnog sektora, unosom podataka iz odjevne industrije u razvijeni program za terminiranje proizvodnje. Evaluacija razvijenog programa za terminiranje proizvodnje bit će provedena na temelju rezultata rada programa u realnom sektoru.

4. Zaključci

Terminiranje procesa proizvodnje odjeće predstavlja složen proces u proizvodnji odjeće zbog glavnih ciljeva koji se istim žele postići. Primjena jednog od prioritetnih pravila raspoređivanja, uvođenje njihovih modifikacija te ispravno određivanje ovisnosti između tehnoloških operacija izrade određenog odjevnog predmeta i njihova slijeda izvođenja osigurat će postizanje definiranih ciljeva u procesu proizvodnje odjeće te traženog odgovora odjevne industrije na zahtjeve tržišta, odnosno kupaca.

5. Literatura

[1] Rogale, D., Dragčević, Z. & Ujević, D.: Utjecaj dizajna na suvremene procese proizvodnje odjeće, *Tekstil*, **46** (1997), 1, str. 16-23, ISSN 0492-5882

[2] Afolalu, A. S. et al.: Analysis of Production Scheduling Initiatives in the Manufacturing Systems, *International journal of mechanical and production engineering research and development*, **10** (2020) 3, pp. 1301-1318, ISSN 2249-8001

[3] Žugaj, M. & Varga, M.: O terminiranju proizvodnje pomoću električkog računala, *Journal of Information and Organizational Sciences*, (1987) 11, str. 209-221, ISSN 1846-9418

[4] Ünal, C.: A new line balancing algorithm for manufacturing cell transformation in apparel industry, *Industria Textilă*, **64** (2013) 3, pp. 155-161, ISSN 1222-5347

Josip Jelić

Životopis	Josip Jelić rođen je 1980. god. u Zagrebu. Osnovnu i srednju školu završio je u Zagrebu. Tekstilno-tehnološki fakultet Sveučilišta u Zagrebu završio je 2015 god. Na Tekstilno-tehnološkom fakultetu Sveučilišta u Zagrebu upisao je poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija 2017 god.
Naslov teme doktorskog rada	Ciljana izrada vlaknastog nosača za uzgoj tkivnih stanica kombiniranim elektroispredanjem
Mentor	prof. dr. sc. Budimir Mijović
Datum obrane doktorskog rada	

ISPITIVANJE VLAČNIH SVOJSTAVA ELEKTROISPREDENOG TEKSTILNOG NETKANOG KOMPOZITA

Josip JELIĆ

Carwizz, Slavonska avenija 26/9, Zagreb, josipjelic2004@gmail.com, josip.jelic@ttf.hr

Sažetak: *Tekstilni kompozitni materijali napredni su materijali koji kombiniraju tekstil (kao što su tkani ili netkani materijali) s drugim materijalima, često polimerima ili vlaknima za ojačavanje, kako bi se stvorili materijali s poboljšanim svojstvima i učinkom. Mehanička svojstva tekstilnih kompozitnih materijala mogu značajno varirati ovisno o specifičnim korištenim materijalima, proizvodnom procesu i namjeravanoj primjeni. Vlačna svojstva bitna su mehanička svojstva koja se koriste za procjenu učinkovitosti kompozitnih tekstilnih materijala. Vlačna svojstva opisuju kako se materijal ponaša pod djelovanjem vanjskih vlačnih sila.*

1. Uvod

Kompozit ili kompozitni materijal građen je od međusobno čvrsto spojenih različitih materijala radi dobivanja novog, drugačijeg materijala, s fizikalnim ili kemijskim svojstvima koja nadmašuju svojstva pojedinačnih dijelova ili sa svojstvima koje ti pojedinačni dijelovi nemaju [1]. Većina kompozita sadrži jedan materijal kao kontinuiranu fazu (matricu), a u nju su uklopljeni odvojeni dijelovi druge faze, koja najčešće ima funkciju ojačala. Mehanička svojstva kompozitnih materijala poput: vlačnih, tlačnih svojstava, savitljivosti, čvrstoće i krutosti ovise o različitim čimbenicima, a neki od njih su: sastav materijala, njihovi volumni udjeli i primijenjeni proizvodni procesi. Istraživanje različitih tehnika proizvodnje kompozitnih materijala je veoma bitno [2,3]. To može uključivati proučavanje procesa poput ručnog postavljanja, namotavanja filamenta, kompresijskog kalupljenja i još mnogo toga kako bi se optimizirala mehanička svojstva konačnog proizvoda. Različite vrste vlakana (npr. ugljikova, staklena, aramidna) nude različite razine čvrstoće i krutosti. Materijal matrice koji povezuje vlakna također utječe na vlačna svojstva. Matrica mora učinkovito prenijeti opterećenje na vlakna i osigurati zaštitu od čimbenika okoline. Procjena vlačnih svojstava tekstilnih kompozitnih materijala ključna je za osiguranje ispunjavanja zahtjeva specifičnih primjena, kao što su zrakoplovna, automobilska, građevinska i sportska oprema.

2. Materijal i metode rada

U radu je korišten Shieldex Bonn koji je visoko vodljivi termički vezan netkani materijal izrađen od 100% poliamida (Nylon 6.6) sa sadržajem srebra od cca. 17%. Zbog sadržaja srebra ovaj netkani materijal djeluje antimikrobno, električki je i toplinski vodljiv te štiti od elektromagnetskog zračenja. Unatoč svojim antimikrobnim svojstvima, Shieldex Bonn se također koristi za tehničke svrhe u industriji. Osim elektromagnetske zaštite, ovaj tehnički materijal osigurava antistatičku disipaciju i vrlo dobru električnu vodljivost do < 0,5 Ω. Shieldex Bonn je posebno prikladan za senzore u medicinskoj tehnologiji, zaštitne tapete u zaštiti prostorija ili antistatičko pražnjenje u elektroničkim komponentama. Također materijal je usklađen s OEKO-TEX® STANDARD 100, REACH i RoHS direktivama i normama. Učinkovitost zaštite (0,2–2 GHz) prosječno < 63 dB od 0,2 GHz – 2 GHz. Učinkovitost zaštite (2–5 GHz) prosječno < 70 dB od 2 GHz – 5 GHz. Učinkovitost zaštite (5–14 GHz) prosječno < 78 dB od 5 GHz – 14 GHz. Plošna masa od 56 g/m2 ± 15% i debljina 0,35 mm ± 30%.

2.1. Mjerna oprema i uzorci

Norma „*Netkani tekstil - Metode ispitivanja - 3. dio: Određivanje prekidne sile i prekidnog istezanja metodom trake*“ (HRN EN ISO 9073-3:2023), opisuje metodu ispitivanja za određivanje vlačnih svojstava netkanog tekstila metodom posmične trake, odnosno jednoosnog vlačnog istezanje do prekida [4]. Ispitivanja prekidnih i vlačnih svojstava uzoraka netkanog tekstila provedena je na dinamometru Statimat M, tt. Textechno. Točnost aparata odgovara klasi 1, s razinom značajnosti zabilježene maksimalne sile ± 1%. Prekidna sila (Fp, N) općenito je poznata kao vlačna čvrstoća ili krajnja vlačna čvrstoća, koja je definirana kao otpor kojim se uzorak suprotstavlja kidanju uslijed djelovanja vanjske vlačne sile. Produljenje (p, mm) materijala primjenom vlačne sile se određuje promjenom duljine uzorka u odnosu na početnu duljinu te se izražava kao postotak u odnosu na izvornu duljinu ispitivanog uzorka i označava se kao prekidno istezanje (ε, %). Mjerenja su provedena na uzorcima netkanog kompozitnog tekstila u obliku traka širine 50 ± 0,5 mm i duljine 200 ± 0,5 mm. Ispitivanje je provedeno na 10 uzoraka u 3 smjera (oznake smjera: X smjer 0°, Y smjer 90°, Z smjer 45°).

3. Rezultati vlačne sile na suhim uzorcima

Prema rezultatima može se vidjeti da najveću čvrstoću u X smjeru u suhom stanju ima uzorak 5 i ona iznosi 158,41 cN/mm. Najmanju čvrstoću ima uzorak 3 i ona iznosi 115,15 cN/mm. Uzorak 5 također ima i najveće prekidno istezanje koje iznosi 53,96 %, dok najmanje prekidno istezanje ima uzorak 3 i ono iznosi 39,88 %. Najveću čvrstoću u Y smjeru u suhom stanju ima uzorak 5 i ona iznosi 89,27 cN/mm. Najmanju čvrstoću ima uzorak 1 i ona iznosi 71,78 cN/mm. Uzorak 5 također ima i najveće prekidno istezanje koje iznosi 63%, dok najmanje prekidno istezanje ima uzorak 4 i ono iznosi 49,44 %. Nadalje, može se vidjeti da najveću čvrstoću u Z smjeru u suhom stanju ima uzorak 1 i ona iznosi 122,76 cN/mm. Najmanju čvrstoću ima uzorak 2 i ona iznosi 90,9 cN/mm. Uzorak 3 ima najveće prekidno istezanje koje iznosi 59,44 %, dok najmanje prekidno istezanje ima uzorak 2 i ono iznosi 44,04 %.

4. Zaključak

Vlačna svojstva bitna su mehanička svojstva koja se koriste za procjenu učinkovitosti kompozitnih netkanih tekstilnih materijala i opisuju kako se materijal ponaša pod djelovanjem vlačnih sila. Vlačna čvrstoća predstavlja maksimalno naprezanje koje materijal može izdržati prije nego što pukne. Vlačna čvrstoća je kritični parametar jer ukazuje na sposobnost materijala da se odupre vanjskim silama bez prekida. Provedena ispitivanja netkanih kompozitnih uzoraka pokazala su kako u suhom stanju najveću vlačnu čvrstoću i najveće prekidno istezanje pokazuje uzorak 5 pri istezanju u X smjeru (0°) i Y smjeru (90°). Pri istezanju u Z smjeru (45°) u suhom stanju najveća čvrstoća izmjerena je kod uzorka 1 u iznosu od 122,76 cN/mm, dok je najveće prekidno istezanje od 59,44 % izmjereno kod uzorka 3, što vjerojatno ovisi o smjeru izrade i strukturi odnosno usmjerenosti vlakana u strukturi netkanog kompozita, ali i korištenim komponentama (matrici) u postupku elektroispredanja.

5. Literatura

[1] De Luycker, E., et al.: Simulation of 3D interlock composite preforming, *Composite Structures*, **88** (2009) 4: str. 615-62, ISSN 0263-8223

[2] Yi, H. L.; Ding, X.: Conventional Approach on Manufacturing 3D Woven Preforms Used for Composites. *Journal of Industrial Textiles*, **34** (2004) : str. 39-50, ISSN 1528-0837

[3] Tsai, K. H.; Chiu, C. H.; Wu, T. H.: Fatigue Behaviour of 3D Multi-Layer Angle Interlock Woven Composite Plates, *Composites Science and Technology*, **60** (2000), str 241-248, ISSN 1879-1050.

[4] HRN EN ISO 9073-3:2023 *Netkani tekstil - Metode ispitivanja - 3. dio: Određivanje prekidne sile i prekidnog istezanja metodom trake*

Tea Jovanović

Životopis	Rođena je 1993. god, u Metkoviću. Srednju ekonomsku školu završava u Pločama 2012. god. God 2015. završila je prijediplomski sveučilišni studij na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu u Zagrebu, a 2018. god. diplomski studij. Doktorandica je treće godine Sveučilišta u Zagrebu Tekstilno-tehnološkog fakulteta. Trenutno je zaposlena kao voditelj ureda i član podrške za prodaju pretplate.
Naslov teme doktorskog rada	Utjecaj sirovinskog sastava i strukture pletiva na njegova elastična svojstva pri djelovanju statičkog i cikličkog opterećenja
Mentor	prof. dr. sc. Željko Penava
Datum obrane doktorskog rada	

ANALIZA RADA PRI ISTEZANAJU PLETIVA DO PREKIDA

Tea JOVANOVIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, prilaz baruna Filipovića 28a, Zagreb, teajovanovic81@gmail.com

Sažetak: *Analiziran je dijagram sila/istezanje nastao pri jednoosnom vlačnom opterećenju do prekida dva uzorka kulirnih platirnih desno-desnih pletiva namijenjenih izradi rekreacijskih majica dugačkih rukava ili zimskih potkošulja. Temeljna pređa je pamučna finoće 20 tex, a platirna PA multifilamentna finoće 44 dtex. Krivulja dijagrama sila/istezanje zadovoljavajuće se opisuje polinomnom jednadžbom trećeg ili četvrtog stupnja. Primjenom određenih integrala i prikladnih matematičkih metoda određen je ukupni i djelomični rad pri istezanju pletiva do trganja. Udio rada do kraja elastične deformacije pletiva iznosi 0,2 do 3,5 %, a do početka plastične deformacija 1,3 do 20 % od ukupnog rada.*

1. Uvod

Pri tzv. statičkim vlačnim opterećenjima na dinamometru, pletiva se istežu najčešće poprečno i/ili uzdužno do prekida. Temeljem analize dijagrama sila/istezanje do prekida mogu se analizirati udjeli uloženog rada pri istezanju pletiva u smjeru redova očica i u smjeru nizova očica [1,2]. Za pojedine primjene uvijek se traže nove strukture pletiva ili se upotrebljavaju pređe novih konstrukcijskih značajki i svojstava te se usklađivanjem parametara pređa i strojeva te oplemenjivanja izrađuju planirane strukture pletiva i potom odjevni predmeti [3,4].

2. Eksperimentalni dio

Projektirana su, izrađena i analizirana dva uzorka kulirnih desno-desnih pletiva u dva prepleta: 1. djelomično platirni (oznaka uzorka DD-1+1) i 2. (potpuno) platirni preplet (DD-PP), Tab. 1. Temeljna pređa za pletenje je pamučna finoće 20 tex, a pređa za platiranje je PA multifilamentna finoće 44 dtex f 10. Kod djelomično platirnog pletiva 1+1, PA pređa se upliće u svaki drugi red (90 % pamuk, 10 % PA) plošne masa 200 g/m2. Kod platirnog pletiva u svaki red se upliću pamučna i PA pređa (82 % pamuk, 18 % PA) plošne masa 233 g/m2. Izrezani uzorci pletiva za jednoosno vlačno istezanje do prekida ispitani su na dinamometru t. Statimat M – Textechno (širina uzoraka 50 mm, duljina 300 mm; razmak između stezaljki dinamometra 100 mm; brzina istezanja 100 mm/min) [5].

3. Rezultati i rasprava

Tablica 1: Utvrđene polinomne jednadžbe i koeficijenti korelacije za uzorke pletiva

Smjer istezanja pletiva	djelomično platirni preplet 1+1	potpuno platirni preplet
u smjeru redova očica (poprečno)	$F=0{,}0091 \cdot \Delta L^3 – 0{,}232 \cdot \Delta L^2 + 1{,}6142 \cdot \Delta L$; r=0,99	$F=-0{,}7998 \cdot \Delta L^4 + 9{,}5958 \cdot \Delta L^3 – 20{,}18 \cdot \Delta L^2 + 17{,}711 \cdot \Delta L$; r=0,99
u smjeru nizova očica (uzdužno)	$F=0{,}0138 \cdot \Delta L^3 – 0{,}1946 \cdot \Delta L^2 + 1{,}1237 \cdot \Delta L$; r=0,99	$F=-0{,}5989 \cdot \Delta L^4 + 7{,}1427 \cdot \Delta L^3 – 12{,}249 \cdot \Delta L^2 + 13{,}852 \cdot \Delta L$; r=0,99

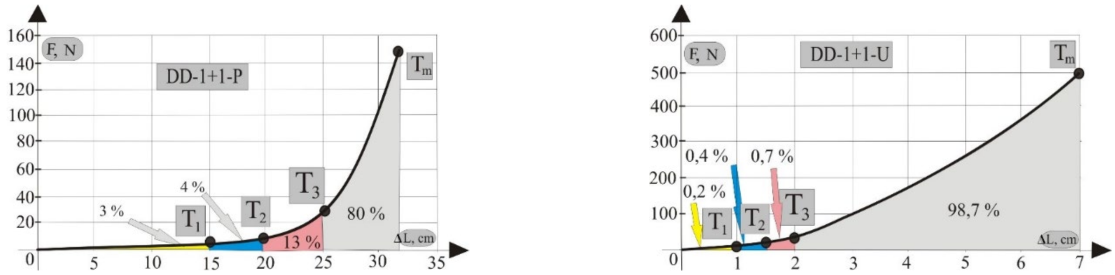
*objašnjenje simbola: F – vlačna sila; ΔL – istezanje, r - koeficijent korelacije

Istezanje pletiva u smjeru redova očica znatno je veće nego u smjeru nizova očica pa se opisuje polinomnom funkcijom III. stupnja (Tab. 1). dok je istezanje pletiva u smjeru nizova očica znatno manje pa se opisuje polinomnom funkcijom IV. stupnja. Kod istezanja djelomično platirnog pletiva 1+1 u smjeru redova očica istezanje do prekida iznosi 338 %, a najveća sila koja je približno jednaka sili prekida iznosi 148 N.

Tablica 2: Iznosi značajnih parametara i koordinate značajnih točaka

Smjer istezanja pletiva	Ti (istezanje, cm; sila, N)	Rad ispod dijagrama sila/istezanje (W, N·cm)
djelomično platirno pletivo		
u smjeru redova očica	T1 (15; 4,6), T2 (20; 13), T3 (25; 36) i Tm (33,8; 148)	899
u smjeru nizova očica	T1 (1; 5), T2 (1,5; 10), T3 (2; 21) i Tm (7; 500)	1128
(potpuno) platirno pletivo		
u smjeru redova očica	T1 (8; 3,8), T2 (15; 20), T3 (18; 37) i Tm (28,3; 189)	1199
u smjeru nizova očica	T1 (1,3; 11), T2 (2,5; 50), T3 (3; 75) i Tm (8; 535)	1707

Istezanje pletiva u smjeru nizova očica je znatno manje i iznosi svega 70 % pri čemu je najveća sila pri istezanju znatno veća nego kod istezanja u smjeru redova očica i iznosi 500 N. Kod potpuno platirnih pletiva u svaki red se upliću dvije pređe pa je uloženi rad pri istezanju ovakvog pletiva veći nego kod djelomično platirnog pletiva 1+1 (Tab. 2). Zbog veće gustoće pletiva istezanje u smjeru redova očica iznosi 283 %. Prekidna sila je znatno veća kod djelomično platirnog pletiva i iznosi 189 N. Istezanje pletiva u smjeru nizova očica iznosi 80 % i nešto je veće nego kod djelomično platirnog pletiva 1+1 gdje iznosi 70 %. Jedan od ciljeva platiranja je da se dobije punija i čvršća struktura pletiva pa po toj osnovi platirno pletivo ima najveću registriranu silu prekida pletiva koja iznosi pri istezanju u smjeru nizova očica 535 N.



a b

Slika 1: Dijagrami sila/istezanje do prekida kulirnog nedorađenog desno-desnog djelomično platirnog pletiva 1+1 s udjelima uloženog rada pri istezanju pletiva: a) istezanje u smjeru redova očica - poprečno, b) istezanje u smjeru nizova očica – uzdužno; ordinata – sila F, (N) i apscisa, istezanje ΔL, (cm)

Iznos uloženog rada od početka istezanja pletiva pa do tjemena krivulje (od 0 do točke T2) iznosi svega 7 % od ukupno uloženog rada (899 N·cm). Od tjemena krivulje (točka T2) do početka plastične deformacije (točka T3) iznos uloženog rada iznosi 13 % od ukupno uloženog rada. Nakon početka trajne deformacije pletiva pri istezanju u smjeru redova očica (od točke T3), rezultati istezanja pletiva u izradi odjevnih predmeta više nisu zanimljivi. Međutim, potrebno je navesti da je uloženo svega 20 % rada za istezanje pletiva do početka trajne deformacije. Ostali rad se ulaže pri izrazitim opterećenjima pletiva pri čemu dolazi do pucanja niti u strukturi pletiva, a time stvaranja rupica u pletivu što narušava izgled i upotrebu odjevnog predmeta. Istezanje pletiva u smjeru nizova očica je znatno manje pa je iznos uloženog rada do početka trajne deformacije (do točke T3) samo 1,3 %, a ostalih 98,7 % se utroši u trajnoj deformaciji pletiva.

4. Zaključci

Analizirana pletiva prikladna su za izradu majica s dugačkim rukavima, a izrađena su u dva slična temeljena platirna prepleta koji omogućuju različita vlačna svojstva u smjeru redova očica (poprečno) i nizova očica (uzdužno). Iznos ukupno uloženog rada za istezanje djelomično platirnog pletiva u smjeru redova očica (poprečno) do početka trajne deformacije je 899 N·cm. dok je iznos ukupno uloženog rada za istezanje istog pletiva u smjeru nizova očica (uzdužno) 1128 N·cm. Udio rada do kraja elastične deformacije djelomično platirnog pletiva iznosi 0,2 do 3,5 %, a do početka plastične deformacija 1,3 do 20 % od ukupnog rada.

5. Literatura

[1] DIN 53835-2: 1981 *Testing of textiles; determination of the elastic behaviour of single and plied elastomeric yarns by repeated application of tensile load between constant extension limits*

[2] Penava, Ž. i sur.: Deformacijske karakteristike tkanine pri različitim smjerovima djelovanja jednoosnog vlačnog opterećenja, *Tekstil*, **70** (2021) 1-3, str. 1-11, ISSN 1849-1537

[3] Stojanović, S. i Geršak, J.: Tekstilne strukture namijenjene za sportsku odjeću, *Tekstil*, **68** (2019) 4-6, str. 55-71, ISSN 1849-1537

[4] Katić Križmanić, I. i Salopek Čubrić, I.: Tehnike kreativnog mišljenja u istraživanju materijala za povećanu udobnost u sportu, *Tekstil*, **69** (2020) 1-3, str. 45-53, ISSN 1849-1537

[5] HRN EN ISO 13934-1:2013 *Tekstil - Vlačna svojstva plošnog tekstila - 1. dio: Određivanje maksimalne sile i istezanja pri maksimalnoj sili metodom trake*

Ana Kalazić

Životopis

Rođena 1993. god. u Zagrebu. Nakon završetka opće Gimnazije Tituša Brezovačkog u Zagrebu, akad. god. 2012./2013. upisuje studij Računovodstva i financija na Ekonomskom fakultetu u Zagrebu gdje stječe zvanje stručne prvostupnice poslovne ekonomije. God. 2015./2016. upisuje preddiplomski studij Tekstilne tehnologije i inženjerstva na Tekstilno-tehnološkom fakultetu u Zagrebu te 2019./2020. god. diplomira i stječe zvanje magistra inženjerka tekstilne tehnologije i inženjerstva. U razdoblju od 2020.-2023. god. radi na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu kao stručni suradnik na projektu IRI II „Razvoj multifunkcionalne negorive tkanine za dualnu namjenu“, financiranog od EU iz Europskog fonda za regionalni razvoj. U akad. god. 2020./2021. upisuje poslijediplomski doktorski studij Tekstilna znanost i tehnologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu.

Naslov teme doktorskog rada

Studijski savjetnik doc. dr. sc. Snježana Brnada

Datum obrane doktorskog rada

UTJECAJ STRUKTURE NA HRAPAVOST POVRŠINE TKANINA

Ana KALAZIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
Zagreb, ana.kalazic@ttf.unizg.hr

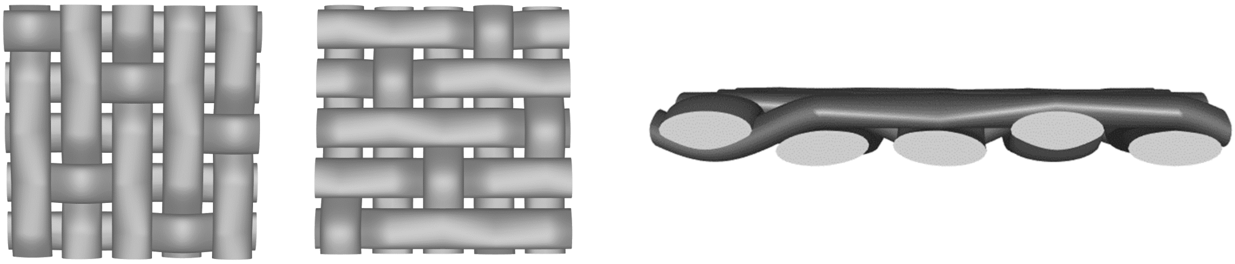
Sažetak: *Prilikom kupovine, kupci često dodiruju tkaninu, a dojam koji tkanina ostavlja, zajedno s ostalim kriterijima, ključan je faktor u donošenju odluke o kupnji. Zbog toga proizvođači ulažu napore u poboljšanje taktilnih svojstava tkanina, pridajući im veliku važnost. Postizanje željenih karakteristika tkanine odvija se kroz pažljiv odabir veza, gustoće, finoće niti, sirovine i dizajna. Tehnološki napredak obuhvaća sve faze, uključujući proizvodnju i prerade vlakana, izrade niti, njezine pripreme za tkanje, proces tkanja, površinske obrade i oblikovanja u konačan proizvod.*

1. Uvod

Tehnički tekstil danas je prisutan u svim područjima ljudskog života i gotovo da i ne postoji grana industrije u kojoj se ne primjenjuje. Proizvodnja tehničkog tekstila smatra se vrlo uspješnim sektorom tekstilne industrije koji se vrlo brzo razvija i napreduje. Tehnički tekstil obuhvaća široki spektar materijala s posebnom namjenom, uključujući tkanine za domaćinstvo, poput onih za posteljno rublje. Ove tkanine često kombiniraju pamučna s poliesterskih vlaknima, pružajući funkcionalnost i udobnost. Svojstva vlakana prenose se na svojstva pređa, zatim na tkaninu koja se naknadnim obradama poboljšava. Veću udobnost, prozračnost i smanjene alergijske reakcije pružaju tkanine od prirodnih vlakana, dok umjetna vlakna pružaju veću čvrstoću tkanine. [1,2]. Pri analizi uzoraka tkanina u ovom radu značajnu ulogu ima uređaj za objektivno vrednovanje senzorske udobnosti tekstilnih materijala (eng. *Fabric touch tester*), tt. SDL Atlas.

2. Eksperimentalni dio

U eksperimentalnom dijelu rada korišteni su uzorci tkanina posteljnog rublja. 14 uzoraka otkano je 100 % pamučnom pređom u atlas vezu (slika 1). Uzorci su otkani u četiri različite razine uzorkovanja u tkanju, i to: glatki, prugasti, karirani i žakardski uzorak te u različitim bojama.



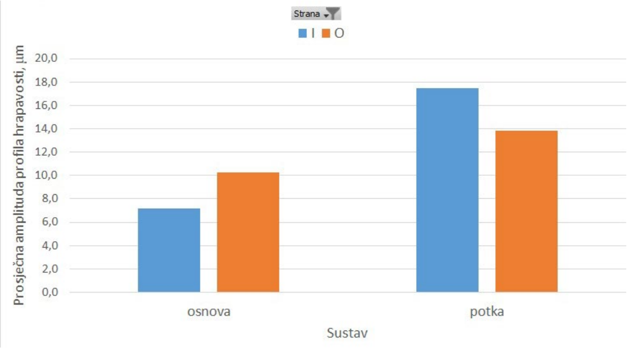
a b c

Slika 1: Simulacija atlas veza korištene tkanine: a) Lice; b) Naličje, c) Provezivanje niti

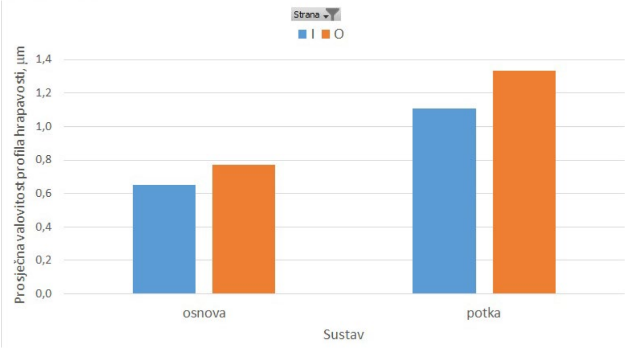
Uzorci tkanina obrađeni su s doradnim sredstvom te su podvrgnuti ispitivanju na uređaju za objektivno vrednovanje senzorske udobnosti tekstilnih materijala (eng. *Fabric touch tester*), tt. SDL Atlas. Fokus ovog istraživanja bio je usmjeren na evaluaciju parametara hrapavosti (prosječne amplitude profila hrapavosti te prosječna valovitost profila hrapavosti) [3, 4].

3. Rezultati i rasprava

Radi utvrđivanja utjecaja dorade na hrapavost površine, analizirani su podaci dobiveni ispitivanjem na Uređaju za objektivno vrednovanje senzorske udobnosti tekstilnih materijala.
Provedena je usporedba prosječne amplitude profila hrapavosti te prosječna valovitost profila hrapavosti u smjeru osnove i potke na licu i naličju tkanine.



a



b

Slika 2: a) Prosječna amplituda profila hrapavosti; b) Prosječna valovitost profila hrapavosti

Hrapavost je definirana usko raspoređenim nepravilnostima, dok se valovitost očituje u široko raspoređenim nepravilnostima na površini tkanine. Na grafu na slici 2 a vidljivo je kako tkanina u smjeru osnove na licu ima veću prosječnu amplitudu profila hrapavosti, dok u smjeru potke ima manju u odnosu na naličje tkanine u istom smjeru.

Što se tiče prosječne valovitosti (Slika 2b) profila hrapavosti i u smjeru osnove i u smjeru potke veća je prosječna valovitost na naličju tkanine u oba ispitivana smjera.

4. Zaključci

Prema navedenim rezultatima, na licu tkanine duž osnove razvidne su veće amplitude u odnosu na naličje tkanine u istom smjeru što je uvjetovano dominacijom jednog sustava niti na licu, a drugog na naličju tkanine. Kod smjera potke situacija je obrnuta. Kod prosječne valovitosti profila hrapavosti tkanine, na licu postoje učestalije i izraženije promjene.

Zbog kompleksnosti strukture tkanina treba se uzeti u obzir, odnosno ispitati više proizvoljnih smjerova kako bi se dobila konačna slika hrapavosti tkanine.

5. Literatura

[1] Kovačić, S.; Schwarz, I. & Brnada, S.: *Tehničke tkanine*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, 978-953-7105-78-5, Zagreb (2020)

[2] Nawab, Y.; Hamdani, S.T.A. & Shaker, K: *Structural Textile Design: Interlacing and Interlooping.* CRC Press, 9781315390406, Boca Raton (2017)

[3] Akgun, M.: Assessment of the surface roughness of cotton fabrics through different yarn and fabric structural properties, *Fibers and Polymers*, **15** (2014), pp. 405-413

[4] Mao, N.; Wang Y.; & Qu, J.: Smoothness and roughness: characteristics of fabric-to-fabric self-friction properties, *The Proceedings of 90th Textile Institute World Conference,* The 90th Textile Institute World Conference, str. 125-134, ISBN: 978-1-5108-4079-9, Poznan, Poland, Travanj 2016, The Textile Institute, Manchester, United Kingdom (2016)

Franka Karin

Životopis	Franka Karin rođena 1986. god. u Zagrebu. U lipnju 2012. god. stekla je akademski naziv: Magistra inženjerka tekstilne tehnologije i inženjerstva na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, smjer: Industrijski dizajn odjeće. Od listopada 2017. god. zaposlena je kao asistent na Sveučilištu u Zagrebu Tekstilno- tehnološkom fakultetu, na Zavodu za dizajn tekstila i odjeće. U prosincu 2017. god. upisala je poslijediplomski doktorski studij Tekstilna znanost i tehnologija. Područje istraživanja usmjerila je na održivi dizajn i metode dizajniranja i izrade odjeće prema konceptu bez otpada.
Naslov teme doktorskog rada	
Studijski savjetnik	izv. prof. dr. sc. Blaženka Brlobašić Šajatović
Datum obrane doktorskog rada	

RAZVOJ OSNOVNIH SILUETA ŽENSKE ODJEĆE PRILAGOĐENE TEMELJNIM POSTAVKAMA ODRŽIVOSTI U MODI

Franka KARIN

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, franka.karin@ttf.unizg.hr

Sažetak: *Modna industrija snosi veliku odgovornost za stvaranje tekstilnog otpada u svijetu i jedna je od najvećih zagađivača okoliša zbog čega se probudila svijest o održivom razvoju. Održivi razvoj važan je za proizvodne procese kako bi se očuvala ekologija i spriječilo iscrpljivanje prirodnih resursa. Održiva moda poštuje aspekte održivog razvoja i teži prema ekološki prihvatljivom dizajnu u proizvodnji u kojem se racionalno iskorištava tkanina. Cilj rada je istražiti dosadašnje metode koncepta bez otpada (eng. zero waste) i predložiti novu metodu u procesu dizajniranja i krojenja odjeće kojom se postiže maksimalno iskorištenje tkanine, u svrhu smanjenja ili potpune eliminacije ostataka od krojenja. Metoda će se primijeniti na osnovnim siluetama ženske odjeće.*

1. Uvod

Koncept bez otpada (engl. zero waste) je metoda koja se razvila kao odgovor na brzu modu koja je svojim djelovanjem dovela do prekomjerne količine tekstilnog otpada i do potrebe za novim rješenjima zbog neodrživih praksi modne industrije. Koncept bez otpada u dizajnerskom procesu i u proizvodnji odjeće minimalizira ili eliminira tekstilni otpad. U dosadašnjem pristupu konstrukcije, modeliranja i krojenja odjeće otpad od krojenja iznosi od 15 % do 25 %. Takva proizvodnja nije održiva jer zagađuje okoliš, koristi jeftine materijale i slabo plaćenu radnu snagu. Protuteža brzoj modi je spora moda koja ne podliježe brzim promjenama modnih trendova već se bazira na tradicijskom dizajnu i kvalitetnoj izradi što produžuje životni vijek proizvoda [1,2]. Koncept bez otpada svoj zamah u modi bilježi od početka 2010. godine kao rezultat ekološkog, gospodarskog i političkog ozračja. Okarakteriziran je kao eksperimentalna metoda koja se etički odnosi prema ekologiji u svrhu dugoročne održive proizvodnje [3]. U konceptu bez otpada, unaprijed se promišlja o iskorištenju tkanine kako ne bi došlo do rasipanja tekstila već u samoj proizvodnji, a tu veliku odgovornost imaju dizajneri. Najznačajnije rezultate u dizajnu odjeće prema konceptu bez otpada ostvarili su modni dizajneri Timo Rissanen i Holly McQuillan. Postavili su dobre temelje za daljnje istraživanje i eksperimentiranje [4].

2. Istražene metode koncepta bez otpada

Konceptu bez otpada primarni cilj je što bolje iskorištenje tkanine. Važni su tehnički i estetski elementi s pomoću kojih se odjevni predmet uklapa u dimenzije tkanine, što nije slučaj u dosadašnjoj praksi. Potrebno je u procesu krojenja razmotriti najpovoljnije opcije uklapanja krojnih dijelova kako bi se eliminirao otpad od krojenja [5]. Dizajneri Timo Rissanen i Holly Mcquillan eksperimentalno su pristupili održivom dizajnu odjeće prema smjernicama koncepta bez otpada s ciljem da je otpad minimalan ili ga uopće nema. Pri tome navode dvije vrste tekstilnog otpada. Oni naglašavaju da je u metodi potrebno zadovoljiti pet osnovnih kriterija tijekom dizajnerskog procesa. To su: estetika, pristalost, trošak, koliki je ostatak od tkanine i mogućnost proizvodnje. Izbjegavanje tekstilnog otpada ne smije utjecati na estetiku i pristalost odjevnog predmeta [4]. Dosadašnja istraživanja donose razna inovativna rješenja u dizajnu koji se uspješno primjenjuju i ostvaruju dobre rezultate [6]. Pristupaju dizajnu primjenom inovativnih tehnika u dizajniranju i krojenju odjeće pri čemu su usredotočeni na geometrijska i matematička načela. Tako dolaze do krojnih dijelova koji optimalno iskorištavaju tkaninu i smanjuju otpad. Metode uglavnom primjenjuju uklapanje krojnih dijelova na širine tkanine koje nisu standardne, krojni dijelovi uklapaju se u različitim smjerovima, ne prati se smjer osnove i uglavnom se koristi pletivo što rezultira voluminoznim odjevnim predmetima neprepoznatljivih osnovnih odjevnih silueta različitih oblika ženske odjeće.

3. Plan istraživanja i metodologija nove predložene metode koncepta bez otpada

Područje održive mode neprestano se razvija i sukladno tom razvoju dizajneri u svojim istraženim različitim metodama teže prema smanjenju otpada u modnoj industriji kao odgovor na ekološke izazove modne industrije, koja je poznata po svojim rastrošnim praksama. Analizom do sad istraženih metoda u dizajnu odjeće prema konceptu bez otpada ustanovljeno je da odjevni predmeti uglavnom ne odgovaraju osnovnim siluetama ženske odjeće stoga će se predložiti nova metoda koncepta bez otpada za dizajn i konstrukciju osnovnih silueta koja zadovoljava pet osnovnih kriterija dizajnerskog procesa. Osnovni kriteriju su: estetika, pristalost, trošak, ostatak od tkanine pri iskrojavanju i mogućnost proizvodnje. Novom metodom razvit će se postupak za dobivanje temeljnih krojeva prema konceptu bez otpada i njihova prilagodba osnovnim siluetama ženske odjeće. Polazište za postupak temeljnih krojeva osnovnih silueta ženske odjeće je mreža koja je određena širinom tkanine i glavnim tjelesnim mjerama dobivenih matematičkim izrazima. Matematičkim izrazima definirat će se površine krojnih dijelova i duljine kontura krojnih dijelova. Za svaku pojedinu osnovnu siluetu ženske odjeće izradit će se temeljni kroj prema temeljnoj konstrukciji i prema novoj metodi. Računalno će se izraditi krojne slike, izračunati i usporediti dobiveno iskorištenje tkanine. Temeljni krojevi dobiveni novom metodom prema odabranom dizajnu i osnovnim siluetama ženske odjeće modelirat će se. Konstrukcijski elementi (ušici, šavovi, nabori) implementirat će se na području struka i bokova, duljine ramena i duljine odjevnog predmeta kako bi se zadovoljila pristalost odjeće i naglasila pojedina osnovna silueta ženske odjeće.

4. Zaključak

Nove metode u okviru održivog razvoja razvile su se iz potrebe da se osvijesti važnost održivih smjernica u modi i minimalizira tekstilni otpad. Koncept bez otpada jedan je od primjera koji zahtijeva kontinuirani rad i istraživanje kako bi se ostvarili dobri rezultati u skladu s održivom modom u dizajnerskom i proizvodnom procesu. Metodama koncepta bez otpada uz primjenu novih tehnologija moguće je izraditi odjevne predmete koji će minimalizirati ili eliminirati tekstilni otpad, a da se pri tome zadrže estetski kriteriji i pristalost prema osnovnim siluetama ženske odjeće te dugoročno vrati ugled tekstilnoj industriji uz brigu za okoliš.

5. Literatura

[1] McQuillen, H.: *Zero Waste design thinking*, University of Boras, ISBN: 978-91-88838-33-9, (2019)

[2] Niinimäki, K.: *Sustainable fashion: New approaches. Aalto University publication series*, Aalto ARTS Books, ISBN 9789526055732, Helsinki, Finland, (2003)

[3] Hsiou-Lien, C.; Davis Burns, L.: Environmental Analysis of Textile Products. *Clothing and Textiles Research Journal*, **24** (2006) 3, pp. 248-261, https://doi.org/10.1177/0887302X06293065

[4] Rissanen, T.; McQuillen, H.: *Zero-waste Fashion Design*, Bloomsbury Publishing, ISBN 9781350094833, London, New York, (2016)

[5] Baumgarten, L.; Wilson J., Carr F.: *Costume Close Up: Clothing Construction and Pattern*, 1750-1790. The Colonial Williamsburg Foundation, ISBN 10: 0896762262, Virginia, (1999)

[6] Hye-Won, L.: A systematic review of zero waste fashion construction techniques. *The 91st Textile Institute World Conference: Integrating Design with Sustainable Technology*, University of Leeds, July 2018, Leeds, UK, (2018)

Ines Katić Križmančić

Životopis	Ines Katić Križmančić rođena je u Zagrebu 1965. god. Diplomski studij završila je na Tekstilno-tehnološkom fakultetu u Zagrebu i stekla zvanje mag. ing. des. text. Poslijediplomski doktorski studij Tekstilna znanost i tehnologija upisala je 2019/2020. god. Trenutno ima više od trideset godina iskustva u tekstilnoj industriji, koje je stekla radeći kao tekstilni i odjevni dizajner, tehnolog te voditelj tekstilnog i kožarskog klastera. Njezin znanstveni interes vezan je uz temu inovativnih tekstilnih materijala za povećanje udobnosti sportske odjeće.
Naslov teme doktorskog rada	Razvoj i karakterizacija materijala za nogometnu odjeću radi optimizacije udobnosti i trajnosti
Mentor	prof. dr. sc. Ivana Salopek Čubrić
Datum obrane doktorskog rada	

PRIJEDLOG DIZAJNA FUNKCIONALNOG SPORTSKOG ODJEVNOG PREDMETA S OBZIROM NA SVOJSTVA PROJEKTIRANIH PLETIVA

Ines KATIĆ KRIŽMANČIĆ

Sveučilište u Zagrebu Tekstilno tehnološki fakultet u Zagrebu, Prilaz baruna Filipovića 28a, Zagreb, ikatickri@ttf.hr

Sažetak: *Funkcije odjeće mogu biti raznolike. Velik je naglasak na istodobnom postizanju dviju značajki, zaštiti tijela i poboljšanju funkcija tijela. Na tržištu tekstila postoje permanentni zahtjevi za proširenjem postojećih i razvojem novih inovativnih rješenja. Kako bi se što uspješnije udovoljilo tim zahtjevima znanstvenici kontinuirano rade na razvoju novih funkcionalnih materijala posebice u segmentu sportske odjeće koji bilježi kontinuirani rast. Stoga su u ovome radu ispitana svojstva projektiranih pletiva u cilju izrade prijedloga dizajna sportskog odjevnog predmeta.*

1. Uvod

Prilikom procesa dizajniranja odjeće fokus prije svega treba biti na njezinoj svrsi, a onda na njezinoj estetskoj privlačnosti. Dizajn funkcionalne odjeće istodobno treba pružiti odgovore na pitanja o: zaštiti tijela, sigurnosti, zdravlju, poboljšanju učinkovitost i unapređenju tjelesnih funkcija. Segment funkcionalne odjeće koji bilježi kontinuiran rast je sportska odjeća. Na učinkovitost sportske odjeće utječu termodinamička, aerodinamička i hidrodinamička svojstva korištenih materijala i njihovih kombinacija. Sportska odjeća mora biti projektirana na način da sportaša podržava u sportskoj aktivnosti, osigurava mu maksimalnu potporu i pruža maksimalnu udobnost i zaštitu.

2. Eksperimentalni dio

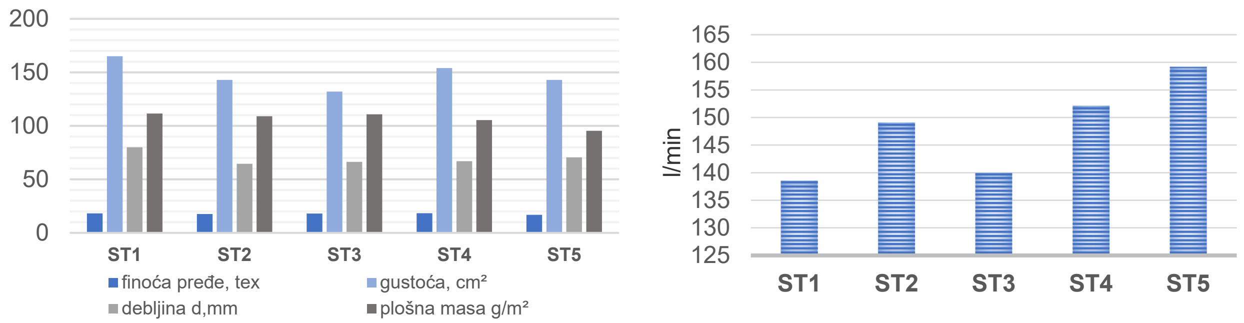
U ovom radu ispitan je set od pet projektiranih pletiva ST1-ST5, desno-lijevog kulirnog prepleta, izrađenih od poliamidne pređe. Unutar eksperimentalnog dijela istraženi su parametri pletiva i propusnost zraka. Rezultati ispitanih svojstava važni su za percepciju udobnosti odjevnog predmeta i pružili su smjernice za izradu prijedloga dizajna ženskog sportskog topa.

2.1. Metode ispitivanja

U eksperimentalnom dijelu istražena se sljedeća svojstva: finoća pređe, gustoća pletiva, debljina pletiva, plošna masa i propusnost zraka. Prije ispitivanja uzorci su kondicionirani u standardnoj ispitnoj atmosferi. Finoća pređe određena je pomoću masenog sustava i izražena ju u jedinici tex. Gustoće pletiva definirana je standardom HRN EN 1497:2008 [1]. Pošto je set dizajniranih pletiva visoke finoće, gustoća je mjerena pomoću digitalnog mikroskopa Dino-Lite PRO HR. Debljina pletiva određeno je i opisana ISO standardom 5084 [2], a za ispitivanje je korišten Debljinomjer marke DM-2000. Određivanje mase pletiva definirano je normom HRN ISO 3801:2003 [3]. Za mjerenje je korištena precizna analitička vaga proizvođača Kern ALJ 220-4. Propusnost zraka izmjerena je pomoću uređaj Air Tronic, proizvođača Mesdan S.p.A. a ispitivanje je određeno standardom SS-NE ISO 9237- 1995 [4].

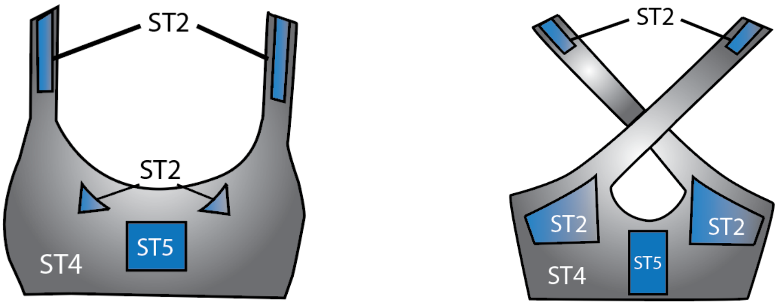
3. Rezultati i rasprava

Jedno je od najvažnijih svojstava koje utječe na udobnost materijala za izradu sportske odjeće odnosi se na parametre pletiva i propusnost zraka. Rezultati ispitivanja prikazani su i sažeti na sl. 1.



Slika 1. Usporedni prikaz rezultata mjerenja a) finoće, gustoće, debljine i plošne mase pletiva ST1-ST5 b) propusnosti zraka za pletiva ST1-ST5

Pošto je razlika u finoćama pređa, izabranih pletiva, relativno mala, parametar koji najznačajnije utječe na plošnu masu i debljinu pletiva je gustoća pletiva. Najvišu propusnost zraka prikazuju pletiva ST5, ST4 i ST2, ujedno i pletiva najmanjih masa i debljina. Prijedlog dizajna ženskog sportskog topa, sl. 2., izrađen je s obzirom na ispitana svojstva projektiranih pletiva i dobivenih rezultata, apsolutnih i regionalnih stopa znojenja ženskog tijela tijekom pojačane fizičke aktivnosti, koje je u svom radu mapirao i publicirao Havenith sa suradnicima [5]. Najviše stope znojenja nalaze se u predjelima između lopatica, prsiju i na dijelovima ramena.



Slika 2. Prijedlog dizajna ženskog sportskog grudnjaka s obzirom na ispitana svojstava parametara pletiva ST1-ST5

4. Zaključak

Od svih ispitanih pletiva najoptimalniju kombinaciju svih svojstava, za izradu ženskog sportskog topa, ima pletivo ST4, dok su pletiva ST5 i ST2 optimalna za izradu dijelove grudnjaka koji naliježu na kožu u predjelima koja pokazuju visoku stopu tjelesnog znoja nastalu tijekom izraženije fizičke aktivnosti. Daljnji znanstveni napori trebali bi se usmjeriti na proučavanje niza ostalih parametara koji mogu značajno utjecati na udobnost i trajnost ženskog sportskog grudnjaka.

Zahvala

Ovaj rad u potpunosti je podržala Hrvatska zaklada za znanost u sklopu projekta HRZZ IP- 2020-02-5041 Tekstilni materijali za povećanu udobnost u sportu – TEMPO, voditeljice prof. dr. sc. Ivane Salopek Čubrić.

5. Literatura

[1] HRN EN 1497:2008 *Tekstilije - Pletiva - određivanje broja očica po jedinici duljine i površine*
[2] TS 7128 EN ISO 5084: 1996 *Određivanje debljine tekstilnih proizvoda*
[3] HRN ISO 3801:2003 *Tekstil - Tkanine - Određivanje mase po jedinici duljine i mase i po jedinici površine*
[4] ISO 9237:1995 *Textiles - Determination of the permeability of fabrics to air*
[5] Smith, C. J.; Havenith, G.: Body Mapping of Sweating Patterns in Athletes: A Sex Comparison, *Medicine and Science in Sports and Exercise*, **44** (2012) 12, pp.2350–236

Ana Kiš

Životopis	Rođena je 1985. god. u Čakovcu. Po završetku srednje škole 'Rudarska i kemijska škola Varaždin', upisuje Fakultet kemijskog inženjerstva i tehnologije u Zagrebu na kojem 2010. god. brani diplomski rad te stječe zvanje diplomirani kemijski inženjer. Po završetku studija zapošljava se u tvrtki Čateks d.d. 2018. god. upisuje poslijediplomski sveučilišni studij notpornosta Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Od 2021. god. zapošljava se u tvrtki Franck d.d. na poziciji Analitičara kontrole, a od siječnja 2022. god. je zaposlena u tvrtki Vertiv Croatia d.o.o. na radnom mjestu Quality Suppliers Engineer.
Naslov teme doktorskog rada	Razvoj novih struktura negorivih tkanina s optimalnim omjerom toplinske zaštite i udobnosti
Mentor	prof. dr. sc. Stana Kovačević
Datum obrane doktorskog rada	

UTJECAJ STRUKTURA 3D TKANINA NA OTPORNOST NA RADIJACIJSKU TOPLINU I TERMOFIZIOLOŠKA SVOJSTVA

Ana KIŠ

Vertiv Croatia d.o.o., Oreškovićeva ul. 6n-2, 10000 Zagreb, akis@ttf.hr

Sažetak: *Cilj istraživanja je istražiti utjecaj složenih struktura 3D tkanina na otpornost radijacijske topline (EN ISO 6942:2022) i otpornost prolazu vode pare (HRN EN ISO 11092:2014) - dva značajna parametra za tkanine za toplinsku zaštitnu odjeću. Šest uzoraka 3D-tkanine tkano je od iste osnove, sa tri gustoće potke i u dva različita tkanja. Rezultati su pokazali da je uzorak 2pp dao nabolje rezultate toplinske otpornosti na radijaciju i otpornost prolazu vode pare. Struktura uzorka zaslužna je za ove rezultate, jer zarobljen zrak u džepovima pora tkanina osim što daje veću otpornost na radijacijsku toplinu, nastali nabori daju tkanini i bolja fiziološka svojstva.*

1. Uvod

Različite vrste tkanja rezultiraju različitim parametrima strukture tkanine kao što su debljina tkanine, plošna masa i zaštita od zračenja topline. U slučaju otpornosti tkanine na zračenje topline može se pronaći značajna razlika među strukturama tkanja te se zapravo dokazalo da najbolji učinak u smislu toplinske zaštite daju uzorci složene tkane strukture. Dvodimenzionalne strukture tkanja: platno tkanje, atlas tkanje i keper tkanje daju manju otpornost na toplinsku radijaciju [1]. 3D tkanine koje imaju naglašenu treću dimenziju (debljina), dvije tkanine vežu zajedno s pojedinačnim osnovama ili se stvaraju pređe potke istovremeno stvarajući jedinstvenu cjelovitu strukturu. Sastoje se od dvije skupine pređe: osnove, potke i prepletene pređe osnova ili potka, koji povremeno spajaju gornje i donje tkanine [2,3]. Poprečni presjek 3D tkanine obilježen je oznakama "pp" i "tp". Mikroskopska analiza uzoraka obrađena u radu [4] pokazuje da gornja tkanina, koja čini lice tkanine od aramidnih vlakana veće gustoće, ima ujednačenu površinu. Donja tkanina od pamuka i modakrila manje gustoće ima naboranu površinu, stvorenu preplitanjem s gornjom tkaninom. Površinski nabori tkanine, nastali tkanjem, stvaraju razmak između tkanina koji je ispunjen zrakom. Povećanjem gustoće potke nabori postaju gušći i češći, sa manjim volumenom zraka, što utječe na volumen, debljinu i težinu tkanine. Nabori pp tkanina izraženiji u donosu na tp uzorake. U ovom radu se istražilo što na koji način takva struktura 3D tkanina utječe na dva bitna parametra sa aspekta zaštite od topline.

2. Eksperimentalni dio

Za istraživanje je korišteno šest 3D tkanina od iste osnove sa tri gustoće potke i u dva različita tkanja (platno i keper 3/1), Tab. 1. Sastav pređe gornje i donje tkanine osnove i potke je isti kod svih uzoraka. Gornja tkanina: osnova – 95 % M-aramid Conex NEO / potka – 5 % P-aramid Twaron. Donja tkanina: osnova – 45 % dugovlaknati češljani pamuk / potka – 55 % modkril Sevel FRSA/L.

Tablica 1. Parametri uzoraka 3D tkanina

Uzorak	Tkanina	Vez gornja / donja tkanina	Gustoća osnova - potka (niti/cm)	Finoća pređe (tex)		Plošna masa (g/m²)	Debljina (mm)
				Osnova	Potka		
1pp[1]	Gornja	Platno	40 - 35	12,5×2	16,7×2	356	0,63
	Donja	Platno	20 - 17	12,5×2	25		
2pp	Gornja	Platno	40 - 32	12,5×2	16,7×2	336	0,61
	Donja	Platno	20 - 16	17×2	25		
3pp	Gornja	Platno	40 - 30	12,5×2	16,7×2	303	0,59
	Donja	Platno	20 - 14	17×2	25		
1tp[2]	Gornja	Keper 3/1	40 - 35	12,5×2	16,7×2	316	0,61
	Donja	Platno	20 - 17	17×2	25		
2tp	Gornja	Keper 3/1	40 - 32	12,5×2	16,7×2	293	0,58
	Donja	Platno	20 - 16	17×2	25		
3tp	Gornja	Keper 3/1	40 - 30	12,5×2	16,7×2	287	0,58
	Donja	Platno	20 - 14	17×2	25		

*Presjek tkanine u smjeru potke s oznakom „pp“ i oznakom „tp“

3. Rezultati i rasprava

Prikaz rezultata ispitivanja radijacijske topline, Q_c (EN ISO 6942:2022) i otpornosti prolazu vode pare R_{et} (HRN EN ISO 11092:2014), tab. 2.

Tablica 2. Prosječne vrijednosti propuštenog toplinskog toka, Q_c (kW/m^2) i vrijednosti otpornosti prolazu vode pare, R_{et} (m^{2}Pa/W)

Uzorci	1pp	2pp	3pp	1tp	2tp	3tp
Q_c (kW/m^2)	10,33	10,02	10,17	10,02	10,33	10,50
R_{et} (m^{2}Pa/W)	5,02	5,39	5,11	6,18	5,73	4,95

3D-tkanine 2pp i 1tp pružile su najveću otpornost na radijacijsku toplinu, propušteni toplinski tok 10,02 kW/m^2, iako je plošna masa tkanine 1tp manja za 6 % od plošne mase tkanine 2pp. Uzorak 3tp pružao je najmanju otpornost na radijacijsku toplinu – Q_c = 10,50 kW/m^2 sa faktorom prijenosa topline od 0,5250. Otpornost prolazu vode pare, R_{et} kreće se u rasponu od 4,94 m^{2}Pa/W za 3D tkaninu 3tp do 6,18 m^{2}Pa/W za 3D tkaninu 1tp. Najmanji otpor vodenoj pari, R_{et}, imao je uzorak 3tp sa 4,95, dok je najveći R_{et} pružao uzorak 1tp sa vrijednošću od 6,18 m^{2}Pa/W. Najmanja vrijednost R_{et} = 4,95 m^{2}Pa/W pripada uzorku 3pt sa najmanjom plošnom masom od 287 g/m^2. Ono što je zanimljivo što sljedeća vrijednost R_{et} = 5,02 m^{2}Pa/W pripada uzorku 1pp sa najvećom plošnom masom od 356 g/m^2. Općenito, uzorci 3D tkanina većih plošnih masa (1pp, 2pp, 3pp) kod kojih je gornja tkanina od aramidnih vlakana u platnu vezu te donja tkanina izrađena od modakrilnih vlakana također u platnu vezu imaju manje vrijednosti R_{et}, tj. pružaju manju otpornost prolazu vode pare od 3D tp tkanina, što znači da su samim time i ugodnije za nošenje. Tkanina 1pp koja ima najveću plošnu masu od 356 g/m^2, pripada joj Q_c 10,33 kW/m^2. Dok uzorci 2pp i 3pp sa manjom plošnom masom pružaju bolju otpornost na radijacijsku toplinu, tj. bolju vrijednost Q_c od 10,02 kW/m^2, tj. 10,17 kW/m^2.

4. Zaključci

Ako promatramo pp uzorke, uzorak 2pp je dao nabolje rezultate Q_c=10,02 m^{2}K/W. Najmanju vrijednost R_{et} dao je uzorak 1pp sa najvećom gustoćom i plošnom masom, R_{et} = 5,02 m^{2}Pa/W. Upravo opisana struktura tog uzorka je zaslužna za ove rezultate. Jer zarobljen zrak u džepovima pora tkanina osim što daje veću otpornost na radijacijsku toplinu, nastali nabori daju tkanini i bolja fiziološka svojstva, bolju dišljivost što znači da se razvijena metabolička toplina lakše oslobodi u okolinu.

Zahvala

Istraživanja je podržala Hrvatska zaklada za znanost u sklopu projekata IP-2018-01-3170 Multi-funkcionalni tkani kompoziti za toplinsku zaštitnu odjeću (MF-WCOMPROTECT), voditeljice prof. dr. sc. Stane Kovačević.

5. Literatura

[1] Kiš, A.; Brnada, S.; Kovačević, S.: Influence of Fabric Weave on Thermal Radiation Resistance and Water Vapor Permeability, *Polymers,* **12** (2020) 3, pp. 1-15
[2] Bilisk, K.: New method of weaving multiaxis three dimensional flat woven fabric: Feasibility of prototype tube carrier weaving, *Fibers and Textiles in Eastern Europe*, **17** (2009), pp. 63-69
[3] Bilisik, K.: Multiaxis three dimensional (3D) woven fabric, In *Advances in Modern Woven Fabrics Technology*, IntechOpen: London, UH, 2011
[4] Kovačević, S.; Rogina-Car, B.; Kiš, A.: Application of 3D-Woven Fabrics for Packaging Materials for Terminally Sterilized Medical Devices, *Polymers*, **14** (2022) 12: 4952, pp. 1-15

Mateo Miguel Kodrič Kesovia

Životopis	Mateo Miguel Kodrič Kesovia rođen je 1987. god. u Dubrovniku. God. 2006. upisuje redovit studij restauracije i konzervacije na Sveučilištu u Dubrovniku, gdje 2012. god. završava i diplomski studij. Dio naobrazbe stječe na Institutu Palazzo Spinelli u Firenci i na Institutu za konzervaciju i restauraciju u Beču. Specijalizaciju analiziranja i katalogiziranja povijesnog tekstila (CIETA) usavršava 2011. god. u Firenci. Od rujna 2013. god. zaposlen na Odjelu za umjetnost i restauraciju Sveučilišta u Dubrovniku, a od 2021. god. na mjesto docenta. God. 2014. upisuje doktorski studij na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Restauraciju tekstila usavršava 2017. god. na renomiranom institutu Abegg Stiftung, u Švicarskoj. Znanstveni interes su mu interdisciplinarna istraživanja u području povijesti tekstilne tehnologije, metode rekonstrukcije i reprodukcije, te digitalizacije povijesnog tekstila.
Naslov teme doktorskog rada	Metoda analize i digitalizacije tehnološke dokumentacije povijesnih damastnih tkanina s područja Dubrovnika
Mentori	prof. dr. sc. Željko Penava; prof. dr. sc. Katarina Nina Simončić
Datum obrane doktorskog rada	

TIPOLOGIJA I TERMINOLOGIJA POVIJESNIH DAMASTNIH TKANINA

Mateo Miguel KODRIČ KESOVIA

Sveučilište u Dubrovniku, Branitelja Dubrovnika 41, mmkesov@unidu.hr

Sažetak: *U okviru teme istraživanja doktorskog rada provedena su detaljna istraživanja tekstilnih i tehnoloških karakteristika povijesnih damasta s područja Dubrovnika, s ciljem prezentacije mogućnosti primjene i obrade podataka prikupljenim suvremenim metodama tehničke analize i digitalizacije povijesnih tekstilnih materijala. Jedan od glavnih izazova u postupku dokumentacije i definicije analiziranih tkanina svakako predstavlja problematika stručne terminologije koja na nacionalnoj razini još nije dovoljno usklađena i prilagođena za opisivanje povijesne građe. Ovim radom prikazat će se preporučena međunarodna kategorizacija damastnih struktura kao i njihova zastupljenost na ispitanom uzorku od 52 povijesnih damasta očuvanim na dubrovačkom području, koji datiraju u rasponu od 16. do 20. stoljeća.*

1. Uvod

Damast (tal. *Damasco,* fr. *Damas,* eng. *Damask,* njem. *Damast*) je po svojoj definiciji vrsta uzorkovane tkanine koja sadrži isključivo jedan sustav niti osnove i jedan sustav niti potke. Uzorci na damastu nastaju suprotstavljanjem osnovinog i potkinog efekta istog ili različitog veza u tkanju, od kojih jedan efekt čini naličje, a drugi uzorak na licu tkanine [1]. Prvi oblici tehnike damasta pojavljuju se u drevnoj Kini tijekom vladavine dinastije Han (206. pr. Kr. – 221. g.), no tek će se ustaliti s dinastijom Tang (618. – 907. god.). Već od 2.-3. stoljeća pojavljuju se i na prostoru Bliskog Istoka, gdje se među glavnim centrima ističe grad Damask po kojem će ova tipologija tkanine kasnije i dobiti svoj naziv u Europi [2,3]. Povijesni damasti najčešće su ručno tkani. S izumom žakardnog mehanizma početkom 19. stoljeća sva ograničenja u vezu damasta u potpunosti razriješena te se povećava se broj efekata u uzorku [4]. Uvodeći dodatne broširane i/ili lancirane potke prilikom uzorkovanja damasta postiže se još bogatiji dekor na već skupocjenoj i jedinstvenoj tipologiji tkanine [5,6].

2. Eksperimentalni dio

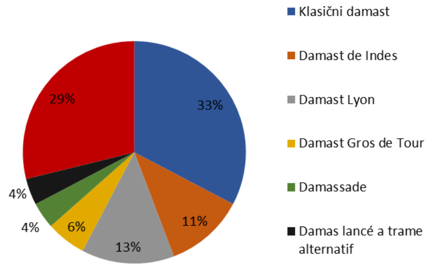
Istraživanje je provedeno na uglavnom zaštićenim povijesnim damastima iz različitih dijelova dubrovačkog područja: fundus tekstila Kulturno-povijesnog muzeja Dubrovačkih muzeja, zbirke liturgijskog ruha iz crkvice Navještenja Blažene Djevice Marije na Lokrumu, zbirka tekstilnih predmeta iz crkvice Gospe od Šunja na otoku Lopudu, zbirka Hrvatske akademije znanosti i umjetnosti, te privatnih zbirki. Primjerci su analizirani u sastavu cjelovitih predmeta ili kao očuvani fragmenti, datiranim od 16. do 20. stoljeća.
Provedenom tehničkom analizom utvrđeni su konstrukcijski parametri korištenih pređa (vrsta, debljina, finoća, smjer i kut uvoja) i strukture tkanina (debljina, gustoća niti i vez u tkanju), te analiza grešaka u tkanju. U tu svrhu korištena je kombinacija klasične metode konstrukcijske analize, koristeći precizno povećalo za optičko brojanje niti Fadenzähler "Print" (Baladéo Art.Nr: PLR000161) pod povećanjem od 10x, ali i suvremenim alatima poput digitalnog mikroskopa Dino Lite Pro AM413T5 (povećanje do x500) s odgovarajućim softverom Dino Capture 2.0 v.1.5.18A.

3. Rezultati i rasprava

Od ukupno 52 analiziranih povijesnih primjeraka, utvrđeno je kako su gotovo svi tipovi damasta zastupljeni na dubrovačkom području. Međutim, očekivano je kako nisu evidentirani arhetipovi rano kineskih (kepernih) damasta iz razdoblja dinastija Han i Tang. Zastupljenost većine tipologije damasta u zbirkama na dubrovačkom području svjedoči o bogatstvu i raznolikosti tekstilne građe na ovim prostorima (Tablica 1).
U doktorskom radu iznesen je detaljan pregled svih tipologija damasta, saznanja o razvoju tehnike i tehnologije izrade kroz određena povijesna područja i razdoblja, kako bi se povijesne primjerke s područja Dubrovnika i okolice moglo ispravno sistematizirati. Obrađene su i nedostajuće tipologije s ciljem cjelovitije obrade povijesnog konteksta i razvoja tehnike damasta. Poznavanjem povijesnog razvoja metode tkanja i mehanizma za uzorkovanje postiže se uvid u tehnološki aspekt i karakteristike pojedinih tipologija što omogućuje okvirno datiranje ili određivanje izvornog porijekla damastnih tkanina. Međutim, potrebno je također naglasiti kako su određene tehnike ili tipologije damasta mogle biti zastupljene i u drugim zemljama jer je tehnologija, kao i umjetnost, slobodno migrirala između različitih kultura pa time pojavljivati na više mjesta istodobno.

Tablica 1: Kvantitativna analiza vrsta damasta na analiziranim primjercima s područja Dubrovnika

Tipologija damasta	Količina
Klasični 5-vezni damast	17
Damast de Indes	6
Damast Lyon	7
Damast Gros de Tour	3
Damassade	2
Damas lancé a trame alternatif	2
Damast žakard	15
Ukupno	**52**



4. Zaključci

Ključan postupak u očuvanju kulturnih dobara izrada je temeljite dokumentacije koja obuhvaća sve relevantne informacije o predmetu te ostaje trajno dostupna za buduće generacije na proučavanje i razumijevanje kulturološkog, sociološkog i tehnološkog aspekta razvoja bogate kulturne baštine i društva općenito. Povijesni je tekstil vrlo raznolika i kompleksna materija koja zahtijeva interdisciplinarno, specijalizirano znanje i vještine za proučavanje i dokumentiranje. Najčešće je riječ o tekstilnim fragmentima i predmetima bez popratne dokumentacije, potpisa ili indikacija o porijeklu njihova nastanka, što predstavlja velik izazov određivanja konteksta i grupiranja s primjercima sličnih fizičkih, tehničkih ili estetskih obilježja.
S obzirom da se povijesne tkanine – uključujući damaste – definiraju na osnovu vizualnih i tekstilno-tehnoloških svojstava, od presudne je važnosti standardizirati i promovirati odgovarajuće stručne tehničke termine, primjerene za opisivanje i dokumentiranje povijesnih tekstilnih materijala. Terminologija vezova u tkanju, tekstilnih struktura, kao i specifičnih efekata prisutnih na tkaninama mora se odrediti prema strogo zadanim pravilima kako bi se izbjegla kriva interpretacija, nesporazumijevanje ili korištenje komercijalnih naziva.

Zahvala

Zahvale upućujem svojim mentorima na dugogodišnjoj podršci, te svim kolegicama i kolegama u području povijesti umjetnosti, tekstilne tehnologije i konzervacije-restauracije tekstila koji su mi pružili uvid u povijesne materijale i zbirke, dijelili znanstvene informacije i literaturu, te redovito iznosili svoje stručno i konstruktivno mišljenje na relevantnost ovog doktorskog istraživanja za našu struku.

5. Literatura

[1] Centre International d'Etude des Textiles Anciens: Vocabulaires techniques textiles – Français, CIETA., Lyon, 1997

[2] Banić, S.: Damast i vez iz druge polovine 15. stoljeća na misnom ornatu u Franjevačkom samostanu u Hvaru, *Ars adriatica*, **1** (2011), str 117-132, ISSN 1848-1590

[3] Schulz, V.-S.: Crossroads of Cloth - Textile Arts and Aesthetics in and beyond the Medieval Islamic World, *Perspective,* **1** (2016), ISSN 1777-7852

[4] Atasoy, N. et al: *IPEK – Imperial Ottoman Silks and Velvets*, Azimuth Editions Limitied, ISBN 1898592195, Velika Britanija, (2001)

[5] Sonday, M.: Damask: Definition and Technique, *Riggisberger berichte 7 - Leinendamaste*, Schorta, R. (ur.), pp. 113-130, ISBN 10: 3905014122, Abegg Stiftung, Riggisberg, (1999)

[6] Kodrič Kesovia, M.M.; Penava, Ž.; Jemo, D.: The story of two historical textile fragments: Technical analysis and reconstruction of the lost textile pattern, *Textile Research Journal*, **91** (2021) 23–24, pp. 2859–2871, ISSN 0040-5175

Ivan Kraljević

Životopis

Ivan Kraljević je rođen 1991. god. Upisuje studij na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu 2010. god. Uspješno završava prijediplomski sveučilišni studij Tekstilna tehnologija i inženjerstvo, smjer Projektiranje i menadžment tekstila 2013. god., a dvije godine poslije diplomski sveučilišni studij pod mentorstvom prof. dr. sc. Antonete Tomljenović. U studenom 2016. god. upisuje poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija. Od veljače 2016. god. je zaposlen u Jadran Tvornici čarapa d.d. kao voditelj pletionice i šivaonice. Kao doktorand suradnik je bio uključen u HRZZ projekt IP-2016-06-5278. U koautorstvu je objavio 9 znanstvenih radova i 1 stručni rad, a područje znanstvenog interesa vezuje uz kvalitetu i ispitivanje inovativnih materijala za izradu čarapa i kože.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Antoneta Tomljenović

Datum obrane doktorskog rada

VRJEDNOVANJE OTPORNOSTI NA HABANJE PAMUČNIH KRATKIH ČARAPA

Ivan KRALJEVIĆ

Jadran Tvornica čarapa d.d., Vinka Žganeca 2, HR- 10000 Zagreb,
ivan.kraljevic@ttf.unizg.hr

Sažetak: *Ispitana je otpornost na habanje finih muških kratkih čarapa, izrađenih s najvećim udjelom pamuka u potpunom platiranju s teksturiranom multifilamentnom poliamidnom pređom različite finoće. Primijenjen je postupak ispitivanja prema zahtjevima norme HRN EN 13770, metode 1, primjenom habalice prema Martindale-u.*

1. Uvod

Kratke čarape su pleteni odjevni predmeti koji se nalaze u izravnom dodiru s kožom korisnika, prekrivajući pritom stopalo, petu i dio potkoljenice [1]. Tijekom uporabe trebaju ispunjavati visoke zahtjeve na kvalitetu, a posebice otpornosti na habanje. Habanje, odnosno trošenje materijala, je nezaobilazna pojava koja se najčešće javlja na peti i stopalnom dijelu čarapa pri čemu dolazi do prohabavanja u obliku rupe ili vidljivog stanjenja njihove pletene strukture. Kako otpornost na habanje značajno ovisi o konstrukciji čarapa i sirovinskom sastavu, veoma je značajno odabrati odgovarajuće pređe za njihovu izradu [2]. Muške kratke čarape se najčešće izrađuju s visokim udjelom pamuka koji osigurava mekoću i udobnost odijevanja, a u mješavini s poliamidnom pređom poradi poboljšanja pristalosti i trajnosti čarapa. Stoga je u okviru istraživanja vrjednovana otpornost na habanje muških kratkih čarapa izrađenih s najvećim udjelom pamuka u potpunom platiranju s pređom iz poliamida 6.6 različitih finoća. Primijenjen je postupak ispitivanja otpornosti pletiva čarapa na plošno habanje prema zahtjevima norme HRN EN 13770:2008, metode 1 [3], primjenom habalice prema Martindale-u uz uzorkovanje pletiva iz stopalnog dijela i pete čarape.

2. Eksperimentalni dio

Istraživanje je provedeno na pet skupina finih muških kratkih čarapa crne boje izrađenih u veličini 42 s najvećim udjelom pamuka (primjenom jednonitne prstenasto predene pređe finoće 29,4 tex) u potpunom platiranju s teksturiranom multifilamentnom pređom iz poliamida 6.6 različitih finoća, označenih: 22 dtex f7 × 2, 33 dtex f10 × 2, 44 dtex f13 × 2, 78 dtex f23 × 2, 110 dtex f34 × 2. Čarape su izrađene u jednostavnom desno-lijevom prepletu, uz izuzetak okrajka koji je izrađen u desno-desnom rebrastom prepletu 1×1. Pletene su u Jadran Tvornici čarapa d.d. na čaraparskom automatu finoće E14 tt. Lonati promjera cilindra 95 mm, (3 ¾") koji je pleo sa 168 igala te izglačane pri temperaturi od 120 °C na stroju tt. Cortese [4]. Svojstva muških kratkih čarapa, označenih prema oznaci finoće poliamidne pređe primijenjene za platiranje (CO/PA 22×2 – CO/PA110×2), prikazana su u tablici 1, a uključujući vrijednosti mase jedne čarape te plošne mase, debljine i gustoće pletiva čarapa.

Tablica 1: Svojstva pet skupina pamučnih kratkih čarapa [4]

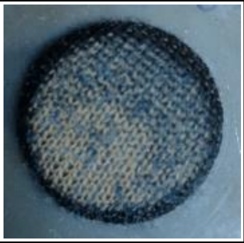
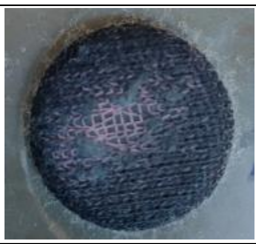
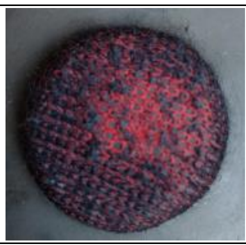
Uzorak čarapa	Masa čarape (g)	Plošna masa pletiva (g/m^2)	Debljina pletiva (mm)	Broj nizova/cm	Broj redova/cm
CO/PA 22×2	15,5	177,7	0,90	11	12
CO/PA 33×2	16,5	189,7	0,93	11	12
CO/PA 44×2	17,9	202,7	1,00	10	11
CO/PA 78×2	21,8	223,6	1,13	10	11
CO/PA 110×2	25,2	262,5	1,25	9	10

Prije ispitivanja uzorci čarapa su kondicionirani položeni na ravnu površinu u trajanju od najmanje 24 sata u uvjetima referentne atmosfere, temperature 20 ± 2 °C i relativne vlažnosti 65 ± 4 %. Otpornost na habanje pletiva čarapa je ispitana primjenom habalice prema Martindale-u tt. Mesdan-Lab prema zahtjevima norme HRN EN 13770:2008, metode 1, pri čemu su uzorci pletiva habani o referentnu vunenu tkaninu plošno se gibajući, simulirajući pritom Lissajous-ovu krivulju. Po dva kružna ispitna uzorka promjera 38 mm uzorkovana su iz pete i stopalnog dijela čarape. Postupak habanja se završava po pojavi vidljivog značajnog stanjenja pamučne pređe i pojave zaostale sintetske podloge iz niti pređe za platiranje po periodičnom provjeravanju, a kao rezultat bilježi broj habajućih prolaza.

3. Rezultati i rasprava

Povećanjem duljinske mase poliamidne pređe primijenjene za platiranje pletiva čarapa povećava se masa čarape te debljina i plošna masa pletiva čarapa, dok se broj nizova i redova očica u pletenoj strukturi smanjuje (Tablica 1). S povećanjem duljinske mase platirne pređe također se povećava i otpornost pletiva čarapa na habanje, što je vidljivo iz rezultata prikazanih u tablici 2 te pripadajućih slika habane površine čarapa koje je moguće razlikovati i prema boji primijenjene platirne pređe.

Tablica 2: Otpornost na habanje pletiva uzorkovanom iz stopalnog dijela i pete čarapa

Uzorak čarapa, peta				
CO/PA 22×2	CO/PA 33×2	CO/PA 44×2	CO/PA 78×2	CO/PA 110×2
				
Broj habajućih prolaza pri završetku ispitivanja				
4000	6000	7000	8000	14000
Uzorak čarapa, stopalo				
CO/PA 22×2	CO/PA 33×2	CO/PA 44×2	CO/PA 78×2	CO/PA 110×2
				
Broj habajućih prolaza pri završetku ispitivanja				
4000	6000	7000	8000	12000

4. Zaključak

Utvrđeno je da se značajno stanjenje pletiva pamučnih kratkih čarapa pletenih u potpunom platiranju s grubljom teksturiranom multifilamentnom pređom iz poliamida 6.6 javlja po većem broju provedenih habajućih prolaza, što ukazuje i na veću otpornost na habanje.

5. Literatura

[1] Tomljenović, A. *et al*.: Usage Durability and Comfort Properties of Socks Made of Differently Spun Modal and Micro Modal Yarns, *Materials*, **16** (2023), 1684, ISSN 1996-1944
[2] Kraljević, I. *et al*.: The Abrasion Wear Resista*nce of Men's Socks, Proceedings of International Conference MATRIB 2021, Materials, Tribology, Recycling 2021*, Ćorić, D. *et al.* (Ur.), pp. 281-290, ISSN 2459-5608, Vela Luka, Croatia, 30.6.-2.7. 2021., Croatian Society for Materials and Tribology, Zagreb, (2021)
[3] HRN EN 13770:2008 *Tekstilije – Određivanje otpornosti čarapa na habanje*
[4] Tomljenović, A. *et al*.: Influence of Linear Density of Polyamide Plating Yarn on the Usage and Comfort Properties of Men's Cotton Socks, *Book of Abstracts from 22nd AUTEX World Textile Conference 2023*, Wang, L. (Ur.), pp. 43, ISBN 9783036414188, Melbourne, Australia, 26.-28.6.2023., Trans Tech Publications Ltd, Baech, Switzerland, (2023)

Anja Ludaš

Životopis

Anja Ludaš rođena je 1993. god. u Zagrebu. Titulu magistrice inženjerke stječe 2019. god. završetkom sveučilišnog studija Tekstilna tehnologija i inženjerstvo na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija upisuje 2019. god. i zapošljava se kao asistent na Zavodu za materijale, vlakna i ispitivanje tekstila. Kao suradnik sudjeluje na istraživačkom projektu Hrvatske zaklade za znanost HRZZ IP-2019-04-6418 „*Laserska sinteza nanočestica i primjene*“ te na Erasmus+ projektu Aequalis4TCLF Blueprint Project.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Sanja Ercegović Ražić

Datum obrane doktorskog rada

MODIFIKACIJA SVOJSTAVA UMJETNIH VLAKANA ISPREDENIH IZ TALINE RECIKLIRANOG PA 6 POLIMERA DODATKOM BIOAKTIVNIH TVARI I NAKNADNOM OBRADOM HLADNOM PLAZMOM

Anja LUDAŠ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, anja.ludas@ttf.unizg.hr

Sažetak: *Optimirat će se postupak kemijskog ispredanja PA 6 polimera iz taline s dodatkom bioaktivnih tvari (ZnO, TiO_2 i kitozana). Takve obrade su učinkovitije jer se željeno sredstvo ispreda direktno s polimerom, dok se kod naknadnih obrada sredstvo veže na površinu vlakna i lakše uklanja tijekom uporabe. Naknadna obrada modificiranog filamenata provest će se hladnom niskotlačnom plazmom u optimiranim uvjetima, s ciljem postizanja višefunkcijskih svojstava i primjena, pri čemu osnovna svojstva materijala ostaju gotovo nepromijenjena. Svojstva dobivenog filamenta ispitat će se uz primjenu pouzdanih metoda ispitivanja.*

1. Uvod

Krajem 20. stoljeća prati se razvoj vlakana novih svojstava kao četvrte generacije vlakna za visokozahtjevne materijale poput mikrovlakana, biorazgradivih vlakana, nanovlakna te vlakana novih struktura i svojstava. Postupak kemijskog ispredanja vlakana iz taline jedan je od najzastupljenijih postupaka za proizvodnju umjetnih vlakana zbog ekonomičnog pristupa, odsutnosti otapala i jednostavnosti procesa. Primjenjuje se uvijek kada se iz polimera može prirediti termostabilna talina potrebnih reoloških svojstava i provesti ekstruzija taline kroz mlaznicu bez veće degradacije polimera te oblikovati filamentno vlakno. Najčešće korišteni polimeri za kemijsko ispredanje iz taline su poliamidi, poliesteri i (linearni) poliolefini [1]. Poliamid 6 često se koristi za proizvodnju vlakana, koja su izuzetno čvrsta, otporna na habanje i održiva, što ih čini idealnim za proizvodnju različitih vrsta proizvoda, za tekstilnu i tehničku primjenu. Bioaktivna sredstva poput cinkovog oksida (ZnO), titanijeva dioksida (TiO_2) i kitozana koriste se u tekstilnoj industriji kako bi se poboljšala funkcionalnost tekstilnih materijala, zbog specifičnih svojstava kao što su samoočišćenje, odbijanje prljavštine i vode, antistatičnost, zaštita od UV zračenja, antibakterijsko djelovanje [2, 3]. Paralelno s razvojem nanotehnologije, razvijaju se i napredni procesi primjenom ekološki prihvatljive tehnologije hladne plazme s ciljem dobivanja tekstilnih materijala modificiranih svojstava. Tekstilni materijali podvrgnuti obradi plazmom prolaze kroz fizikalno-kemijske promjene u površinskom sloju (do 100 nm), pri čemu osnovna svojstva materijala ostaju gotovo nepromijenjena [4].

2. Eksperimentalni dio

Za provedbu istraživanja koristit će se reciklirani granulat PA 6 polimera dobiven recikliranjem otpadnih ribarskih mreža, (AquafilSLO). Istraživanja će se provesti kroz tri faze: u prvoj fazi optimirat će se parametri postupka kemijskog ispredanja umjetnih vlakana iz taline na uređaju za ispredanje ovisno o toplinskim karakteristikama PA 6 polimera. Modifikacija recikliranog polimera PA 6 s bioaktivnim sredstvima provest će se na laboratorijskom dvopužnom ektruderu radi jednoličnog miješanja polimera i aditiva, nakon čega će se modificirani filament kemijski ispredati na laboratorijskom jednopužnom ekstruderu s jedinicom za ispredanje filamenata (Areka, Turska). U drugoj fazi optimirat će se količina nanočestica ZnO i TiO_2 te bioaktivnog sredstva kitozana kao i čestica ZnO dobivenih zelenom sintezom, u optimiranim uvjetima na masu PA 6 polimera kako bi se proizveo filament modificiranih svojstava. U trećoj fazi istraživanja dobiveni filamenti će se modificirati ekološki prihvatljivom niskotlačnom plazmom (LP-Nano LF-40kHz, Diener Electronic GmbH), koja bi mogla doprinijeti otpuštanju aktivne tvari s ciljem postizanja višefunkcijskih svojstava, budući da se njezino djelovanje očituje fizikalno-kemijskim promjenama u površinskom sloju supstrata i modifikacijom svojstava površine. Obzirom na prirodu plina i način djelovanja aktivnih čestica plazme na površinu materijala, dodatno se očekuje postizanje hrapavosti površine obrađenog materijala, time i poboljšanje adhezijskih svojstava dobivenog materijala.

3. Rezultati i rasprava

Karakterizacija ispredenih filamenata bez / uz dodatak bioaktivnih tvari u svrhu procjene stupnja modifikacije i jednoličnosti primjenjive obrade provest će se primjenom normiranih i instrumentalnih metoda analize. Ekstrudiranom polimernom filamentu izmjerit će stupanj bjeline odnosno požućenja primjenom remisijskog spektrofotometra. Morfološke i kemijske karakteristike dobivenih filamenata analizirat će se primjenom pretražne elektronske mikroskopije (SEM) uz EDS analizu, primjenom Prisma E mikroskopa. Infracrvenom spektroskopijom s Fourierovom transformacijom analizirat će se eventualne promjene na funkcionalnim skupinama i kemijskim vezama, tj. dobit će se uvid u omjer pojedinih komponenti u uzorku. Diferencijalnom pretražnom kalorimetrijom provesti će se analiza termalnih karakteristika uzoraka. Također će se provesti analiza uzoraka primjenom ICP uređaja za ekstrakciju ili otapanje uzoraka metala ili minerala za analizu tragova ili koncentracije određenih elemenata u uzorku. Postupak ispitivanja antimikrobne učinkovitosti obrađenih uzoraka provesti će se sukladno normama ISO 20645:2004 (kvalitativni test) i ISO 20743:2021 (kvantitativni test) spram ciljanih bakterijskih vrsta, te genotoksični potencijal bioaktivnih tvari. Starenje polimernih filamenata će se ispitati blijeđenjem Xenon lampom prema normi ISO 105-BO2+A1:2014 uz izmjenu filtera na B04. Na kraju će se provesti statistička obrada dobivenih rezultata primjenom pouzdanih statističkih alata u donošenju zaključaka i procjene učinkovitosti modifikacija.

4. Zaključak

Glavni cilj ovog doktorskog rada je istražiti mogućnost inkorporiranja nanočestica ZnO i TiO_2 te bioaktivnog sredstva kitozana u reciklirani PA 6 polimer, mogućnost dobivanja ZnO primjenom zelene sinteze i kemijsko ispredanje modificiranog polimera iz taline. Naknadna obrada dobivenog modificiranog filamenata niskotlačnom plazmom u optimiranim uvjetima, može doprinijeti otpuštanju aktivne tvari s ciljem postizanja višefunkcijskih svojstava i primjena.

Zahvala

Ovaj je rad financirala Hrvatska zaklada za znanost projektom HRZZ IP-2019-04-6418 Laserska sinteza nanočestica i primjene voditelja doc. dr. sc. Nikše Krstulovića.

5. Literatura

[1] Hufenus, R. et al.: Melt-Spun Fibers for Textile Applications, *Materials*, **13** (2020) 19, pp. 1-32, doi: 10.3390/ma13194298

[2] Ghaffari, S.; Mojtahedi, M. R. M. & Dastjerdi, R.: Comparison of the Morphological, Mechanical and UV Protection, Properties of TiO2/Polyamide 6 (PA6) and ZnO/PA6 Nanocomposite Multifilament Yarns, *Journal of Macromolecular Science, Part B: Physics*, (2015), pp. 1-38

[3] Piekarska, K. et al.: Chitin and Chitosan as Polymers of the Future—Obtaining, Modification, Life Cycle Assessment and Main Directions of Application, *Polymers,* **15** (2023) 793, pp. 1-31

[4] Ercegović Ražić, S. & Čunko, R.: Modifikacija svojstava tekstilija primjenom plazme, *Tekstil*, **58** (2009) 3, str. 55-74, ISSN 0492-5882

Maja Mahnić Naglić

Životopis	Maja Mahnić Naglić rođena je u Slavonskom Brodu. Na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu 2009. god. je završila preddiplomski studij Tekstilna tehnologija i inženjerstvo smjer Odjevno inženjerstvo, a 2011. god. diplomski studij smjer Industrijski dizajn odjeće. Od 2012. god. zaposlena je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu kao vanjski suradnik, a od 2015. u suradničkom zvanju asistenta na Zavodu za odjevnu tehnologiju. Sudjeluje u izvođenju nastave na kolegijima iz područja 2D/3D CAD/CAM sustava za računalni dizajn i projektiranje odjeće. 2013. god. je upisala doktorski studij Tekstilna znanost i tehnologija. Kao koautor je do sada objavila 2 poglavlja u znanstvenim knjigama, 8 izvornih znanstvenih radova u časopisima citiranim u bazama WoS i Scopus, 4 izvorna znanstvena rada u drugim časopisima te 17 izvornih znanstvenih radova u zbornicima međunarodnih skupova.
Naslov teme doktorskog rada	Dinamičko ponašanje odjeće pod utjecajem biomehanike tijela
Mentor	prof. dr. sc. Slavenka Petrak
Datum obrane teme doktorskog rada	

DINAMIČKO PONAŠANJE ODJEĆE POD UTJECAJEM BIOMEHANIKE TIJELA

Maja MAHNIĆ NAGLIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a
Zagreb, maja.mahnic@ttf.hr

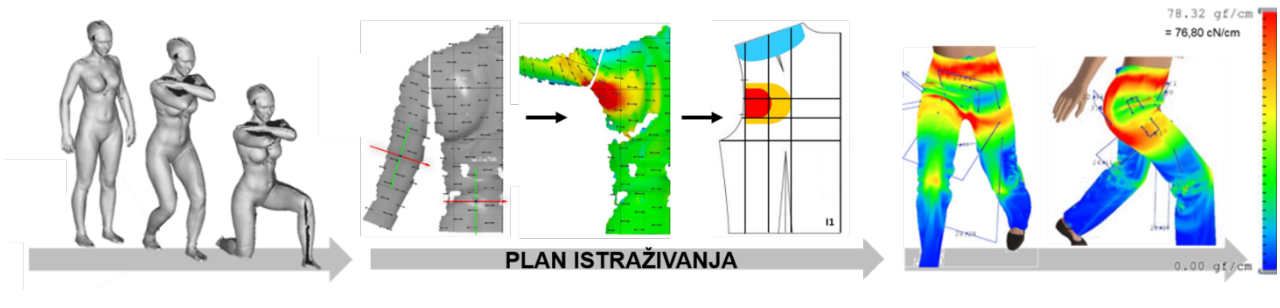
Sažetak: *U okviru doktorskog istraživanja razvit će se metoda za računalnu analizu dinamičke pristalosti odjeće. Provest će se analiza promjena tjelesnih mjera i dimenzija segmenata površine različitih tipova oblika ženskog tijela u dinamičkim uvjetima. Istražit će se mogućnosti povezivanja sustava za 3D skeniranje tijela i procesa 3D animacije na temelju čega će se razviti animirani modeli za primjenu kod 3D simulacije odjeće i ispitivanja dinamičke pristalosti računalnih prototipova. Sa svrhom verifikacije metode i primjenjivosti za računalno 3D projektiranje odjeće i ispitivanje pristalosti u dinamičkim uvjetima, provest će se analiza deformacija realnih prototipova odjeće u ciljanim pokretima.*

1. Uvod

Ljudsko tijelo, njegov oblik i kinematika kretanja, temelj su istraživanja u području dizajna i razvoja novih modela odjevnih predmeta. Razvoj računalnih tehnologija i CAD sustava za 2D/3D projektiranje odjeće omogućili su 3D simulaciju odjeće i analizu pristalosti računalnih prototipova, sa svrhom predviđanja izgleda i funkcionalnosti novih modela odjevnih predmeta u procesu konstrukcijske pripreme. Pristalost odjeće u statičkim uvjetima odnosi se na pristalost odjevnog predmeta obliku ljudskog tijela, a stupanj pristalosti ovisi o vrsti i namjeni odjevnog predmeta, kvaliteti konstrukcijskog rješenja te o vrsti i mehaničkim svojstvima tekstilnog materijala. Pristalost odjeće u dinamičkim uvjetima odnosi se na pristalost odjeće na tijelu u pokretu, pri čemu odjevni predmet ne smije ograničavati pokret tijela niti pokret smije izazvati pretjerano naprezanje u tekstilnom materijalu od kojeg je odjevni predmet izrađen, a visoki zahtjevi posebno su izraženi kod odjeće specijalnih namjena [1,2]. Integriranjem različitih 3D sustava za analizu ljudskog tijela i pokreta u proces računalnog 3D projektiranja odjeće, omogućena je detaljna analiza antropometrijskih i kinematičkih karakteristika tijela te primjena njihovih parametara u procesu razvoja novih modela odjeće [3-6]. Istraživanja i računalne analize pristalosti odjeće temelje se na fizikalnoj simulaciji ponašanja odjevnog predmeta na modelu tijela pri čemu se analiziraju deformacije geometrije računalnog prototipa odjevnog predmeta u interakciji s tijelom, određene kontaktnom mehanikom tijela i odjeće te parametrima fizikalnih i mehaničkih svojstava određene tkanine [7,8].

2. Eksperimentalni dio

U okviru eksperimentalnog dijela doktorskog rada provest će se analiza promjena tjelesnih mjera i dimenzija segmenata površine tijela u dinamičkim uvjetima na različitim tipovima oblika ženskog tijela. Na temelju utvrđenih rezultata definirat će se parametri za prilagodbu kroja i analizu računalnih 3D prototipova odjeće s aspekta dinamičke antropometrije. Na temelju skeniranih 3D modela tijela, razvit će se kinematički modeli i animacija za ciljani set pokreta koji će se primjeniti za računalnu simulaciju modela odjevnih predmeta i analizu pristalosti u dinamičkim uvjetima, slika 1.



Slika 1: Plan istraživanja doktorskog rada

Na temelju rezultata analize računalnih 3D prototipova istražit će se odnos između mehaničkih svojstava materijala, konstrukcije kroja i biomehanike tijela u pokretu te će se usporedbom s realno izrađenim odjevnim predmetima i rezultatima analize deformacija realnih prototipova na tijelu u pokretu ispitati mogućnosti predviđanja ponašanja odjevnog predmeta u dinamičkim uvjetima i provesti verifikacija postavljene metode.

3. Rezultati

Na temelju cjelovitog istraživanja razvit će se nova metoda za računalnu analizu dinamičkog naprezanja odjeće temeljena na 3D simulaciji mehaničkog ponašanja modela odjevnog predmeta na animiranom skeniranom modelu tijela. Modeliranjem ciljanih mehaničkih svojstava i ponašanja odjevnog predmeta pri 3D simulaciji na tijelu u pokretu omogućit će se analiza deformabilnosti površine računalnih prototipova, a time i analiza naprezanja na kritičnim zonama odjevnog predmeta. Doktorski rada rezultirat će metodom koja predstavlja inovativni pristup problematici ocjene pristalosti modela odjeće na individualiziranom računalnom modelu tijela u dinamičkim uvjetima.

4. Zaključci

Glavni cilj doktorskog rada je razviti metodu za računalnu analizu pristalosti odjeće u dinamičkim uvjetima. U skladu s ciljem istraživanja postavljene su slijedeće hipoteze:

H1: Deformacije površine tijela u pokretu ovise o razvijenosti i obliku tijela te se razvojem i primjenom matematičkih modela za prilagodbu kinematičkih točaka na tijelu i deformaciju segmenata površine ovisno o pojedinom tipu tijela može ostvariti realistična animacija skeniranog modela tijela primjenjiva za računalnu 3D simulaciju odjeće u dinamičkim uvjetima.

H2: Modeliranjem ciljanog mehaničkog ponašanja tkanine pri simulaciji odjevnog predmeta, ostvarit će se deformabilnost površine odjevnog predmeta u korelaciji s deformabilnošću tipa tijela u zadanom pokretu.

H3: Na temelju analize deformacija geometrije računalnog modela odjevnog predmeta u interakciji s modelom tijela u pokretu, može se vjerodostojno vrednovati naprezanje odjevnog predmeta u dinamičkim uvjetima.

5. Literatura

[1] Geršak, J. & Marčić, M.: The complex design concept for functional protective clothing, *Tekstil*, **62** (2013) 1/2, str. 38-44, ISSN 0492-5882

[2] Lee, H. et al.: Ergonomic Mapping of Skin Deformation in Dynamic Postures to Provide Fundamental Data for Functional Design Lines of Outdoor Pants, *Fibres and Polymers,* **14** (2013) 12, pp. 2197-2201, ISSN 1229-9197

[3] Ashdown, S. et al.: Use of body scan data to design sizing systems based on targeted markets, *National Textile Center Annual Report,* **11** (2001) 4, pp. 1-5

[4] Petrak, S. & Rogale, D.; Mandekić-Botteri, V.: Systematic Representation and Application of a 3D computer-Aided Garment Construction Method, Part II Spatial transformation of 3D garment cut segments, *International Journal of Clothing Science and Technology,* **18** (2006) 3, pp. 188-199, ISSN 0955-6222

[5] Medved, V.: Kinematika i kineziologija lokomocije, U *Principi biomehanike,* Naklada Ljevak, ISBN 978-953-303-435-5, Zagreb, (2011), str. 463-496

[6] Ma, Y.Y.; Zhang, H. & Jiang, S.W.: Realistic Modelling and Animation of Human Body Based on Scanned Data, *Journal of Computational Science & Technology,* **19** (2004) 4, pp. 529-537, ISSN 1000-9000

[7] Choi, K.J. & Ko, H.S.: Research problems in clothing simulation, *Computer-Aided Design*, **37** (2005) 6, pp. 585-592, ISSN 0010-4485

[8] Yeung, K.W.; Li, Y. & Zhand, X.: A 3D Biomechanical Human Model for Numerical Simulation of Garment-Body Dynamic Mechanical Interactions During Wear, *The Journal of Textile Institute,* **95** (2004), pp. 59-79, ISSN 0040-5000

Mislav Majdak

Životopis	Mislav Majdak je rođen 1995. god. u Zagrebu. 2020. god. završava diplomski sveučilišni studij Tekstilna tehnologija i inženjerstvo smjer Tekstilna kemija, materijali i ekologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. 2021. godine upisuje poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Iste godine zapošljava se na projektu Antibakterijska prevlaka za biorazgradive medicinske materijale, pod mentorstvom prof. dr. dr. sc. Ive Rezić. Temu doktorskog rada Antimikrobne prevlake s nanočesticama za biorazgradljive polimere i tekstilne materijale uspješno je obranio 22.2.2023. god.
Naslov teme doktorskog rada	Antimikrobne prevlake s nanočesticama za biorazgradljive polimere i tekstilne materijale
Mentor	prof. dr. dr. sc. Iva Rezić
Datum obrane doktorskog rada	

PRIMJENA 3D TEHNOLOGIJA ZA IZRADU INDIVIDUALIZIRANE POTPORNE ORTOZE

Mislav MAJDAK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
Zagreb, mislav.majdak@ttf.unizg.hr

Sažetak: *3D tehnologije poput 3D skeniranja, 3D modeliranja i 3D ispisa, omogućuju izradu individualiziranih medicinskih pomagala. U ovome radu predstavljena je izrada prototipa polimerne potporne ortoze koja je namijenjena za potencijalno liječenje prijeloma distalnog radijusa. Potporna ortoza je izrađena prema konturama ruke, što ga čini individualiziranim pomagalom.*

1. Uvod

Prijelomi udova, pogotovo podlaktice (prijelom distalnog radijusa) su jedne od najučestalijih ozljeda. Zahvaljujući iscrpnim i dugogodišnjim istraživanjima, provedenim na nizu pacijenata, ustanovljeno je da frakture podlaktičnih kosti najčešće zahvaćaju maloljetnu (7 do 13 godina) i stariju (60+) populaciju [1]. Za uspješno liječenje spomenutih prijeloma danas se najčešće koriste konzervativne metode liječenja odnosno, imobilizacije. Te metode podrazumijevaju primjenu sadrenih ili polimernih (stakloplastika) materijala za izradu potpornih medicinskih pomagala [2]. Nažalost mogućnost pojave opeklina tijekom nanošenja, te sindroma odjeljka uzrokovanog nedovoljnim uračunavanjem naticanja uda, su česti problemi koji mogu imati ozbiljne posljedice po zdravlju pacijenta [3]. Primjenom 3D tehnologija, prije svega 3D skeniranja, moguće je brzo i učinkovito dobiti precizni 3D model tijela ili dijela tijela [4]. Nadalje, primjenom 3D modeliranja, omogućena je jednostavna izrada individualiziranog 3D objekta, dok je primjenom 3D ispisa omogućena automatizirana proizvodnja tog istog 3D objekta [5]. Stoga, u sklopu ovog rada, predstavljena će biti izrada individualizirane potporne ortoze primjenom 3D tehnologija.

2. Eksperimentalni dio

Postupak izrade ortoze je tekao u tri koraka: (I) 3D skeniranje; (II) 3D modeliranje; (III) 3D ispis. Svaki od tih koraka je bio neizbježan za proizvodnju završnog medicinskog pomagala. U prvome koraku je primjenom 3D skenera tijela Vitus Smart (Human Solutions GmbH) uzet digitalizirani model ruke. Potom, primjenom programa za 3D modeliranje Rhinoceros 3D (TLM Inc.) 3D model ortoze je bio izrađen prema konturama digitaliziranog 3D modela ruke. Digitalizirani 3D model ruke, kao i 3D model ortoze su prikazani na slici 1.

a b

Slika 1: 3D modeli: a) podlaktice dobiven digitalizacijom nakon postupka 3D skeniranja, b) ortoze dobiven primjenom programa za 3D modeliranje, te predstavljen u odnosu na model podlaktice

Završetkom 3D modeliranja, dobiveni modeli su bili pripremljeni za 3D ispis primjenom programa *PrusaSlicer* (Prusa Research by Josef Prusa), pri čemu su postavljeni parametri koji su prikazani u tablici 1.

Tablica 1: Parametri ispisa podešeni primjenom programa *PrusaSlicer*

Visina sloja [mm]	Kut ispune [°]	Brzina očvršćivanja [mm/s]	Temperatura ekstruzije [°C]	Temperatura podloge [°C]
0,3	45	60	215	60

Slika 2: Prikaz gotovog modela ortoze

3. Rezultati i rasprava

3D tehnologije omogućuju učinkovitu izradu individualiziranih medicinskih pomagala, u ovom slučaju ortoze. Postupak 3D skeniranja je bio učinkovit i najvažnije od svega brz postupak koji je trajao 12 sekundi. Štoviše, zahvaljujući odličnoj brzini, omogućuje se bezbolno zaprimanje antropometrijskih mjera. Nadalje, postupak 3D modeliranja je sam po sebi bio jednostavan, te nije zahtijevao veliko znanje 3D modeliranja. Primjenom 3D modeliranja, izrada 3D modela ortoze je u potpunosti usmjerena na individualnost. Završno, za izradu dva dijela, bilo je potrebno 9 sati i 30 minuta, odnosno 19 sati ukoliko s koristi jedan taložni očvršćivač. Pošto je za sadrena pomagala potrebno 72 sata za potpuno stvrdnjavanje [6], vrijeme očvršćivanja je prihvatljivo.

4. Zaključak

Medicinska pomagala, poput ortoza neizbježna su za uspješno liječenje te provođenje zdravstvenih zahvata. Iako su još uvijek sveprisutne, konvencionalne ortoze imaju mane koje je moguće riješiti primjenom novih tehnologija. Tako, primjenom 3D tehnologija, omogućena je brza i učinkovita izrada potpornih ortoza koje zahvaljujući svojoj individualnosti izbjegavaju ranije spomenute mane.

Zahvale

Istraživanja/doktorski rad izrađen je u okviru istraživačkog projekta ABBAMEDICA IP - 2019-04-1381 voditeljice prof. dr. dr. sc. Ive Rezić koji financira Hrvatska zaklada za znanost. Zahvaljujem se izv. prof. dr. sc. Slavici Bogović na savjetima i pomoći u izradi gotovog 3D objekta.

5. Literatura

[1] Patel, S., D.; Statuta, M., D. & Ahmed, N.: Common Fractures of Radius and Ulna, *American Family Physician*, **103** (2021) 6, pp. 345-354, ISSN 15320650
[2] Mauck, B., M. & Swigler, C., W.: Evidence-Based Review of Distal Radius Fractures, *Orthopedic Clinics of North America*, **49** (2018) 2, pp. 211-222, ISSN 0030-5898
[3] Szostakowski, B.; Smitham, P. & Khan, W., S.,: Plaster of Paris – Short History of Coatings and Injured Limb Immobilization, *Open Orhtopedic Journal*, **11** (2017) 1, pp. 291-296, ISSN 1874-3250
[4] Najafabadi, D., F.; Rezaie, M., R. & Forghany, S.: The Validity and Reliability of a low-cost handheld 3D Scanner for Use in Orthotics and Prosthetics, *Journal of Rehabilitation Sciences and Research*, **7** (2020) 1, pp. 8-14, ISSN 19961944
[5] Rezaie, F.; et. al.: 3D Printing of Dental Prostheses: Current and Emerging Applications, *Journal of Composite Sciences*, **7** (2023) 80, pp. 1-24, ISSN 23065354
[6] Ekanayake, C. et. al: Revolution in orthopedic immobilization materials: A comprehensive review, *Heilyon*, **9** (2023) 3, pp. 1-24, ISSN 24058440

Paula Marasović

Životopis

Paula Marasović, rođena 1994. god. u Šibeniku, završila je diplomski studij Tekstilne tehnologije i inženjerstva smjera Projektiranje i menadžment tekstila na Sveučilištu u Zagrebu. Tijekom studija bila je demonstratorica na kolegijima Netkani i tehnički tekstil, Netkani tekstil i Predenje. God. 2018. upisuje poslijediplomski doktorski studij Tekstilna znanosti i tehnologija. Od 2018. do 2019. god. radila je kao planerka proizvodnje u tvornici tkanina Kelteks d.o.o. Pisala je članke o kulturi i održivoj modi za web portale. Članica je uredništva časopisa Textile & Leather Review od 2020. god. Od 2021. god. zaposlena je kao doktorand na projektu Razvoj biorazgradivog netkanog agrotekstila iz prirodnih i obnovljivih izvora. Objavila je 7 znanstvenih radova citiranih u WOS i Scopus bibliografskim bazama podataka te 16 znanstvenih radova na međunarodnim znanstvenim konferencijama.

Naslov teme doktorskog rada

Razvoj netkanog agrotekstila iz prirodnih i obnovljivih izvora za primjenu u malčiranju

Mentor

izv. prof. dr. sc. Dragana Kopitar

Datum obrane doktorskog rada

RAZGRADNJA NETKANIH TEKSTILA PROIZVEDENIH OD POLIMERA IZ OBNOVLJIVIH IZVORA IZLOŽENIH VANJSKIM UTJECAJIMA

Paula MARASOVIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, paula.marasovic@ttf.unizg.hr

Sažetak: *Današnje vrijeme postavlja imperativ ekološke proizvodnje, obuhvaćajući ne samo proizvodnju, već i uporabu i zbrinjavanje proizvoda, te je ovaj trend posebno izražen u području agrotekstila. U ovoj studiji istražena je biorazgradnja netkanih tekstila s primjenom u malčiranju, proizvedeni od vlakana konoplje, viskoze i PLA, te njihova izloženost vremenskim uvjetima na polju tijekom 180 dana. Rezultati otkrivaju značajne promjene u tekstilu od viskoznih vlakana, dok je konopljeni malč pokazao smanjenje prekidne sile. Malč od PLA vlakana pokazuje sporu biorazgradnju, naglašavajući na potrebu pažljivog odabira održivih sirovina za izradu netkanih tekstila za malčiranje, zbog različitog utjecaja vremenskih uvjeta na fizikalno-mehanička svojstava.*

1. Uvod

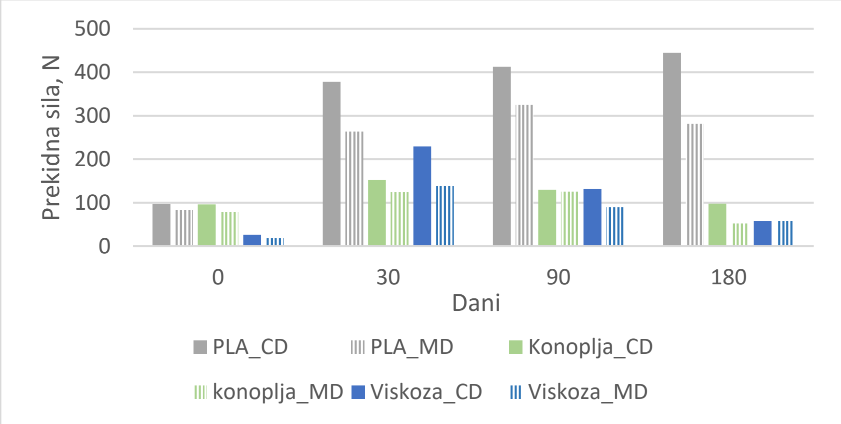
Malčiranje je uobičajena praksa u granama poljoprivrede i hortikulture, gdje se većina agrotekstila i malčeva proizvodi od umjetnih materijala dobivenih iz nafte. Korištenjem umjetnih materijala za malčiranje, vremenom dolazi do njihove razgradnje i nakupljanja u tlu što nepovoljno utječe na rast usjeva [1,2]. Brojna istraživanja ukazuju na znatno onečišćenje okoliša, s pozitivnim trendom potražnje ekološki prihvatljivim alternativama. Istraživanja podupiru superiornost netkanih malčeva od prirodnih vlakana i biopolimera, koji poboljšavaju uvjete tla, povećavaju prinos usjeva i imaju pozitivan ekološki utjecaj [3]. U radu je ispitatano vrijeme razgradnje netkanih tekstila za malčiranje, proizvedenih od prirodnih i obnovljivih materijala (vlakna konoplje, viskoze i PLA) uz iste parametre proizvodnje. Svi netkani malčevi pokazali su učinkovitost u malčiranju, a istraživanje je odredilo vrijeme razgradnje. Proizvedeni netkani malčevi su ekološki prihvatljiva alternativa konvencionalnim agro folijama proizvedenim od poletilenskog polimera niske gustoće.

2. Eksperimentalni dio

Netkani tekstili proizvedeni su u tvornici Renotex d.o.o., mehaničkim postupkom na grebenaljci, učvršćeni procesom iglanja s istim proizvodnim parametrima i nominalnom površinskom masom od 400 gm^{-2}. Kako su korišteni istu parametri proizvodnje, izmjerene površinske mase netkanog tekstila od konopljinih vlakana je 470 g m^{-2}, viskoznih 410 g m^{-2} te od vlakana polimliječne kiseline (PLA) 360 g m^{-2}. Netkani agrotekstili dimenzija 1,5 x 1,5 m su na polje postavljeni nasumično, u blokove od četiri replikacijske plohe. Vremenski uvjeti kojima su netkani tekstili izloženi (temperatura zraka, relativna vlažnost zraka i količina oborina) praćeni su tijekom eksperimenta. Uzorci netkanog tekstila periodički su uklonjeni nakon 30, 90 i 180 dana od dana polaganja. Masa po jedinici površine (HRN EN ISO 9073-1:2023), debljina (HRN EN ISO 9073-2:2021), vlačna svojstva (HRN EN ISO 9073-3:2023) i propusnost zraka (HRN EN ISO 9073-15:2007) ispitani su prema važećim normama. Dio uzoraka ostavljen je na polju, a utjecaj vremenskih uvjeta se i dalje prati budući da se ispitana svojstava nisu smanjila za 90 %, kako to navode važeće norme za ispitivanje biorazgradnje.

3. Rezultati i rasprava

Vidljivo je linearno smanjenje površinske mase i debljine netkanog tekstila u ovisnosti o vremenu izlaganja. Nakon 180 dana izlaganja, površinska masa netkanog tekstila od viskoznih (24 %) i konopljinih (13 %) vlakana se smanjila, dok je površinska masa netkanog tekstila od PLA vlakana ostala nepromijenjena. Debljina netkanih tekstila od viskoznih (46,7 %) i konopljinih (6,2 %) se također smanjila, dok je debljina netkanog tekstila od PLA vlakana ostala nepromijenjena. Prekidna sila svih netkanih tekstila značajno se povećala, i to u oba smjera proizvodnje (MD i CD) nakon 30 dana izlaganja. Nakon 90 dana izlaganja, prekidna sila netkanih tekstila od konopljinih i viskoznih vlakana se smanjuje, dok prekidna sila netkanog tekstila od PLA vlakana se nastavlja povećavati. Propusnost zraka netkanog tekstila se nakon 30 dana izlaganja povećala, nakon čega je zabilježen trend smanjenja vrijednosti što se pripisuje promjeni dimenzija netkanog tekstila, odnosno njegovom skupljanju i širenju (smanjenju/povećanju inicijalne dimenzije malča). Rezultati ukazuju na znatnu otpornost netkanog tekstila od PLA vlakana na vremenske utjecaje.



Slika 1. Prekidna sila netkanog tekstila u MD i CD smjeru proizvodnje tijekom 180 dana izlaganja vremenskim utjecajima

4. Zaključak

Ponašanje netkanog tekstila proizvedenog od konopljinih, viskoznih i PLA vlakana uslijed izlaganja vremenskim utjecajima pokazuje značajne razlike. Nakon 180 dana izlaganja vremenskim utjecajima vidljiva je razlika u smanjenju površinske mase i debljine netkanog tekstila proizvedenog od viskoznih i konopljinih vlakana. Netkani tekstili od vlakana PLA bilježe porast vlačnih svojstava uspoređujući s neizloženim, što ukazuje na promjenu strukture netkanih tekstila uslijed izloženosti vremenskim utjecajima.

Zahvala

Istraživanje je poduprla Europska unija iz Europskih strukturnih i investicijskih fondova, Operativnog programa Konkurentnost i kohezija, Europskog fonda za regionalni razvoj u sklopu projekta KK.01.2.1.02.0270.

5. Literatura

[1] Chen, Y., et.al. Microplastic pollution in vegetable farmlands of suburb Wuhan, central China, *Environmental Pollution*, **257** (2020), pp.113449, ISSN 1873-6424
[2] Weber, C.J. & Opp, C.: Spatial patterns of mesoplastics and coarse microplastics in floodplain soils as resulting from land use and fluvial processes, *Environmental Pollution*, **267** (2020), pp.115390, ISSN 1873-6424
[3] Liu, X., et.al. Development of natural fiber-based degradable nonwoven mulch from recyclable mill waste, *Waste Management*, **121** (2021), pp. 432–440, ISSN 0956-053X

Lela Martinaga

Životopis

Lela Martinaga završila je studij Ekoinženjerstva na Fakultetu kemijskog inženjerstva i tehnologije nakon čega upisuje Poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Na istoj instituciji, u okviru projekta Hrvatske zaklade za znanost, od 2016.-2022. god. radi kao asistentica na Zavodu za primijenjenu kemiju i bavi se proučavanjem biokatalitičkih procesa sinteze metalnih nanočestica u svrhu njihove primjene za razvoj funkcionalnih materijala. Koautorica je 11 znanstvenih radova te 19 sažetaka objavljenih u časopisima i zbornicima skupova. Dosad je održala 4 usmene i 10 poster prezentacija na skupovima te bila neposredni voditelj 5 diplomskih i završnih radova. Dobitnica je stipendije Republike Austrije za znanstveno usavršavanje na Sveučilištu za prirodne resurse i primijenjene znanosti u Beču (BOKU), Austrija.

Naslov teme doktorskog rada

Enzimatska sinteza i karakterizacija nanočestica metala i metalnih oksida te njihova primjena u svrhu poboljšanja funkcionalnih svojstava tekstilnih materijala

Mentori

prof. dr. dr. sc. Iva Rezić prof. dr. sc. Ana Vrsalović Presečki

Datum obrane doktorskog rada

SINTEZA NANOČESTICA ZLATA PRIMJENOM ENZIMA GLUKOZA DEHIDROGENAZE

Lela MARTINAGA

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, Hrvatska; lela.pintaric@ttf.unizg.hr

Sažetak: *Upotrebom nanočestica zlata (Au-NPs) u proizvodima tekstilne industrije mogu se unaprijediti njihova antibakterijska, UV zaštitna, vatrootporna i/ili hidrofobna svojstva. U okviru istraživanja, sintetizirane su Au-NPs primjenom oksidoreduktivnog enzima Glomerella cingulata glukoza dehidrogenaze (Gc GDH) kao bioreducensa. Ispitan je i optimiran utjecaj reakcijskih uvjeta na sintezu, određena je reakcijska kinetika i utjecaj iona zlata (Au) na brzinu reakcije. Prema rezultatima karakterizacije UV-Vis spektroskopijom, sintetizirane čestice su prosječne veličine oko 50 nm, dok rezultati karakterizacije transmisijskim elektronskim mikroskopom (TEM), ukazuju na sintezu Au-NPs sferičnog oblika i prosječne vrijednosti oko 2,83 nm nakon 24 h reakcije, odnosno 6,63 nm nakon 48 h reakcije.*

1. Uvod

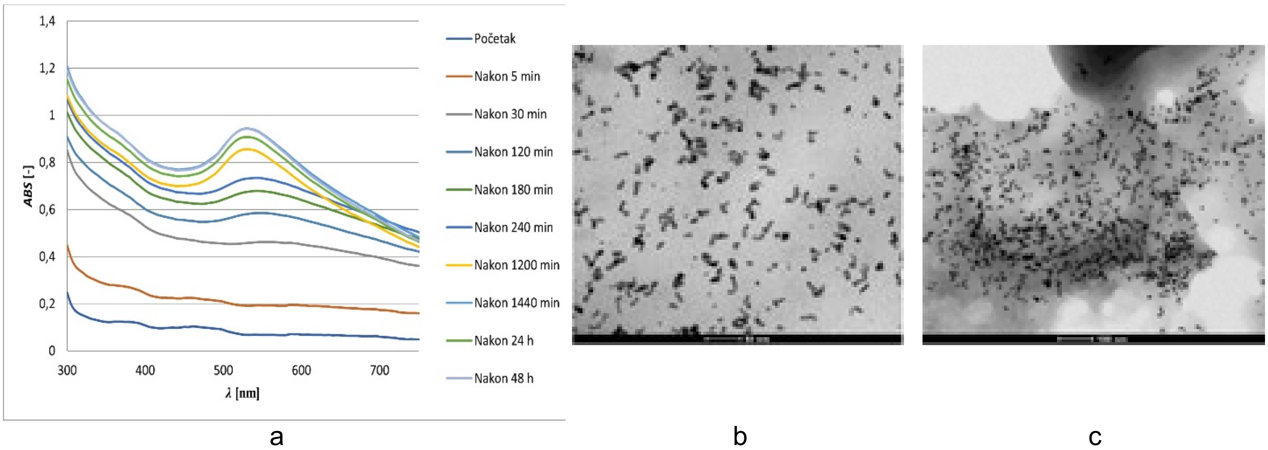
„Zelena sinteza“ nanočestica je brzo razvijajuća grana nanotehnologije koja za sintezu metalnih nanočestica koristi bioreducense kao što su agrootpad, biljni ekstrakti i enzimi, čime se osigurava ekološki prihvatljiv, jednostavan, isplativ i ponovljiv proces sinteze [1]. Nanočestice plemenitih metala, među kojima se ističu biokompatibilne nanočestice zlata (Au) karakteriziraju jedinstvena fizikalna, kemijska i biološka svojstva koja ovise o obliku i veličini čestica te uvjetuju i njihovu primjenu u biomedicini, prehrambenoj, kozmetičkoj i tekstilnoj industriji, optičkim uređajima, biosenzorima, itd. [2]. U okviru ovog istraživanja ispitana je i optimirana sinteza Au-NPs korištenjem enzima *Glomerella cingulata* glukoza dehidrogenaze (*Gc* GDH). Ispitana je kinetika reakcije te je predložen matematički model reakcije, a sintetizirane nanočestice karakterizirane su UV-Vis spektroskopijom i transmisijskim elektronskim mikroskopom (TEM).

2. Eksperimentalni dio

Enzimatska sinteza Au-NPs optimirana je provođenjem reakcija pri različitim koncentracijama enzima *Gc* GDH u nekoliko reakcijskih medija različitih vrijednost pH i pri različitim temperaturama. Korištenjem reakcije oksidacije glukoze katalizirane enzimom *Gc* GDH u kotlastom reaktoru uz dodatak soli zlato(III) klorid trihidrata (HAuCl4 · 3 H2O) provedena je enzimatska sinteza Au-NPs pri uvjetima reakcije određenim kao optimalnim: 0.1 M fosfatni pufer pH 5,5, koncentracija *Gc* GDH 0,3 mg cm^{-3}, koncentracija glukoze 1000 µM, koncentracija $HAuCl_4 \cdot 3 H_2O$ 550 µM, 37 °C, bez miješanja, prisustva svijetla i kisika. Kinetika reakcije oksidacije glukoze uz *Gc* GDH određena je pri optimalnim uvjetima korištenjem metode početne brzine reakcije, odnosno praćenjem koncentracije glukoze tekućinskom kromatografijom visoke djelotvornosti (HPLC), a ispitan je i utjecaj iona Au na brzinu reakcije. Sintetizirane Au-NPs karakterizirane su praćenjem UV-Vis spektara u području 300-750 nm pri rezoluciji 5 nm na spektrofotometru Multimode Plate Reader EnSpire (Perkin Elmer, SAD) i TEM analizom uzoraka resuspendiranih u destiliranoj vodi i osušenih na zraku na bakrenoj rešetki presvučenoj ugljikom korištenjem napona od 160 kV i uređaja FEI Tecnai G^2 Spirit (Thermofisher Scientific, Nizozemska).

3. Rezultati i rasprava

Rezultati spektroskopskog praćenja reakcije tijekom 48 h pokazali su maksimalnu apsorbanciju u području između 525 i 530 nm nakon 24 h reakcije ukazujući na prosječnu veličinu sintetiziranih Au-NPs oko 50 nm (Slika 1a) [3]. Kinetika enzima Gc GDH ispitana je u navedenoj reakciji i opisana jednosupstratnom Michaelis-Menteničinom kinetikom. Ispitivanjem utjecaja iona Au na aktivnost enzima u istoj reakciji, ustanovljena je značajna inhibicija reakcije opisana jednosupstratnom Michaelis-Menteničinom kinetikom s kompetitivnom inhibicijom ionima Au. Temeljem rezultata kinetičkih mjerenja i provedenih kontrolnih eksperimenata, zaključeno je kako je za sintezu Au-NPs zaslužno sinergijsko djelovanje glukoze i aminokiselina iz enzima Gc GDH. Prema rezultatima TEM analize, sintetizirane Au-NPs sferičnog su oblika i prosječne veličine 2,83 ± 2,40 nm nakon 24 h sinteze (Slika 1b), odnosno 6,63 ± 3,03 nm nakon 48 h sinteze (Slika 1c) što upućuje na aglomeraciju nanočestica s vremenom.



Slika 1: Rezultati karakterizacije sintetiziranih Au-NPs: a) UV-Vis spektri tijekom 48 h reakcije; b) TEM analiza Au-NPs nakon 24 h reakcije; c) TEM analiza Au-NPs nakon 48 h reakcije

4. Zaključci

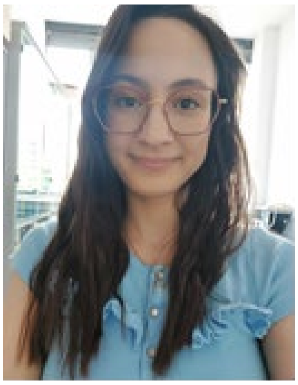
Temeljem određenih reakcijske kinetike i modela reakcije, predložen je, a provođenjem reakcija i potvrđen, reakcijski mehanizam enzimatske sinteze Au-NPs korištenjem Gc GDH. Uspješna sinteza Au-NPs potvrđena je spektrofotometrijski (maksimumi apsorbancije na oko 525 – 530 nm) i TEM analizom (2,83 nm nakon 24 h, odnosno 6,63 nm nakon 48 h reakcije).

Zahvala

Istraživanje je provedeno u okviru aktivnosti na projektima voditeljice prof. dr. dr. sc. Ive Rezić financiranih od Hrvatske zaklade za znanost – Projekt razvoja karijera mladih istraživača – izobrazba novih doktora znanosti (DOK-10-2015) i "Antibakterijska prevlaka za biorazgradive medicinske materijale – ABBAMEDICA" (HRZZ IP-2019-04-1381) te u okviru stipendije Republike Austrije, Agencije za međunarodnu suradnju u obrazovanju i istraživanju (OeAD-GmbH) u suradnji prof. dr. dr. sc. Ive Rezić i suradnika na projektu doc. dr. sc. Rolanda Ludwiga.

5. Literatura

[1] Adelere, I. A.; Lateef, A.: A novel approach to the green synthesis of metallic nanoparticles: the use of agro-wastes, enzymes, and pigments, *Nanotechnology Reviews*, **5** (2016), pp. 567-587, ISSN 2191-9089
[2] Ahmed, S. et al.: Biosynthesis of gold nanoparticles: a green approach, *Journal of Photochemistry and Photobiology B: Biology*, **161** (2016), pp. 141-153, ISSN 1011-1344
[3] Zuber, A. et al.: Detection of gold nanoparticles with different sizes using absorption and fluorescence based method, *Sensors and Actuators B-Chemical*, **227** (2016), pp. 117-127, ISSN 0925-4005



Petra Mihovilović

Životopis

Petra Mihovilović rođena je 1997. god. u Splitu. God. 2021. završava diplomski studij Kemija istraživačkog smjera na Kemijskom odsjeku Sveučilišta u Zagrebu Prirodoslovno-matematičkom fakultetu). Za izvrstan uspjeh tokom studija 2021. god. nagrađena je Medaljom Kemijskog odsjeka. 2022. god. zapošljava se kao asistent na Zavodu za primijenjenu kemiju Sveučilišta u Zagrebu Tekstilno-tehnološkog fakulteta, gdje i upisuje doktorski studij Tekstilna znanost i tehnologija. Svoj znanstveni interes usmjerava na inženjerstvo materijala te razvoj održivih i okolišno prihvatljivih tehnologija za pročišćavanje otpadnih voda s naglaskom na uklanjanje mikroplastičnih čestica. 2023. god. postaje dio istraživačke skupine na projektu Hrvatske zaklade za znanost "*Procjena otpuštanja čestica mikroplastike iz poliesterskih tekstilija u procesu pranja-* InWashed-MP“, voditeljice prof. dr. sc. Tanje Pušić.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Branka Vojnović

Datum obrane doktorskog rada

RAZVOJ METODE PRIPREME UZORAKA ZA ANALIZU ČESTICA MIKROPLASTIKE U OTPADNIM VODAMA NAKON PRANJA TEKSTILA

Petra MIHOVILOVIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, petra.mihovilovic@ttf.unizg.hr

Sažetak: *Mikroplastično onečišćenje pronađeno je u gotovo svim ekosustavima, zbog čega je prepoznato kao jedan od glavnih ekoloških problema današnjice. Tekstilije sintetskog porijekla jedan su od glavnih izvora čestica mikroplastike (MP), a utvrđeno je da čestice MP djeluju kao potencijalni vektor za prijenos adsorbiranih različitih zagađivala i patogena. Raznolikost izvora emisije te složenost fizikalno-kemijskih i bioloških svojstava plastičnog materijala odražava se u otežanoj reproducibilnoj izolaciji i analizi MP-a. Dok prisutnost mikroplastike u okolini stvara brojne izazove pri kontroli pozadinske kontaminacije. U doktorskom radu razvit će se i optimizirati metoda kojim bi se učinak matrice sveo na minimum u sustavima otpadnih voda iz praonica, nakon čega slijedi istraživanje čestica mikroplastike kao vektora za prijenos zagađivala.*

1. Uvod

Kontinuirani rast proizvodnje, neodrživog načina uporabe i nepropisnog odlaganja plastičnih materijala uzrokovala je pojavu nove vrste zagađivala pod nazivom mikroplastika. Pojam mikroplastika koristi se za opisivanje manjih fragmenta plastičnog materijala, a podrazumijeva čestičnu tvar čija dimenzije poprima veličinu manju od 5 mm [1]. Onečišćenje okoliša mikroplastikom predstavlja ekološki problem iz nekoliko razloga. Plastični materijali s složenom kemijskom strukturom manje su skloni degradaciji, a ujedno pod utjecajem atmosferilija (sunčevo zračenje, temperatura vode i procesi abrazije) dolazi do fragmentacije ovih materijala i ispiranja potencijalno otrovnih aditiva u vodeni okoliš [2]. Fragmentirane čestice s povećanom specifičnom površinom predstavljaju dobar adsorbens za različite vrste zagađivala (bojila, teški metali, patogeni organizmi), koji naposljetku putem vodenih organizama ulaze u hranidbeni lanac [3].
Veliki udio mikroplastičnih čestica prisutnih u okolišu upravo dolazi u obliku fragmenata vlakana, oslobođenih uglavnom tijekom strojnog pranja tekstilnih materijala, čiji se efluenti zatim ispuštaju u postrojenja za pročišćavanje otpadnih voda [4]. Tendencija otpuštanja ovih čestica ovisi o svojstvima tekstilnih materijala (vrsti plošne tekstilije, teksturi te vrsti pređe i vlakana), kao i čimbenicima Sinnerovog kruga u procesu pranja (uporaba deterdženta, temperatura pranja, trajanje procesa, mehanika) [5]. Budući da postrojenja za pročišćavanje otpadnih voda nisu u potpunosti prilagođena uklanjanju MP čestica, predstavljaju glavnu točku ulaza čestičnih tvari sintetskog porijekla u vodeni okoliš.
Jedna od glavnih problematika ovoga doktorskog rada ogledava se u pogledu metodologije uzorkovanja, izolacije i karakterizacije mikroplastičnih čestica. Mnogobrojne studije pružaju uvid u količinu detektiranih MP čestica, no primijenjene metode uzorkovanja, izolacije, pročišćavanja i identifikacije MP-a uvelike se razlikuju, što onemogućava opsežno tumačenje i usporedbu rezultata studija. Dodatnu komplikaciju u razvoju standardizirane metode za praćenje MP-a predstavlja širok raspon koncentracija, veoma raznoliki oblici (kuglasti/sferni oblici, nepravilne čestice, vlakna, filmovi, pjene), kemijski sastav (uključujući konvencionalne i biopolimere) i stupanj starenja tekstilnog materijala. Također, čestice u svojoj strukturi sadrže i različite aditive (antioksidansi, svjetlosni stabilizatori, plastifikatori, usporivači gorenja, pigmenti itd.) i adosrbirane kontaminante (postojana organska zagađivala, antibiotici, metali itd.) [6].

2. Eksperimentalni dio

Izbor odgovarajuće analitičke tehnike za izolaciju MP čestica prvenstveno će ovisiti o odabranim metodama identifikacije, karakterizacije i kvantifikacije čestica, ali i o složenosti matrice uzoraka. Zbog kompleksnosti matrice voda iz praonica (visok sadržaj suspendirane tvari i organskih specija) nužna je primjena kombinacija više tehnika separacije i ekstrakcije. Separacija u gradijentu gustoće koristit će se za izolaciju čestica mikroplastike iz uzoraka matrice uzorka otpadnih voda od pranja, koje sadrže visok udio suspendiranih tvari. U tu svrhu koristit će se otopine različitih soli (NaCl, NaBr, NaI, $ZnCl_2$, $ZnBr_2$,itd.), koje se međusobno po topljivosti, gustoći, toksičnosti i cijeni. Tehnika separacije u gradijentu gustoće neučinkovita je za uklanjanje prisutnih organskih specija iz suspenzija deterdženta (tenzidi, bilderi, enzimi, itd.). U svrhu uklanjanja organske matrice mogu se koristiti različiti reagensi (npr. kiseline, baze, oksidacijski reagensi, itd.), kao i napredne tehnologije ekstrakcije (protokol ekstrakcije ulja, mikrovalna ekstrakcija, itd.). U sklopu optimizacije metodologije izolacije mikroplastičnih čestica utvrditi će se imaju li korišteni reagensi štetan utjecaj na polimerne čestice (čestice moraju ostati nepromijenjene u pogledu težine, volumena, oblika i boje). Takvi efekti utvrdit će se fizikalnom karakterizacijom izoliranih čestica (digitalni mikroskop, SEM-EDX, itd.), što obuhvaća određivanje veličine čestica, boje, oblika i morfologije. Kemijska karakterizacija kromatografskim i spektroskopskim metodama (pyro-GC/MS, FTIR, itd.) pružiti će dodatan uvid u promjenu karakterističnih skupina odabranog polimernog materijala.

3. Rezultati i rasprava

Pri odabiru optimalne metodologije prikupljanja, obrade i analize uzorka, osim analitičkih parametra poput točnosti, preciznosti i selektivnosti, u obzir će se uzeti i praktični aspekti poput vremena i troškova analize, jednostavnosti analitičke tehnike te ekološki utjecaj odabrane tehnike. Uzimajući u obzir sve moguće metode obrade uzoraka, prednost će se dati reagensu kompatibilnom sastavu matrice, uz uvjet da nakon tretmana čestice moraju ostati nepromijenjene u pogledu težine, volumena, oblika i boje.

4. Zaključak

Mikroplastično onečišćenje okoliša predstavlja jedno od važnijih ekoloških pitanja današnjice. Ovaj doktorski rad doprinijet će razvoju konsenzusa uzorkovanju, pripravi i analizi uzoraka s ciljem određivanja MP-a u sustavima otpadnih voda iz praonica, ali i vektorskim svojstvima otpuštenih čestica. Razumijevanje pojedinih vrsta predobrade s obzirom na prikupljeni uzorak utječe i na samu kvalitetu dobivenih eksperimentalnih podataka. Tada je moguće i opsežno provesti usporedbu rezultata različitih istraživačkih skupina, tumačiti izvore ovakve vrste zagađivala, njegov utjecaj na žive organizme, ali i njegovu buduću prevenciju.

Zahvala

HrZZ Hrvatska zaklada za znanost

Istraživanja je podržala Hrvatska zaklada za znanost u sklopu projekta HRZZ-IP-2020-02-7575 „Procjena otpuštanja čestica mikroplastike iz poliesterskih tekstilija u procesu pranja“ InWaShed-MP, voditeljice prof. dr. sc. Tanje Pušić.

5. Literatura

[1] Zhang, C., Zhang, D.: Microplastics. U *Encyclopedia of Ocean Engineering*. Springer, ISBN 978-981-10-6963-5, Singapore, (2021)
[2] Liu, L. et al.: On the degradation of (micro) plastics: degradation methods, influencing factors, environmental impacts, *Science of the Total Environment*, **806** (2022): 151312
[3] Prata, J.C. et al.: Environmental exposure to microplastics: An overview on possible human health effects, *The Science of the total environment*, **702** (2020): 134455
[4] Bayo, J.; Olmos, S. & López-Castellanos, J.: Microplastics in an urban wastewater treatment plant: The influence of physicochemical parameters and environmental factors, *Chemosphere*, **238** (2020): 124593, ISSN 0045-6535
[5] Periyasamy, A. P. & Tehrani-Bagha, A.: A review on microplastic emission from textile materials and its reduction techniques, *Polymer Degradation and Stability*, **199** (2022) 109901, ISSN 0141-3910
[6] Ivleva, N. P.: Chemical Analysis of Microplastics and Nanoplastics: Challenges: Advanced Methods, and Perspectives, *Chemical Reviews*, **121** (2021) 19, pp. 11886- 11936

Marija Nakić

Životopis	Rođena je u Širokom Brijegu, gdje je završila osnovnu i srednju školu. Završila je studij na Sveučilištu u Zagrebu Tekstilno-tehnološki fakultet, smjer projektiranje i oblikovanje tekstila i odjeće, te magistrirala na temu "Hrvatska etno baština na području Rame". Trenutno pohađa sveučilišni poslijediplomski studij Tekstilna znanost i tehnologija. Radila je kao dizajner za interijere u nekoliko tvrtki u Hercegovini. Trenutno radi u Uredu za međunarodnu suradnju na Sveučilištu u Mostaru.
Naslov teme doktorskog rada	Projektiranje replike Dubrovačkoga šudara i trajna pohrana njegovih tehničkih značajki
Mentori	izv. prof. dr. sc. Željko Knezić doc. dr. sc. Daniel Vasić
Datum obrane doktorskog rada	

PROJEKTIRANJE REPLIKE DUBROVAČKOGA ŠUDARA I TRAJNA POHRANA NJEGOVIH TEHNIČKIH ZNAČAJKI

Marija NAKIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, Hrvatska, mnakic@ttf.hr

Sažetak: *Istraživanje obuhvaća hrvatsku tekstilnu baštinu kroz detaljnu analizu tehničkih značajki ženske marame kaštelanskog kraja - Dubrovački šudar, kao dio težačke, građanske i plemenitaške nošnje, sačuvane u muzejima hrvatskog primorja. Temeljem cjelokupnih rezultata istraživanja realizirat će se replika Dubrovačkoga šudara i izraditi mapa kao doprinos očuvanju tekstilne baštine u Hrvatskoj. Digitalizacijom i trajnom pohranom dobivenih rezultata istraživanja omogućit će se javni pristup i upoznavanje Dubrovačkog šudara kao vrijednog muzejskog primjerka tekstilne baštine.*

1. Uvod

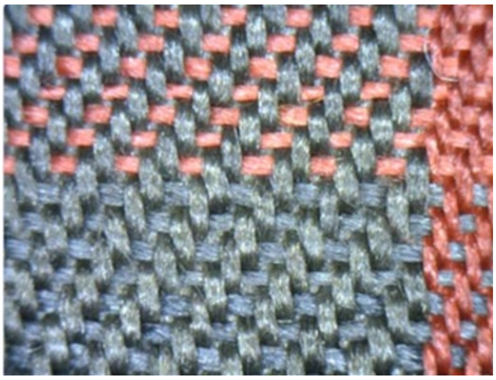
U kulturi odijevanja žena hrvatskog primorja marame su imale veliku ulogu. Kao pokrivalo za glavu pojavljuju se nazivi *rubac*, *šudar*, *bevelaš dubrovački šudar* i *blonda* [1]. Hrvatsko rukotvorstvo razlikuje izradu svakodnevne odjeće od grublje pređe te svečane odjeće izrađene od vrlo finih svilenih niti. [2]. Pretpostavlja se da su marame imale naziv *dubrovački šudar* zbog slično tkanih marama naziva *dumanjski ubručići*, koje su već postojale u Dubrovniku, a gdje se manufakturna proizvodnja svile najduže zadržala [3]. Novija istraživanja osim digitalizacije donose i nove postupke 3D virtualne simulacije tekstilnog artefakta [4].

2. Eksperimentalni dio

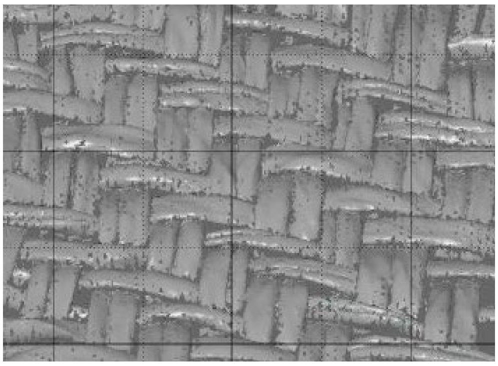
U ovom proširenom sažetku prikazani su rezultati analize površine muzejskog primjerak šudara digitalnim mikroskopom Dino-Lite Pro AM413T i simulacije 3D skeniranjem. Nakon temeljne analize uslijedila je faza izrade replike *Dubrovačkoga šudara* kroz dekompoziciju, te pripremne faze za tkanje. Horizontalni tkalački stan s četiri lista, vlasništvo Muzeja grada Kaštela, restauriran je za tkanje replike. Pripremne faze i tkanje se odvijalo u vanjskom i unutarnjem prostoru muzeja kako bi postupak izrade replike bio proveden u što sličnijim uvjetima izrade izvornika.

3. Rezultati i rasprava

Slika 1 prikazuje snimak površine digitalnim mikroskopom i simulaciju 3D skenerom gdje se vidi ispreplitanje osnove i potke, a na prvoj snimci je također vidljiv sklad veza i boja.



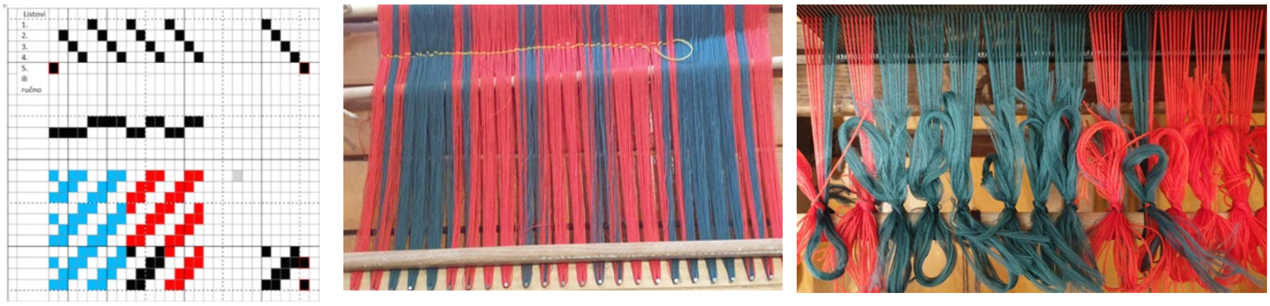
a



b

Slika 1: Snimke uzroka: a. digitalni mikroskop; b. simulacija 3D skenerom

Slika 2 prikazuje pojedine faze neophodne za izradu replike Dubrovačkoga šudara po konceptu ovoga doktorskoga rada.



a b c

Slika 2: Izrada replike Dubrovačkoga šudara: a. uzornica; b. snovanje osnove; b. ujednačavanje napetosti osnove prije početka procesa tkanja

Dekompozicijom je utvrđen vez keper cirkas, sl.2a. Na sl. 2b prikazano je snovanje osnove, a na sl. 2c ujednačavanje napetosti osnove prije početka procesa tkanja. Postupak snovanja na vodoravnim češljevima zahtijeva ujednačenu napetost osnovinih niti koju je vrlo teško postići osobama bez prethodnog iskustva u ovakvim poslovima. Prilikom postupka snovanja potrebno je pripaziti na stvaranje pravilnog križa niti koji je ključan za raspored osnove. Otežavajući element u samom postupku je bilo snovanje zelene osnove koja se zbog dvostruko veće finoće u odnosu na crvenu pređu snovala duplo. Sama pređa nije končana pa se tijekom postupka snovanja događalo da se zelena pređa zapetlja i pukne što je dodatno usporavalo cijeli proces. Postupak uvođenja osnove u brdo je bilo otežano kod niti osnove zelene pređe jer se često događalo da su se zapetljane niti morale prekinuti i nadovezati na novu kako bi se mogla uvesti u brdo. Ujednačavanje napetosti niti osnove prije početka faze tkanja zahtijeva provjeravanje napetosti niti u više navrata na način da se vanjski dio dlana lagano povuče po površini niti osnove te se potom olabavljene niti ponovno napinju i na koncu vežu u mašnu koja se u slučaju labavosti niti u početnoj fazi tkanja može ponovno razvezati kako bi se ujednačila napetost.

4. Zaključci

Istraživanje usmjereno na uspostavljanje novih kriterija u očuvanju tekstilne baštine uz korištenje suvremenih tehnologija izravno doprinosi primjeni znanstvenog pristupa u očuvanju povijesnog tekstila hrvatskog primorja. Vrednovanje tekstilne baštine uvođenjem novih metoda i alata omogućit će interaktivno prenošenje i njegovanje tradicijskih znanja, umijeća i vještina budućim generacijama na suvremen način.

Zahvala

Muzeju grada Kaštela u Kaštel Lukšiću, Etnografskom muzeju u Splitu te Tekstilno-tehnološkom fakultetu Sveučilišta u Zagrebu za pomoć pri analizi uzoraka.

5. Literatura

[1] Ivančić, S., Acalija, S.: *Povismo i sukno: kaštelansko tradicijsko ruho*, Etnografski muzej Split & Muzej grada Kaštela, ISBN 978-953-6866-36-6 & 978-953-7276-37-9, Split (2015), str. 68-72

[2] Firšt Rogale, S.; Rogale, D. & Knezić, Ž.: Povijest izrade i proizvodnje odjeće u Hrvatskoj, In: *Godišnjak 2019 Hrvatske akademije tehničkih znanosti – Hrvatska tehnička i industrijska baština*, Akademija tehničkih znanosti Hrvatske, ISSN 1332-3482, Zagreb (2020), str.145-160

[3] Vojnović Traživuk, B.: Tekstilno rukotvorstvo u Dalmaciji, *Ethnologica Dalmatica*, **28** (2021), str. 19-49, ISSN 0353-9210

[4] Portalés, C. et al.: Interactive Tools for the Preservation, Dissemination and Study of Silk Heritage—An Introduction to the SILKNOW Project, *Multimodal Technologies and Interaction*, **2** (2018) 2, pp. 1-28, ISSN 2414-4088

Eanamul Haque Nizam

Životopis

Eanamul Haque Nizam je trenutno zaposlen kao docent na Sveučilištu Southeast (Tejgaon, Dhaka, Bangladesh). Obranio je 2 magisterija, magisterij modnog dizajna i tekstilnog inženjerstva na Tekstilnom sveučilištu Wuhan (Hubei, Wuhan, Kina). Njegov istraživački interes uključuje razvoj tablica odjevnih veličina, morfologiju tijela, razvoj novih proizvoda i implementaciju mode u tekstilnom sektoru. Ima više od 13 godina nastavnog staža i godinu dana neposrednog radnog iskustva u industrijskom sektoru te je objavio više od 55 znanstvenih i stručnih članaka u časopisima te 2 znanstvene knjige.

Naslov teme doktorskog rada

Studijski savjetnici prof. emer. dr. sc. Darko Ujević prof. dr. sc. Ayub Nabi Khan

Datum obrane doktorskog rada

ANALIZA ANTROPOMETRIJSKIH PODATAKA I RAZVOJ TABLICA ODJEVNIH VELIČINA ZA MUŠKU POPULACIJU U BANGLADEŠU U DOBI OD 21 DO 25 GODINA

Eanamul Haque NIZAM

Department of Textile Engineering, Southeast University, Tejgaon, and Dhaka, Bangladesh, eanamul.nizam@seu.edu.bd

Sažetak: *Glavni cilj doktorskoga rada je razviti tablicu mjera odjevnih veličina za bangladeško tržište muške odjeće. U ovoj studiji primijenjen je kvantitativni sustav za provođenje istraživanja. Istraživanje je provedeno na uzorku od 459 muških studenata dobne skupine između 20 i 25 godina. Na navedenoj skupini studenata su načinjene izmjere na 25 antropometrijskih ključnih točaka prema navedenim normama ISO 3635, ISO 8559 i ISO 9407 kako bi se dobili podaci potrebni za izradu antropometrijskog sustava odjevnih veličina. Dobiveni podaci su statistički obrađeni prema jednosmjernom ANOVA testu ($F_{5,144}=0{,}0739$, $p\leq0{,}05$), Tukeyjevom testu višestruke usporedbe (veći od 0,05) i Shapiro-Wilkovom testu normalnosti (vrijednost značajnosti svih podataka Shipiro-Wilkovog testa veća je od 0,05 ($W\geq0{,}05$)) Rezultati istraživanja podržavaju razvoj tablica odjevnih veličina. Analiza Pearsonovog koeficijenta korelacije pokazuje da izmjere studenata u dobi od 20 godina nisu značajna za izradu tablice odjevnih veličina u skladu s ISO i EN normama. Stoga su na temelju dobivenih rezultata načinjene tablice odjevnih veličina za dobne skupine od 21 do 25 godina za mušku populaciju Bangladeša. Istraživanja su pokazala da je tjelesna visina značajna za podjelu u odjevne razrede te je načinjena podjela za svaku dob u tri razreda (S, M i L) kako bi se dobile odgovarajuće tablice odjevnih veličina za izradu odjeće.*

1. Uvod

Antropometrija je istraživačka metoda antropologije koja se bavi utvrđivanjem dimenzija ljudskog tijela i njihovim prosuđivanjem s ciljem da što točnijim mjerenjem kvantitativno okarakterizira morfološke (morfološka antropometrija) i fiziološke (fiziološka antropometrija) osobine čovječjeg tijela koje su različite u različitim populacijama [1]. Antropometrija ispituje kako se te mjere mijenjaju ovisno o čimbenicima poput dobi, rase, spola i nacionalnosti. U medicinskim i forenzičkim istraživanjima koriste se antropometrijski podaci i formule [2]. Stoga se može reći kako je antropometrija jedno od ključnih polja u znanosti koje pruža informacije i o zdravstvenom stanju populacije. Iako nije uvijek moguće da se proizvod i korisnik savršeno podudaraju, ugradnja antropometrijskih podataka u ergonomski dizajn osigurava siguran i jednostavan odnos između proizvoda i korisnika, koji doprinosi visokoj radnoj učinkovitosti i produktivnost. Razvijene zemlje desetljećima provode antropometrijska mjerenja [3]. Međutim, antropometrijski podaci muške populacije Bangladeša nisu do sada utvrđeni. Bangladeš ima oko 160 milijuna ljudi, što ga čini osmom najmnogoljudnijom nacijom na svijetu [4]. Dobni raspon od 21 do 25 godina smatra se mladom populacijom i oko 43% populacije pripada ovoj dobnoj skupini u Bangladešu. Istraživanja doktorskog rada temelje se na odabiru muške populacije studenata u dobnoj skupini od 21 do 25 godina na temelju čijih 25 antropometrijskih izmjera je načinjena tablica mjera odjevnih veličina potrebnih za izradu odjeće.

2. Eksperimentalni dio

Uzorak: Odabrani su studenti u dobi od 20-25 godina (n=459) za antropometrijske izmjere. Zbog financijskih ograničenja nije bilo mogućnosti izmjere većeg broja studenata.
Tjelesne mjere: Na ispitanicima je načinjeno 25 antropometrijskih izmjera koje su potrebne za izradu sustava odjevnih veličina za izradu odjeće. Međunarodna organizacija za standardizaciju (ISO) izdala je kao preporuku niz standarda krajem 70-ih godina prošlog stoljeća koji čine temelj jedinstvenog sustava označavanja odjeće u cijelom svijetu. Kasnije su izdavanjem standarda ISO 3635, ISO 8559 i ISO 9407 postavljeni temelji definiranja tjelesnih mjera za potrebe odjevne industrije kao i za provedbu antropometrijskih mjerenja.
Analiza antropometrijskih podataka: Program Minitab 17.1 Statistical Package za Windows korišten je za analizu podataka studije nakon antropometrijskog istraživanja. Test normalnosti korišten je da se ustvrdi odgovaraju li prikupljeni podaci normalnoj distribuciji. Podaci za svako mjerenje imali su normalnu distribuciju, kao što je bilo i za očekivati. Zatim je korištena ANOVA analiza za utvrđivanje razlika između različitih godišta (21-25 godina). Odnosi između različitih tjelesnih mjera ispitani su pomoću Pearsonovih korelacijskih koeficijenata. Sustav odjevnih veličina razvijen je na temelju dobivenih rezultata [5].

3. Rezultati i rasprava

Na dobivenim podacima načinjena je deskriptivna analiza na temelju koje se može uočiti kako su srednje vrijednosti tjelesne visine za mušku populaciju studenata u dobi od 20 do 25 godina sljedeće: 169,81;168,06; 168,47; 170,59; 168,93 i 165,55 i sva mjerenja slijede normalnu distribuciju. Također su izračunate prosječna i standardna devijacija, varijanca (CV%) i kvadratne vrijednosti. Standardna devijacija (SD) za većinu antropometrijskih mjerenja je velika, što ukazuje na visoku varijabilnost mjerenja te je potrebno provesti t-test. Rezultati Shapiro-Wilkovog testa normalnosti pokazuju ako je vrijednost značajnosti veća od 0,05 podaci su u normalnoj distribuciji, a ukoliko je manja od 0,05 podaci značajno odstupaju od normalne distribucije. Za obradu dobivenih podataka korištena je i linearna regresijska analiza, gdje se linearnom jednadžbom za kvantitativno modeliranje dobivaju odnosi između nepoznate ili zavisne varijable i poznate ili nezavisne varijable. Tablice odjevnih veličina izrađene su na temelju dobivenih rezultata navedenim statističkim metodama.

4. Zaključci

Istraživanja doktorskog rada temelje se na odabiru muške populacije od 459 studenata u dobnoj skupini od 21 do 25 godina na temelju čijih 25 antropometrijskih izmjera je načinjena tablica mjera odjevnih veličina potrebnih za izradu odjeće. Dobiveni antropometrijski podaci su statistički obrađeni pomoću Program Minitab 17.1 Statistical Package za Windows, ANOVA testa, Tukeyjev test višestruke usporedbe i Shapiro-Wilkov test normalnosti te podijeljeni u tri razreda (S, M, L). Dobivene tablice odjevnih veličina su osnova za proizvodnju odjeće za muškarce u dobi od 21 do 25 godina u Bangladešu.

5. Literatura

[1] Ujević, D., et al.: Hrvatski antropometrijski sustav, Tekstilno-tehnološki fakultet Sveučilišta u Zagrebu, Zagreb, (2006), str. 224.

[2] *Body Measurements (Anthropometry), National health and nutrition examination survey III*, Westat, Inc. 1650 Research Boulevard Rockville, MD 20850, October 1988, *Pristupljeno* https://wwwn.cdc.gov/nchs/data/nhanes3/manuals/anthro.pdf

[3] Abeysekera, J. D., & Shahnavaz, H. Body size variability between people in developed and developing countries and its impact on the use of imported goods. *International Journal of Industrial Ergonomics*, **4** (1989) 2, pp. 139-149

[4] *Division of Bangladesh*, Last update 2023, *Pristupljeno* https://en.wikipedia.org/wiki/Divisions_of_Bangladesh

[5] Ujević, D., Rogale, D., Hrastinski: *Tehnike konstruiranja i modeliranja odjeće*, Tekstilno-tehnološki fakultet, (2000)

Željka Pavlović

Životopis

Željka Pavlović je rođena 1987. god. u Zaboku. Nakon završene osnovne škole u Samoboru, upisuje Ekonomsku, trgovačku i ugostiteljsku školu te je završava 2005. god.. U periodu od 2005. do 2012. god. studira na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, gdje je diplomirala s temom „Upotrebna svojstva kratkih čarapa“, mentor prof. dr. sc. Zlatko Vrljičak. Nakon završenog studija zapošljava se u Tvornici čarapa Jadran d.d., gdje je 3,5 godine radila kao tehnolog u proizvodnji. U 2015. godini zaposlena je kao asistent na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, na Zavodu za projektiranje i menadžment tekstila. U 2016. god. upisuje poslijediplomski sveučilišni studij „Tekstilna znanost i tehnologija“ na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Područja od posebnog interesa su joj projektiranje i proizvodnja čarapa te analiza rada pletaćih strojeva.

Naslov teme doktorskog rada

Termofiziološka svojstva pletiva uvjetovana procesom pletenja i strukturom pletiva

Mentor

prof. dr. sc. Vesna Marija Potočić Matković

Datum obrane doktorskog rada

ANALIZA STRUKTURNIH PARAMETARA PLETIVA

Željka PAVLOVIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
zeljka.pavlovic@ttf.unizg.hr

***Sažetak:** Proces pletenja i struktura pletiva značajno utječu na svojstva tekstila, igrajući ključnu ulogu u njegovoj udobnosti i performansama. Naglašava se važnost proučavanja konstrukcijskih svojstava. Proces pletenja i struktura pletiva ključni su čimbenici u oblikovanju termalne izolacije, prozračnosti te sposobnosti održavanja optimalne temperature u dodiru s tijelom. Kroz pažljivo prilagođavanje ovih elemenata, postižu se inovacije u tekstilnoj industriji, stvarajući materijale koji pružaju optimalnu termalnu udobnost u različitim uvjetima.*

1. Uvod

U fokusu ovog istraživanja stoji analiza ključnih parametara tekstilnih uzoraka te njihova ključna uloga u ostvarivanju udobnosti tekstilnih materijala [1]. Strukturalni parametri poput horizontalne i vertikalne gustoće, utroška niti u očici, debljine pletiva te plošne i zapreminske mase značajno utječu na kvalitetu tekstilnih materijala [2]. Analizom ovih parametara, ne samo da se istražuju njihove međusobne korelacijske veze, već i dublje razumijevanje njihove uloge u stvaranju udobnih tekstilnih proizvoda. Udobnost odjeće, često ocijenjena subjektivnim dojmom nositelja, ima čvrstu povezanost s fizikalnim karakteristikama tekstila [3]. Horizontalna i vertikalna gustoća mogu utjecati na prozračnost i fleksibilnost pletiva, dok debljina pletiva može igrati ključnu ulogu u termalnoj izolaciji [4]. Utrošak niti u očici može utjecati na prozračnost materijala, dok plošna i zapreminska masa odražavaju gustoću i volumen pletiva [5]. Proučavanje ovih parametara stoga postaje temeljni korak prema optimizaciji tekstilnih materijala kako bi se postigla optimalna udobnost [6]. Kroz analizu, ne samo da se identificiraju međusobni odnosi, već se i potvrđuje važnost svakog pojedinog parametra u kontekstu stvaranja tekstila koji zadovoljava visoke standarde udobnosti, poboljšavajući time ukupno iskustvo korisnika.

2. Eksperimentalni dio

Za izradu uzoraka korišten je kružnopletaći dvoiglenični stroj finoće E17. Metoda rada obuhvaća detaljnu analizu parametara strukture pletiva kako bi se bolje razumjele njihove karakteristike. Uzorci su kulirni, glatki, desno-desni, izrađeni jednostrukim pređama finoće 20 tex. Korištene su pređe izrađene različitim tehnologijama predenja: prstenasto, rotorsko, zračno-mlazno i SIRO. Također, korištena su različita vlakna poput pamučnih, viskoznih, liocelnih, modalnih, mikromodalnih i poliesterskih. U doradi su pletiva prana na temperaturi od 110 °C s udjelom 0,05% NaOH i trajanju 110 min. Nakon pranja pletiva su bojadisana i potom sušena na temperaturi od 120 °C, pri prolazu materijala kroz sušnicu 0,15 m/s. Analiza obuhvaća ključne elemente poput horizontalne i vertikalne gustoće, utroška niti u očici, debljine pletiva, plošne mase i zapreminske mase. Ovim pristupom se temeljito sagledavaju strukturalne karakteristike pletiva te identifikaciju njihovih međusobnih povezanosti, čime se stvorila osnova za detaljan uvid u rezultate korelacijske analize prikazane u nastavku.

3. Rezultati i rasprava

Razumijevanje korelacijskih veza između konstrukcijskih parametara ključno je za bolje sagledavanje strukturalnih karakteristika pletiva i njihovog utjecaja na krajnje performanse materijala. Prikazani su rezultati korelacijske analize horizontalne gustoće, vertikalne gustoće, utroška niti u očici, debljine pletiva, plošne mase i zapreminske mase.

U tablicama 1. i 2. prikazana je korelacijska povezanost ispitanih parametara. Povezanost debljine i gustoće pletiva jasno pokazuje snažnu vezu, s koeficijentima korelacije između 0,79 i 0,90. Promjene u debljini pletiva prate slične promjene u gustoći, istaknuta je i vezom s vertikalnom gustoćom. S druge strane, povezanost plošne mase pletiva s drugim ispitivanim parametrima varira. Otkrivena je manje izražena veza s utroškom niti u očici -0,32, ukazujući na obrnut odnos gdje povećanje utroška niti u očici prati smanjenje plošna mase pletiva. Dodatno, primijećena je umjerena povezanost plošne mase s debljinom pletiva. Ovaj podatak sugerira određenu proporcionalnost između debljine pletiva i plošne mase, iako nije izražena kao u slučaju debljine i gustoće.

Tablica 1: Korelacijska veza između konstrukcijskih parametara sirovih uzoraka pletiva

	Horizontalna gustoća	Vertikalna gustoća	Utrošak niti u očici	Debljina pletiva	Plošna masa	Zapreminska masa
Horizontalna gustoća	1					
Vertikalna gustoća	0,622271	1				
Utrošak niti	0,075104	-0,5108	1			
Debljina pletiva	0,904658	0,790334	0,021117	1		
Plošna masa	0,545635	0,762054	-0,32587	0,675223	1	
Zapreminska masa	-0,32403	0,052977	-0,46435	-0,29496	0,500809	1

Tablica 2: Korelacijska veza između konstrukcijskih parametara dorađenih uzoraka pletiva

	Horizontalna gustoća	Vertikalna gustoća	Utrošak niti u očici	Debljina pletiva	Plošna masa	Zapreminska masa
Horizontalna gustoća	1					
Vertikalna gustoća	0,712179	1				
Utrošak niti	0,118394	0,023309	1			
Debljina pletiva	0,928206	0,854205	0,199231	1		
Plošna masa	0,896468	0,869061	0,175782	0,949657	1	
Zapreminska masa	-0,81935	-0,77165	-0,30072	-0,94374	-0,84162	1

Primijećena je značajno veća povezanost među parametrima kod dorađenih pletiva u usporedbi s sirovim. Izuzetno visoke korelacijske veze, od 0,85 do 0,92, ističu se između debljine dorađenog pletiva i gustoće, ukazujući na vrlo čvrstu vezu između tih parametara. Osim toga, najizraženije povezanosti primijećene su između debljine dorađenog pletiva i plošne mase, s korelacijskim koeficijentom od iznimnih 0,94.

4. Zaključci

Iz danih podataka može se zaključiti da postoji značajna korelacija između ispitanih parametara, kako u slučaju sirovih tako i dorađenih pletiva. Posebno, debljina i gustoća pokazuju čvrstu vezu (od 0,79 do 0,90) kod sirovih pletiva. Također, jaka korelacija uočena je između debljine dorađenog pletiva i gustoće (0,85 do 0,92), te debljine i plošne mase pletiva (0,94). S druge strane, manje izražene povezanosti primjećuju se između plošne mase i ostalih parametara.

5. Literatura

[1] Li, L.: The science of clothing comfort, *Textile Progress*, **31** (2001), 1–2, pp. 1–135, ISSN 1754-2278

[2] Vrljičak, Z.: *Pletiva*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 9789537105792, Zagreb, (2019)

[3] Oglakcioglu, N. et al.: Thermal comfort properties of some knitted structures, *Fibres and Textiles in Eastern Europe*, **15** (2007) 5-6, pp. 94–96, ISSN 1230-3666

[4] Stanković, S. B. et al.: Thermal properties of textile fabrics made of natural and regenerated cellulose fibers, *Polymer Testing*, **27** (2008) 1, pp. 41-48, ISSN 1873-2348

[5] Ogulata, R.T. et al.: Investigation of porosity and air permeability values of plain knitted fabrics, *Fibres and Textiles in Eastern Europe*, 82 (2010), 5, pp. 71–75, ISSN 1230-3666

[6] Fabbri, K.: *Indoor Thermal Comfort Perception*, Springer International Publishing, ISBN 978-3-319-18651-1, Švicarska, (2015)

Marijana Pavunc Samaržija

Životopis

Marijana Pavunc Samaržija 2012. god. završila je diplomski sveučilišni studij Tekstilna tehnologija i inženjerstvo, modul Tekstilna kemija, materijali i ekologija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. Od 2013. do 2020. god. radila je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu na Zavodu za materijale, vlakna i ispitivanje tekstila kao asistent, a od 2021. god. zaposlena je kao predavač. Od početka znanstvenog rada njezin znanstveni interes usmjeren je na tekstilna vlakna, vlaknima ojačane kompozite te recikliranje tekstilnih materijala, konzervaciju i restauraciju tekstila.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Edita Vujasinović

Datum obrane doktorskog rada

ISTRAŽIVANJE CJELOŽIVOTNOG CIKLUSA VLAKNIMA OJAČANIH KOMPOZITA – KEMIJSKO RECIKLIRANJE BIOKOMPOZITA

Marijana PAVUNC SAMARŽIJA

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, marijana.pavunc@ttf.unizg.hr

***Sažetak**: U svijetu naglog porasta svijesti o zaštiti okoliša, ključno je usredotočiti se na smanjenje otpada kroz recikliranje i ponovnu upotrebu recikliranih materijala, no to može biti izazovno, posebno kada su u pitanju kompoziti materijali. Razlog tomu je činjenica da su kompozitni materijali heterogeni i da dobivene reciklirane komponente često imaju nižu kvalitetu. U ovom radu istražena je mogućnost kemijskog recikliranja biokompozita s naglaskom na zelenu kemiju.*

1. Uvod

Suvremeni kompozitni materijali su postali ključni u mnogim industrijama poput automobilske, zrakoplovne, građevinske i drugih, zahvaljujući svojim jedinstvenim svojstvima. Međutim, njihov ubrzani razvoj, započet početkom 21. stoljeća, povukao je za sobom niz izazova, posebno u ekološkom smislu. Jedan od tih izazova odnosi se na njihovo zbrinjavanje, s obzirom da se većinom radi o heterogenim materijalima izrađenim uglavnom od sintetičkih polimera otpornih na razne okolišne utjecaje. U kontekstu rastućih ekoloških problema kao što su globalno zatopljenje, oštećenje ozonskog omotača, zagađenje vode i zraka, prekomjerna potrošnja neobnovljivih resursa te razni problemi vezani uz zbrinjavanje otpada, koji pogađaju ljude, društva i ekosustav, vlade mnogih zemalja počele su donositi sve strože zakonske regulative koje se odnose na zaštitu okoliša. Trenutno i buduće zakonodavstvo o gospodarenju otpadom i zaštiti okoliša zahtijeva od industrije da svi inženjerski materijali koji se koriste u izgradnji proizvoda poput automobila, zrakoplova, vjetroturbina i slično budu oporabljivi i/ili odgovarajuće zbrinuti na kraju svog životnog vijeka [1, 2]. Stoga se znanstvenici i inženjeri posljednjih godina sve više usmjeravaju prema pronalaženju ekološki prihvatljivijih i/ili biorazgradivih materijala pogodnih za izradu kompozita u nadi će ti materijali imati jednaka ako ne i bolja svojstva kao do sada preferirani materijali na bazi nafte, ali bez štetnih posljedica za okoliš. Sve veću pozornost dobivaju biokompoziti tj. kompoziti bazirani na biorazgradivim polimerima ojačani prirodnim vlaknima prvenstveno biljnim poput lana, kudelje, jute, sisala i dr. [3]. Biokompoziti su često opisani kao ekološki prihvatljivi materijali, s mogućnošću biorazgradnje na kraju svog životnog ciklusa (npr. putem kompostiranja). Međutim, iako je kompostiranje važan aspekt održivosti, najnovije težnje su usmjerene k očuvanju ishodišnih sirovina tj. njihovoj oporabivosti i mogućnosti korištenja u nekim novim proizvodima čime se doprinosi smanjenju otpada i promicanju cirkularne ekonomije [4].

2. Eksperimentalni dio

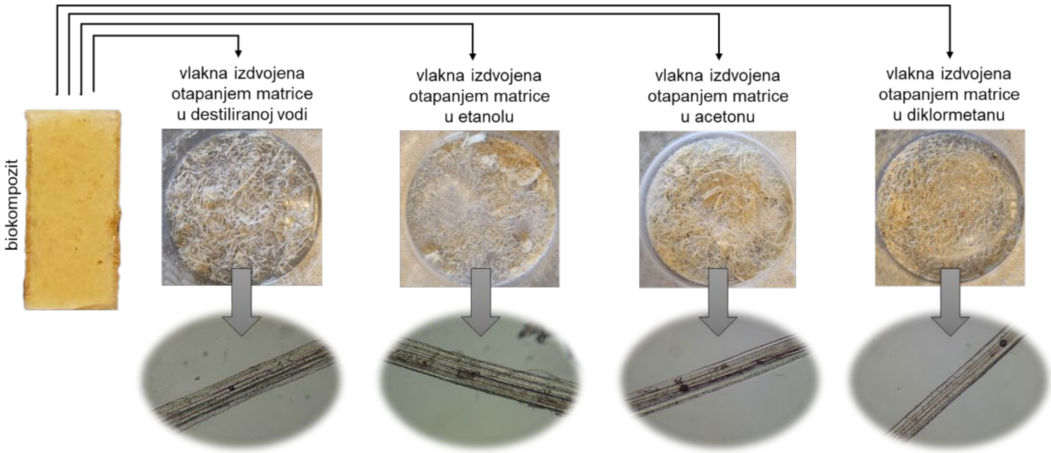
Mogući načini recikliranja kompozita su mehaničko, termičko, kemijsko i biološko pri čemu se kemijsko recikliranje najčešće klasificira kao ono kojim je moguće u potpunosti oporabiti vlaknatu sirovinu u njezinoj ishodišnoj formi kako bi se ista mogla ponovno upotrijebiti u nekom novom proizvodu. U ovom radu prikazan je mogući način kemijskog recikliranja biokompozita koji je izrađen ojačavanjem polilaktidne kiseline (PLA) kao matrice nasumično usmjerenim vlaknima brnistre (duljina vlakana 2 do 5 mm). Kemijsko recikliranje ovih biokompozita provedeno je korištenjem destilirane vode (hidroliza), acetona, etanola i diklormetana (solvoliza) kao otapala za matricu, a koji istovremeno nemaju utjecaja na kvalitetu vlakana čime se omogućava odvajanje pojedinačnih komponenti heterogenog kompozitnog sustava.

3. Rezultati i rasprava

Na slici 1 prikazana su vlakna izdvojena nakon uklanjanja matrice s korištenim otapalima. Iako vlakna zadržavaju svoje osnovne morfološke karakteristike (duljina, debljina, površina i dr.) u kontekstu LCT (eng. Life Cycle Thinking) istraživanja cjeloživotnog ciklusa brnistrinim vlaknima ojačanog kompozita nameće se potreba analize ekonomičnosti i isplativosti upotrebe pojedinog korištenog otapala u ovom istraživanju:

- diklormetan (CAS broj 75-09-2) - visoko hlapivo organsko otapalo; zahtjeva posebno postrojenje; potencijalno negativan utjecaj na ljude i okoliš,
- aceton (CAS broj 67-64-1) - visoko hlapivo organsko otapalo; zapaljivo; zahtjeva posebno postrojenje; potencijalno negativan utjecaj na ljude i okoliš,

• etanol (CAS broj 64-17-5) - hlapivo organsko otapalo; zapaljivo; zahtjeva posebno postrojenje; dodatnu toplinsku energiju (zagrijavanje do 40 °C, 10 min); manja opasnost za ljude,
• destilirana voda (CAS broj 7732-18-5) - široko rasprostranjeno otapalo; zahtjeva toplinsku energiju (zagrijavanje do 100 °C, 10 min); nema opasnosti za ljude i okoliš.



Slika 1: Vlakna izdvojena nakon uklanjanja materice

4. Zaključak

Prikazani rezultati i razmatranja u skladu s cjeloživotnom filozofijom ukazuju na učinkovitost hidrolize u postupku recikliranja biokompozita izrađenog iz brnistrinih vlakana i PLA matrice.

5. Literatura

[1] Korniejenko, K. et al.: Tackling the Circular Economy Challenges - Composites Recycling: Used Tyres, Wind Turbine Blades, and Solar Panels, *Journal of Composites Science*, **5** (2021) 9, pp. 1-18, ISSN 2504-4777
[2] Shanmugam, V. et al.: Circular economy in biocomposite development: State-of-the-art, challenges and emerging trends, *Composites Part C: Open Access*, **5** (2021) 100138, pp. 1-16, ISSN 2666-6820
[3] Vujasinović, E. & Pavunc Samaržija, M.: Biokompoziti – materijali budućnosti, U *Održivi razvoj biokompozita i biogoriva iz obnovljivih izvora energije*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 978-953-8418-09-9, Zagreb (2023.), str.113-152
[4] Morici, E. et al.: Recycled (Bio)Plastics and (Bio)Plastic Composites: A Trade Opportunity in a Green Future, *Polymers*, **14** (2022) 10, pp. 1-24, ISSN 2073-436

Antonija Petrov

Životopis

Antonija Petrov rođena je 1993. god.u Zagrebu. God. 2017. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu završila je sveučilišni prijediplomski studij Tekstilne tehnologije i inženjerstva, smjer Projektiranje i menadžment tekstila. Diplomski studij Tekstilne tehnologije i inženjerstva završila je 2019. god. i stekla naziv magistre inženjerke tekstilne tehnologije i inženjerstva. Trenutno je zaposlena kao asistent na istraživačkom projektu Hrvatske zaklade za znanost „*Tekstilni materijali za povećanu udobnost u sportu* - *TEMPO*, IP–2019-04-1381“, voditeljice prof. dr. sc. Ivane Salopek Čubrić. U okviru razvoja karijere doktorandica je od 2021. god. uključena na poslijediplomski doktorski studij Tekstilna znanost i gospodarstvo (TZT) u okviru projekta Razvoj karijera mladih istraživača - izobrazba novih doktora znanosti: „*Aspekti primjene termografije u evaluaciji termofiziološke udobnosti sportske odjeće* – *ATLETO*, DOK-2021-02-4746“, voditelja izv. prof. dr. sc. Gorana Čubrića, gdje usmjerava svoj znanstveni interes prema primjeni infracrvene termografije u vrednovanju udobnosti sportske odjeće.

Naslov teme doktorskog rada

Studijski savjetnik izv. prof. dr. sc. Goran Čubrić

Datum obrane doktorskog rada

PRIMJENA TERMOGRAFIJE U EVALUACIJI TERMOFIZIOLOŠKE UDOBNOSTI SPORTSKE ODJEĆE

Antonija PETROV

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28 a, Zagreb, antonija.petrov@ttf.unizg.hr

Sažetak: *Udobnost sportske odjeće ključna je za poticanje optimalne sportske izvedbe. Kroz pažljivo planiranje dizajna i odabir materijala, postiže se funkcionalnost u upravljanju toplinom i vlagom, omogućujući održavanje toplinske ravnoteže tijekom tjelesne aktivnosti. Materijali namijenjeni sportskoj odjeći trebaju efikasno prenositi toplinu i olakšavati gubitak topline kroz isparavanje znoja kako bi osigurali potrebnu udobnost tijekom sportskih aktivnosti. Brz prijenos tekućine putem upijanja, uz efikasnu sposobnost sušenja, sprječava kondenzaciju znoja na koži, osiguravajući suhu i ugodnu temperaturu. Korištenjem infracrvene termografije omogućuje se vrednovanje termofiziološke udobnosti odjeće, analizirajući dinamičke promjene temperature kože tijekom fizičkih aktivnosti. Ovi podaci omogućuju odabir materijala točno određenih karakteristika kako bi se osigurala optimalna udobnost tijekom različitih sportskih aktivnosti.*

1. Uvod

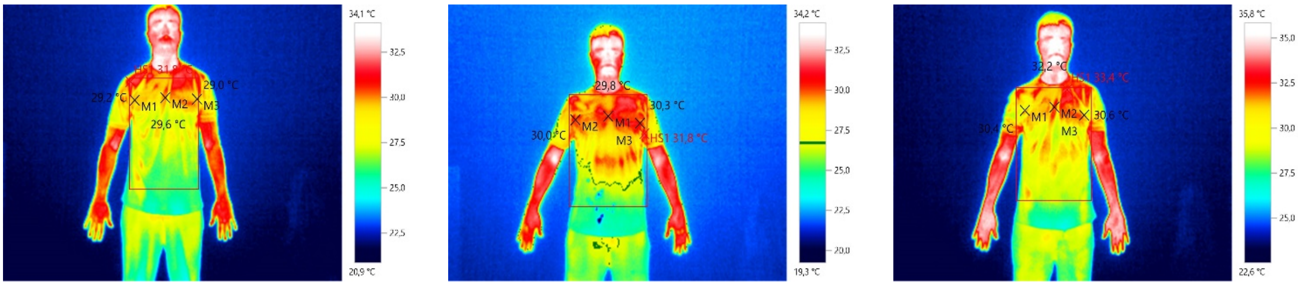
Odjeća je kroz povijest bila ključna za zaštitu tijela od vanjskih utjecaja, a sportska odjeća je postala vrlo perspektivna i dinamična s aspekta inovacija [1]. Globalno tržište sportske odjeće je u porastu, potaknuto rastućom popularnosti sporta kao profesionalne karijere i potrebom za visokokvalitetnom odjećom koja pruža udobnost i zaštitu pri određenim aktivnostima i u ovisnosti od uvjeta okoline [2]. Sportska odjeća se može podijeliti u dvije osnovne skupine: profesionalna sportska odjeća prilagođena za vrhunsku tjelesnu izvedbu i odjeća za slobodno vrijeme, pružajući udobnost, stil i svestranost [3]. Umjetna vlakna od sintetičkih polimera poput poliesterskih, poliamidnih i elastanskih vlakana dominiraju prilikom izrade sportske odjeće zbog svojih prednosti poput brzog sušenja, male mase i elastičnosti [4]. Ključni fokus dizajna sportske odjeće je udobnost, koja može značajno utjecati na izvedbu sportaša. Metode mjerenja udobnosti uključuju objektivne (termalni manekeni, vruća ploča, propusnost vodene pare) i subjektivne metode (ankete i upitnici) [5]. Infracrvena termografija (ICT) u sportu pruža neinvazivan uvid u tjelesnu temperaturu sportaša tijekom aktivnosti, što može biti korisno za analizu temperaturnih promjena. Na taj način može se vrednovati udobnost sportske odjeće. Istraživači koji koriste ICT često su usmjereni na detekciju sportskih ozljeda, a manje pažnje posvećuju istraživanju udobnosti sportske odjeće pomoću ove metode [6]. S obzirom na naglašeni nedostatak istraživanja udobnosti pomoću ICT-a, postoji potreba za proširenjem ovog područja. Istraživanje pomoću infracrvene termografije pridonosi boljem razumijevanju kako ova metoda može optimizirati udobnost i performanse sportske odjeće u različitim uvjetima tjelesne aktivnosti.

2. Eksperimentalni dio

Primjena infracrvene termografije u sportu i sportskoj odjeći omogućuje značajne uvide u performanse sportaša i udobnost odjeće tijekom tjelesnih aktivnosti. U okviru doktorskog rada koristit će se reprezentativni uzorci pletiva za nogometne dresove, istražujući njihove fizikalno-mehaničke karakteristike poput plošne mase, debljine, gustoće i vlačnih svojstava. Istraživanje također uključuje određivanje hrapavosti površine materijala i poroznosti. Nadalje, analizirat će se svojstva koja utječu na udobnost sportaša, posebice propusnost vodene pare, važna za termofiziološku udobnost. Istraživanje će se fokusirati na infracrvenu termografiju za detekciju temperaturnih promjena kod sportaša tijekom specifičnih sportskih aktivnosti.

3. Rezultati i rasprava

Promjene temperature kože kod nogometaša nakon intenzivnih aktivnosti očituju se kao reakcija organizma na napor. Nakon fizičkog napora, tijelo generira dodatnu toplinu zbog povećane metaboličke aktivnosti, što dovodi do porasta temperature kože (Slika 1b). Ovaj porast temperature može biti povezan s povećanim znojenjem, jer tijelo nastoji rashladiti sebe putem procesa znojenja kako bi održalo optimalnu temperaturu. Nadalje, nakon perioda odmora od 10 minuta, primijećen je i daljnji porast temperature kože (Slika 1c). Ovo može ukazivati na kontinuirano procesiranje metabolizma i naknadno rasipanje topline tijekom oporavka, iako je intenzitet aktivnosti pao. Ako odjeća nije učinkovita u upravljanju vlagom i toplinom, može doći do zadržavanja znoja uz kožu, što otežava prirodni proces hlađenja. Kvalitetna sportska odjeća trebala bi omogućiti učinkovit prijenos vlage i brzo sušenje kako bi spriječila nakupljanje znoja, pridonoseći tako udobnosti tijekom i nakon tjelesnih aktivnosti. Upravo ove karakteristike mogu pomoći u održavanju stabilne temperature kože i udobnosti sportaša tijekom različitih faza aktivnosti i oporavka.



a b c

Slika 1: Primjeri termograma: a) prije aktivnosti b) poslije aktivnosti c) poslije 10 min odmora

4. Zaključak

Analiza temperaturnih promjena kod sportaša uz pomoć infracrvene termografije pruža egzaktne informacije o termofiziološkoj udobnosti odjeće tijekom sportskih aktivnosti. Proširenje istraživanja ove vrste omogućava daljnje poboljšanja karakteristika sportske odjeće za postizanje optimalne udobnosti i performansi sportaša.

Zahvala

Ovaj je rad financirala Hrvatska zaklada za znanost projektom HRZZ IP-2020-02-5041 „Tekstilni materijali za povećanu udobnost u sportu - TEMPO“ voditeljice prof. dr. sc. Ivane Salopek Čubrić te projektom DOK-2021-02-4746 „Razvoj karijera mladih istraživača – izobrazba novih doktora znanosti – ATLETO“ voditelja“ izv. prof. dr. sc. Goran Čubrić.

5. Literatura

[1] Dolez, P.; Vermeersch, O.: Izquierdo, V.: *Advanced Characterization and Testing of Textiles*. Elsevier, 1st Edition, (2018)

[2] Faheem, A. et al.: Recent Developments in Materials and Manufacturing Techniques Used for Sports Textiles, *International Journal of Polymer Science*, (2023), pp. 1-20

[3] Elmogahzy, Y.E.: Performance Characteristics of Traditional Textiles: Denim and Sportswear Products, U *Engineering Textiles*, 2nd Edition. Elsevier, 978-0-08-102488-1, (2019), pp. 319-346

[4] Guru, R.; Kumar, A.; Kumar, R.: Functional Textile for Active Wear Clothing, In *Textiles for Functional Applications,* IntechOpen (2021)

[5] Ziemele, I.; Šroma, I.; Kakarane, A.: Comfort in sportswear, *Key Engineering Materials*, **762** (2018), pp. 402-407

[6] Marins, J. C. B. et al: Applications of infrared thermography in sports. A review, *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, **15** (2015) 60, pp. 805-824

Luka Savić

Životopis

Rođen 1988. god. u Zagrebu, Hrvatska. Diplomirao na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu nakon završenog programa Erasmus+ stručna praksa u trajanju od 4. mjeseca na Sveučilištu u Oxfordu 2019. godine. Od 2019. do 2021. god. radio je kao asistent u području elektroispredanja na istraživačkom projektu Sveučilišta u Oxfordu. Trenutno radi kao asistent na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu i pohađa poslijediplomski doktorski studij Tekstilna znanost i tehnologija. U funkciji potpredsjednika volontira u udruzi Penkala i udruzi Upcikliči. Znanstveno-istraživački interes usmjeren je prema postupku elektroispredanja i dobivanju nano vlakana za primjenu u medicini (potpomognuti rast tkiva i živčanih stanica), a nastavni interes prema tehničkom tekstilu i medicinskom tekstilu te mu je to i istraživačko polje.

Naslov teme doktorskog rada

Studijski savjetnik izv. prof. dr. sc. Maja Somogyi Škoc

Datum obrane doktorskog rada

ELEKTROISPREDENI ELEKTROAKTIVNI BIOPOLIMERI S CILJEM DOBIVANJA VODLJIVIH VLAKANA

Luka SAVIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, luka.savic@ttf.unizg.hr

***Sažetak**: Proučavaju se elektroispredeni, elektroaktivni i vodljivi polimeri s ciljem inovativne primjene za medicinski tekstila. Naglasak je na istraživanju njihovog potencijala u poticanju proliferacije i diferencijacije stanica, a što ima ključnu ulogu u regenerativnoj medicini. Cilj je razviti tekstilne materijale koji bi mogli biti temelj za naprednu terapeutsku primjenu, koja uključuje liječenje i obnovu tkiva. Elektroispredeni tekstilni materijali mogu poslužiti kao platforma za rast stanica, omogućujući stvaranje funkcionalnih tkiva i organa.*

1. Uvod

Elektroaktivni/vodljivi polimeri (EAP/ECP) pokazuju dobre rezultate kao medicinski tekstil za tkivno i neuronsko inženjerstvo [1,2]. Primjena struje kroz elektroispredana elektroaktivna tekstilna mikro/nano filamentna vlakna daje obećavajuće rezultate za uzgoj stanica, gdje električni podražaj pomaže bržem i boljem rastu stanica na tekstilnim podupiračima. Zbog svoje električne vodljivosti tekstili izrađeni od elektroaktivnih polimera izvrsni su za oponašanje stvarnog tjelesnog okruženja u kojem se stanice električno stimuliraju za rast [3]. U medicinskom tekstilu, tekstili od elektroaktivnih polimera su iznimno korisni zbog svoje sposobnosti električne vodljivosti, simulirajući tjelesno okruženje u kojem stanice rastu uz električnu stimulaciju.
Sve tjelesne stanice, ne samo živci i mišići, proizvode i reagiraju na električne signale. U tijelu čovjeka, bioelektrični krugovi stvarani električnim impulsima usmjeravaju aktivnosti stanica prema određenim anatomskim lokacijama [4]. Elektroispredanje se ističe kao idealna metoda za proizvodnju novih elektroaktivnih netkanih tekstila koji oponašaju izvanstaničnu matricu. U medicinskom istraživanju potrebno je dalje istražiti elektroispredene elektroaktivne polimere, kako biorazgradive tako i biološki nerazgradive, za primjenu u liječenju raznih bolesti, poput rijetke bolesti motornih neurona, Alzheimerove bolesti, neuromuskularne skolioze, spinalne mišićne atrofije (SMA) i ozljeda leđne moždine [5].
Polimeri poput polipirola (PPy), polianilina (PANI), politiofena (PT), poliviniliden fluorida (PVDF) i poli(viniliden fluorida-trifluoroetilena) (P(VDF-TrFE)) su posebno obećavajući zbog svojih elektrovodljivih svojstava. Integracija EAP-a sa stanicama ključna je za razvoj tekstilnih kompozita iz organskih i anorganskih materijala koji su funkcionalno isprepleteni.

2. Eksperimentalni dio

Istražuje se mogućnost primjene elektroaktivnih i elektrovodljivih polimera za primjenu u području medicine, a s ciljem razvoja novog medicinskog tekstila.
Pri planiranju i provođenju istraživanja koristiti će se općim znanjima iz područja znanstvenog rada. Postaviti će se hipoteza, a nakon čega će uslijediti različite cjeline istraživanja. Dobiveni rezultati istražiti će se i obraditi u svrhu realizacije i potvrđivanja hipoteza koje će se preispitati nakon višestrukog pregleda dostupne literature i kontakta s raznim domaćim i stranim istraživačkim skupinama.
Obrada i morfologija novih tekstilnih materijala provesti će se pouzdanim i standardiziranim mjernim tehnikama (FTIR-ATR, SEM-EDS, AFM, DSC/TGA, raznim mikrobiološkim testovima, itd.) za ocjenu njihove učinkovitosti. Metode i procesi koji će se koristiti osiguravaju ponovljivost rezultata. Koristiti će se odgovarajući matematički statistički postupci kako bi se osigurala određena pouzdanost pri obradi, analizi i evaluaciji dobivenih rezultata.

Plan istraživanja uključuje sljedeće cjeline:
I Nabave opreme i kemikalija

1. Oprema za elektroispredanje je nabavljena i čeka svoju lokaciju koju će odrediti studijska savjetnica.
2. Izvršen je odabir i nabava najpogodnijih polimera koji će služiti kao bio-komponenta i elektroaktivna komponenta.
3. Otapalo potrebno za obradu polimera je određeno i nabavljeno.

II Optimizacija i validacija parametara postupka elektroispredanja
1. Ispitivanje koncentracije otopina za optimalno elektroispredanje.
2. Određivanje optimalnih parametara za elektroispredanje.
3. Ispitivanje dobivenih tekstilnih materijala - vlačna ispitivanja, mikrobiološka ispitivanja, ispitivanja električne vodljivosti, toplinska ispitivanja vlakana, studije razgradnje.
4. Savjetovanje s drugim institucijama o provedbi istraživanja.

III Naknadne obrade i aplikativne primjene
1. Naknadna obrada ispredanih tekstilnih materijala.
2. Ispitivanje tekstilnih materijala i mogućnosti njihove aplikativne primjene.

3. Zaključak

Znanstveni doprinos ove doktorske disertacije ostvariti će se u teorijskom i aplikativnom smislu. Razviti će se, istražiti i ispitati elektroaktivni i elektrovodljivi polimeri kao novi tekstilni materijali – medicinski tekstil za primjenu u medicini.

4. Literatura

[1] Kumar, D.; Sharma, R.C.: Advances in Conductive Polymers, *European Polymer Journal*, **34** (1998) 8, pp. 1053-1060, ISSN 0014-3057
[2] Zhang, X. et al.: Electroactive Electrospun Nanofibers for Tissue Engineering, *Nano Today*, **39** (2021): 101196, ISSN 1748-0132
[3] Chen, C. et al.: Electrical Stimulation as a Novel Tool for Regulating Cell Behavior in Tissue Engineering, *Biomaterials Research*, **23** (2019) 25, pp. 1 – 12, ISSN 1226-4601
[4] Levin, M.; Pezzulo, G.; Finkelstein, J.M.: Endogenous Bioelectric Signaling Networks: Exploiting Voltage Gradients for Control of Growth and Form, *Annual Review of Biomedical Engineering*, **19** (2017), pp. 353–387, ISSN 1523-9829
[5] Picciani, P. et al.: Advances in Electroactive Electrospun Nanofibers, *Dostupan na:* https://doi.org/10.5772/23229, *Pristupljeno*: 15.12.2023.

Vanja Šantak

Životopis

Nakon završetka studija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, 2003. god. kao diplomirani inženjer tekstilne tehnologije, započeo je svoj profesionalni put 2003. god. kao uredski administrator u tvrtki Birokorekt d.o.o. Njegova sposobnost prilagođavanja raznim poslovima došla je do izražaja dok je radio u Orka Zagreb d.o.o., Esotehna d.o.o., Color Trade d.o.o. i Orka Lab d.o.o. Karijerni razvoj veže se u Interallis Chemicals d.o.o. gdje je radio kao voditelj prodaje od 2011 do 2013. god. stekao značajno iskustvo u prodaji i tehnologiji. Danas je prodajni inženjer specijaliziran za vodne tehnologije u tvrtki NTI d.o.o. i službeni distributer Solenis kemikalija.

Naslov teme doktorskog rada

Studijski savjetnik

prof. dr. sc. Tanja Pušić

Datum obrane doktorskog rada

OZONOM POTPOMOGNUTI PROCES PRANJA TEKSTILIJA

Vanja ŠANTAK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28,
Zagreb, vsantak@ttf.hr

Sažetak: Ozon u pranju tekstilija zbog visokog oksidacijskog potencijala predstavlja naprednu alternativu postojećim procesima pranja radi doprinosa higijeni, učinkovitosti i održivosti. U radu će se analizirati učinak ozonom potpomognutog procesa pranja različitih vrsta tekstilija kako bi se objektivno vrednovala njegova prilagodljivost, fleksibilnost i održivost. Primarni i sekundarni učinak, te dezinfekcija analizirat će se standardnim, konvencionalnim i naprednim metodama kako bi se utvrdile prednosti i nedostaci ozonom potpomognutog procesa pranja u odnosu na postojeće procese.

1. Uvod

Ozon (O3) kao snažno oksidacijsko sredstvo prepoznat je u tehnologiji pranja tekstilija jer ima određene prednosti u odnosu na učinak postojećih sredstava, a koje se primarno očituju u higijeni i ekološkoj održivosti. Ozonski proces je zbog učinkovitosti uklanjanja mikroorganizama, te ostalih održivih benefita smanjenja upotrebe vode i energije prihvaćen i kao jedan od ključnih tehnologija (KET-Key Enabling Tecnologies). U posljednje vrijeme dobiva na značenju radi učinka dezinfekcije i sprečavanja križne kontaminacije kod pranja bolničkih tekstilija, te drugih tekstilija gdje je potrebno zadovoljiti visoke higijenske kriterije.
Recentna istraživanja ističu kako pranje ozonom osigurava dubinsko čišćenje i dezinfekciju, smanjuje potrošnju energije i vode, čime doprinosi ekološkoj održivosti i smanjenju ugljičnog otiska tehnologije pranja [1-3]. U kontekstu sve veće globalne skrbi za okoliš i promicanju načela održivosti, pranje ozonom predstavlja ključnu tehnologiju u nastojanju za zelenijim i održivijim pristupima u procesnom inženjerstvu.
Osim toga, ozon se pokazao iznimno učinkovitim u uklanjanju različitih vrsta nečistoća i patogena, uključujući viruse i bakterije, što ga čini idealnim rješenjem u kontekstu trenutnih i budućih javnozdravstvenih izazova. Njegova sposobnost prilagođavanja različitim vrstama tkanina, primjerice od pamuka, poliestera i njihovih mješavina, dodatno potvrđuje njegovu primjenjivost i fleksibilnost.
Tema doktorske disertacije obuhvatiti će ozonom potpomognuti proces pranja tekstilija s posebnim fokusom na njegove ekološke prednosti, učinkovitost i prilagodljivost u uklanjanju mrlja s različitih vrsta tkanina uz varijaciju čimbenika Sinnerovog kruga.

2. Eksperimentalni dio

Pokusi će uključiti analizu učinkovitosti procesa pranja tekstilija suvremenim deterdžentima i ozonom potpomognutog procesa pranja istim sredstvima pri različitim temperaturama 20 °C, 40 °C i 60 °C i omjeru kupelji (niski, srednji i visoki). Za analizu primarnog učinka će se koristiti prirodna i standardna zaprljanja, a za sekundarni učinak analiziranih procesa standardne tkanine od pamuka i poliestera. Nakon provedbe svih procesa, odabrat će se optimalni ozonom potpomognuti procesi pranja koji će se analizirati i kroz dezinfekcijski učinak. Osim primarnog učinka, analizirat će se i sekundarni učinci kako bi se procijenilo očuvanje kvalitete tkanina u procesima pranja. Kroz fizikalno-kemijsku analizu tekstilija i efluenta provjeriti će se održivost ozonom potpomognutih procesa pranja.
Posebna pažnja posvetit će se analizi utjecaja različitih temperatura pranja na učinkovitost ozoniziranja s obzirom da prethodna istraživanja pokazuju da temperatura ima ključnu ulogu u stabilnosti i učinkovitosti ozona, a time i u kvaliteti konačnog učinka procesa pranja [4,5].
Analiza primarnog i sekundarnog učinka procesa pranja provest će se standardnim metodama i ostalim klasičnim i naprednim metodama za karakterizaciju tekstilija i efluenta prije i nakon procesa pranja.

3. Rezultati i rasprava

Eksperimentalni dio istraživanja još nije započeo, ali je postavljen konceptualni pristup istraživanju. Pomno su pregledani objavljeni znanstveni radovi na temelju kojih je razvidno da ozonom potpomognut proces pranja pri nižim temperaturama (20 °C, 40 °C) može biti jednako učinkovit ili čak bolji u uklanjanju nečistoća u odnosu na tradicionalne procese pranja pri višim temperaturama.
Hipotetski se očekuje da će ozonom potpomognut proces pranja ponuditi tehnološka i ekološka poboljšanja u odnosu na postojeće procese.

4. Zaključak

Na temelju pregleda dostupne literature i anticipacije objavljenih rezultata istraživanja, hipotetski se postavlja da pranje tekstila ozonom nudi značajne prednosti u odnosu na tradicionalne procese pranja. Očekuje se da će prilagodljivost ozonom potpomognutog procesa pranja za različite vrste tekstilija, specifičnih i tvrdokornih zaprljanja pri različitim temperaturama otvoriti nove mogućnosti za unapređenje postojećih procesa, a posebice u smislu smanjenja ekološkog otiska i unapređenja javnozdravstvenih standarda. Doprinos ovog istraživanja može se sagledati u razumijevanju i optimizaciji upotrebe ozona u procesu pranja tekstilija.

5. Literatura

[1] Owen, L.; Shivkumar, M. & Laird, K.: The Stability of Model Human Coronaviruses on Textiles in the Environment and During Health Care Laundering, *mSphere*, **6** (2021) 2, 6:e00316-21, ISSN 2379-5042

[2] Rice, R.G.; Magnanti, J. & Washbrook, T.: The CaroMont Health Ozone Laundry System: Energy Savings, Improved Laundered Product Qualities and Return on Investment at Gaston Memorial Hospital, Gastonia, *NC,* Ozone: Science & Engineering, **35** (2013) 5, pp. 399-419, ISSN 0191-9512

[3] Neral, B.: Kvaliteta pranja u kućanskom stroju za pranje s ozonatorom, *Tekstil*, **65** (2016) 7-8, str. 241-251, ISSN 0492-5882

[4] Neral, B.: Efficiency and Ecological Impacts of Household Ozone Laundering, *International Scientific Journal Science. Business. Society*, **2** (2017) 2, pp. 54-57, ISSN 2367-8380

[5] Valls, C., Cusola, O., Roncero, M. B. Evaluating the potential of ozone in creating functional groups on cellulose, *Cellulose*, **29** (2022), pp. 6595-6610, ISSN 0969-0239

Ana Šaravanja

Životopis

Ana Šaravanja rođena je 1998. god. u Zagrebu. 2021. god. diplomirala je na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu (TTF), smjer Tekstilna kemija, materijali i ekologija. Dobitnica je Dekanove nagrade za postignut uspjeh tijekom sveučilišnog prijediplomskog i diplomskog studija Tekstilna tehnologija i inženjerstvo. 2021. god. upisuje doktorski studij Tekstilna znanost i tehnologija na TTF-u te zapošljava kao asistent na „Projektu razvoja karijera mladih istraživača – izobrazba novih doktora znanosti“ Hrvatske zaklade za znanost, naziva „*Utjecaj starenja na svojstva poliesterskih tkanina u pranju*“ (DOK-2021-02-6750). Istraživač je na projektu "*Procjena otpuštanja čestica mikroplastike iz poliesterskih tekstilija u procesu pranja*"- InWashed-MP (HRZZ-IP-2020-02-7575) Hrvatske zaklade za znanost.

Naslov teme doktorskog rada

Studijski savjetnik

izv. prof. dr. sc. Tihana Dekanić

Datum obrane doktorskog rada

UTJECAJ STARENJA NA SVOJSTVA POLIESTERSKIH TKANINA U PRANJU

Ana ŠARAVANJA

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a, Zagreb, ana.saravanja@ttf.unizg.hr

***Sažetak**: Poliesterske tkanine su podložne promjenama svojstava uslijed djelovanja različitih okolišnih čimbenika, što posljedično ima utjecaj ne samo na uporabna svojstva, već i na ekosustav općenito. U ovom radu praćen je učinak simuliranog starenja u laboratorijskim uvjetima na svojstva poliesterske tkanine, te efluenata, filtrata i filtarskog kolača po provedenom procesu pranja.*

1. Uvod

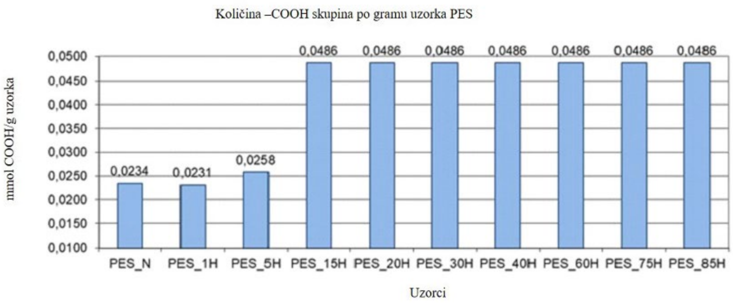
Tekstil se ubraja u skupinu glavnih zagađivača okoliša zbog tendencije otpuštanja mikrovlakana, a proces pranja se smatra jednih od glavnih uzročnika [1]. Proces pranja sintetskih tekstilija je identificiran kao izvor primarne mikroplastike, MP, koje dopijevaju do uređaja za pročišćavanja otpadnih voda [2-4]. S obzirom na spomenute probleme prisutnosti MP u okolišu, istraživanja u okviru doktorskog rada usredotočit će se na praćenje učinka umjetnog starenja na svojstva standardne poliesterske (PES) i poliester/pamuk (PES/P) tkanine kao i efekta varijacije umjetnog starenja (duljine, načina i intenziteta zračenja) na otpuštanje MP i mikrovlakana u procesu pranja standardnim i inovativnim postupkom. U ovom radu istražen je učinak umjetnog starenja na standardnu PES tkaninu kroz procese kontroliranog starenja i pranja, te analiziranjem starenih tkanina, efluenata, filtrata i filtarskog kolača.

2. Eksperimentalni dio

Za istraživanje je upotrebljena standardna PES tkanina (PES_N), plošne mase 150 g/m2, gustoće osnovinih i potkinih niti 27,7/20,0 niti/cm u platno vezu, dobavljača Center for Testmaterials BV Employees, CFT. Tkanine dimenzija 30x20 cm su izložene simulaciji umjetnog starenja u uređaju Xenotest, SDL Atlas, u različitim vremenskim intervalima osvjetljavanja (5, 10, 15, 20, 30, 40, 60, 75 i 85 sati (h)). U svrhu uvida u ponašanje PES tkanine tijekom starenja, korištena je norma HRN EN ISO 105-B02+A1:2013. Karboksilne skupine (-COOH) određene su metodom apsorpcije metilenskog plavila u uzorku na temelju apsorpcije metilenskog plavila i spektrometrijskog praćenja apsorbancije filtrata, pri čemu se bojilo veže na kisele karboksilne skupine vlakna. PES tkanine su dodatno podvrgnute procesu pranja u uređaju Rotawash, SDL Atlas, prema normi HRN EN ISO 6330:2012, uz standardni deterdžent ECE A, uz omjer kupelji 1:7 pri temperaturi 60 °C tijekom 30 minuta kroz 10 ciklusa. Po završetku pranja prikupljeni su efluenti za daljnju fizikalno-kemijsku analizu i karakterizaciju efluenata, filtrata i filtarskog kolača s aspekta otpuštanja MP, mikrovlakana i sadržaja čestične tvari. Infracrvena spektroskopija s Fourierovom transformacijom (FTIR) korištena je za karakterizaciju filtarskog kolača i poliesterskih tkanina prije i nakon umjetnog starenja te provedenih procesa pranja. Za detekciju i razdvajanje efluenata na filtrat i filtarski kolač korišten je polietersulfonski membranski filtar, proizvođača Sartorius, veličine pora 0,2 μm i zlatna podloga za ciljanu detekciju PES mikrofibrila s filtera.

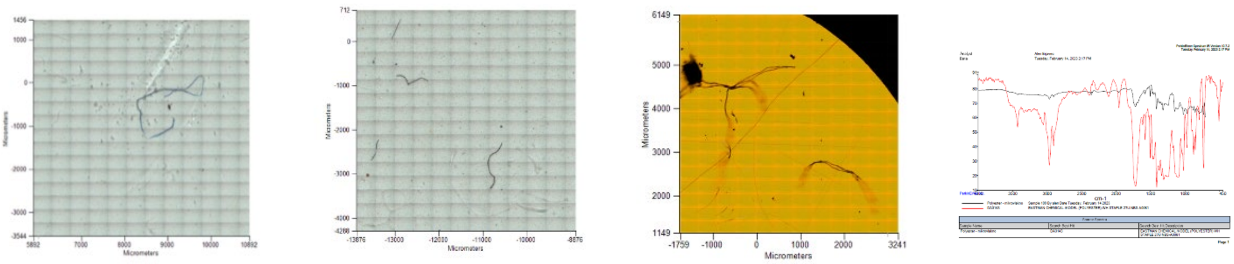
3. Rezultati i rasprava

Rezultati dosadašnjih istraživanja u okviru doktorskog rada pokazala su višestruke promjene svojstava PES tkanine do kojih dolazi osvjetljavanjem: fotooksidacijsku razgradnju zbog spore difuzije kisika u polimer čime se mijenjaju fizička svojstva tkanine (hrapavost, gubitak sjaja, krutost), kao i smanjenje čvrstoće i slabljenje mehaničkih svojstava, dok na molekulskoj razini dolazi do oksidacije polimernog lanca na C-H vezi, cijepanja esterskih veza i stvaranja novih karboksilnih skupina (–COOH).
Na sl. 1 dat je prikaz rezultata određivanja -COOH skupina s metilenskim plavilom, koji pokazuju kako je količina –COOH skupina proporcionalna vremenu izlaganja. Nakon umjetnog starenja dolazi do povećanja količine -COOH skupina po gramu uzorka, dok je primjetno da se kod uzoraka starenih 15 i više sati količina ne mijenja te ostaje konstantna neovisno o duljini osvjetljavanja.



Slika 1: Grafički prikaz količine –COOH skupina po g uzorka

Slika 2. prikazuje izdvojeni primjer filtarskog kolača standardne tkanine (PES_N) i nakon 85 sati osvjetljavanja (PES_85H), otpuštena vlakna te FTIR spektar kao dokaz otpuštenih PES vlakana s tkanine izložene umjetnom starenju i oprane standardnim postupkom.



a b c d

Slika 2: Slike uzoraka: a) filtarski kolač PES_N; b) filtarski kolač PES_85H; b) vlakno na zlatnoj podlozi; c) FTIR spektar PES vlakna

Na filtru su identificirana mikrovlakana umjetno starene i oprane PES tkanine, pri čemu su nakon starenja zamjetniji kraći fragmenti PES mikrovlakana.

4. Zaključak

Rezultati su pokazali da starenje utječe na svojstva PES tkanina. Količina –COOH skupina, se povećava procesom starenja i pranja poliesterske tkanine. Analizom efluenta od procesa pranja na površini filtera su detektirani fibrilni segmenti koji potječu od PES vlakna, što je primjenom FTIR spektroskopije potvrđeno.

Zahvala

Doktorski rad se izrađuje i sufinancira dijelom u okviru aktivnosti na istraživačkom projektu HRZZ IP-2020-02-7575, „Procjena otpuštanja čestica mikroplastike iz sintetskih tekstilija u procesu pranja, InWaShed-MP“, voditeljice prof. dr. sc. Tanje Pušić, te HRZZ DOK-2021-02-6750 „Projektu razvoja karijere mladih istraživača - osposobljavanje doktoranada“, voditeljice izv. prof. dr. sc. Tihane Dekanić, financiranih od Hrvatske zaklade za znanost.

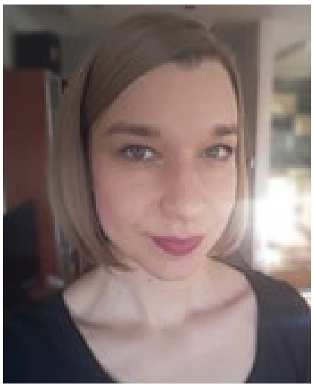
5. Literatura

[1] Čorak, I. i sur.: Enzimi za hidrolizu poliestera, *Tekstil*, **68** (2019) 7-9, str. 142-151, ISSN 0492-5882

[2] Haap, J.: Analytical approach for the detection of micro-sized fibers from textile laundry, In: *Proceedings of the International Conference on Microplastic Pollution in the Mediterranean Sea*, Springer, ISBN 978-3-319-7179-6, Cham, (2018), pp. 73-79

[3] Bule, K. i sur.: Mikroplastika u morskom okolišu Jadrana, *Kemija u industriji*, **69** (2020) 5-6, str. 303-310, ISBN 978-953-6894-70-3

[4] Hernandez, E; Nowack, B. & Mitrano, D. M.: Polyester textiles as a source of microplastics from households: a mechanistic sturdy to understand microfiber release during washing, *Environmental science & technology*, **51** (2017) 12, pp. 7036-7046, ISSN 1520-5851



Marijana Tkalec

Životopis

Marijana Tkalec rođena je 1986. god. u Čakovcu. Nakon završetka diplomskog studija na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu radila je u tekstilnoj industriji kao tekstilna i modna dizajnerica i inženjerka. Dobitnica je nekoliko nagrada za svoj rad u području tekstilnog dizajna. Poslijediplomski sveučilišni studij na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu upisala je 2017. god. Trenutno je zaposlena kao asistent na Tekstilno-tehnološkom fakultetu.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Martinia Ira Glogar

Datum obrane doktorskog rada

UTJECAJ TOPOGRAFIJE POVRŠINE TEKSTILNOGA SUPSTRATA NA KARAKTERISTIKE BOJE U REPRODUKCIJI DIGITALNIM TISKOM

Marijana TKALEC

Sveučilište u Zagrebu Tekstilno tehnološki-fakultet, Prilaz baruna Filipovića 28a,
Zagreb, marijana.tkalec@ttf.unizg.hr

Sažetak: *Topografske karakteristike tekstilnih materijala neminovno utječu na percepciju teksture tkanine i izgled boje na površini tkanine. Kako bi se objasnila složenost različitih tekstilnih materijala i izgleda boja, u radu se analizira ovaj fenomen – kvaliteta reprodukcije i izgled boje na tkanini otisnutoj digitalnom inkjet tehnologijom, ovisno o konstrukcijskim i strukturnim karakteristikama, odnosno teksturi tkanine. Uzorci su digitalno otisnuti na uređaju za digitalni tisak Tx2-1600 Mimaki s reaktivnim bojama, prethodno obrađenima u kupelji određene otopine. Svi rezultati prikazani su kroz analizu karakteristika obojenja, temeljene na objektivizaciji boja i razlika u boji. Objektivne vrijednosti parametara svjetlina L*, zasićenosti C* i tona h° pokazuju značajan utjecaj strukture i karakteristika podloge na reprodukciju boja, te su dobivene značajne promjene, što potvrđuje i procjena razlika u boji. Provedena je analiza mikroskopskih slika dobivenih digitalnim mikroskopom Dino-Lite Premier AM-7013MZT. Rezultati potvrđuju utjecaj strukture podloge na karakteristike boje.*

1. Uvod

Digital inkjet je grafička višebojna tehnologija reprodukcije slike, izvorno razvijena za homogene, ujednačene površinske strukture kao što je papir. Tekstil kao jedinstvena, heterogena, trodimenzionalna forma ima svoje površinske nepravilnosti što uzrokuje deformaciju kapljice i veću dubinu prodiranja kapljice boje. Dosadašnja istraživanja odnose se na utjecaj površinske teksture tekstila na izgled boje [1-6]. Ona potvrđuju značajan utjecaj teksture na vizualnu percepciju boje, kao i na rezultate instrumentalnog mjerenja boje, ali kvantiteta i kvaliteta tog učinka još nisu u potpunosti razjašnjene. Istraživanje prikazano u ovom radu analizira međuovisnost kvalitete reprodukcije i izgleda boje otisnute digitalnom inkjet tehnologijom, ovisno o konstrukcijskim i strukturnim karakteristikama tkanine. Cilj istraživanja je pridonijeti razumijevanju temeljnih mehanizama interakcije bojila, boje i tekstilnih podloga.

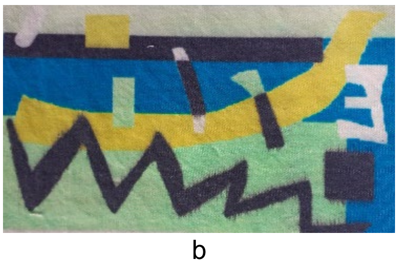
2. Eksperimentalni dio

U istraživanju su korišteni uzorci tkanina sirovinskog sastava 50 % pamuk i 50 % PA. Uzorci su namjenski proizvedeni u tvornici Čateks; identični po parametrima pređe, ali različiti po konstrukcijskim parametrima tkanine što je rezultiralo tkaninama različitih struktura i površinskih tekstura: P 1/1 (platneni), K 1/2 Z (keperni) i atlasni 1/5 vez. U eksperimentalnom radu proveden je inkjet digitalni ispis uzoraka (prethodno obrađenih u kupelji određene otopine); nakon tiska uzorci su sušeni na zraku te potom fiksirani parom. Na uzorcima je provedena analiza mikroskopskih slika dobivenih digitalnim mikroskopom DinoLite i spektrofotometrijsko mjerenje karakteristika boja remisijskim spektrofotometrom DataColour 850, veličine mjernog otvora 2,5 cm i mjerne geometrije d/8°.

3. Rezultati i rasprava

Slika 1 prikazuje otisnute uzorke na odabranim tkaninama, nakon fiksiranja parenjem, pranja i sušenja. Vidljiv je značajan utjecaj supstrata te razlike u kvaliteti reprodukcije boja i uzoraka zbog strukture tekstilnog materijala.

a

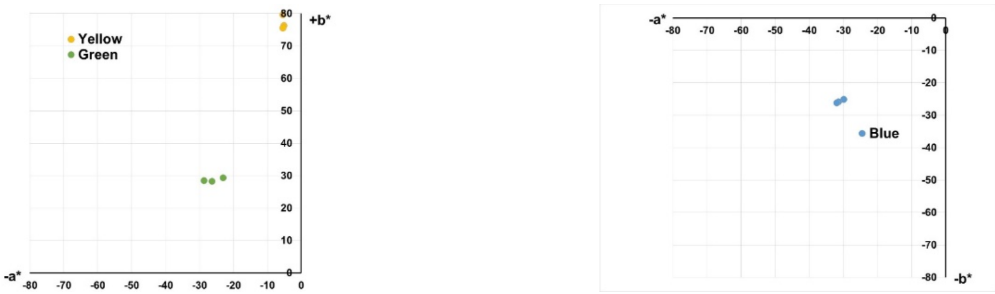


b

c

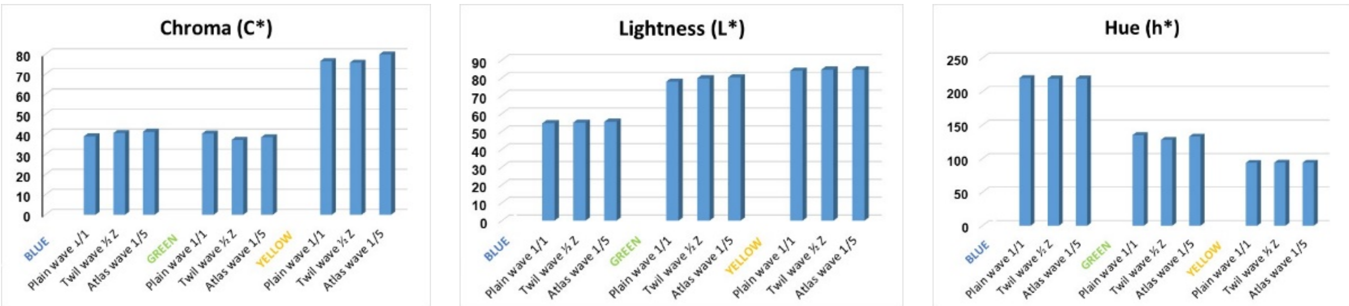
Slika 1: Slike tkanina otisnute digitalnom inkjet tehnologijom: a) Platneni P 1/1 b) Keperni K 1/2 Z c) Atlasni A 1/5

Uočava se pojava kapilarnog širenja tiskarske boje i nemogućnost zadržavanja pojedinih elemenata dizajna unutar zadanih kontura. Spektrofotometrijska mjerenja karakteristika boja prikazana su na slici 2 kao prikaz u a*/b* prostoru boja te na slici 3 kao usporedni histogrami s rezultatima promjena svjetline (L*), zasićenosti (C*) i tona (h°) za otisnute boje zbog različitih struktura tkanina. Prikazani rezultati analiziranih boja ukazuju na utjecaj strukture i topografskih karakteristika na boju.



a b

Slika 2: Rezultati spektrofotometrijskog mjerenja: vrijednosti otisnutih uzoraka smještenih u a*/b* prostor boja



a b c

Slika 3: Rezultati spektrofotometrijskog mjerenja: vrijednosti parametara svjetline, zasićenosti i tona

4. Zaključak

Istraživanja prikazana u ovom radu potvrđuju kompleksnost interakcije boje i strukture površine tekstilnog materijala. Dobiveni rezultati objektivnih vrijednosti parametara svjetline L*, zasićenosti C* i tona h° pokazuju značajan utjecaj strukture i karakteristika površine na reprodukciju boja, a dobivene su i značajne promjene u boji, što potvrđuju i vrijednosti razlike u boji. Rezultati potvrđuju utjecaj strukture podloge na karakteristike boje. U procesu digitalnog tiska, potrebno je dublje razumijevanje ovakvih specifičnosti, kako bi se omogućilo optimiranje procesnih parametara te predviđanje mogućih pogrešaka i pomaka u karakteristikama boje otiska.

5. Literatura

[1] Moussa, A. et al. : Colour change as a result of textile transformations, *Coloration Technology*, **124** (2008), 4; pp. 234-242, ISSN 1478-4408

[2] Gorji Kandi, S., Tehrana, M. A., Rahmatib, M.: Colour dependency of textile samples on the surface texture, *Coloration Technology*, **124** (2008) 6; pp. 348-354, ISSN 1478-4408

[3] Huertas, R., Melgosa, M., Hita, E.: Influence of random-dot textures on perception of suprathreshold color differences, *Journal of the Optical Society of America*, **23** (2006) 9; pp. 2067-2076, ISSN 1520-8540

[4] Xin, J. H., Hui-Liang S., Chuen C. L.: Investigation of Texture Effect on Visual Colour Difference Evaluation, *Color research and Application*, **30** (2005), 5; pp. 341-347, ISSN1520-6378

[5] Bae, J. H., Hong, K. H., Lamar, T. M.: Effect of Texture on Color Variation in Inkjet-Printed Woven Textiles, *Color Research and Application*, **40** (2015), 3; pp. 297-303, ISSN 0361-2317

[6] Yang, H. et al.: Influence of cotton fabric structure on ink droplet spreading and color performance, *Journal of Textile Research*, **40** (2019), 7; pp. 78-84, ISSN 0253-9721

Irena Topić

Životopis

Irena Topić rođena je 1983. god. u Zagrebu i radi kao profesorica likovne kulture. 2011. god. diplomirala je sveučilišni diplomski studij kostimografije na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu (TTF), a 2013. god. sveučilišni studij likovne kulture na Akademiji likovnih umjetnosti. Od 2004. do 2006. god. radila je kao terenski mjeritelj na projektu Hrvatski antropometrijski sustav (HAS) voditelja prof. emer. dr. sc. D. Ujevića. Na TTFu prvo je radila kao asistent (2011. - 2017.), a kasnije kao vanjski suradnik (2018. - 2021.). Tijekom karijere ostvarila je brojna stručna usavršavanja: u CFPIC Institutu, Felgueiras, Portugal (projekt Tied Shoe, voditeljice prof. emer. A. M. Grancarić), na Fakultetu Tekstila, kože i industrijskog menadžmenta, "Gheorghe Asachi", Iaşi, Rumunjska te u Cité des Arts, Pariz. Sudjelovala je na projektu Knowledge for footwear (K4F).

Naslov teme doktorskog rada

Studijski savjetnik prof. emer. dr. sc. Darko Ujević

Datum obrane doktorskog rada

UTJECAJ TJELESNIH PROPORCIJA U POSTUPCIMA KONSTRUIRANJA ODJEĆE ZA OSOBE S PRETILOŠĆU

Irena TOPIĆ

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
irena.topic@ttf.hr

Sažetak: *Istraživanja tjelesnih proporcija mogu doprinijeti novim kvalitetnijim postupcima konstruiranja i modeliranja odjeće za muške i ženske osobe s pretilošću. U okviru doktorskog rada cilj je znanstveno utvrditi trend u pretilosti odraslih žena i muškaraca u Gradu Zagrebu, koji će poslužiti za unaprjeđenje postupaka konstruiranja i dizajniranja svakodnevne odjeće. Također će se ustanoviti odstupanja od Hrvatskog tehničkog izvještaja od 2012. godine o porastu pretilosti kod odraslih muškaraca i žena, provedenog u okviru projekta STIRP HAS. Na osnovu rezultata provedenih antropometrijskih mjerenja odabrane muške i ženske populacije cilj doktorskoga rada je utvrditi relevantne kriterije za navedenu populaciju i omogućiti prijedlog novih tipova tijela te unapređenje postupaka konstruiranja i dizajniranja odjeće za dnevnu uporabu.*

1. Uvod

Antropometrijska mjerenja provode se već od 1900. godine s ciljem unapređenja i razvoja sustava veličina i tipova tijela. Pristupi istraživača i načini mjerenja mijenjali su se i unaprjeđivali razvojem antropometrijskih instrumenata. Tjelesnim proporcijama određuje se sukladnost i međusobni odnos pojedini tjelesnih mjera. Istraživanja u okviru doktorskoga rada temeljiti će se na utvrđivanju antropometrijskih izmjera kod muškaraca i žena s pretilošću te odstupanja od prosječne građe. Novim kvalitetnijim postupcima konstruiranja i modeliranja odjeće za osobe s pretilošću moguće je pristupiti istraživanjima njihovih tjelesnih proporcija. Navedenim istraživanjima želi se postići povećanje kvalitete života i zaštite zdravlja osoba s pretilošću. Tjelesne proporcije osoba s pretilošću određuju se sustavnim antropometrijskim mjerenjima.

2. Eksperimentalni dio

Mjerenje za potrebe doktorskoga rada provoditi će se u KBC Zagreb, nasumičnim odabirom (kriterij dolaska) ispitanika koji odgovaraju kriterijima određivanja pretilosti muške i ženske populacije. U istraživanje će biti uključeni ispitanici u dobi od 18 do 65 godina, koje imaju indeks tjelesne mase (u daljnjem tekstu ITM) >30kg/m^2, opseg struka veći od 88 cm za žene i opseg struka veći od 102 cm za muškarce. Istraživanje će obuhvatiti dvije skupine: 50 žena i 50 muškaraca. Za ispitanike isključni kriteriji su uzimanje kortikosteroidne terapije ili Cushingovo oboljenje ili Cushingovog sindroma. Prilikom ispunjavanja anketnih upitnika i njihovom statističkom obradom utvrditi će se podaci osobnim preferencijama ispitanika, osjećaju udobnosti prilikom odijevanja i poteškoćama u pronalaženju prikladne odjeće. Antropometrijska mjerenja u okviru doktorskog rada provodit će se s pomoću kompleta antropometrijskih instrumenata: antropometrom s jednim i /ili dva kraka, mjerne vrpce, jednostranog i/ili obostranog kutomjera, kljunastog kliznog antropometra, mjerne trake za određivanje opsega vrata i digitalne vage.

Istraživanje se provodi u četiri faze i to:
1. faza: priprema plana istraživanja, pregled publicirane literature, razvoj suradnje s drugi znanstvenim i istraživačkim institucijama i proizvođačkim tvrtkama.
2. faza: umjeravanje istraživačke opreme, izrada anketnih upitnika i obrazaca te antropometrijski mjerenja za ispitanike: 57 izmjera za žene i 54 za muškarce.
3. faza: provedba ispitivanja i antropometrijskih mjerenja tijekom ambulantnog endokrinološkog pregleda (KBC Zagreb).
4. faza: matematičko-statistička obrada podataka antropometrijskih izmjera, definiranje novih tipova tijela, dopuna postojećih razmjernika odjevnih veličina i potencijalna primjena pri konstruiranju i dizajniranju odjeće.

3. Rezultati i rasprava

Rezultati antropometrijskih mjerenja koja će se provesti ovim istraživanjem imat će tendenciju utvrđivanja trenda promjene tjelesnih proporcija u osobama s pretilošću (ženama s opsegom struka većim od 80 cm i muškarcima s opsegom struka većim od 102 cm), čime će se omogućiti utvrđivanje novih tipova tijela. Ovim radom dat će se doprinos razvoju i utvrđivanju smjernica ka stvaranju novih normi i razmjernika odjevnih veličina u zemljama članicama Europske unije. Tjelesnim proporcijama se određuje sukladnost i međusobni odnos pojedinih tjelesni mjera, u konkretnom slučaju pretilost kod žena i muškaraca i/ili odstupanja od prosječne građe, čime se može egzaktno utvrditi postojanje nesukladnosti pri dizajniranju i konstruiranju odjeće za dnevnu uporabu.

4. Zaključci

Na temelju provedenih istraživanja i dobivenih rezultata utvrdit će se relevantni kriteriji za populaciju s problemom pretilosti kod žena i muškaraca u Republici Hrvatskoj što će omogućiti prijedlog novih tipova tijela sukladno utvrđenim odstupanjima od prosječne građe tijela. Time će se omogućiti objektivna znanstvena usporedba, kao i usporedba s populacijom drugih država, zemalja članica EU i šire. Također se planira uspostava suradnje s europskim institutima, koji također prate trendove povećanja pretilosti kod žena i muškaraca. Time će se stvoriti osnova za izradu muške i ženske dnevne odjeće te zaštita zdravlja u području stražnjeg dijela tijela. Primjenom rezultata istraživanja doprinijet će se daljnjoj dopuni razmjernika odjevnih veličina, izradi novog tehničkog izvještaja za populaciju s pretilosti u muškaraca i žena, a time i cjelovito unaprjeđenje konstruiranja i dizajniranja te izrade odjeće za dnevnu uporabu.

5. Literatura

[1] Ujević, D. et al.: Osnove antropometrije ljudskog tijela i osvrt na razvoj sustava određivanja veličina za odjeću, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 113-124

[2] Hrastinski, M.et al.: Problematika sustava određivanja veličina i tržište, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 132-137

[3] Ujević, D., Doležal, K., Brlobašić Šajatović, B.: Hrvatski antropometrijski sustav, U: *Inovacijska kultura i tehnologijski razvoj*, Hrvatsko društvo za sustave, Zagreb, (2009), str. 133-137

[4] Ujević, D.: Hrvatski antropometrijski sustav – stanje, realizacija, primjena, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 16-23

Juro Živičnjak

Životopis

Juro Živičnjak rođen je 1995. god. u Zagrebu. Zvanje magistar inženjer tekstilne tehnologije i inženjerstva stekao je 2018. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, nakon kojeg svoje obrazovanje nastavlja na poslijediplomskom, doktorskom studiju Tekstilna znanost i tehnologija, gdje od 2019. god. radi kao asistent na Zavodu za materijale, vlakna i ispitivanje tekstila. Znanstveni interes vezuje uz područje ispitivanja svojstva različitih tekstilnih materijala i kože. Kao istraživač je bio uključen u provedbi HRZZ projekta IP-2016-06-5278 te je u koautorstvu objavio 7 znanstvenih radova, 1 stručni rad i 4 poglavlja u knjizi.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Antoneta Tomljenović

Datum obrane doktorskog rada

UNAPRJEĐENJE METODIKE PROCJENE SKLONOSTI PLETIVA POVRŠINSKIM PROMJENAMA NAKON IZLAGANJA U KOMORI ZA PILING

Juro ŽIVIČNJAK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Prilaz baruna Filipovića 28a,
Zagreb, juro.zivicnjak@ttf.unizg.hr

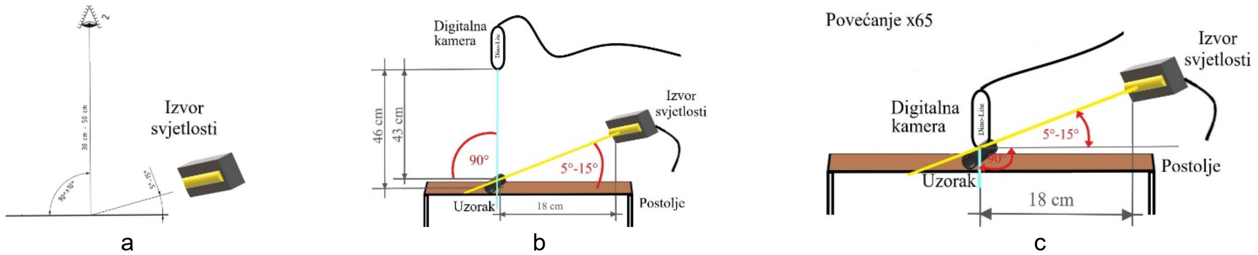
Sažetak: *Laboratorijsko ispitivanje sklonosti nastanka površinskog pilinga na pletivima, osmišljeno je na način da se vjerno i ubrzano simulira proces nastajanja pilinga, ali i pojava stršećih vlakana te matiranje, pojava koje se zasebno prate i ocjenjuju u skladu s tekstualnim opisom danim u normi HRN EN ISO 12945-4:2020. Ocjena opisuje razinu nastale površinske promjene (5 – nepromijenjen izgled do 1 – jako promijenjen izgled) koju ispitivači dodjeljuju na temelju subjektivne vizualne procjene prethodno obrađenih i početnog uzorka. Kako se jedino u slučaju ocjene pilinga usporedba uzoraka provodi uz primjenu odgovarajućih 2D etalona, u ovome radu je istražena mogućnost unaprjeđenja metodike procjene nastalih površinskih promjena primjenom digitalne kamere te izradom odgovarajućih fotografija površine ispitivanih uzoraka pletiva koje je moguće ocijeniti.*

1. Uvod

Sklonost nastanku površinskih promjena na pletivu se ocjenjuje nakon laboratorijske simulacije uporabe prema normiranim metodama HRN EN ISO 12945-1, 2 ili 3:2020. Pritom se najčešće primjenjuju metode u komori za piling i preinačena metoda prema Martindale-u [1]. U ovom je radu primijenjena metoda u komori za piling te je praćen utjecaj normirane brzine (od 60 o/min) i provedenog broja okretaja komore (7200, 10800 i 14400) na pojavu površinskih promjena odabranih uzoraka kulirnih dvostrano desnih cjevastih pletiva, pletenih iz jednonitne prstenasto predene viskozne pređe (CV) [2, 3].

2. Eksperimentalni dio

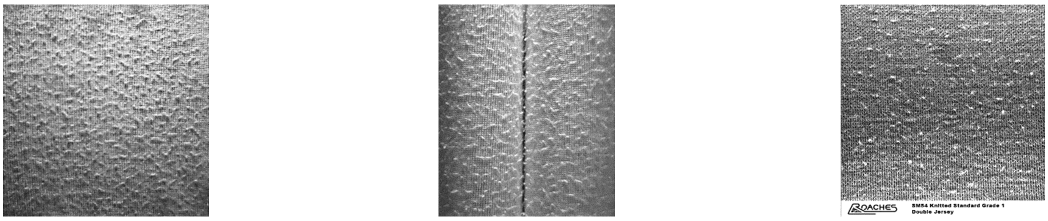
Obrada se provodi nasumičnim pokretanjem ispitivanih uzoraka pletiva postavljenih na poliuretanske cjevaste cilindre i njihovim habanjem o stjenke kvadratne komore za piling obložene plutom. Istovremeno se unutar komore ispituju 4 uzorka pletiva, od kojih su dva prošivena u smjeru izrade i dva okomito na smjer izrade pletiva. Prema naputku norme HRN EN ISO 12945-1:2020, vizualna procjena se provodi na uzorcima po njihovom uklanjanju s cilindra (Slike 1a i 2a), čime se omogućuje usporedba cijele površine uzorka s 2D etalonom (Slika 2c), ali se istovremeno onemogućuje nastavak obrade na istome uzorku.



Slika 1: Shematski prikaz: a) izravne vizualne procjene površine uzorka, b) izrade fotografije cijelog uzorka (za ocjenu pilinga) i c) izrade fotografije dijela uzorka (za ocjenu stršećih vlakana)

U svrhu unapređenja metodike procjene nakon izlaganja u komori za piling, primijenjena je digitalna kamera mikroskopa (Dino-Lite AM 413 ZT) koja spojena na računalo putem programske podrške ocjenjivaču pruža mogućnost izrade i pohrane fotografija površine ispitivanog uzorka, koju je moguće ocijeniti. Stoga su za potrebe procjene pilinga načinjene dvije fotografije površine uzorka na jednom poliuretanskom cilindru u prirodnoj veličini (Slika 1b) i postavljene jedna pokraj druge (Slika 2b). Za ocjenu pojave stršećih vlakana za koju ne postoje usporedni 2D etaloni, kamera je postavljena na površinu ispitnog uzorka te su fotografije načinjene uz povećanje slike od 65x (Slika 1c).

Na njima se pojava stršećih vlakana uočava kao zamršenost površine pletiva ispod koje se struktura pletiva, odnosno nizovi i redovi očica teže razaznaju. Pri ocjeni se u tom slučaju izuzimaju nakupine zamršenih vlakana (odnosno piling).



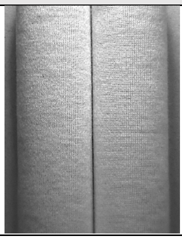
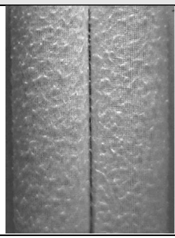
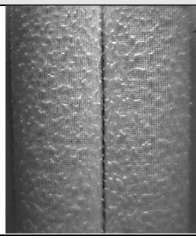
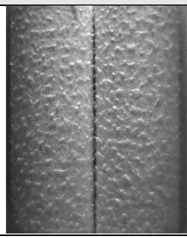
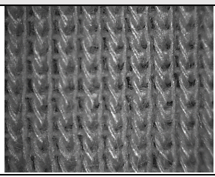
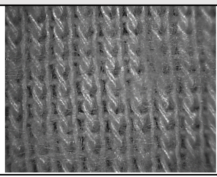
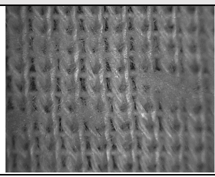
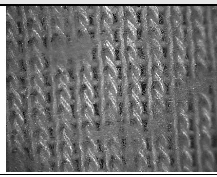
a b c

Slika 2: Fotografije izgleda površine CV pletiva u prirodnoj veličini nakon 14400 okretaja komore: a) uzorak uklonjen s poliuretanskog cilindra (površine 121 cm^2) i b) uzorak na poliuretanskom cilindru (površine 66 cm^2); c) izgled 2D referentnog etalona za piling (ocjena 1)

3. Rezultati i rasprava

Provedenim ispitivanjem je utvrđeno da se jednaka ocjena sklonosti nastanku pilinga postiže izravnim vizualnim pregledom površine uzorka pletiva i neizravnim pregledom izrađenih fotografija površine pletiva (bez cilindra i na cilindru). Ocjenu razine stršećih vlakana je moguće preciznije odrediti na fotografiji i to uz primjenu povećanja od 65x (Tablica 1).

Tablica 1. Izgled površine ispitivanog CV pletiva na cilindru nakon 7200, 10800 i 14400 okretaja komore

Piling	0	7200	10800	14400
Šav u smjeru nizova pletiva				
Ocjena	5	1	1	1
Stršeća vlakna	0	7200	10800	14400
Šav u smjeru nizova pletiva Povećanje: 65x				
Ocjena	5	2	2	4

4. Zaključci

Unaprjeđenjem metodike procjene površinskih promjena omogućena je procjena i analiza nastale razine pilinga i stršećih vlakana na istim uzorcima pletiva tijekom više uzastopnih kontrolnih pregleda, a bez njihova uklanjanja s poliuretanskog cilindra.

5. Literatura

[1] Jasinska, I.; Stempien, Z.: An alternative instrumental method for fabric pilling evaluation based on computer image analysis, *Textile Research Journal*, **84** (2014) 5, pp.488-499, ISSN 1746-7748
[2] Eldessouki, M.; et al.: Integrated Computer Vision and Soft Computing System for Classifying the Pilling Resistance of Knitted Fabrics, *Fibres & Textiles in Eastern Europe*, **22** (2014) 6 (108), pp. 106-112, ISSN 1230-3666
[3] Telli, A.: The Relationship Between Subjective Pilling Evaluation Results and Detecting Pills and Textural Features in Knitted Fabrics, *Fibers and Polymers*, **21** (2020) 8, pp. 1841–1848, ISSN 1875-0052

Franka Žuvela Bošnjak

Životopis

Franka Žuvela Bošnjak rođena je 1978. god. u Splitu. Zvanje dipl. ing. stječe 2003. god. na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu. 1999. god. proglašena je najboljom studenticom kemijskog smjera a 2000. god. dobiva Rektorovu nagradu za znanstveni rad. Nakon 13 godina rada u industriji, 2016. god. zapošljava se na radnom mjestu asistenta na Sveučilištu u Zagrebu Tekstilno-tehnološkom fakultetu, a od 2022. godine radi kao predavač u Studijskoj jedinici Varaždin. Nakon zaposlenja upisala je poslijediplomski sveučilišni studij Tekstilna znanost i tehnologija. Područja znanstvenog interesa su istraživanje struktura i svojstava različitih vrsta koža te priprema i obrada koža.

Naslov teme doktorskog rada

Studijski savjetnik prof. dr. sc. Sandra Flinčec Grgac

Datum obrane doktorskog rada

EKOLOŠKI I EKONOMSKI ASPEKTI PRIMJENE ZEOLITA U OBRADI KOŽE S CILJEM ANTIMIKROBNE ZAŠTITE

Franka ŽUVELA BOŠNJAK

Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, Hallerova aleja 6, Varaždin, franka.zuvela.bosnjak@ttf.unizg.hr

Sažetak: *S obzirom na široku primjenu goveđe kože u odjevnoj, obućarskoj i drugim granama industrije, postoje velike potrebe poboljšanja procesa obrade i dorade kože. Zakonodavne direktive nameću stroga pravila i normative vezane uz zaštitu okoliša. Iz tog razloga u radu je sagledana mogućnost zamjene ekološki nepovoljnog fungicidnog sredstva sa zeolitom. Osim ekološkog aspekta istražen je i ekonomska isplativost prilikom primjene zeolita uz ispitivanje učinkovitosti antimikrobne zaštite kože obrađene zeolitom.*

1. Uvod

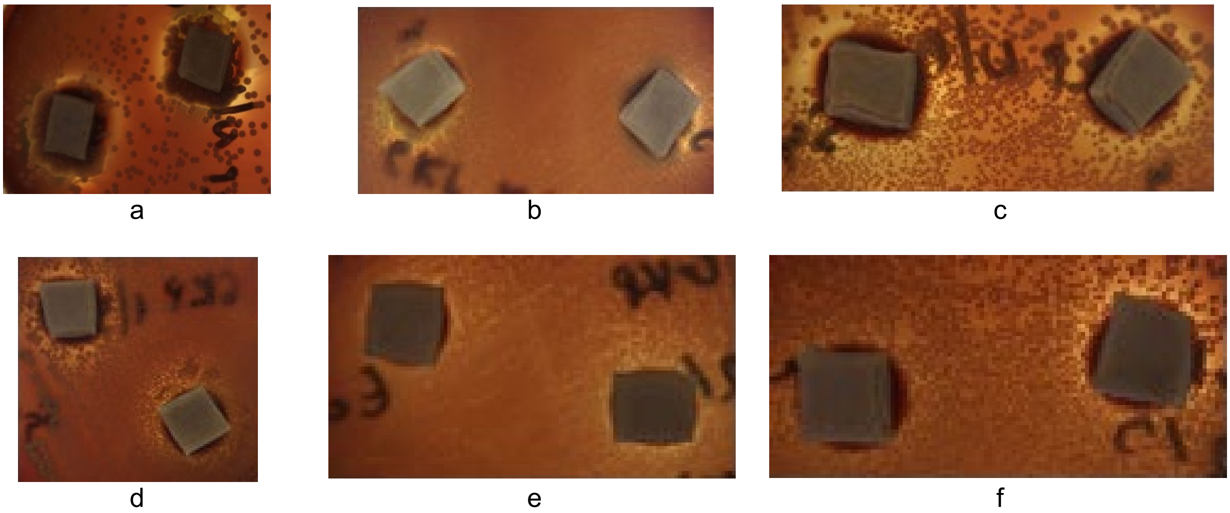
Dugi niz godina kožarska je industrija koristila kemikalije kao što su živini spojevi i klorofenati koji su zabranjeni zbog visoke razine opasnosti za okoliš i ljude prilikom izloženosti. Posljednjih desetljeća oni su zamijenjeni s kemikalijama koje su učinkovite i povoljnije za okoliš kao što su: 2-(tiocijanometiltio)benzotiazol (TCMTB), 3-jodopropinilbutilkarbamat (IPBC), n-oktilizotiazolinon (OIT), dijodometil-p-tolilsulfon (DIMTS), i neki fenoli. Iako je ova generacija biocida prihvatljivija od prethodne, utjecaj na okoliš je i dalje značajan. Zeoliti, s obzirom na kemijski sastav mogu doprinijeti učinkovitoj antimikrobnoj zaštiti i kao takvi uspješno zamijeniti navedene biocide. Nužnost primjene biocida je sprječavanje oštećenja kože uslijed djelovanja mikroorganizama koji u suprotnom uzrokuju mrlje, neujednačenost u daljnjoj obradi, oštećenje lica, promjene fizikalnih parametara što je u korelaciji s kasnijim direktnim i indirektnim troškovima prilikom dorade kože. Prethodno navedene promjene na koži predstavljaju opasnost za zdravlje radnika što upućuje na nužnost kvalitetne primjene antimikrobne zaštite [1-3].

2. Eksperimentalni dio

Procesi pripremnih radova koji uključuju namakanje, luženje, odvapnjivanje, enzimiranje i piklanje provedeni su u konvencionalnim industrijskim uvjetima. Količina sredstva dozira se prema težini vode. Količina vode iznosi 50 % težine piklane kože. Uzorak kože obrađivan je 2 sata na temperaturi od 30 °C u kupelji slijedećeg sastava: limunska kiselina (Sigma Aldrich, St. Louies, SAD), 70 gdm^{-3}; Zeolit 5A 65 gdm^{-3} i sredstvo za namakanje Felosan RG-N (CHT, Švicarska) 1 gdm^{-3}. Obrada je provedena u laboratorijskom uređaju Mathis turbomat P4502. Nakon obrade provedena su antimikrobna ispitivanja prema HRN EN ISO 20645:2018 na slijedeće sojeve *Staphylococcus aureus (S. aureus*), *Escherichiu coli (E. coli)* i *Candidu albicans (C. albicans)* [4]. Piklana koža koja zbog skladištenja na strani lica dobije oštećenja u obliku plijesni i gljivica prolazi proces pranja prije daljnje obrade (štavljenja). Koža se pere u omjeru vode od 200 % na težinu kože. U kupelj se dodaje sredstvo za pranje 0,15 % Borron SAF (TFL, Njemačka) na 30 °C tijekom 60 minuta. Nakon ispusta ulijeva se čista voda, dodaje se 0,15 % mravlje kiseline (Ivero, Hrvatska) i 0,15 % fungicid Busan 1401 WB (Buckman, Belgija).

3. Rezultati i rasprava

Navedena receptura korištena je za izračun profitabilnosti. Ukupni navedeni troškovi ne uključuju sve varijabilne troškove (električna energija i ostali režijski troškovi vezani uz proizvodni proces) niti fiksne troškove (određene plaće radnika), već samo izravne varijabilne troškove koji definiraju procese. Ukupni troškovi sredstava korištenih u obradi kože zeolitom za 1000 kg piklane kože iznose 149,85 €, vrijeme trajanja obrade je 120 minuta dok je utrošena količina vode 500 l. Za pranje kože nakon pojave plijesni i mrlja zbog skladištenja ukupni troškovi korištenih sredstava za 1000 kg piklane kože iznose 205,87 €, proces traje 135 minuta, utrošeno 2000 l vode.



Slika 1: Piklana goveđa koža sa strane lica neobrađena a) CA, b) EC i c) SA i obrađena zeolitom d) CA, e) EC i f) SA

Rezultati pokazuju da piklana koža tretirana zeolitom ima određenu otpornost na navedene mikroorganizme. Vidljivo je da uzorci obrađeni zeolitom stvaraju dodatnu antimikrobnu zaštitu prema gram pozitivnoj bakteriji *Staphylococcus aureus*, gram negativnoj bakteriji *Escherichia coli* te na gljivicu *Candida albicans* u usporedbi s rezultatima prikazanih neobrađenih piklanih uzoraka (Slika 1).

4. Zaključak

Može se zaključiti da postoji ekonomski i ekološki pozitivan učinak obrade koža zeolitom kako bi se postigla poboljšana zaštita od mikroba i plijesni. Prednost je vidljiva kroz smanjenu potrošnju vode čak do 80% u odnosu na proces skidanja plijesni i gljivica. Osim toga izbjegava se upotrebe dodatnih kemikalija što uvelike pridonosi zaštiti okoliša. Obzirom na proces proizvodnje i dorade kože jasno je vidljivo smanjenje vremena dorade i poboljšanje radnih uvjeta. Prikazana struktura varijabilnih troškova određena je pod jednakim uvjetima (lat.*ceteris paribus*) na temelju fiksnih veleprodajnih cijena za jedinicu mjere i korištenih pojedinačnih resursa. Zeoliti u obradi kože imaju kumulativne ekonomski opravdane troškove. Sa stajališta analize troškova, postoji financijska isplativost, koja može pozitivno utjecati na učinkovitost poslovanja i povećati prihode.

5. Literatura

[1] Žuvela Bošnjak, F.; Flinčec Grgac, S. & Maršić, K.: Economic efficiency of leather treated with zeolite after the picking process, *Zbornik radova International textile clothing & design conference*, Dragčević, Z.; Hursa Šajatović, A.; Vujasinović, E. (Eds.), pp. 291-294, Dubrovnik, October 2022, University of Zagreb Faculty of Textile Technology, ISSN 0955-6222

[2] Zugno, L. et al: Fungal Growth on Wetblue: Methods to Measure Impact on Leather Quality, *Journal of the American Leather Chemists Association,* **106** (2011) 1, pp. 1-17, ISSN 0002-9726

[3] Birbir, M. et al: Mold strains isolated from unfinished and finished leather goods and shoes. *Journal of the American Leather Chemists Association,* **89** (1994) 1, pp. 14-19, ISSN 0002-9726

[4] HRN EN ISO 20645:2018 Textile fabric – Determination of antibacterial activity – Agar diffusion plate test

University of Zagreb Faculty of Textile Technology
Doctoral study Textile Science and Technology

PhD Students´ day 2024
Book of Proceedings

Zagreb, February 23rd, 2024

Title
PhD Students Day 2024 – Book of Proceedings

Publisher
University of Zagreb Faculty of Textile Technology
Prilaz baruna Filipovića 28a, 10000 Zagreb

Editor in chief
assist. prof. Ivana Špelić, PhD, vice dean for scietific study and art affairs

Prepress
Ivana Špelić

Logo of PhD Students' day created by:
Rajna Malinar

ISSN 2991-924X (Online)

ISSN 2584-6604 (Print)

Content

Introduction

The doctoral study ***Textile Science and Technology*** is a continuation of the university graduate study that combines theoretical knowledge, research work and experience in solving problems based on knowledge of modern production systems. The University of Zagreb Faculty of Textile Technology is the holder of this study from the scientific field of technical sciences, the scientific field of textile technology.

The doctoral programme Textile Science and Technology (https://www.ttf.unizg.hr/teksilna-znanost-i-tehnologija/226) is the only doctoral programme in the field of textile science and technology in the Republic of Croatia and the most important in the region.

The main goal of the studies is to train doctoral students for independent scientific research work, encourage innovation and transfer the results of scientific research to the improvement of modern production processes in the textile and clothing industry. Global progress in the field of technical sciences particularly emphasizes the research of materials and their characteristics, with an emphasis on the application of biotechnology and nanotechnology. High range in this is represented by composite materials, smart textiles, functional protective and intelligent clothing. The International Council of Academies of Technical Sciences (CAETS) has placed the research of materials, including textiles, on the list of priorities.

The doctoral study Textile Science and Technology enables doctoral students to continue working in research institutions, institutions with a partial share of research activity, the public sector and the economy. Upon completion of the studies, applicants are trained for team work and independent management of national, bilateral and European scientific projects in the field of doctoral research. The acquired knowledge and research potential enable them to continue their scientific and research work through postdoctoral training after completing their studies.

Head of the doctoral study

prof. Sanja Ercegović Ražić, PhD

Dean of the University of Zagreb
Faculty of Textile Technology

prof. Anica Hursa Šajatović, PhD

Foreword

The University of Zagreb Faculty of Textile Technology, as the holder of the doctoral study ***Textile Science and Technology***, organizes the PhD Students' Day scientific conference for the fourth time. This scientific manifestation proudly presents the scientific - research work of its doctoral candidates under the guidance of their respected mentors.

In the Proceedings of the PhD Students' Day 2024, 29 extended summaries of papers under PhD research topics written in Croatian and English were published. In addition to the extended summaries of papers under PhD research topics, the full papers of seven Doctors of Science were published, which finished their doctorates at the University of Zagreb, Faculty of Textile Technology since the previous PhD Students' Day.

The collection of papers provides insight into the diversity and quality of scientific research topics and the involvement of our doctoral students in the development of new, innovative methods, materials and technologies through the application of new ideas and engineering solutions.

Head of the doctoral study

prof. Sanja Ercegović Ražić, PhD

Martina Bobovčan Marcelić

Biography	Martina Bobovčan Marcelić was born in 1979 in Koprivnica. She graduated at the University of Zagreb, Faculty of Textile Technology in February 2008. From 2006 till 2010 she worked in company Galko d.o.o., from 2011 till 2021 she was employed at the University of Zagreb, Faculty of Textile Technology on Department of Clothing Technology. In 2022, she founded his own business, which deals with designing and making clothes, organizes creative workshops related to textiles, etc. She completed her doctoral dissertation under supervision and mentorship of prof. Dubravko Rogale, PhD, in the field of welding thermoplastic polymer materials, process parameters of high-tech welding techniques and properties of welded seams on protective and intelligent clothing.
Title of PhD thesis	Process parameters of high-tech welding methods and properties of welds on protective and intelligent clothing
Mentor	prof. Dubravko Rogale, PhD
Date or dissertation defense	May 5th, 2023

PROCESS PARAMETERS OF HIGH-TECH WELDING TECHNIQUES AND THEIR INFLUENCE ON WEDED SEAMS PROPERTIES

Martina BOBOVČAN MARCELIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
mbobovcanm@gmail.com

Abstract: *In this paper, the influence of process parameters of applied high-tech techniques on the properties of welded seams will be investigated. The welds to be tested were formed by welding parts of a clothing using ultrasonic welding and high frequency (HF) welding. These welding techniques are most often used in the production of protective and intelligent clothing where the welded seams must meet certain properties (airtightness, watertightness, elasticity, strength, thickness of the extruded edge, compression properties, etc). In the paper, the relationship between the influence of the welding parameters on the thickness of the extruded edge, on the strength of the welded seams and the energy density per volume was investigated. Also, the interrelationship between welded seam strength and energy density per volume is presented.*

1. Introduction

Some parts of intelligent clothing can be performed by using conventional technique of sewing, but advanced welding techniques must be used, as conventional technique of sewing cannot obtain satisfactory technical and technological conditions [1]. The welding techniques used to make the welded seams are differ in terms of supplying and/or initiating heat at the welding zone [2, 3]. In all welding techniques, the correct implementation of the process usually depends on the values of three welding process parameters, namely temperature/energy, pressure force and time in stationary welding, i.e., speed in continuous welding [4].
Certain requirements such as strength, elasticity, durability, quality, aesthetics and other technical conditions, especially air-tightness and water-tightness, are placed on all welded seams when assembling parts of clothing, especially protective and intelligent clothing.
Such clothing is made of specific textiles. In order for the welded seams to have the mentioned properties, it is necessary to determine the optimal welding parameters depending on the type of material and the selected welding technique. Based on the stated requirements, which define the features of the welded seam, it is considered the way in which the welded seam should be designed and the welding technique that will be used to join the parts of the clothing [5].
Research by other authors shows how important the use of optimal values of welding parameters is and how significant their influence is on the quality of the welded seam, but also on other properties of the welded seam, which are very important in order for the clothing to meet all the requirements defined according to its purpose [6].

2. Experimental

The paper presents research on the influence of welding process parameters on the properties of the welded seams of protective and intelligent clothing. Two different material samples M10 (PU 100 %) and M11 (PES 53 % and PU 47 %) were welded using ultrasonic and HF welding techniques. The material samples were welded in several ways of arranging the material layers, face to face, face to back and back to back.
An extremely large range of welding process parameters was used for research in the work, so for the experimental part, a large number of different welded seam samples were made, which were measured, analyzed and evaluated, where the ranges of optimal values of the welding process parameters were determined for both welding techniques.
Evaluation of the quality of the welded seams based on the visual appearance of the welded seam evaluated in several stages. On the welded seam samples that were evaluated with a good visual quality rating, tests were performed on the strength of the welded seams, the thickness of the extruded edge, and calculations of the energy density per volume were given.
The visual assessment of the welded seam was evaluated regard to the achieved welding quality, the intensity of the extruded edges in the welding zone, Fig. 1 and the material bulk along the welding area.

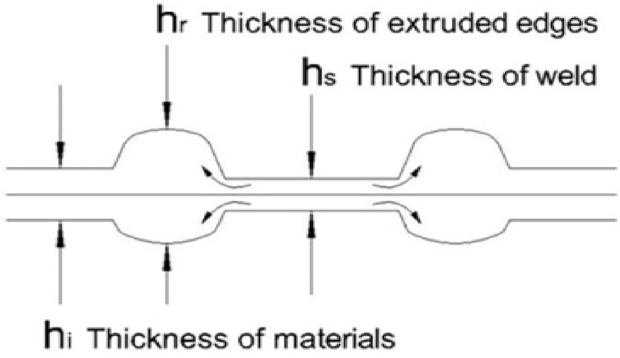


Figure 1: Schematic presentation cross-section of the welded seam showing the characteristic welded seam thicknesses: the thickness of the extruded edges (h_r), the thickness in the welding zone (h_s) and the thickness of the material outside the welding zone (h_i)

To test the mechanical properties of the strength of the welded seam, a tester manufactured by Mesdan S.p.A, TensoLab 3000, was used, and to test the value of the thickness of the extruded edge, a measuring device was used to measure the characteristics of the welded seams.

By analyzing the measurement results of the examined properties of the welded seams, the values of which change depending on the applied welding process parameters, the relationship between the influence of the welding process parameters on the strength of the welded seams and the thickness of the extruded edges was determined. Based on the input welding parameters, values of energy density per volume for ultrasonic and HF welding techniques were also calculated, and their influence on the quality of the welded seams was investigated.

3. Results and Discussion

By studying the relationship between the influence of welding parameters on the values of the measured strengths of the welded seams, it was observed that a very important factor that affects the values of all the studied properties of the welded seams is the thickness of the extruded edges.

Lower values of the thickness of extruded edges indicate that the welded seam has slightly extruded edges, and higher measured values indicate a higher intensity of extruded edges. The highly accentuated extruded edges are deformations that occur when a large amount of heat is introduced and/or initiated in the welding zone. The softened material is pushed out of the area affected by the heat, by the action of pressure force, into the edges of the welding seam.

From the results of testing the strength of the welded seams and the influence of different welding parameters, it can be concluded that the strength of the welded seams is significantly influenced by the welding parameters as well as the number of the material layers and their position. The highest values of the strength of the welded seams in the ultrasonic welding technique were measured in the welded seams welded at lower welding speeds and higher values of the power of the ultrasonic generator. With the HF welding technique, the highest strength values were measured with a longer welding time and higher values of the anode current strength.

In order to determine the amount of energy applied to the material during welding, calculations were carried out and based on the input of welding parameters, energy density values per volume were calculated. By comparing the values, data was obtained on the amount of energy that needs to be used to achieve a quality connection for the material samples.

Based on the calculation of data for the energy density per volume during ultrasonic and HF welding on material samples of M10 and M11 marks welded face-to-face, an analysis of the impact on the strength of the tested samples was made. The results of the analysis of the samples welded by ultrasonic and HF techniques are shown in Fig. 2 and 3, and the influence of the energy density per cubic centimetre on the strength of the welded seams welded by the HF welding technique is given.

The analysis determined that the welded seams where it was calculated that they initiate a higher energy density per volume have both greater strength and a greater thickness of the extruded edge.

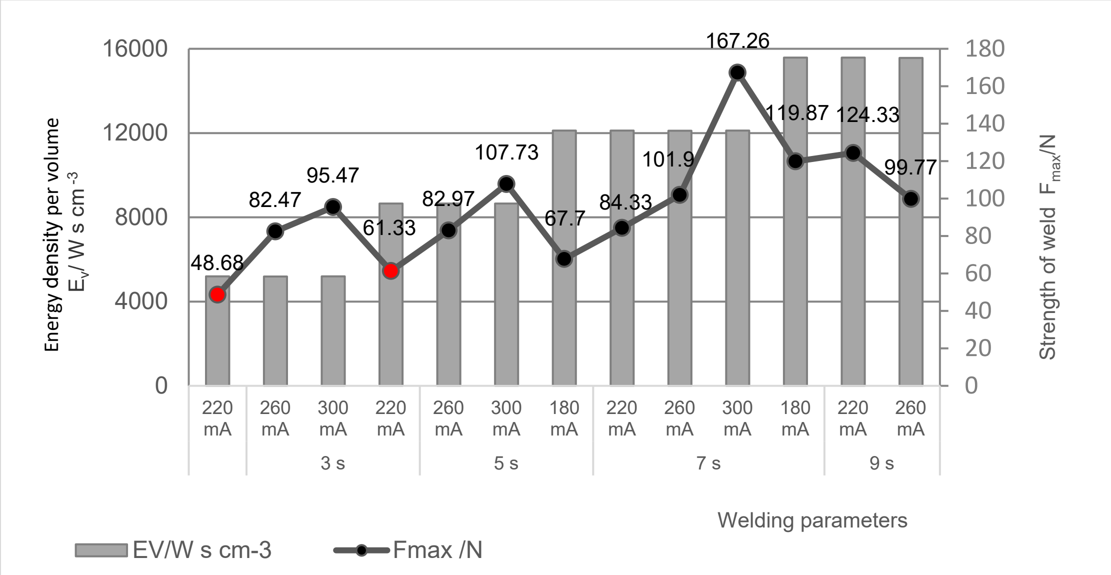


Figure 2: Presentation of the influence of the energy density per volume Ev/W s cm^{-3} on the strength of weld F_{max}/N during ultrasonic welding material sample M10

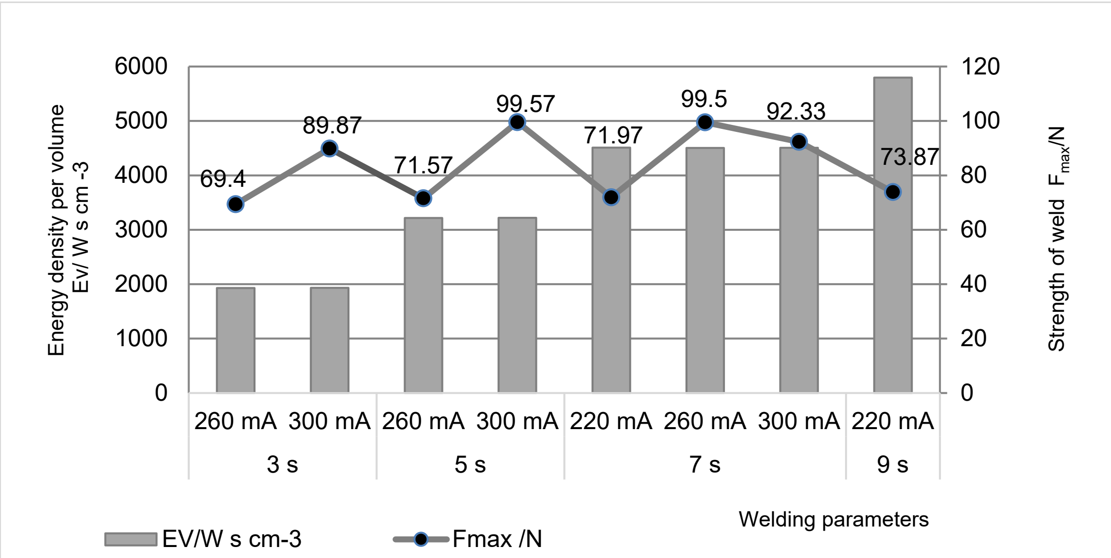


Figure 3: Presentation of the influence of the energy density per volume Ev/W s cm^{-3} on the strength of weld F_{max}/N during HF welding material sample M11

The analysis determined that the welded seams where it was calculated that they initiate a higher energy density per volume have higher values of the welded seams strength and a higher values of the thickness of the extruded edge.

4. Conclusion

The results of the research clearly indicate that using mechanical parameters it is possible to accurately and scientifically evaluate the properties of welded seam on textile materials from which protective and intelligent clothing is made.
The research determined that the use of optimal values of welding parameters has a significant impact not only on the quality of the welded seams, but also on other properties of the welded seam (strength, thickness of the extruded edge and energy density per volume) which are very important in order for a specific clothing to meet all the requirements that have been defined according to its purpose.
The established results of testing the strength of the welded seams, the thickness of the extruded edge and the energy density per volume for the welded seams welded by ultrasonic and HF welding techniques provide a technological analysis of the most influential process parameters of the welded seam, where the ranges of optimal values of the process parameters of the welded sea, are determined. The knowledge presented in this paper will help in the further development of modern protective and intelligent clothing as valuable items of use with high added value. The results of this work enable further scientific, technical and technological development of modern high-tech welded seams on specific clothing items.

Acknowledgment

This work was supported by the Croatian Science Foundation (project IP-2018-01-6363 Development and Thermal Properties of Intelligent Clothing [ThermIC] under supervision of prof. Dubravko Rogale, PhD.

5. References

[1] Firšt Rogale, S. i sur.: *Inteligentna odjeća*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 978-953-7105-52-5, Zagreb, (2014)
[2] Grewell, D.; Benatar, A. i Park, J.: *Ultrasonic Welding in: Plastics and Composites Welding Handbook,* Grewell, Benatar, Park, (Ed.), Hanser, ISBN 1-56990-313-1 (2003), pp. 142-188
[3] Zhang, Z. et al: Study on Heating Process of Ultrasonic Welding for Thermoplastics, *Journal of Thermoplastic Composite Materials*, **23** (2010) 5, pp. 647-664
[4] Shi, W. and Littel, T.: Mechanisms of Ultrasonic Joining of Textile Materials, *International Journal of Clotinhg Science and Technology*, **12** (2000) 5, pp. 331-350
[5] Marcelić Bobovčan M. et al.: Study of Compression Properties of Welded Seams Formed Using Hot Wedge, Hot Air, Ultrasonic and High-Frequency Welding Techniques, *Textile Research Journal*, **92** (2022) 23-2, pp. 4736-4752
[6] Jakubčioniene, Ž. et al.: Investigation of the strength of textile bonded seams, *Materials Science,* **18** (2012) 2, pp. 172-176

Iva Brlek

Biography	Iva Brlek, PhD was born in 1988 in Zagreb, and in 2013 she completed her graduate studies at the University of Zagreb Faculty of Textile Technology, and in 2014 enrolled doctoral study at the same faculty. In 2023, she finished her doctorate with the topic "*Cosmetotextiles - carriers of active natural substances to the skin*" under the mentorship of prof. Sandra Bischof, PhD From 2015 to 2017, she worked as an expert associate on the project "*Advanced textile materials obtained by targeted surface modification* - ADVANCETEX", and from 2017 until present as an assistant at the Department of Textile Chemistry and Ecology, University of Zagreb Faculty of Textile Technology. Awarded for the best e-course in Ac. Yr. 2017/2018 and with Dean's Award in the category assistants for the publication of a scientific paper in the journal with the highest impact factor in Ac. Yr. 2020/2021.
Title of PhD thesis	Cosmetotextiles – carriers of active natural substances to the skin
Mentor	prof. Sandra Bischof, PhD
Date or dissertation defense	February 17th, 2023

COSMETOTEXTILES – CARRIERS OF ACTIVE NATURAL SUBSTANCES TO THE SKIN

Iva BRLEK

University of Zagreb Faculty of textile technology, Prilaz baruna Filipovića 28a,
iva.brlek@ttf.hr

Abstract: *The main goal of the dissertation was to determine the most suitable method for quantifying active substances on cosmetotextiles before and after their release and washing. Synthesis of microcapsules was carried out and synthesised microcapsules were analysed. Microcapsules containing α-toc and the microcapsules containing EOI were selected for application to cotton. The textiles treated with microcapsules are subjected to washing, friction and light fastness tests to determine the binding of the microcapsules and their release during use. A prototype of cosmetotextiles made of cotton material for use in garments that are in close contact with the skin.*

1. Introduction

1.1. Cosmetotextiles

According to a manual [1] based on a European Commission regulative for cosmetic products [2], textile can be a "carrier" that delivers active substances or mixtures of substances to the human skin. The active substance(s) can be delivered to different parts of the human body, especially the skin. They have specific functions, such as cleansing the skin, adding fragrance, changing the appearance of the skin, correcting odours or, most importantly, keeping the skin healthy. Cosmetic preparation, or mixture of preparations, can be of natural or synthetic origin. For an active preparation or a mixture applied to a textile substrate to be considered an active substance at all, it is necessary to possess the ability to be released to the skin. Preparations that are not released to the skin are not considered cosmetic products, nor are the textiles with active substances applied to them that are not released to the skin, classified as cosmetotextiles [1].
Various literature references [3,4] classify cosmetotextiles using different bases and concepts, most often using the impacts on human body as a basis of classification, or the method of applying them onto textile substrates.

1.2. Microcapsules

Microcapsules are particles ranging in size from 1 to 1000 µm, containing an active substance (in liquid or solid phase), surrounded by natural, semi synthetic or synthetic polymer membrane. They consist of two parts, the core and the membrane. Numerous active substances are sensitive to heat, prone to oxidation or change. Microencapsulation or bonding into complexes enables the protection of sensitive active substances from detrimental influences, such as degradation by oxidation or by polymerisation during drying and / or thermal treatments and garment storing. These processes prevent evaporation of volatile compounds and prolong their lifetime, which is of high importance when using perfumes and essential oils [5,6].

1.3. Active substances release

After the active substance has been incorporated into the textile material, it is important to define and understand the mechanism of its release. Primary aim is sometimes to release the active substance completely at a particular moment, while sometimes it is supposed to be slowly released, so that the product retains its functionality as long as possible. Active substances diffuse through the microcapsule envelope at a particular rate [7,8].

2. Experimental

The active substances, α-tocopherol and immortelle essential oil were selected and the ethyl cellulose microcapsules were synthesised using the phase separation method (Figure 1). Both α-tocopherol and immortelle essential oil are very sensitive to external influences and encapsulation was a logical choice to prevent their degradation, i.e. premature evaporation during and after application to textiles. The microcapsules were analysed gravimetrically and microscopically to determine their morphology and to detect the presence of oil in the microcapsules.

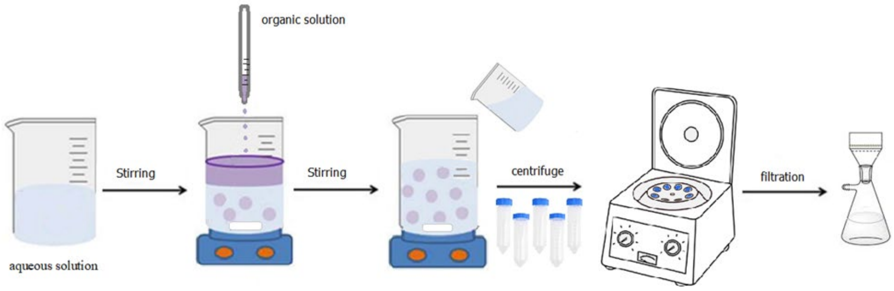


Figure 1: Ethyl cellulose microcapsules synthesised by the phase separation method

Antioxidant analysis was performed and demonstrated using Electron Spin Resonance (ESR) technique. Microcapsules were applied to textiles by impregnating, exhaustion and electrospinning process. The textiles treated with microcapsules (cosmetotextiles) were subjected to a washing, rubbing and light fastness test to determine the binding of the microcapsules and their release during use. Spectrophotometry, chromatography and microscopy were used to analyse the active substances qualitatively and quantitatively before and after the fastness test. Remission spectrophotometry was used to analyse the degree of whiteness before and after processing the textiles. The dermatological test (Patch test) was performed on 50 test subjects to determine the possibility of an allergic reaction to cosmetotextiles.

3. Results and Discussion

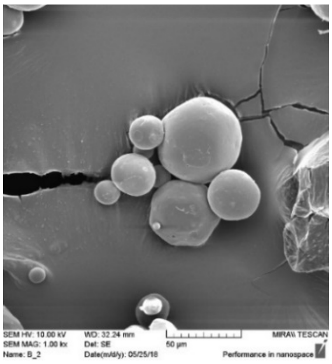
Several types of active substances (α-toc, EOI and combination of α-toc and EOI) were used in this research and for final prototype EOI was chosen as the best one. The synthesis of the microcapsules was optimised and the best amount of active substance and ethyl cellulose, which plays the role of a membrane in the synthesised microcapsules, in a ratio of 1:3 (oil:ethyl cellulose) was selected for further investigations.
Cotton fabric was selected as a potential cosmetotextile due to its natural origin, its hydrophilicity and its pleasant properties in contact with the skin. Studies were also carried out with other textile materials (e.g. PES/cotton, silk, modal and liocel). The exhaustion method proved to be the most acceptable method of application as it allowed uniform binding of the microcapsules to the textiles under controlled conditions of temperature, time and concentration of chemicals, which was not the case with impregnation and electrospinning.

Table 1: Active substances release after fastness tests

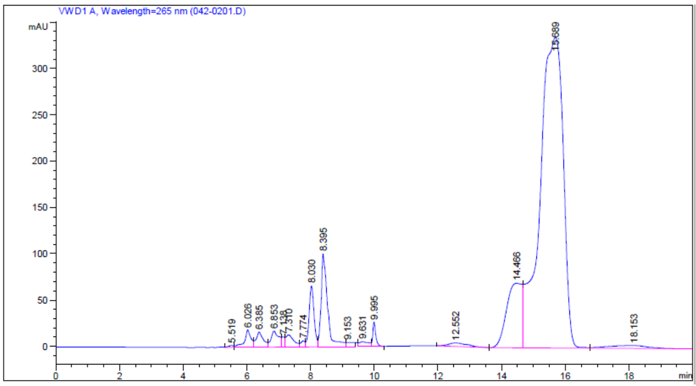
Fastness test		**Cosmetotextiles with EC microcapsules containing α-toc**	**Cosmetotextiles with EC microcapsules containing EOI**
		active substance release (%)	
rubbing test		5,54	73,77
light test		16,63	44,26
wash test	1 cycles	/	68,85
	10 cycles	/	88,11

The textiles treated with microcapsules were subjected to washing, rubbing and light fastness tests to determine the binding of the microcapsules and their release during use. The cosmetotextiles containing microcapsules with essential oil showed good light fastness (55,74 % of the active substance was still present on the cosmetotextile after the test), but were not wash-resistant, as no essential oil could be detected on the textiles after 10 washing cycles. The obtained rubbing fastness results showed that the oil was gradually released when rubbed against the skin, which was a necessary prerequisite for the prototype to be categorised as a cosmetotextile. Effects achieved were presented in Table 1.
Optimal results in synthesis were obtained under the following conditions: solvent evaporation method for synthesis, oil:EC rate 1:3, stirring speed in synthesis 400 rpm. Prototype of EC microcapsules containing EOI

analysed by Scaning electron microscope (SEM) are presented on Figure 2 a. On Figure 2 b is presented HPLC chromatogram of EC-EOI microcapsules.



a



b

Figure 2: Prototype of EC microcapsules containing EOI: a) SEM images of EC-EOI, magnification 1000x, b) HPLC chromatogram of EC-EOI microcapsules

Optimal results in application were obtained under the following conditions: exhaustion for application on textiles, binder Tubicoat WLI, in concentration 5,6 % on mass of material, concentration of microcapsules 8 % on mass of material. The results of analyse with remission spectrophotometry revealed unsignificant change in the whiteness of the material after processing with microcapsules.
After dermatological test (Patch test) was performed on 50 subjects all patients were negative for the tested textile samples. Since the tested patients were most likely to have sensitised skin, it can be assumed that the tested textiles are hypoallergenic. Results of antioxidant analysis using ESR technique are presented at figure 3. EOI as an active substance showed an important antioxidant potential. Relative signal intensity measured 12 minutes after contact of the active substance with DPPH (free radical 2,2-diphenyl-picrylhydrazyl) solution was about 8 % and it remained relative constant until the end of measurement.

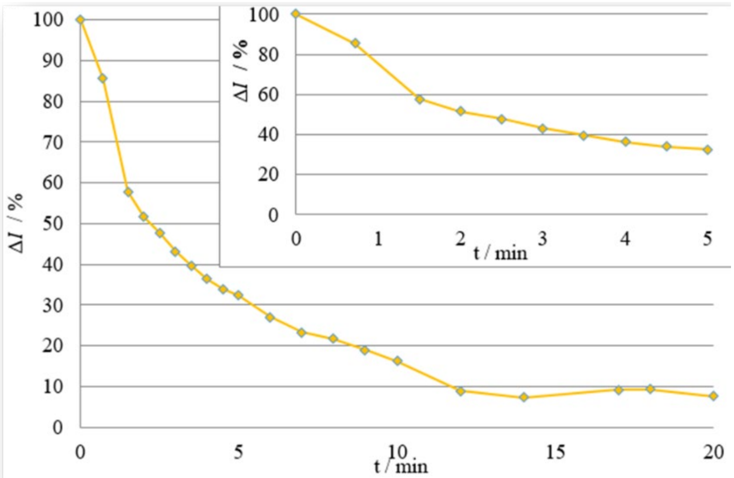


Figure 3: The relative signal intensity of the DPPH as a function of the reaction time *t* for active substance EOI

4. Conclusion

All research hypotheses of the dissertation have been confirmed as follows:
1. **It is possible to achieve targeted efficiency of cosmetotextiles by applying active, natural products based on vitamins or essential oils on textiles.** *The targeted effects of the cosmetotextiles were: good antioxidant activity and hypoalergenic of cosmetotextiles.*
2. **Synthesized microcapsules will be attached to textile substrate and gradually released from cosmetotextiles.** *For this purpose, the following fastness tests were performed on cosmetotextiles: washing cycles, rubbing and light test (Table 1).*
3. **Developed methodology will allow quantitative determination of the amount of active products in the cosmetotextiles, which is directly related to the effectiveness of treatment and washing durability.** *High pressure liquid chromatography analysis was used for quantitative determination of α-toc and UV spectroscopy was used for quantitative analysis of EOI.*

The scientific contribution of the dissertation is demonstrated by:
1. Development of innovative, environmentally friendly and biodegradable cosmetotextiles that can also have a medicinal effect.
2. Improving the effectiveness of cosmetics and textiles by optimising microencapsulation methods and processes.
3. Contribution to the classification and standardisation of methods for testing the cosmetic, aromatherapeutic or medical effects of cosmetotextiles.
Disertation confirmed all the hypotheses as well as the expected scientific contribution of the research, as the dissertation led to the development of a prototype of cosmetotextiles, a cotton material with ethyl cellulose microcapsules containing immortelle essential oil, which has the possibility of wide application in the field of wellness textiles, but also in the cosmetics industry and in the field of medicine.

Acknowledgment

HrZZ Croatian Science Foundation

This paper was produced as part of the project of the Croatian Science Foundation, no. 9967 "Advanced textile materials obtained by targeted surface modification" - ADVANCETEX, led by prof. Sandra Bischof, PhD.

5. References

[1] Official website of the Europenian Union, *Dostupan na*: https://ec.europa.eu/docsroom/documents/42850 *Pristupljeno:* 2024-01-02
[2] The European Commission: Regulation (EC) No 1223/2009 of the european parliament and of the council of 30 November 2009 on cosmetic products, *Official Journal of the European Union* (2009) 1223, 342/59–209
[3] Singh, M. K. et al.: Cosmetotextiles: State of art, *Fibres & Textiles In Eastern Europe*, **19** (2011) 4, pp. 27–33, ISSN 1230-3666
[4] Rodrigues, S. N. et al.: Scentfashion®: Microencapsulated perfumes for textile application, *Chemical Engineering Journal*, **149** (2009) 1-3, pp. 463–472, ISSN 1873-3212
[5] Lam, P. L., Gambari, R.: Advanced progress of microencapsulation technologies: In vivo and in vitro models for studying oral and transdermal drug deliveries, *Journal of Controlled Release: Official Journal of the Controlled Release Society*, **178** (2014), pp. 25–45, ISSN 0168-3659
[6] Carvalho, I. T. et al.: Application of microencapsulated essential oils in cosmetic and personal health care products—A review, *International Journal of Cosmetic Science*, **38** (2016), pp. 109–119, ISSN 1468-2494
[7] Martins, I. M. et al.: Microencapsulation of essential oils with biodegradable polymeric carriers for cosmetic applications, *Chemical Engineering Journal*, 245 (2014), pp. 191–200, ISSN 1385-8947
[8] Nesterenko, A. et al.: Vegetable proteins in microencapsulation: A review of recent interventions and their effectiveness, *Industrial Crops and Products*, **42** (2013) 1, pp. 469–479, ISSN 0926-6690

Tea Bušac

Biography	She was born in 1992 in Zagreb. She graduated in 2016 at the University of Zagreb, Faculty of Textile Technology, and in 2023 she earned her PhD position. After completing her studies, she was awarded the Dean's Award for Success. In 2018, she worked as a replacement assistant at the Institute for Materials, Fibers and Textile Testing, and in 2019, she started working as an assistant to the plant manager at the Salesianer Miettex Lotos d.o.o. laundry. From 2020, he will be employed as an expert associate on the project KK.01.2.1.02.0064, and in 2023 he will be employed as an administrator on the project KK.01.1.1.04.0091. In addition to working on European projects, she is also involved as a collaborator on national research projects of the Croatian Science Foundation. She published several scientific and professional papers and participated in international and domestic conferences.
Title of PhD thesis	Modification of polyester fabric to improve the binding of the biopolymer chitosan and reduce the particle content in wastewater from the washing process
Mentor	prof. Sanja Ercegović Ražić, PhD prof. Mirjana Čurlin, PhD
Date or dissertation defense	December 13th, 2023

MODIFICATION OF POLYESTER FABRIC TO IMPROVE THE BINDING OF THE BIOPOLYMER CHITOSAN AND REDUCE THE PARTICLE CONTENT IN WASTEWATER FROM THE WASHING PROCESS

Tea BUŠAC

University of Zagreb, Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
10000 Zagreb, tea.busac@ttf.unizg.hr

Abstract: *In this study, the influence of conventional and advanced pretreatment processes (plasma and ozonation) for polyester fabrics was investigated to improve the binding of the biopolymer chitosan and to reduce the content of particles in effluents from the washing of polyester/chitosan structures.*

1. Introduction

The production and consumption of textiles is constantly increasing due to the growing population and the shorter shelf life of clothing, which inevitably leads to a worldwide increase in textile waste. During the use cycle and especially during washing, synthetic clothing releases fibres of different lengths and fineness.
Various preventive and curative methods are used to protect aquatic ecosystems from this type of pollution. In addition to the preventive measures taken during the production process, it is also important to emphasise the environmentally friendly modifications applied to textiles (permanent, non-permanent and semi-permanent), which have the task of improving the performance characteristics of the substance and protecting against the pollution of aquatic ecosystems by potentially released particles [1-3]. Particles released during the use cycle of synthetic textiles fall within the scope of microplastic pollution, which, according to the literature, includes all synthetic solid particles or polymer matrices with a regular or irregular shape and a size of 1 µm to 5 mm, which are either of primary or secondary origin and insoluble in water [4-5].
Research into the release of particles/fragments from textile materials, their impact on the aquatic ecosystem and the contribution to the identification and characterization of the released particles are the subject of numerous scientific studies [6]. By applying standardised and physico-chemical methods for the characterisation of textile material, the influence of the washing process on the functional properties achieved and on the potential for the release of fibre fragments was investigated. This paper presents part of the results related to the stability of the polyester/chitosan structure monitored during exposure to factors in the washing process. To confirm the presence of chitosan, the identification method with Remazol® Red RB dye was applied, and the content of released particles was monitored by laser diffraction.

2. Experimental part

The study was carried out on a standard polyester fiber fabric, the properties of which are listed in Table 1. The fabric was prepared with a manual ultrasonic cutter, *Ultrasonic cutter TTS-400, Sonowave*.

Table 1: Properties of standard polyester fabric

Label		PN-01
Color		White
Mass per unit area (g/m^2)		156,0
Density (threads/cm)	warp	27,7
	weft	20,0
Thickness (mm)		0,35
Counts of yarn (tex)	warp	30,4
	weft	31,9
Weave structure		Plain weave

Alkaline hydrolysis of standard polyester fabric (AH) was carried out with 2 % NaOH with OK 1 : 5 at a temperature of 98 °C for 30 minutes, washing it in two cycles with hot water and two cycles with cold water. Alkaline hydrolysis with the addition of 3 g/L cationic surfactant *Barquat BC50*, alkyldimethylbenzalkonium chloride, *Quat-Chem Ltd*, (AH_K) was carried out under the same conditions.

The functional coating of biopolymeric chitosan on untreated polyester fabric and on selected pre-treated samples of polyester fabric was carried out using a chitosan solution (CH) with a concentration of 0,5 %, which was prepared by dissolving chitosan in distilled water under constant stirring on a magnetic stirrer (200 rpm) and adding 0.1 mol/L hydrochloric acid ($HCl_{(aq)}$).

Throughout the study, the influence of conventional and advanced pretreatments on the stability of the formed polyester/chitosan structure exposed to the factors in the washing process and on the content of particulate matter in the wash effluents was monitored by i) the properties and stability of the obtained polyester/chitosan polymer structures; ii) the properties and stability of the obtained polyester/chitosan polymer structures after washing; iii) the wash effluents with emphasis on the particulate content; iv) the filter cake obtained by membrane filtration of the wash effluents were analyzed.

In this paper, only part of the results related to the confirmation of the chitosan modification of conventionally pretreated polyester fabrics and the stability of the structure exposed to factors during washing with a standard ECE-A detergent at 60 °C for 30 minutes are presented.

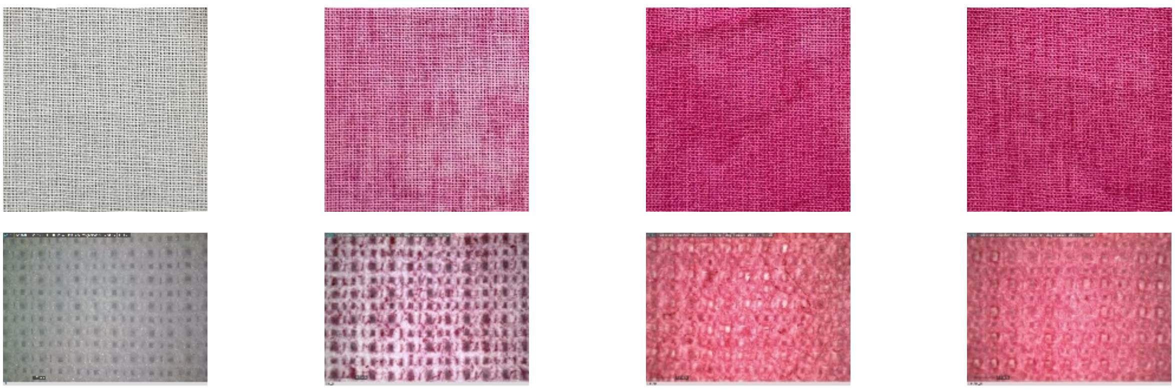
The presence of chitosan on the polyester fabric was detected using an anthraquinone structural dye, Remazol® Red RB 133 % (C.I. Reactive Red 2). The samples were dyed with 1 % dye per mass of material at a temperature of 60 ºC for 30 minutes at a speed of 100 rpm with OK 1: 50 in a laboratory device *Polymat P 4502 (M), Mathis*. Rinsing was carried out in four cycles in cold water, followed by soaping with *Kempon 30, Kemo*, 2 g/L, at 90 ºC for 10 minutes. The content of particulate matter in the effluents from the washing of chitosan-modified structures, where a contribution to the release from individual components of the structure was observed, was determined according to the HRN ISO 13320:2020 standard using a *PSA 1090 LD* particle size analyzer, *Anton Paar*.

3. Results and discussion

The characterization results relate to the properties and structural features, and it is important to monitor these to assess the individual pretreatment and efficiency of modification with chitosan as well as the stability of the polyester/chitosan structure during washing. Numerous methods are used to identify chitosan on textiles, for example various ionic dyes and the streaming potential method. In this work, the method of staining with the dye Remazol® Red RB was used to confirm the presence of chitosan, whereby the presence of chitosan is detected by selected spectral values.

The results obtained, Figure 1, show the untreated polyester fabric (N) and the red hue with the corresponding hue values (K/S) for other samples pretreated by conventional alkaline hydrolysis (AH) and alkaline hydrolysis with addition of promoter (AH_K) and modified with chitosan (CH), indicating the presence of chitosan on the surface.

N	CH	CH-AH	CH-AH_K



/	K/S 1.51	K/S 2.98	K/S 3.27

Figure 1: Micrographs of polyester fabric samples before and after modification, dyed with the dye Remazol® Red RB at 50x and 230x magnification and their K/S values

The stability of the structures was monitored during 5 (_V) and 10 (_X) wash cycles, and the staining results are shown in Figure 2. The reduced colour strength, expressed as K/S values (Figure 2), indicates that chitosan is not completely stable when washed under alkaline process conditions.

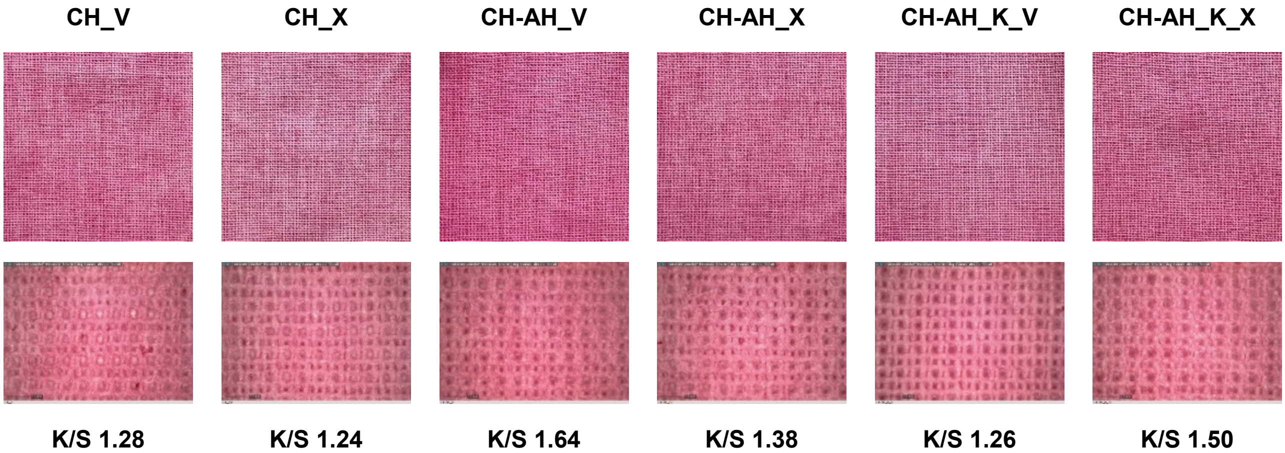


Figure 2: Micrographs of samples of washed modified polyester fabrics dyed with the dye Remazol® Red RB at 50x and 230x magnification and their K/S values

The displayed values show the highest loss after 5 wash cycles. Alkaline hydrolysed polyester fabrics treated with chitosan are still coloured after 5 and 10 wash cycles (CH, CH-AH and CH-AH_K), confirming the presence of chitosan on the surface even after 10 wash cycles.
The solids in the wash water may contain detergent particles, released fibril components from the polyester component in the structure or particles from the biopolymer component in the polyester/chitosan structure. In order to characterise the effluent from the washing process, with a focus on the particle content, a particle size analysis was carried out (Figure 3) on the mixed samples from the washing and rinsing process.

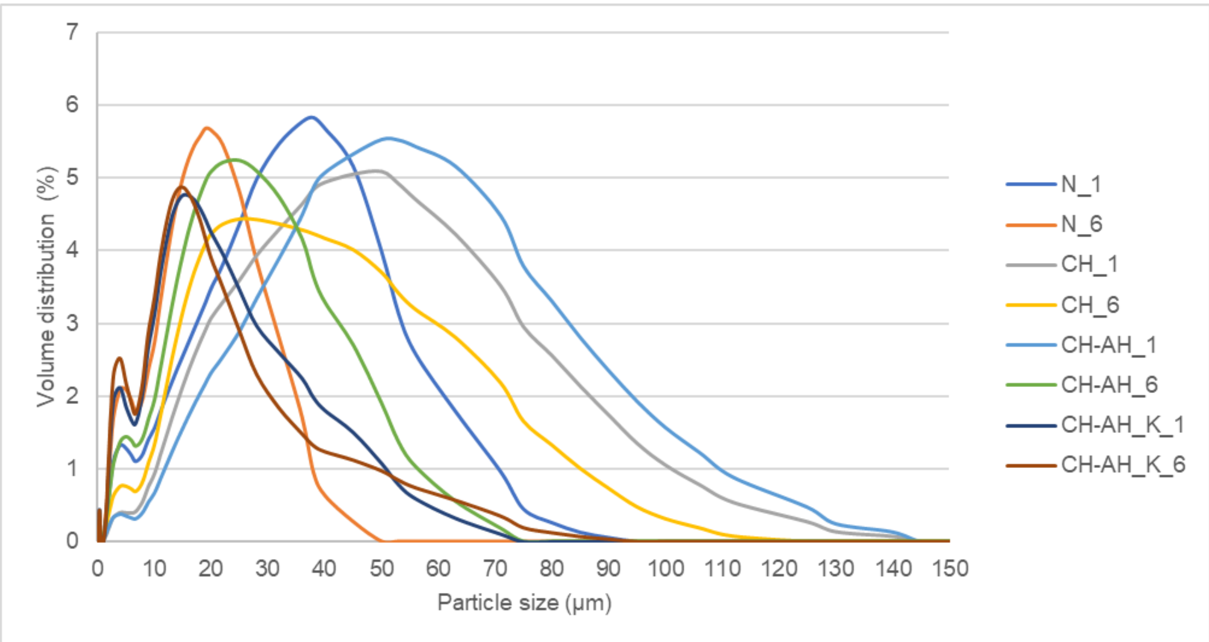


Figure 3: Distribution of particle sizes in effluents from 1-5 (labelled _1) and 6-10 (labelled _6) wash cycles

A lower number of washing cycles of untreated polyester fabric has an effect on the particle size distribution, which shifts towards larger particles. The effect of chitosan on untreated polyester fabric when exposed to the factors of the washing process can be seen in the results of the particle size distribution in the effluent, which in this case shifts towards larger particles in all washing cycles compared to untreated polyester fabric. The pre-treatment of polyester fabric has an effect on the distribution of particle sizes in the wash water, whereby

a different distribution can be observed for the first wash cycles of alkaline hydrolysed polyester fabric without the addition of promoter and with the addition of promoter. A broader spectrum of particle sizes was achieved in the first wash cycles of alkaline hydrolysed polyester fabric with the addition of promoter.
The results show that the number of washing cycles influences the content of particles originally belonging to the biopolymer and/or the polymer component of the polyester/chitosan structure.

4. Conclusion

Pretreatment of polyester fabric by alkaline hydrolysis with and without promoter affects the stability of the polyester/chitosan structure, which is confirmed by the method of confirming the presence of chitosan with Remazol® Red RB dye. By determining the particle size distribution function in wash effluents, the size categorisation of potentially released particles in the washing process can be determined. The distribution results in effluents from the washing of polyester/chitosan structures depend on the polymer structure, the interaction of chitosan with the structure, the stability of the modification through successive washing cycles, the content and size of suspended particles and the influence of factors in the washing process. The characterisation of the effluents produced during the washing of polyester/chitosan structures using the particle size analysis method is useful and can make a significant contribution to the curative effect.

Acknowledgment

This work was co-financed by the Croatian Science Foundation under project IP 2020 02 7575: Assessment of the release of microplastic particles from polyester textiles in the washing process (2021 - 2025) led by prof. Tanja Pušić, PhD.

5. References

[1] Miraftab, M.; Horrocks, A. R.: *Ecotextiles: The way forward for sustainable development in textiles*, Elsevier, ISBN 978-1-84569-214-8, Engleska, (2007)
[2] Soljačić, I. & Pušić, T.: *Njega tekstila, knjiga 1.*, Sveučilište u Zagrebu, Zagreb, (2005), str 23-139
[3] Kaurin, T.; Pušić, T. & Čurlin, M.: Biopolymer textile structure of chitosan with polyester, *Polymers*, **14** (2022) 15, 3088, ISSN 2073-4360
[4] Frias, J. P. & Nash, R.: Microplastics: Finding a consensus on the definition, *Marine pollution bulletin*, **138** (2019), pp. 145-147, ISSN 1879-3363
[5] Kaurin, T. & Šaravanja, A.: Protokoli za analizu otpuštenih čestica u procesu kućanskog pranja, *15. Znanstveno-stručno savjetovanje Tekstilna znanost i gospodarstvo*, Zagreb (2023)
[6] Pušić, T. et al.: The Stability of the Chitosan Coating on Polyester Fabric in the Washing Process. *Tekstilec*, **66** (2023), pp. 1-20, ISSN 2350-3696

Katia Grgić

Biography	Born in Dubrovnik in 1978. She received her doctorate degree in 2023 at the University of Zagreb Faculty of Textile Technology, on the theme "Adsorption of cetylpyridinium chloride on cellulose substrates" under the mentorship of prof. Tanja Pušić, PhD. From 2009 until today, has been employed as an expert associate at the University of Zagreb Faculty of Textile Technology. In addition to professional work related to teaching, he is engaged in professional and scientific work within the Scientific Research Center for Textiles, TSRC. Achieved numerous collaborations with external stakeholders from the academic, economic and public sectors. Actively participates in the implementation of professional, development, research projects and the organization of workshops related to projects. Participated in international and national projects, FP7, PoC 5, OPKK and HRZZ. From 2021. Together with prof. Tanja Pušić, PhD and assoc. prof. Tihana Dekanić, PhD she participated in international innovation exhibitions: INOVA, EUROINVENT/ICIR, KIDE, ICE-USV, and received several medals and special awards.
Title of PhD thesis	Adsorption of cetylpyridinium chloride on cellulosic substrates
Mentor	prof. Tanja Pušić, PhD
Date or dissertation defense	July 17th, 2023

ADSORPTION OF CETYLPYRIDINIUM CHLORIDE ON CELLULOSIC SUBSTRATES

Katia GRGIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
katia.grgic@ttf.unizg.hr

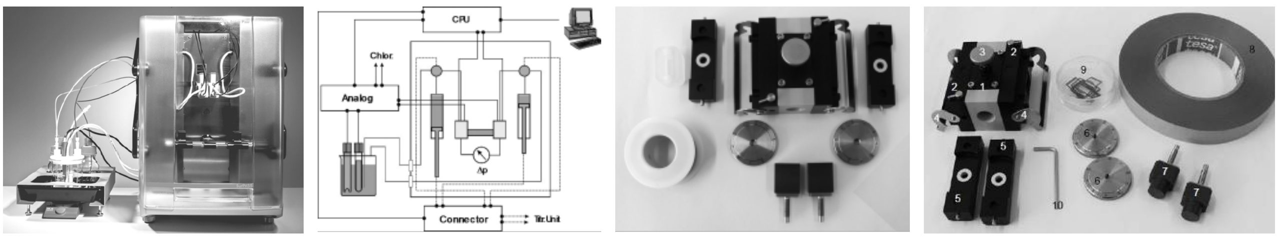
Abstract: *Cetylpyridinium chloride (CPC) is a cationic surfactant that belongs to the group of quaternary ammonium compounds (QAC). It is used in various fields of application, mostly in cosmetics, pharmacology and dentistry due to its bactericidal and antiseptic activity. The aim of this work is investigation of the adsorption of CPC from a micellar solution on two cellulose substrates, cotton fabric and a model cellulose film, was monitored at different pH-values using the streaming potential in an electrokinetic analyzer and the microgravimetric method, QCM-D.*

1. Introduction

The positive charge of the cationic surfactant reacts with negatively charged surfaces in the aqueous medium [1]. The increased concentration of cationic surfactant in aqueous media under the influence of van der Waals forces leads to a process of self-aggregation into micelles. These organic colloidal particles are within the range from one milimicron to one micron [2]. The critical micellar concentration (CMC) depends on the chemical structure of the surfactant, the solvent, the presence of electrolytes and the temperature [3]. According to the literature, the CMC of cetylpyridinium chloride in potassium chloride solution (0,0013 mol/kg) is 0,000266 mol/kg at a temperature of 25 °C [4]. The aim of this study is the adsorption of CPC from micellar solution to standard cotton fabric by the streaming potential method at different pH values (pH 4, pH 6 and pH 9) and desorption of CPC at pH 6 and 25 °C in an electrokinetic analyser using electrolyte solution (KCl). Adsorption of CPC from micellar solution was investigated on two cellulose substrates at 25 °C and different pH values (pH 4, pH 6 and pH 9) was monitored using the streaming potential and the microgravimetric method of a Quartz Crystal Microbalance with Dissipation, QCM-D. The desorption of CPC at pH 6 at 25°C was additionally monitored. Cellulose substrates, cotton fabric (PT) and model cellulose film (MCF) were chosen, because they have multiple applications in medicine and pharmacology, due to their large surface area and adsorption properties, and are suitable carriers for various cosmetic and therapeutic preparations [5-6].

2. Experimental

Cellulose substrates as adsorbents, standard cotton fabric (PT) as a real system and model cellulose film (MCF) as a model system were investigated in this work and using cetylpyridinium chloride (CPC) as adsorbate, in concentration of 2,4 mmol/L.



a b c d

Figure 1: SurPASS electrokinetic analyser: a) SurPASS b) schematic view c) Adjustable Gap Cell (AGC) d) Adjustable Gap Cell for Disk (AGCD) [7]

The adsorption of CPC from the micellar solution on a real and a model system was monitored in an electrokinetic analyser SurPASS (A. Paar) Fig.1 a and Fig.1 b, by the streaming potential method, using an Adjustable Gap Cell (AGC) Fig.1 c and Adjustable Gap Cell for Disk (AGCD), Fig.1 d. The measurement of the zeta potential (ζ) was performed depending on pH values (pH 4, pH 6 and pH 9) with 1 mmol/l KCl an electrolyte.
A microgravimetric method, QCM-D, Fig. 2, was used to monitor the adsorption of CPC from a micellar solution on a model cellulose film, which is based on the piezoelectric effect of a quartz sensor and enables the monitoring of the adsorption of colloidal formulations on the solid surfaces, polymer films [8].

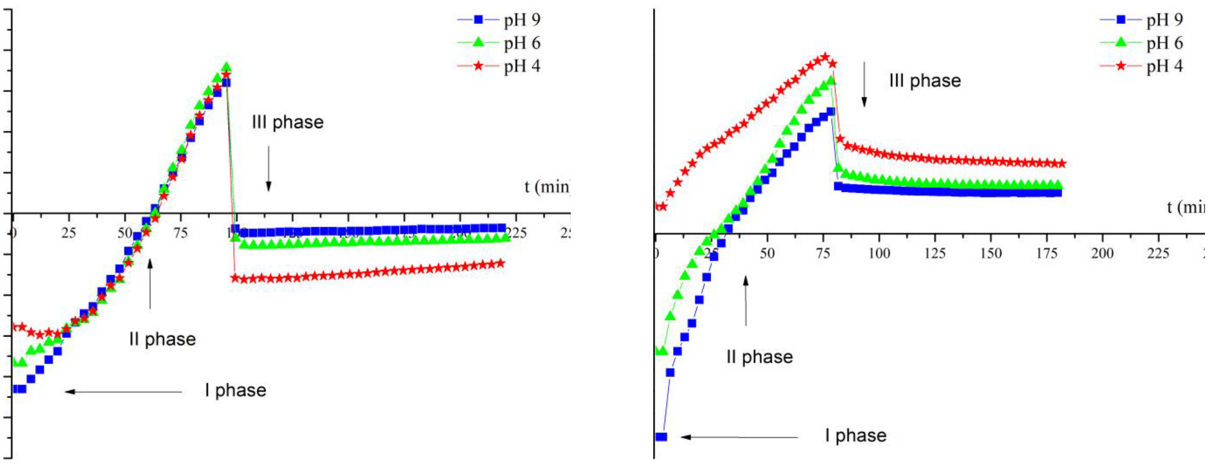
a b

Figure 2: Quartz Crystal Microbalance with Dissipation a) QCM-D b) housing for quartz sensors with cellulose polymer film (MCF).

The adsorption of CPC from a micellar solution (2,4 mmol/L) on MCF was monitored in an electrolyte solution of 1 mmol/L KCl, at different pH-values (pH 4, pH 6 and pH 9) using the microgravimetric method, QCM-D with a change in resonance frequency through the function of time.

3. Results and Discussion

Adsorption of CPC from micellar solution was investigated at different pH values (pH 4, pH 6 and pH 9) in three phases, Fig. 3.



a b

Figure 3: Adsorption of CPC from micellar solution a) on PT and b) MCF at different pH values (pH 4, pH 6 and pH 9) and its desorption at pH 6 in an electrokinetic analyser

The first phase (I.) refers to the determination of zeta potential at pH 4 (ζ = -13,9 mV), pH 6 (ζ = - 18,3 mV) and pH 9 (ζ = -21,5 mV). The second phase (II.) was dedicated to monitoring the rate of CPC adsorption reaching the equilibrium state. The measurement was performed with defined aliquots of the adsorbate for all selected pH values. Figure 2 shows that the adsorption curves at all pH values are monitored throughout the range. The Point of Zero Charge (PZC) of a cotton fabric was specified by 350 µg/g of CPC. The third phase (III.) refers to the desorption of CPC from cotton fabric in electrolyte solution (KCl) at pH 6 and 25 °C. According to the presented results, differences between individual desorption equilibrium curves are visible (phase III.). The less negative desorption curve was obtained for the CPC-cotton fabric system (pH 9). The decrease in negativity is associated with less stable systems at pH 6 and pH 4. Fig.3 b shows the adsorption of CPC from the micellar solution on the MCF, where the influence of the pH-value on the initial value of the zeta potential of the MCF is visible in the first phase (I.). The value of the zeta potential of MCF at pH 4 is positive (ζ = 6,0 mV), while at pH 6 (ζ = -26,2 mV) and pH 9 (ζ =-45,2 mV) they are negative. The initial value of the zeta potential of MCF depends on the pH-value in the system and affects the rate of adsorption in the second phase (II.), as can be seen in Fig. 3 b. The desorption of CPC with MCF in the third phase (III.) in the electrolyte solution at pH 6 is stabilized in a short time and the zeta potential values of MCF are positive, indicating the binding of CPC micelles to MCF.

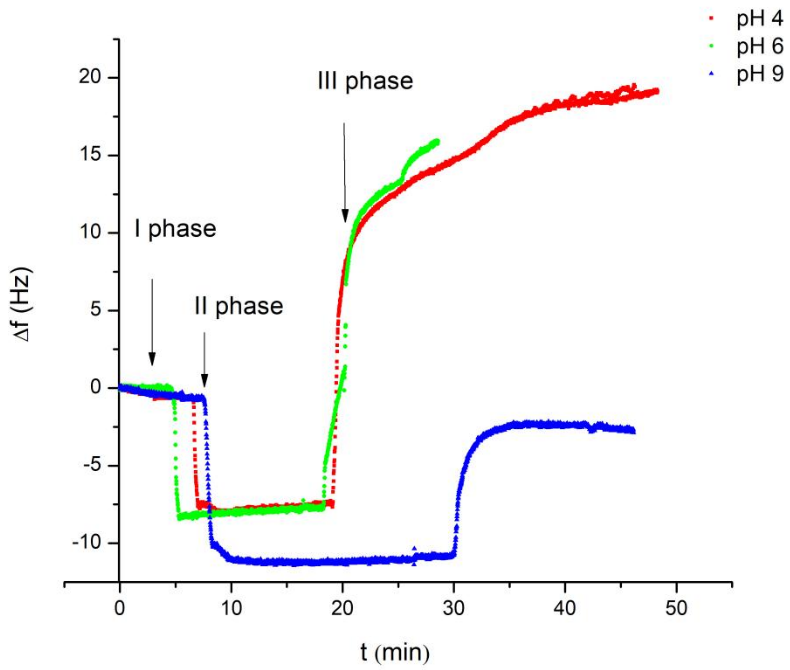


Figure 4: Change in QCM-D frequency as a function of time - adsorption of CPC from micellar solution on MCF at different pH-values (pH 4, pH 6 and pH 9) and its desorption at pH 6

The process of adsorption and desorption of CPC from the micellar solution on MCF was monitored in three phases, Fig. 4. using the microgravimetric method, QCM-D. In the first phase (I.), the MCF is stabilized in an electrolyte solution of 1 mmol/L KCl at pH 6. The second phase (II.) shows the adsorption of CPC from micellar solution where the change occurs in the resonance frequency until a constant frequency is reached. The results indicate that at pH 4 and pH 6 there is no significant difference in the adsorption rate of CPC micelles, while at pH 9 there is. In the third phase (III.), the model cellulose film is eroded with 1 mmol/L KCl at pH 6. The curves at pH 4 and 6 indicate a rapid desorption of CPC micelles compared to the curve at pH 9, where it can be concluded that the surface of MCF, and at pH 9 the most suitable for link CPC micelles.

4. Conclusion

The results of the study CPC adsorption process from the micellar solution at different pH-values (pH 4, pH 6 and pH 9), using different methods on different cellulose substrates indicate the influence of the pH-value on the rate of the adsorption and desorption process of CPC micelles with PT and MCF. In addition to the pH-value, the surface of the cotton fabric and model cellulosic film also has an influence. Differences are visible in the results of the streaming potential method in the first phase (I), where MCF has more negative zeta potential values at pH 9 and positive values at pH 4 compared to cotton fabric. The differences indicate high amorphousness in MCF cellulose macromolecules compared to cotton fabric, which refers a larger number of available carboxyl (-COOH) and hydroxyl (-OH) groups that are responsible for linking CPC micelles. In the desorption process of CPC micelles, the best stability was obtained at pH 9 with both methods and on both substrates. The streaming potential and Quartz Crystal Microbalance with Dissipation proved to be useful to explore the process of adsorption, desorption on cellulosic substrates and enable comparison between real and model systems.

5. References

[1] Soljačić, I. & Pušić, T.: *Cleaning in water media, Textile care - Part I.,* University of Zagreb, Faculty of Textile Technology, ISBN 953-7105-08-3, Zagreb, (2005), pp. 56-68.
[2] Kallay, N. et al. Equilibrium of counterion association in micellar systems, Cetyltrimethylammonium bromide, *Annales Universitatis Mariae Curie - Sklodowska*, **63** (2008) 5, pp. 61-67., Lublin, Polonia, ISSN 2083 - 358X
[3] Bigler, N.: *Die Tenside CIBA Geigy Rundschau 2*, CIBA, ISSN 0366-5453, Zeitschrift / Print (1971)
[4] Mukhim, T. & Ismail, K.: Micellization of cetylpyridinium chloride in aqueous lithium chloride, sodium chloride and potassium chloride media, *Journal of Surface Science and Technology*, **21** (2005) 3/4., pp. 113-127, ISSN 0970 - 1893
[5] Lin, N., et al.: *Advanced Functional Materials from Nanopolysaccharides*, Springer, ISSN 2195-0644, Berlin, Njemačka, (2019), pp. 171-219
[6] Rehan, M., et al.: Design of multi-functional cotton gauze with antimicrobial and drug delivery properties. *Materials Science and Engineering: C*, **80** (2017), pp. 29-37.
[7] Instruction Manual SurPASS™ Electrokinetic Analyzer; Anton Paar GmbH, A48IB046en-B, Graz, Austria, (2013)
[8] NanoScience Instruments: Quartz Crystal Microbalance with Dissipation Monitoring; *Available:*https://www.nanoscience.com/products/qsense-quartz-crystal-microbalance/ *Accessed:* 2023-01-27

Nikolina Jukl

Biography	Nikolina Jukl was born in 1987 in Sv. Nedelja, Croatia. She graduated from the University of Zagreb, Faculty of Textiles and Technology in 2013 and in the same year enrolled doctoral study Textile Science and Technology at the University of Zagreb, Faculty of Textiles and Technology. From 2013 to 2022, she worked as a production manager and constructor at Konfeks d.o.o., a company that produces workwear and protective clothing. Since 2022, she has been working as an assistant at the Faculty of Textile Technology. In 2023, she defended her doctoral thesis under the mentorship of prof. Snježana Firšt Rogale, PhD. Her scientific research, professional and teaching activities are related to the scientific field of technical sciences, the field of textile technology, which is closely related to the technological processes of clothing production and research into the thermal properties of clothing.
Title of PhD thesis	Influence of the type of embedded materials and construction of clothing composites on the overall thermal properties of clothing
Mentor	prof. Snježana Firšt Rogale, PhD
Date or dissertation defense	October 4th, 2023

DETERMINATION OF THE WATER VAPOR RESISTANCE OF EMBEDDING MATERIALS AND CLOTHING COMPOSITE AND ITS SIGNIFICANCE FOR THE TECHNICAL DESIGN OF CLOTHING

Nikolina JUKL

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, nikolina.jukl@ttf.unizg.hr

Abstract: *Water vapor resistance is one of the parameters that affect the overall thermal properties of clothing and can significantly affect the thermal comfort of the wearer. In this paper, part of the results of the doctoral thesis related to the determination of the water vapor resistance of embedded materials and clothing composites are highlighted to emphasize its importance in the technical design of clothing. The results obtained by measurements using the Permetest measuring device are presented. The measurements were carried out on three embedded materials and one clothing composite with the aim of further defining the protocol for technical design of clothing.*

1. Introduction

Embedded materials and clothing composites used to produce special clothing must meet certain criteria in terms of their thermal properties and thermal comfort of the wearer must be guaranteed so that they can carry out their work. Embedded materials with specific properties are used for the production of special clothing and their purpose is to ensure the thermal comfort and waterproofness of the outer shell and at the same time the breathability of the garment [1]. Laminated materials which consist of several layers of textile materials and a membrane layer which is usually based on polytetrafluoroethylene (PTFE) are most commonly used [2]. Rhomboidal sewn materials and fleece materials are commonly used to produce thermal inserts. It is necessary to achieve the set requirements with optimal layering, i.e. as few layers as possible, as more layers mean more mass and bulkiness of the garment, which can lead to less mobility and comfort for the wearer. As part of the doctoral thesis, tests were conducted on air permeability, water vapor and thermal resistance, contact conduction heat transfer in uncompressed and compressed states of embedding materials and clothing composites, differential temperature gradients on clothing composites and clothing systems and thermal properties of clothing systems in static and dynamic modes. One of the hypotheses of the thesis, which relates to the water vapor resistance, is that the total water vapor resistance of the clothing composite is equal to the sum of the serial water vapor resistances of the individual layers of the clothing composites. This paper presents the partial results of determining the thickness and water vapor resistance of three embedding materials and the composite made from them.

2. Experimental part

The thickness of the embedding materials was determined using a Dino-Lite digital USB microscope. To determine the water vapor resistance of three embedding materials and a representative three-layer clothing composit, a measuring device for non-destructive determination of the water vapor resistance Permetest, Senzora, was used in accordance with EN ISO 20344:2012, Fig. 1 [3]. The advantages of the Permetest lie in its small dimensions and weight, relatively short measurement time and non-destructive measurements. Permetest was placed in a climatic chamber in which it is possible to precisely determine the ambient conditions. First, it is necessary to calibrate the device using a reference material with a known water vapor resistance of 4,62 m^{2}Pa/W. The test sample is placed on a round measuring head which is attached to the air tunnel and consists of a circular and porous hot plate with a diameter of 8 cm. The measuring head can be moved vertically to insert the sample, Fig. 1.

The water vapor resistance is defined by the expression [4]:

$$R_{et} = (P_m - P_a) \cdot (q_s^{-1} - q_0^{-1}) \quad (2)$$

where is:
R_{et} - water vapor resistance [m^{2}Pa/W]
P_m - partial pressure of saturated water vapor at ambient temperature/room in which the test is carried out [Pa]
P_a - partial pressure of the water vapor of the environment/room in which the test is performed [Pa]

Figure 1: Device for non-destructive measurement of water vapor resistance, Permetest

The embedding materials were a two-layer laminated material with an expanding polytetrafluoroethylene (ePTFE) membrane labeled MV1, a rhomboidal sewn lining labeled MP2 and a three-layer laminated material with a micro-fleece front and back, and a polyester membrane in between, labeled MP3. The clothing composite labeled OK5 consists of the aforementioned embedding materials. The laboratory analyzes of the embedding materials were obtained from the material manufacturers and the basic data of the analysis are listed in the table 1.

Table 1: Results of the laboratory analysis of the embedding materials

	Elements of testing	Value	Measuring unit
MV1	Raw material composition		
	• Fabric face: polyester	100	%
	• Membrane: ePTFE	100	%
	Surface mass	169,8	g/m^2
MP2	Raw material composition		
	• Fabric face/lining: polyester	100	%
	• Membrane/filler: polypropylene	100	%
	• Back side/lining: poliester	100	%
	Surface mass	316,0	g/m^2
MP3	Raw material composition		
	• Fabric face: micro-fleece	100	%
	• Membrane: polyester	100	%
	• Back side: micro-fleece	100	%
	Surface mass	304,0	g/m^2

3. Results and discussion

The results of the determination of the thickness of the embedding materials and clothing composite are shown in the table 2. It can be seen from the results that the two-layer laminated material (MV1) has the lowest measured thickness, followed by the rhomboidal sewn lining (MP2) and the micro-fleece material (MP3). The results also show that the thickness of the clothing composite, which is 4,74 mm, is 1 mm less than the sum of the serial thicknesses of the individual layers of the embedding materials which make up the clothing composite. It can be explained by the compression of the material layers due to the influence of the mass of the individual material layers.

The results of determining the water vapor resistance of the embedding materials and clothing composite are shown in Table 3. The tests were carried out at an average ambient temperature of 20°C and an average relative humidity of 52 %, which corresponds to the instructions of the manufacturer of the Permetest device.

Table 2: Results of the determination of the thickness of the embedded materials and clothing composite

	Thickness of the material, d_m [mm]					
Sample mark	**1**	**2**	**3**	**4**	**5**	$\bar{x}$
MV1	0,475	0,488	0,486	0,484	0,475	0,49
MP2	2,425	2,425	2,488	2,457	2,361	2,43
MP3	3,025	2,904	2,841	2,764	2,777	2,86
OK5	4,816	4,743	4,752	4,704	4,680	4,74

Table 3: Results of the determination of the water vapor resistance

	Number of measurements	Water vapor resistance of the reference material, R_{et} [m^2Pa/W]	$\bar{x}$	Water vapor resistance of the sample, R_{et} [m^2Pa/W]	$\bar{x}$
MV1	1	4,70	4,63	3,00	2,87
	2	4,60		2,80	
	3	4,60		2,80	
MP2	1	4,30	4,67	5,70	5,93
	2	4,90		6,00	
	3	4,80		6,10	
MP3	1	4,40	4,60	12,80	12,73
	2	4,80		12,60	
	3	4,60		12,80	
OK5	1	4,80	4,67	30,10	30,93
	2	4,90		30,90	
	3	4,30		31,80	

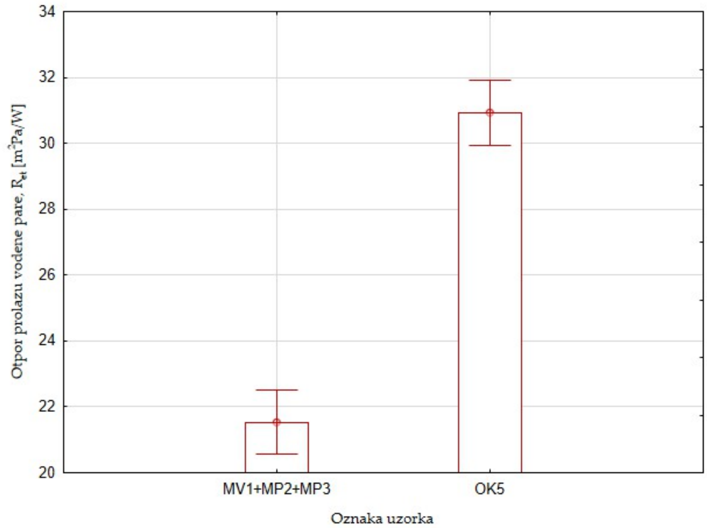


Figure 2: Range of mean values of the results of the sum of the serial water vapor resistances of the individual layers of the embedded materials and the total water vapor resistance of a representative clothing composite OK5 with the indicated variations

The water vapor resistance of the double-layer laminated material marked MV1 is 2,87 m^2Pa/W, which is also the lowest measured value of all tested samples. In general, laminated materials have the possibility of permeating sweat due to the embedded membranes, whose pores are 20,000 times smaller than water droplets but 700 times larger than water vapor molecules. The water vapor resistance of the MV1 sample is relatively low, but it is still sufficient to achieve a feeling of comfort. The water vapor resistance of the rhomboidal sewn lining (MP2) is 5,93 m^2Pa/W. The micro-fleece (MP3) has the highest measured water vapor

resistance at 12,73 m^2Pa/W. The reason for this is the thickness and structure of the material, whose front and back are made of micro-fleece and middle layer is a polyester membrane. The layers of micro-fleece have a high fiber density and a greater thickness than other embedding materials. Together with the polyester membrane layer, they provide higher water vapor resistance.
The results showed that the thicker the material, the greater the water vapor resistance. The two-layer laminated material has the lowest thickness, followed by the rhomboidal sewn lining and the micro-fleece material. This also explains the significantly higher value of the total water vapor resistance of the clothing composite compared to the sum of the serial values of the individual layers of the embedding materials from which it is made. It is clear that the sum of the serial values is significantly lower than the total water vapor resistance of the clothing composite, which was also confirmed by the statistical analysis, Fig. 2.
Based on the obtained results and the statistical analysis carried out, the hypothesis put forward in this work, according to which the total water vapor resistance of the clothing composite is equal to the sum of the serial water vapor resistances of the individual embedded materials of the clothing system, is rejected.

4. Conclusions

When testing the water vapor resistance of certain embedding materials and clothing composites, it was determined that laminated materials can have relatively low values of water vapor resistance, which is mainly influenced by the structure of the material itself and the layers from which it is made, as well as the membrane it contains. None the less, even the lower values of water vapor resistance measured in this work enable the thermal comfort of the wearer, which confirmed the purpose of the used materials and their application for the production of special clothing. The results also prove that the thickness of the material affects the water vapor resistance. As the thickness increases, the water vapor resistance also increases. It was also determined that the overall water vapor resistance of the clothing composite is greater than the sum of the serial water vapor resistances of the individual layers of the embedded materials in the clothing composite. This shows that it is not possible to predict the overall water vapor resistance of the clothing based on the value of the water vapor resistance of the individual layers of the embedding materials of wich the clothing composite is made from. This confirms that extensive testing of the water vapor resistance of not only the embedding materials but also the clothing composites is required to enable successful technical design of specialized clothing.

Acknowledgement

The research was carried out as part of the project IP-2018-01-6363 Development and thermal properties of intelligent clothing (ThermIC), financed by the Croatian Science Foundation, led by prof. Dubravko Rogale, PhD.

5. References

[1] Firšt Rogale, S.; Rogale, D.: Advanced Materials for Clothing and Textile Engineering, *Materials*, **16** (2023), 9, 3407, eISSN 1996-1944
[2] Ebnesajjad, S.: *Expanded PTFE applications handbook: Technology, manufacturing and applications*, William Andrew: Elsevier, ISBN: 9781437778564, Amsterdam; Boston;. (2016)
[3] Hes, L.; Bernardo, C.; Queirós, M.: A new method for the determination of water vapour permeability of polymer films based on the evaluation of the heat of evaporation, *Polymer testing*, **15** (1996), pp. 189-201, ISSN 0142-9418
[4] Akalović, J. et al.: Water Vapor Permeability of Bovine Leather for Making Professional Footwear, *Leather and Footwear*, **67** (2018) 4, pp. 12-17, ISSN 0450-8726

Eva Magovac

Biography

Eva Magovac was born in Karlovac, and in 1996 she entered the University of Zagreb, Faculty of Textile Technology, where she graduated in February 2002, and received her doctorate in July 2023. From 2002 to 2009, she worked for several private companies. In 2009, she got a job at the Faculty of Textile Technology as an associate on the EU project FP7 T-Pot. In 2011, she got a job at the Croatian Chamber of Commerce as an expert associate, and 3 years later she returned to the Faculty of Textile Technology. During her career, she attended numerous trainings organized by the CAE, the CMS, the University of Algebra, as well as ascientific-research stay at Toray Textiles Europe Ltd., UK; at theUniversity of Ljubljana, and at Texas A&M University in the USA. From 2014 to the present, she has been working at the Faculty of Textile Technology of the University of Zagreb as anassociate.

Title of PhD thesis

Flame Retardant Surface Modification of Cotton Textiles Using Layer-by-Layer Deposition

Mentors

prof. Sandra Bischof, PhD prof. Bojana Vončina, PhD

Date or dissertation defense

July 5th, 2023

FLAME RETARDANT SURFACE MODIFICATION OF COTTON TEXTILES USING LAYER-BY-LAYER DEPOSITION

Eva MAGOVAC

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
eva.magovac@ttf.unizg.hr

Abstract*: The goal of this thesis was to develop sustainable flame retardant (FR), as well as FR/antimicrobial (AM) finishing of cotton by means of layer-by-layer (LbL) deposition as a response to technological drawbacks of commercial finishing processes (high amounts of toxic chemicals, loss of tensile strength of fabrics, a number of process steps at high temperatures, high water and energy consumption). In this thesis, a conventional treatment that requires the addition of high amounts of organophosphorus compounds has been replaced with an ecological treatment by using alternative chemicals from renewable sources. The resulting treatment reduced cotton flammability and the bacteria growth.*

1. Introduction

Cotton, as a cellulose fiber, is rich in -O- and -OH functional groups, which are responsible for high flammability, but also high moisture and water uptake, which is also a good substrate for the growth of bacteria. For this reason, cotton fabrics intended for work and protective clothing need to be treated with flame retardants, and those used in for medical care institutions should also be additionally treated with antimicrobial agents. There are durable and non-durable flame retardant (FR) treatments on the market. The durable FRs are based on organo-phosphorus compounds where there is a synergism of nitrogen and phosphorus, and they are attached to cellulose with strong covalent bonds (Pyrovatex, Proban) [1]. Durable FR treatments can be combined with antimicrobial (AM) compounds, which at the same time should not be bound to cellulose by strong covalent bonds, because in this way they cannot be released in a controlled manner in the presence of moisture, thus slowing down the growth of bacteria. Antimicrobial agents (AM) used in commercial wet finishing of cotton are most often quaternary ammonium compounds.
The main disadvantage of commercial FR and multifunctional FR/AM treatments is the use of large amounts of chemicals, the emission of toxic and carcinogenic formaldehyde during production or the life cycle of the product, the loss of tensile strength of treated cotton fabrics, and a large number of production processes at high temperatures. In order to overcome the above-mentioned technological drawbacks of FR treatments, there was a need to introduce new environmentally friendly compounds, as well as methods such as sol-gel, UV treatments, plasma treatments, and layer-by-layer (LbL) deposition.
LbL deposition is the process of immersing cotton fabric alternately in solutions of positively and negatively charged polyelectrolytes until the desired layers are achieved. Between each immersion in the oppositely charged polyelectrolytes, the fabric is rinsed in deionized (DI) water. These structures can be further subjected to post-chemical reactions, such as UV or thermal cross-linking [2].

The goal of this doctoral dissertation was to develop an alternative FR and/or multifunctional FR/AM treatment intended for cotton fabrics by means of a new technique called LbL deposition with the use of compounds from renewable sources (plant and animal waste), and minerals, some of which have been known since ancient times, namely:

- replacing conventional chemicals with ones from renewable sources
- development of inovative non-halogen flame retardant (FR) and multifunctional FR/ antimicrobial (AM) treatment for cotton fabrics by means of layer-by-layer (LbL) deposition
- keep cotton FR effective while reducing the quantity of chemicals
- reducing the energy consumption of the process
- determinating the burning mechanism of LbL FR deposited cotton fabrics

2. Experimental

Materials: Chemically bleached cotton (119 g/m^2), phytic acid (PA, 2 wt%, pH 4), chitosan (CH, 0,5 wt%, pH 4), (BPEI, 5 wt%), urea (U, 10 wt%, pH 4) and copper (II) sulfate pentahydrate ($CuSO_4$ x $5H_2O$, 2 wt%), deionized water (DI).

LbL deposition:
Cotton fabric was first immersed in a cationic solution of BPEI to form a primer for better adhesion of the agents to the cotton. The fabric was then alternately immersed in the anionic PA and the cationic CH-U solution until the desired number of bilayers (BL) was reached. Each layering step was followed by rinsing in DI to remove any unbound polyelectrolytes. At the end of the LbL deposition, the treated fabric was immersed in a solution of $CuSO_4$ x $5H_2O$. The weight gain of all samples was measured after drying at 80 °C for 24 hours, before and after LbL deposition according to following shemes:

1. 8, 10, 12, 15 BL: $PA^-/(CH\text{-}U)^+$, BPEI – primer (Figure 1) [3]
2. 4, 8 BL: PA^-/CH^+ and $PA^-/(CH\text{-}CuSO_4 \text{ x } 5H_2O)^+$, BPEI – primer (Figure 2) [4]
3. 8, 10, 12 BL: $PA^-/(CH\text{-}U)^+$ + immersion into $CuSO_4$ x $5H_2O$ (Figure 3) [5]

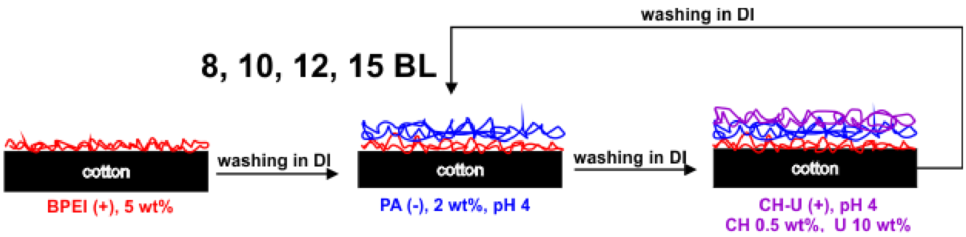


Figure 1: LbL deposition sheme for 8, 10, 12, 15 BL: $PA^-/(CH\text{-}U)^+$ [3]

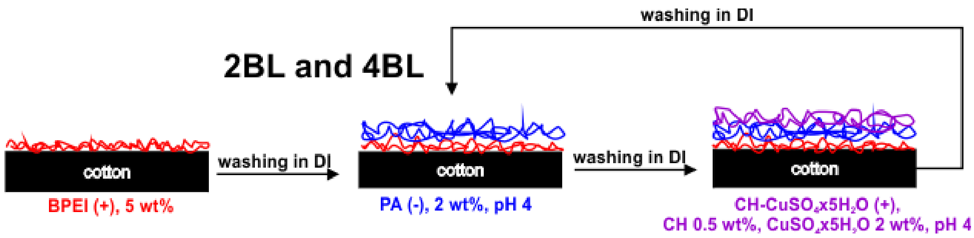


Figure 2: LbL deposition sheme for 4, 8 BL: $PA^-/(CH\text{-}CuSO_4 \text{ x } 5H_2O)^+$ [4]

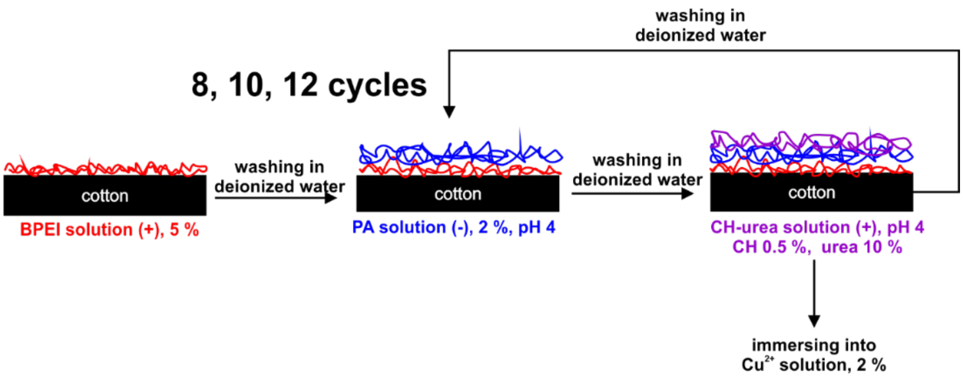


Figure 3: LbL deposition sheme 8, 10, 12 BL: $PA^-/(CH\text{-}U)^+$ + immersion into $CuSO_4$ x $5H_2O$ [5]

Characterization: Weight gain (%), limiting oygen index according to ISO 4589-2:2017 (Concept Equipment, LOI, %), vertical flammability testing according to ASTM D6413/D6413M-15 (Govmark, VFT), microscale combustion calorimetry according to ASTM D6413/D6413M-15 (Govmark, MCC), termogravimetric analysis with FTIR spectrometry (Perkin Elmer, TG-IR), scanning electron microscopy with EDS detection (Tescan – Oxford Instruments, SEM-EDS), bacteria reduction (%) according to AATCC Test Method 100-2019.

3. Results and Discussion

Cotton fabric treated by means of LbL deposition self-extinguished during VFT testing, and LOI values ranged from 24,5 – 28,0 % with 17,3 – 19,0 % weight gain compared to a typical Pyrovatex® process, where weight gain is 20-25 %, and the LOI values are around 28 %. For comparison, the weight gain of non-durable flame retardants, such as boric acid/borax, is about 10 %, and diammonium phosphate/ammonium sulfamate is about 15 %. Furthermore, in this doctoral dissertation, the Pyrovatex® process, which requires about 350 g/l of different agents, was replaced by a more environmentally friendly treatment (LbL deposition) using agents in a concentration usually ≤ 100 g/l with a slight influence on the mechanical properties of the treated cotton fabric (up to ± 14 % break strenght) and at process temperatures below 100 °C. In comparison, the Pyrovatex® process reduces the breaking strenght by 20-25 %, while non-durable agents generally reduce the breaking strength [6-8]. MCC calorimetric values of LbL deposited cotton showed a reduction in peak heat release rate (pHRR) in range 50,9-61,8 % compared to untreated cotton and a reduction in total heat release rate (THR) in range 54,3-70,3 % compared to untreated cotton. This means that the amount of char left after heating and combustion increases, and the formation of volatile gases decreases [3-5]. TG analysis showed a decrease in the maximum decomposition temperature (T_1) of the treated cotton fabric by 57-66 °C compared to the untreated one and an increase in the charr residue (%) at T_1 in the range of 43-46 % for the untreated to 56-63 % for the treated cotton fabric. The FT-IR spectra of volatile gases generated by heating of LbL deposited cotton fabrics (CH/PA-U) showed the presence of water; methane/methanol; carbon dioxide; carbon monoxide; formaldehyde, formic acid ether/ester, cycloalkanes; N-H, as well as PH and NH compounds. Levoglucosan, which is responsible for the high flammability of cellulose, was not found. After immersing the treated coton fabric into the $CuSO_4$ x $5H_2O$ solution, the volatile gases generated by heating additionally contain sulfur compounds (S-S), copper monosulfide and copper (II) oxide. N-P gas intermediates can act in the gas phase as scavengers of free radicals [9]. EDS analysis showed that the post-burn char of treated fabrics mainly contains carbon, oxygen, phosphorus, nitrogen in the case of PA/CH-U treatment, and in the case of subsequent treatment with $CuSO_4$ x $5H_2O$, the post-burn char additionally contains copper. When heated, PA and CH-U produce N-P intermediates, which phosphorylate cellulose at a temperature below 350-400 °C, producing a char residue, which acts as a physical barrier blocking the supply of heat and oxygen to the surface of the polymer, thus acting in the condensed phase. Cu^{2+} ions additionally catalyze the phosphorylation of cellulose acting in the condensed phases, but at the same time CuO or CuS nanoparticles present in volatile gases can act as an inert dust that absorbs and dissipates heat, causing a decrease in temperature [10]. FR/AM nanolayer showed almost 100 % reduction of Gram-negative *K. pneumoniae* and Gram-positive *S. aureus* thanks to Cu^{2+} ions and chitosan. This type of treatment is recommended for decorative textiles.

Proposed mechanism of action:

1. P-rich PA and N-rich CH-U (and $CuSO_4$ x $5H_2O$) chemically interact with each other forming acidic N-P-Cu intermediates, which phosphorylate and dehydrate cellulose at temperatures lower than those of the thermal decomposition of cellulose and generate thermally stable cross-linked char. Char coats the polymer surface, acting as a shield, which prevents further burning and smoldering of the polymer
2. No levoglucosan is found, which confirms that acidic N-P-Cu intermediates from FR treatment successfully phosphorylated the cellulose and inhibited the generation of highly flammable levoglucosan
3. PH and NH compounds are found in IR gas spectra, they may act in the gas phase as free radicals' scavengers, or their intermediates act physically by reducing the O concentration of the surrounding atmosphere
4. CuO or CuS nanoparticles present in volatile gasous products generated by heating may act as the inert dust that absorps and dissipates the heat causing a lowering of temperature
5. the post-burn char of PA/CH-U (and $CuSO_4$ x $5H_2O$) treated cotton consists of C, O, P, and N, (and Cu) which means that P and N trapped C and blocked it from full oxidation by generating charring shield on the polymer surface in the form of bubbling typical for intumescent FR and condensed phase

6. TG-IR analysis of gas products and EDS analysis of post-burn char prove that alternative FRs act in a gas as well as condensed phase, where CH and cellulose act as carbon donors, PA as an acid donor and U as a blowing agent that generates gasous N compounds.

4. Conclusion

In the paper, it was proven that by means of LbL deposition, it is possible to achieve effective combined FR and AM treatment using alternative agents in concentrations ≤ 100 g/l, which is significantly less compared to classic commercial FR treatments in Pyrovatex® process, but the resulting treatment is not durable. It has also been proven that it is possible to produce a multifunctional cotton fabric that meets the commercial requirements of FR/AM treatment: the requirement of non-flammability (LOI ≥ 28 %) and the reduction of gram-negative and gram-positive bacteria by 100 %. With greater availability of biodegradable chemicals from renewable sources at lower costs and improved wash durability, LbL deposition has the potential to become an industrially feasible solution for FR or multipurpose FR/AM functionalization of cotton. Future research will extend to improving wash durability as well as compatibility with conventional dyeing/printing processes.

Acknowledgment

Hrzz Croatian Science Foundation

Prof. Sandra Bischof, PhD, University of Zagreb Faculty of Textile Technology, Croatian Science Foundation 2013-11 9967 ADVANCETEX Advanced textile materials by targeted surface; prof. Bojana Vončina, PhD, University of Maribor Faculty of Mechanical Engineering; prof. Jaime C. Grunlan, PhD, Department of Mechanical Engineering, Texas A&M, College Station, USA; prof. Igor Jordanov, PhD, Department of Textile, Faculty of Technology and Metallurgy, Ss. Cyril and Methodius University in Skopje, North Macedonia; prof. Ana Budimir, PhD, Department for Typing and Monitoring the Causes of Nosocomial Infections, University Hospital Centre Zagreb; Committee members – prof. Sandra Flinčec Grgac, PhD, and prof. Karlo Lelas, PhD, University of Zagreb Faculty of Textile Technology; prof. Olivera Šauperl, PhD, University of Maribor Faculty of Mechanical Engineering.

5. References

[1] Magovac, E.; Bischof, S.: Non-Halogen FR Treatment of Cellulosic Textiles, *Tekstil*, **64** (2015) 9, pp. 298–309, ISSN 0492-5882
[2] Magovac, E. et al.: Layer-by-Layer Deposition: A Promising Environmentally Benign Flame-Retardant Treatment for Cotton, Polyester, Polyamide and Blended Textiles, *Materials*, **15** (2022). 2, pp. 1-30, ISSN 1996-1944
[3] Magovac, E. et al.: Environmentally-Benign Phytic Acid-Based Multilayer Coating for Flame Retardant Cotton, *Materials*, **13** (2020) Br. 23, pp.1-10, ISSN 1996-1944
[4] Magovac, E. et al.: Antibacterial Cotton from Novel Phytic Acid-Based Multilayer Nanocoating, *Green Materials*, **10** (2022) 1, pp. 35-40, ISSN 2049-1220
[5] Magovac, E. et al.: Environmentally Benign Phytic Acid-Based Nanocoating for Multifunctional Flame-Retardant/Antibacterial Cotton, *Fibers*, **9** (2021) 69, pp. 1-13, ISSN 2079-6439
[6] Ginter, A. E. et al.: The Effects of a Borax-Boric Acid Solution on Cotton and Rayon Fabrics, *Research Bulletin*, (1954) 547, pp. 1–23
[7] Veerappagounder, S. et al.: Study on Properties of Cotton Fabric Incorporated with Diammonium Phosphate Flame Retardant through Cyclodextrin and 1,2,3,4-Butane Tetracarboxylic Acid Binding System, *Journal of Industrial Textiles*, **45** (2016) 6, pp. 1204–1220 , ISSN 1528-0837
[8] Pal, A. et al.: Eco-friendly fire-retardant finishing of cotton fabric with mixture of ammonium sulfamate and sodium Stannate with and without zinc acetate as external reagent, *Cellulose,* **30** (2023), pp. 11813–11828, ISSN 0969-0239
[9] Scharte, B.: Phosphorus-Based Flame Retardancy Mechanisms—Old Hat or a Starting Point for Future Development?, *Materials,* **3** (2010) 10, pp. 4710–4745, ISSN 1996-1944
[10]Mitani, T.: A Flame Inhibition Theory by Inert Dust and Spray, *Combustion and Flame*, **43** (1981), pp. 243–253, ISSN 0010-2180

Ksenija Višić

Biography

Born in Varaždin in 1983. She graduated at the University of Zagreb Faculty of Textile Technology (TTF) in 2009. After graduation, she was employed at TTF as an associate/assistant on the FP7 project, FP7-SME-2007-2-217809. At the beginning of 2013, she was engaged as a collaborator on the Eureka project, E! 5785 Flameblend. From 2013 to 2015 she was employed as a sales manager in the company Info Novitas d.o.o. From 2015 to 2016, she was employed at TTF as an assistant at the Department of Textile Chemistry and Ecology. In the period from 2016 to 2018, she was again engaged on the position of marketing director in Info Novitas d.o.o. From 2018 she was engaged at TTF on two positions, an assistant, and 2020 to 2023 as PhD student on the project K.K.01.1.1.04.0091 Biocomposites. She has published two original scientific papers in the citation database WoSCC, three papers in other journals, three abstracts and 14 papers in conference proceedings.

Title of PhD thesis

Impact of physico-chemical properties of anti-redeposition agents on the zeta potential of washed cotton materials

Mentor

prof Tanja Pušić, PhD

Date or dissertation defense

June 10th, 2022

IMPACT OF PHYSICO-CHEMICAL PROPERTIES OF ANTI-REDEPOSITION AGENTS ON THE ZETA POTENTIAL OF WASHED COTTON MATERIALS

Ksenija VIŠIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, ksenija.visic@ttf.unizg.hr

Abstract: *Research in the doctoral thesis included special additives, anti-redeposition agents (ARA), in the formulation of powder detergent. Selected ARAs are carboxymethyl cellulose (CMC), carboxymethyl starch (CMS) and their combination (CMC + CMS) whose concentration is adapted to washing of cellulosic materials at 40 °C, 60 °C and 90 °C in hard and soft water. Characterization of the properties of cotton fabrics after 10 washing cycles in relation to unwashed was made by analysis of residual substances and zeta potential of cotton fabrics in a specified condition.*

1. Introduction

The development of detergents is conditioned by technological guidelines, where it is necessary to make a formulation in which all components act in synergy with the other factors of the Sinner cycle, temperature, mechanical action and time [1]. Recently, environmentally friendly low-temperature processes in small bath ratios have been promoted, which require high-performance surfactants, builders, bleach and their activators, enzymes and special polymers in detergents [2]. Anti-redeposition agents (ARA) play an important role in the primary and secondary effects of washing because, in addition to anionic surfactants and builders, they additionally charge soil and fibre, and physically prevent the deposition of soils from the bath on the fibre [3]. The efficiency of anti-redeposition agents should be based on the fibre affinity, as a basis for deposition to the fibre surface, increasing a negative surface charge and prevent redeposition by repulsion of negatively charged soil particles. Since their action is related to the surface of the material, it is important to know its condition and the degree of load by certain substances.

In this PhD thesis, the impact of hard and soft water on zeta potential of cotton fabric and the content of residual substances on cotton fabrics washed with detergent with the addition of ARAs (CMC, CMS and their combination, CMC+CMS) at 40 °C, 60 °C and 90 °C for 10 cycles was examined compare with pristine cotton fabric.

2. Experimental

Reference cotton fabric without fluorescent whitening agents and finishing agents (F), for which technical characteristics are prescribed by ISO 2267:2001, was selected as a cellulose substrate. Anti-redeposition agents, CMC, CMS and their mixture, CMC + CMS were added in concentration of 0,4 % into a detergent dry slurry, for 10 washing cycles in hard (TW) and soft water (SW) at temperatures of 40 °C, 60 °C and 90 °C. The composition of the basic detergent, supplied by Labud d.d., Zagreb, Croatia is shown in Table 1 and selected ARAs in Table 2.

Table 1: Composition of basic detergent

Ingredients	w, %
Anionic surfactant	3,0
Soap	0,42 - 0,50
Sodium percarbonate	6,0
Zeolite	5,6 - 6,3
Silicates	5,1 - 5,7
Sodium carbonate	35,0 - 40,0
Water	up to 100

Table 2: Characteristics of ARAs

ARA	DS	pH (1%)	Viscosity (1%, 25 °C) mPas
CMC	0,57	8,5 – 10,5	20-100
CMS	0,75	9,0 – 11,5	20 – 100

DS-degree of substitution

The analysis of the potential of CMC, CMS polymers and their mixture through 10 cycles was performed in a laboratory washing machine with temperature variation (40, 60 and 90 °C) and water quality variation (hard (HW) and soft (SW)). The cycles were performed with a bath ratio (1:5), filling ratio (1:12), reversible rotation (40 to 50 rpm), and rinsing and cyclic extraction at 1400 rpm. The degree in loading of cotton fabric with residual substances before and after washing was analysed through the ash content according following a standard protocol according to HRN ISO 4312 [4]. The impact of selected ARAs (CMC, CMS, CMC + CMS) on the properties of cotton fabric (F) washed with base detergent in hard (HW) and soft water (SW) at temperatures of 40 °C, 60 °C and 90 °C was analysed via charge surfaces. The characterization of the charge of the cotton fabric surface before (F) and after washing cycles (MF) was performed by the streaming potential method in an electrokinetic analyser, EKA, A. Paar, Austria, where the cotton fabrics were the solid stationary phase, and the electrolyte solution KCl (1 mmol/L), the mobile phase. From the values of the streaming potential of the cotton fabric embedded in the adjustable gap cell (AGC) and the parameters in the system depending on the pH value of 1 mmol/L of KCl, the zeta potential (ζ) was calculated according to the Helmoltz–Smoluchowski equation [5].

3. Results and Discussion

The detergent used contains builders, zeolite and sodium carbonate, aimed to soften the water during washing process and prevent the deposition of inorganic matters on the surface of the cotton material. Regardless of this action, the analysis of residual substances on standard cotton fabric (F) after washing at all temperatures showed the load of surface by inorganic incrustations. Table 3 shows the values of ash content (P) on cotton fabric (F) before and after washing with detergent in different compositions in hard and soft water at 40 °C, 60 °C and 90 °C in a laboratory device (MF). Unwashed fabric (F) contains 0,2 % ash, which corresponds to the usual value for control cotton fabric. The results in Table 3 show that water hardness and washing temperature affect the ash values of washed cotton fabrics.

Table 3: Ash content (P) after incineration of cotton fabrics before and after 10 washing cycles

Sample	Water	P (%)		
		40 °C	60 °C	90 °C
F	-	0,2		
MF_CMC	TW	0,8	1,0	1,5
MF_CMS		1,0	1,1	1,5
MF_CMC+CMS		0,9	1,1	1,5
MF_CMC	SW	0,2	0,2	0,3
MF_CMS		0,2	0,2	0,3
MF_CMC+CMS		0,2	0,2	0,3

Washing of the cotton fabric with detergent with ARAs in soft water (SW) of 44,5 ppm did not increase the residual ash content. The high degree hardness of tap water (TW, 404,1 ppm affected the ash content values on washed cotton fabrics, that are generally from 6 to 10 times higher than the ash values of cotton fabrics washed in soft water. The generation of incrustations on the surface of cotton fabrics in washing with hard water at 60 °C and 90 °C is higher compared to 40 °C. According to these results, it is clear that the builders are not efficient in binding of alkaline earth ions from hard water at higher temperatures. The ingredients of the detergent for washing of reference cotton fabric (without soiling) for 10 cycles were not oriented towards soil removal. It is possible that some organic components in the detergent, such as soap and anionic surfactants, interact with calcium and magnesium ions and generate sparingly soluble precipitate and/or insoluble deposits, which loaded the surface of the cotton fabric and increase the residual content (total ash). The impact of ARAs, CMC, CMS and their mixture on the surface charge of the reference cotton fabric (F) after 10 cycles of washing (MF) with basic detergent was analysed by titration curves of the zeta potential depending on the pH of 1 mmol/L KCl are shown in Figure 1.

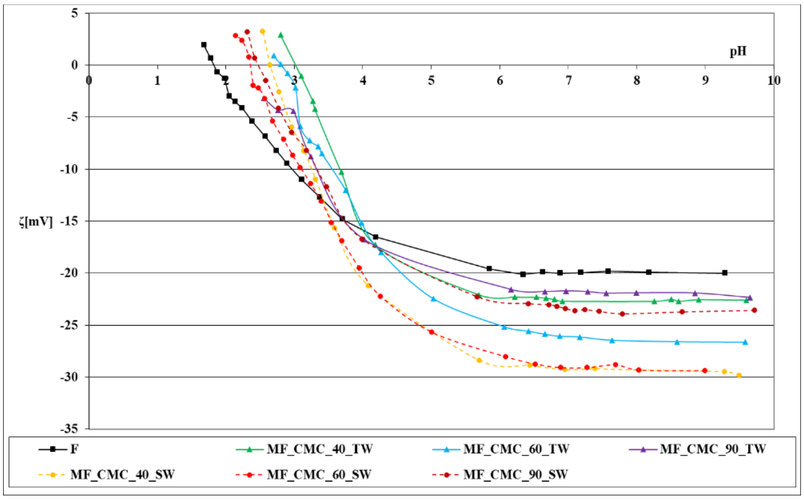


Figure 1: Zeta potential of cotton fabrics before and after 10 cycles of washing with detergent containing CMC in hard and soft water at 40, 60 and 90 °C depending on the pH of 1 mmol/L KCl

The zeta potential values of the washed cotton fabrics (MF) under all the varied conditions in the range of pH 9 to pH 4 are more negative than the zeta potential values of the reference cotton fabric (F), Figure 1. Following the differences between the curves and the values, a behaviour pattern cannot be established, but in general, cotton fabrics washed with CMC in soft water have a more negative surface charge than fabrics washed with CMC in hard water. Based on the obtained ratios, CMC as a polymer affects the increase of the negative charge of the cotton fabric surface modified in soft water at 40 and 60 °C. It agrees with the previous findings, which showed the responsibility of CMC for the zeta potential and the importance of electrostatic interactions in the adsorption process of CMC. Cotton fabrics modified with CMC detergent at 90 °C in hard and soft water have a less negative surface charge compared to almost all the other polymer-modified cotton fabrics. This is linked with the impact of a higher temperature (90 °C) on the weaker potential of CMC, and not with the degree of surface loading with deposits, since their content on the surface of detergent-modified fabrics with CMC in hard water at 40, 60 and 90 °C is almost equal, and in soft water, it is low.

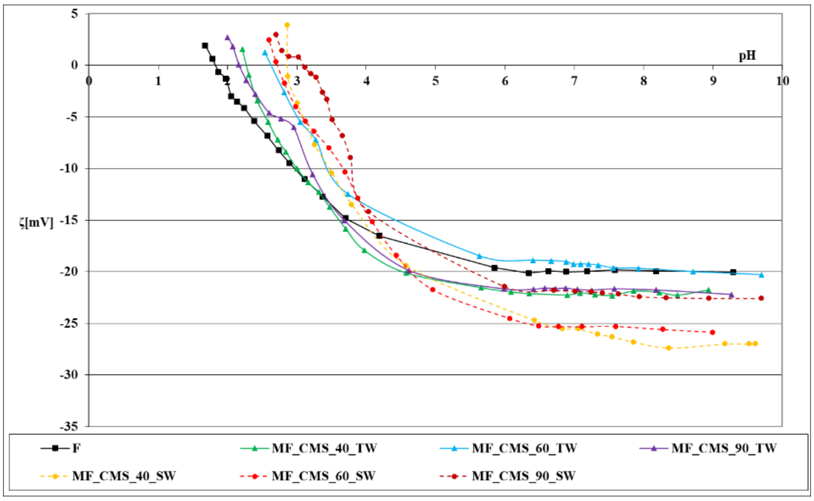


Figure 2: Zeta potential of cotton fabrics before and after 10 cycles of washing with detergent containing CMS in hard and soft water at 40, 60 and 90 °C depending on the pH of 1 mmol/L KCl

The zeta potential values of all cotton fabrics washed with CMS are less negative than the values of cotton fabrics with CMC. The zeta potential curves of cotton fabrics washed with CMS in hard and soft water are characterized by grouping (1st) soft water at 40 and 60 °C, and (2nd) hard water at 40 and 90 °C. The surface charge of the CMS washed fabric in hard water at 60 °C is similar to the surface charge of the reference cotton fabric (F) in the highly alkaline range. Based on the obtained relations, it can be concluded that CMC as ARA in the detergent leads to an increase in the negative charge of the cotton fabric surface in soft water at 40 and 60 °C.

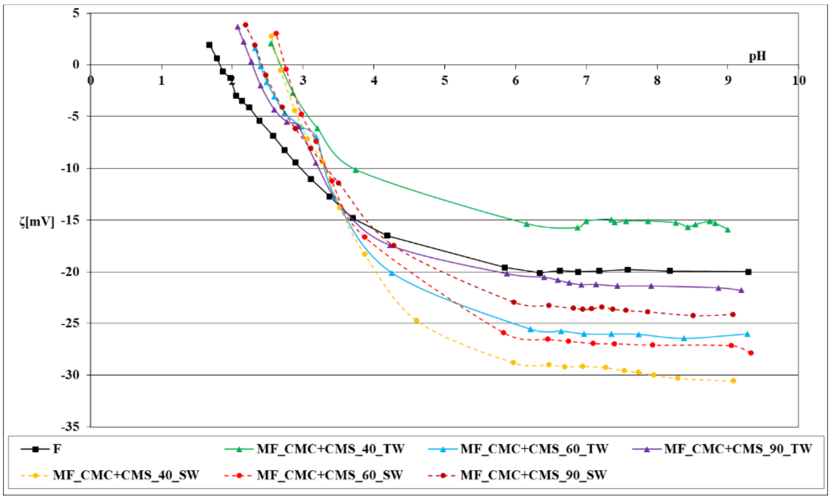


Figure 3: Zeta potential of cotton fabrics before and after 10 cycles of washing with detergent containing CMC + CMS in hard and soft water at 40, 60 and 90 °C depending on the pH of 1 mmol/L KCl

The zeta potential curves are not grouped and are similar to the curves of fabrics washed with CMC, indicating a dominant impact of CMC over CMS in the CMC/CMS blend, which is shown by the grouping and lower surface charge of the washed cotton fabric.

4. Conclusions

All of the obtained results indicate a substantial impact of temperature and water as a washing medium. The values of ash content on washed cotton fabrics in soft water are almost equal to the values of unwashed cotton fabric, which confirms that the detergent composition varied through ARAs and washing temperature in soft water do not affect these values. A review of the presented results shows that the high degree of water hardness and washing temperature have a dominant influence on the total ash content of washed cotton fabrics. The results of the expressed as deposit and zeta potential, show a significant impact of CMC in the mixture of applied polymers CMC + CMS.

5. References

[1] Sinner, H.: Über das Waschen mit Haushaltwaschmaschinen : in welchem Umfange erleichtern Haushaltwaschmaschinen und -geräte das Wäschehaben im Haushalt?, Hamburg: Haus und Heim Verlag, (1960)
[2] Smulders, E. et al.: Recent developments in the field of laundry detergents and cleaners, *Tenside Surfactants Detergents,* **34** (1997) 6, pp. 386-392, ISSN 0932-3414
[3] Soljačić, I., Pušić, T.: *Njega tekstila: Čišćenje u vodenom mediju*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN: 9537105091, Zagreb, (2005)
[4] HRN ISO 4312:2001 Površinski aktivne tvari - Procjena određenih učinaka pranja - Metode analize i ispitivanja za čistu kontrolnu pamučnu tkaninu (ISO 4312:1989)
[5] Luxbacher, T.: 6-Electrokinetic properties of natural fibres, U *Handbook of Natural Fibres: Volume 2: Processing and Applications*, Woodhead Publishing, ISBN 9781845696986, Manchester, UK (2012), pp. 185-215

Darinka Cvetković

Biography

Born in Zagreb in 1962. In 1981 employed in Radio Industry in Zagreb at IETA (Electrical and Telecommunication Research). Worked in the lab for the recording and production of technical films (photographic, dry film, chemical copper double plates, galvanic baths and their analyses) and administrative work. In 1984 enrolled the Faculty of Chemical Engineering and Labour. In 1991 enrolled the Faculty of Chemistry and Technology, graduating in Footwear technology. In 2009, she enrolled a supplemental differential study at the Faculty of Textile Technology, and in 2011 graduated from the Textile Chemistry, majoring in textile chemistry, materials and ecology. She enrolled doctoral study at the Faculty of Textile Technology in 2016, with the aim of improving research.

Title of PhD thesis

Study advisor

assoc. prof. Maja Somogyi Škoc, PhD

Date or dissertation defense

APPLICATION OF PROPOLIS AND MEDICINAL PLANTS FOR PADS DEVELOPMENT IN THE BREAST INFLAMMATION TREATMENT

Darinka CVETKOVIĆ

Gračansko Dolje 44, Zagreb, cvetkovicdarinka@gmail.com

Summary: *Breast pads cannot replace antibiotics, but they can help the symptoms to disappear more quickly. With this in mind, the doctoral thesis focussed on natural remedies that can speed up the healing process. The use of medicinal plants is as old as human civilisation. Plants have always been an indispensable part of everyday human life, either as food or as medicine. In many peoples of the world, the tradition of using medicinal plants has survived to this day. In addition to their traditional use, medicinal plants have become a source of bioactive substances for the production of pharmaceutical preparations that can be used both in medicine and on textiles.*

1. Introduction

Breast inflammation rarely occurs in healthy women who are not breastfeeding. The risk group are women and men with weakened immunity, diabetes or chronic illnesses. Breast inflammation in women or men can occur because of nipple injury, smoking and in women with implants [1]. In breastfeeding women, mastitis occurs when bacteria from the baby's mouth or skin enter the milk duct through a crack in the nipple. Another cause of breast inflammation is milk that remains in the breast, i.e. is not fully expressed, which then leads to a blockage of the milk duct [2]. In the case of infection, antibiotics are used and painkillers such as ibuprofen can help with the pain. Hot or cold compresses before and after breastfeeding can help to relieve the pain [3]. One of the best-known dressings is the one made from green leaves, but there is a risk of infection with the bacterium Listeria (lat. *Listeria monocytogenes*). In addition to their traditional use, medicinal plants have become a source of bioactive substances for the production of pharmaceutical preparations that can be used in medicine, the pharmaceutical industry, in the food industry and in other manufacturing sectors (cosmetics industry, production of plant protection products, colours, etc.) [4]. There is no strict boundary between medicinal, aromatic and spice plants, as one and the same plant can often be used for all three purposes (e.g. mint is used in medicine, it is used to produce essential oil, but it is also used to extract flavours) [5]. For this reason, medicinal and flavouring plants are often referred to by a common name - medicinal plants.

2. Experimental

The starting point of the research is the hypothesis that by utilising previous scientific findings and achievements in the field of material development, a new contribution can be made to the development of nursing pads as inserts for the treatment of breast inflammation.

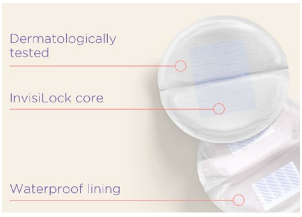


Figure 1: Three-layer nursing pads [6]

In the planning and conducting research, general knowledge from the field of scientific work methodology will be used - preparation of research materials, conducting research and processing the results obtained with the aim of realising and confirming the hypothesis. Methods and procedures will be used that enable reproducibility of the processing and morphological properties of the studied materials through the application of reliable standardised and developed measurement techniques (FTIR-ATR, SEM-EDS, AFM, DSC/TGA, various microbiological tests, safety tests for in vivo application, etc.), but also through new measurement techniques on a global level. The research will include the following units, which will be added to and amended as necessary during the work and changed if necessary, depending on the knowledge gained:

1. Selection of plants from the Republic of Croatia and bee products
2. Consultation and co-operation with potential committee members

3. Development of own tinctures and calculation of the required quantities of extracts/bioactive components of selected plants and bee products
4. Optimisation and preparation of tinctures
5. Application of the optimised tinctures to selected textile coverings by immersion
6. Investigation and evaluation of preliminary samples.
7. Application form DR.SC.01 etc. Writing and publishing a scientific paper.
8. Application of the statistical method of Design of Experiments (DOE).
9. Application of optimised tinctures on selected textile coverings by immersion.
10. Analysing and evaluating the samples.
11. Consultation and co-operation with committee members and other institutions on scientific research.
12. Applicability of dressings for the treatment of breast inflammation and the possibility of commercial production.


dried fenugreek seeds [7]


comfrey [8]


lemon balm [9]


propolis [10]

Figure 2: Some of the selected plants and propolis

3. Conclusion

The expected results of the doctoral thesis are the development of prototypes of pads for breastfeeding mothers as a dressing for the treatment of breast inflammation and the development of a methodology to evaluate their useful and functional quality.

Acknowledgement

Hrzz Croatian Science Foundation

The work of PhD student Darinka Cvetković was co-financed by means of the research project "Antibacterial coating for biodegradable medical materials" - ABBAMEDICA" of the Croatian Science Foundation (IP-2019-04-1381), led by prof. Iva Rezić, PhD, PhD.

4. References

[1] *Available from* https://krenizdravo.dnevnik.hr/zdravlje/bolesti-zdravlje/upala-dojke-kod-zena-koje-ne-doje-mastitis-uzroci-simptomi-lijecenje-i-obloge, *Accessed:* December 14th, 2023
[2] Boakes, E. et al.: Breast Infection: A Review of Diagnosis and Management Practices. *European Journal Of Breast Health*, **14** (2018), pp. 136-143
[3] *Available from* https://poliklinika-mazalin.hr/blog/njega-dojki-nakon-poroda/, *Accessed:* December 14th, 2023
[4] *Available from* https://www.info-ks.net/lifestyle/zdravlje/77415/oblozi-od-kupusa-su-lijek-evo-sta-ce-da-se-desi-ako-ih-stavite-na-grudi-noge-ruke-ili-vrat, *Accessed*: December 14th, 2023
[5] Jovović, Z. i sur.: *Tehnologija proizvodnje ljekovitog, aromatičnog i začinskog bilja*, Univerzitet Crne Gore, ISBN COBISS.CG-ID, Podgorica, (2020.)
[6] *Available from* https://lansinoh.hr/product/jastucici-za-prsa/, *Accessed:* December 14th, 2023
[7] *Available from* https://ba.underextract.com/dietary-supplement/fenugreek-powder.html, *Accessed:* December 14th, 2023
[8] *Available from* https://encian.hr/hr/novosti/gavez-mast-najbolji-lijek-protiv-bolova-21028, *Accessed:* December 14th, 2023
[9] *Available from* https://hr.underextract.com/dietary-supplement/organic-lemon-balm-powder.html, *Accessed*: December 14th, 2023
[10] *Available from* https://www.uppula.hr/proizvodi/propolis, *Accessed:* December 14th, 2023

Ivana Čorak

Biography	She graduated from the University of Zagreb Faculty of Textile Technology (TTF) in 2015. She worked as a quality expert at Boxmark Leather d.o.o. She worked at TTF as an assistant in the project DOK-2018-09-4254 "*Bio-innovated polyester material aimed for use in a hospital environment*" funded by the Croatian Science foundation. She was a researcher in project UIP-05-2019-8780 HPROTEX and a bilateral Croatia and Serbia scientific project *Bio-innovated polyesters*. She received the Interim Deans Award of Excellence at doctoral study Textile Science and Technology in 2019/2020 and TSRC Award for the scientific research work in the field of textiles in category I: young researchers at the TSRC Day 2021. She has been employed as an assistant at TTF since 2023. Her scientific work relates to the surface modification of polyester and the development of antimicrobial textiles while her teaching area is printing and dyeing processes.
Title of PhD thesis	Bio-innovated polyester material aimed for use in a hospital environment
Mentor	prof. Anita Tarbuk, PhD
Date or dissertation defense	

BIO-INNOVATED POLYESTER MATERIAL AIMED FOR USE IN A HOSPITAL ENVIRONMENT

Ivana ČORAK

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, ivana.corak@ttf.unizg.hr

Abstract: *The research within the scope of the dissertation includes the development of bio-innovated polyester materials aimed for use in a hospital environment. The surface of the polyester fabric is activated by alkaline hydrolysis at reduced temperature with the addition of accelerators and environmentally friendly amano lipase enzymes. The functionalization of a homogenized chitosan in aqueous acetic acid solution was carried out by pad-dry-cure method. The explored electrokinetic properties and antimicrobial efficacy of the functionalized fabrics after 10 cycles of adapted washing confirmed the persistence of the processing.*

1. Introduction

Polyester accounts for almost 80% of the total production of synthetic fibers and the most represented is polyethylene terephthalate, PET. PET is hydrophobic due to its high crystallinity, which leads to low adsorption capacity, accumulation of static electricity, preference for dirt, discomfort when worn and creation of exfoliation [1-3] which is the reason for surface modification. Hydrolysis causes the ester bonds to break down and results in an increased number of hydroxyl and carboxyl groups, giving the fabrics better adsorption capacity, appearance and silky sheen. Alkaline hydrolysis is neither environmentally friendly nor energy efficient, and the strength of the fabric can be compromised if the cross-section is reduced. Enzymes, as natural and fully biodegradable protein structures that allow selective treatment of polymer materials at low temperature, are being researched as an alternative. Due to the size of the enzyme, they act exclusively on the fiber surface and do not cause damage. Various enzymes are used for the enzymatic hydrolysis of PET, but the best effects are achieved with lipase and cutinase [2, 3].

Chitosan is a natural biopolymer consisting mainly of 2-amino-2-deoxy-β-D-glucopyranose interconnected by β-1,4 glycosidic bonds. Despite numerous existing antimicrobial agents, public awareness and policy have emphasized the need for new biologics in the development of hospital materials. The great interest in the use of chitosan in the hospital environment stems from its properties: biocompatibility, biodegradability, non-toxicity, antimicrobial, hemostatic and moisturizing effects [4].

2. Experimental

A commercially available polyester fabric made of 100 % polyethylene terephthalate with a surface weight of 60 g/m^2 (Belira) - label PET - was used for the study. Hydrolysis was carried out in 1,5 M NaOH at 80 °C for 10 min with the addition of 2 g/l accelerator, cationic surfactant hexadeciltrimetylammonium chloride (HDTMAC, 25 % aqueous solution, Fluka) - label PET-H. Enzymatic hydrolysis was carried out with 0,2 g/l Amano-Lipase A (*Aspergillus Niger*) Sigma-Aldrich at a pH of 9 at 60 °C for 60 minutes - label PET-ALA. Chitosan was used for functionalization obtained from the Mushroom chitosan (Chibio BioTECH). Fabrics were impregnated in a homogenized chitosan solution in acetic acid (3 g/l), dried at 110 °C for 2 min and thermocondensed at 170 °C for 90 seconds.

To determine the persistence of processing, the electrokinetic properties (Surpass, Anton Paar) and antimicrobial efficacy (EN ISO 20645:2008) of *Staphylococcus aureus* (ATCC 6538), *Escherichia coli* (ATCC 8739) and *Candida albicans* (ATCC 10231) were investigated after 1 and 10 cycles of set washing in the FOM71 CLS washing machine (Electrolux). Washing was carried out in soft water with the addition of an optical bleaching agent (ISO 15797:2002) followed by the addition of PAP, ε-(ftalimido) peroxy hexanoic acid, at 50 °C according to a specially developed programme. Drying was carried out in the T5130-LAB-Type A1 (Electrolux) dryer for 30 min in the NORMAL LAB programme.

3. Results and Discussion

The presence of chitosan on the fabric is confirmed by the values of the zeta potential and the isoelectric point (Fig.1).

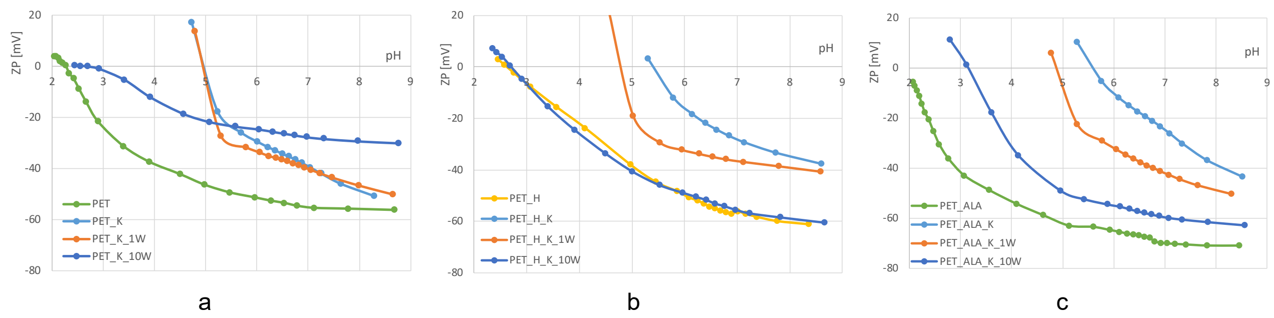


Figure 1: Zeta potential of polyester fabrics: a) untreated, b) alkaline hydrolysed, and c) enzymatically hydrolysed after functionalization and washing

Hydrolysed fabrics are more negative because of higher number of active groups. After functionalization fabrics are more positive because of amino groups in bonded chitosan. During washing, the chitosan is partially removed, but the effect is maintained, which is confirmed by the study of antimicrobial efficacy (Table 1). The best effects were observed with the enzymatically hydrolysed polyethylene terephthalate.

Table 1: Antimicrobial efficacy of polyester fabrics before and after functionalization and washing

Sample	PET			PET-H			PET-ALA		
	Sa	*Ec*	*Ca*	*Sa*	*Ec*	*Ca*	*Sa*	*Ec*	*Ca*
_	-	-	-	+	+/-	-	+/-	+/-	-
_K	+/-	+/-	+/-	+	+/-	+/-	+/-	+/-	+/-
_K_1W	+/-	+/-	-	+/-	+/-	-	+/-	+/-	+/-
_K_10W	+/-	+/-	-	+/-	+/-	-	+/-	+/-	-

Sa - Staphylococcus aureus, *Ec - Escherichia coli*, *Ca - Candida albicans*; + has an inhibition zone, effective; - no zone, growth of microorganisms, ineffective; +/- no zone, no growth of microorganisms on the surface of the fabric or below, effective

4. Conclusion

The achieved results indicate an ecologically, energetically and economically acceptable alkaline and enzymatic hydrolysis of polyester and chitosan functionalization. The results of the zeta potential show the presence of chitosan on both fabrics even after several cycles of adapted washing process.

Acknowledgment

The work of doctoral student Ivana Čorak has been supported in part by the "Young researchers' career development project – training of doctoral students" of the Croatian Science Foundation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the Croatian Science Foundation. This work has been supported in part by Croatian Science Foundation under the project UIP-2017-05-8780 HPROTEX.

5. References

[1] Grancarić, A.M., Pušić, T., Kallay, N.: Modifikacija poliesterskog vlakna alkalnom hidrolizom, Polimeri, 12 (1991), str. 141–145
[2] Guebitz, G.M., Cavaco-Paulo, A.: Enzymes go big: Surface hydrolysis and functionalization of synthetic polymers, Trends Biotechnol, 26 (2008), pp. 32–38
[3] Kardas, I. et al.: The influence of PET fibres surface enzymatic modification on the selected properties, AUTEX Research Journal, 14 (2014) 3, pp. 179-186
[4] Flinčec Grgac, S. et al.: The Chitosan Implementation into Cotton and Polyester/Cotton Blend Fabrics, Materials, 13 (2020) 7, 1616

Selma Imamagić

Biography

Selma Imamagić was born in 1998 in Zagreb. In 2022, she graduated on the University of Zagreb Faculty of Textile Technology, study: Clothing Engineering. After graduating, in the same year she enrolled doctoral study Textile Science and Technology at the University of Zagreb Faculty of Textile Technology. Since July 3rd, 2023, she has been working in the Department of Clothing Technology at the University of Zagreb Faculty of Textile Technology in the associated position as an assistant.

Title of PhD thesis

Study advisor

prof. Anica Hursa Šajatović, PhD

Date or dissertation defense

DEVELOPMENT AND APPLICATION OF THE SOFTWARE SOLUTION FOR PRODUCTION SCHEDULING IN THE APPAREL INDUSTRY

Selma IMAMAGIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, selma.imamagic@ttf.unizg.hr

Abstract: *Production scheduling is a process of managing time slots in which certain work orders must be produced. It involves finding the best possible schedule of machines and devices as well as of processing job operations at the workstations. The doctoral thesis will be based on the development of a software solution for production scheduling in apparel industry and its real-time testing.*

1. Introduction

Nowadays, the pursuit for lifestyle individualisation and the rapid change in fashion designs request flexibility of apparel industry as well as quick and convenient respond to these demands. Small-series production, increase of the number of product collections with different colours, patterns and sizes, a high level of quality, short delivery times and the constant tentation of shortening manufacturing cycle time, i.e. price, are global factors of the development of the apparel industry [1]. Therefore, new solutions are required for the garment manufacturing process. One of these solutions lies in the improvement of production planning, scheduling the available resources (people and machines) and production control, which are the key elements for the successful business operations of garment manufacturers. Consequently, new mathematical models and computer software are being developed in the field of production scheduling which aim to find an optimal schedule of processing technological operations at the workstations, i.e. of production of work orders as well as of machines and devices in order to achieve the desired production results (quality and quantity of garments) within the required delivery time [2].

As regards, the most important objectives of production scheduling are:

- shortening of manufacturing cycle time,
- meeting the planned delivery dates (avoiding possible delays or premature deliveries),
- optimal load of machines and devices,
- shortening flow time through production process and
- reduction of production costs [3].

The basis of this doctoral thesis will be the development of a production scheduling software for apparel industry that can achieve most of the above objectives. The novelties compared to the existing software would be seen in adding the parameter of the complexity of processing the technological operation, i.e. the ability of the worker to perform it during the automatic distribution of technological operations to the workstations, and the automatic calculation of the required number of workers for the production of specific work order.

2. Experimental

The experimental part of the PhD thesis will involve the development of a software solution for production scheduling in the apparel industry. This process will be carried out in the C++ programming language, driven by the idea of applying one of the priority rules for processing technological operations on the workstations (Tab. 1).

Table 1: The examples of priority rules for processing technological operations at workstations [4]

Priority rules for processing technological operations at workstations	Rule explication
LTT (*Longest Task Time*)	the highest priority of processing has the technological operation with the largest (longest) standard time
STT (*Shortest Task Time*)	the highest priority of processing has the technological operation with the shortest standard time
MFT (*Most Following Tasks*)	the highest priority of processing has the technological operation with the largest number of “successors” (technological operations that succeed)
LNFT (*Least Number of Following Tasks*)	the highest priority of processing has the technological operation with the least number of “successors” (technological operations that succeed)
RPW (*Ranked Positional Weight*)	the highest priority of processing has the technological operation whose “successor“ is the longest

3. Results and Discussion

The results of the developed software solution for production scheduling in the apparel industry are aimed at determining the reduction of the manufacturing cycle time for a particular garment and obtaining the best possible schedule of machines and devices as well as of processing of technological operations at the workstations in the production of a particular work order.
The aim is to test the achievement of the above objectives on a real-time example by inputting the real-time data from the garment industry into the developed software solution. The evaluation of the developed software solution for production scheduling will be based on the aforementioned results of the real-time tests.

4. Conclusion

Production scheduling is a complex process in the apparel industry due to its key objectives. The application of one of the priority rules in the scheduling problem and its modification together with the correct determination of the dependencies between the technological operations in the production of a certain garment and the sequence of their processing, will ensure the achievement of the set goals in the garment manufacturing process and the necessary response of the apparel industry to the demands of the market, i.e. customers.

5. References

[1] Rogale, D., Dragčević, Z. & Ujević, D.: Utjecaj dizajna na suvremene procese proizvodnje odjeće, *Tekstil*, **46** (1997), 1, str. 16-23, ISSN 0492-5882

[2] Afolalu, A. S. et al.: Analysis of Production Scheduling Initiatives in the Manufacturing Systems, *International journal of mechanical and production engineering research and development*, **10** (2020) 3, pp. 1301-1318, ISSN 2249-8001

[3] Žugaj, M. & Varga, M.: O terminiranju proizvodnje pomoću električkog računala, *Journal of Information and Organizational Sciences*, (1987) 11, str. 209-221, ISSN 1846-9418

[4] Ünal, C.: A new line balancing algorithm for manufacturing cell transformation in apparel industry, *Industria Textilă*, **64** (2013) 3, pp. 155-161, ISSN 1222-5347

Josip Jelić

Biography	Josip Jelić was born 1980 in Zagreb. He finished secondary school in Zagreb and graduated at the University of Zagreb Faculty of Textile Technology in 2015. In 2017, he enrolled doctoral study Textile Science and Technology at the University of Zagreb Faculty of Textile Technology.
Doctoral thesis topic title	Targeted production of a fibrous support for the cultivation of tissue cells by combined electrospinning
Mentor	prof. Budimir Mijović, PhD
Date of defence of the doctoral thesis	

TESTING OF THE TENSILE PROPERTIES OF ELECTROSPUN TEXTILE NONWOVEN COMPOSITE

Josip JELIĆ

Carwizz, Slavonska avenija 26/9, Zagreb, josipjelic2004@gmail.com,
josip.jelic@ttf.hr

Abstract: *Textile composite materials belong advanced materials that combine textiles (such as woven or nonwoven materials) with other materials, often polymers or reinforcing fibres, to create materials with improved properties and performances. The mechanical properties of textile composite materials can vary significantly depending on the specific materials used, the manufacturing process and the intended application. Tensile properties are important mechanical properties used to evaluate the performance of composite textile materials. Tensile properties describe how the material behaves under tensile forces.*

1. Introduction

A composite or composite material is built from different materials firmly connected to each other in order to obtain a new, different material, with physical or chemical properties that exceed the properties of the individual parts, or with properties that these individual parts do not have [1]. Most composites contain one material as a continuous phase (matrix), and separate parts of the second phase, which usually has the function of reinforcement, are incorporated into it. The mechanical properties of composite materials such as tensile strength, compressive properties, flexibility, strength and stiffness depend on various factors, some of which are: the composition of the materials, their volume fractions and the applied production processes. The research of different production techniques of composite materials is very important [2,3]. This may include studying processes such as hand placement, filament winding, compression moulding and more to optimize the mechanical properties of the final product. Different types of fibers (e.g. carbon, glass, aramid) offer different levels of strength and stiffness. The matrix material connecting the fibers also affects the tensile properties. The matrix must effectively transfer the load to the fibers and provide protection from environmental factors. Assessing the tensile properties of textile composite materials is essential to ensure that they meet the requirements of specific applications, such as aerospace, automotive, construction and sports equipment.

2. Material and methods

The work used Shieldex Bonn, which is a highly conductive thermally bonded nonwoven material made of 100% polyamide (Nylon 6.6) with a silver content of approx. 17%. Due to the silver content, this non-woven material is antimicrobial, electrically and thermally conductive, and protects against electromagnetic radiation. Despite its antimicrobial properties, Shieldex Bonn is also used for technical purposes in industry. In addition to electromagnetic protection, this technical material provides antistatic dissipation and very good electrical conductivity up to < 0.5 Ω. Shieldex Bonn is particularly suitable for sensors in medical technology, protective wallpaper in room protection or antistatic discharge in electronic components. The material is also compliant with OEKO-TEX® STANDARD 100, REACH and RoHS. Shielding efficiency (0.2–2 GHz) Average < 63 dB from 0.2 GHz – 2 GHz. Shielding efficiency (2–5 GHz) Average < 70 dB from 2 GHz – 5 GHz. Shielding efficiency (5–14 GHz) Average < 78 dB from 5 GHz – 14 GHz. Weight 56 g/m2 ± 15 %. Thickness 0.35mm ± 30%.

2.1. Measuring equipment and samples

The standard *Nonwovens - Test methods - Part 3: Determination of tensile strength and elongation at break using the strip method* (ISO 9073-3:2023), describe a test method for determining the tensile properties of nonwoven fabrics by the shear band method [4]. The Statimat M strength tester by tt. Textechno is used for measurement. The accuracy of this device corresponds to class 1, with an error of the recorded maximum force of ± 1%. The breaking force of a material is generally known as tensile strength or ultimate tensile strength, which refers to tension. Elongation (*p*, mm) is measured by applying a tensile force or stretching the material in the same manner as previously described and determining the change in length from the original. Elongation is expressed as a percentage of the original gauge length (ε, %). Ultimate elongation is the percentage change in length from original to break. For measurement, samples are prepared in the form of strips measuring 50±0.5 mm x 200±0.5 mm. 10 samples were cut in 3 directions according to the template from Figure 3, with the following markings: X direction 0 °, Y direction 90 °, Z direction 45 °.

3. Tensile force results on dry samples

According to the results, sample 5 has the highest strength in the X direction in the dry state, and it is 158.41 cN/mm. Sample 5 also has the highest elongation at break, which is 53.96 %, while sample 3 has the lowest elongation at break, which is 39.88%. Sample 5 has the highest strength in the Y direction in the dry state and is 89.27 cN/mm. Sample 1 has the lowest strength and it is 71.78 cN/mm. Sample 5 also has the highest elongation at break, which is 63%, while sample 4 has the lowest elongation at break, which is 49.44%. Furthermore, sample 1 has the highest strength in the Z direction in the dry state, and it is 122.76 cN/mm. Sample 2 has the lowest strength, and it is 90.9 cN/mm. Sample 3 has the highest elongation at break, which is 59.44%, while sample 2 has the lowest elongation at break, which is 44.04%.

4. Conclusion

Tensile properties are important mechanical properties used to evaluate the performance of composite textile materials. Composite textile materials are made by combining two or more different types of fibres or materials to create a single material with improved properties. Tensile properties describe how the material behaves under tensile forces (pulling or stretching). Tensile strength represents the maximum stress that a material can withstand while being stretched or pulled before breaking. Tensile strength is a key parameter that indicates the ability of the material to resist external forces without breaking. Different types of fibres offer different levels of strength and stiffness. The matrix material connecting the fibres also affects the tensile properties. The matrix must effectively transfer the load to the fibres and provide protection from environmental factors. Evaluation of the tensile properties of composite textile materials is essential to ensure that they meet the requirements of specific applications, such as aerospace, automotive, construction and sports equipment. Tests of non-woven composite samples showed that in the dry state, sample 5 shows the highest tensile strength and breaking elongation when stretched in the X direction (0°) and Y direction (90°). When stretched in the Z direction (45°) in the dry state, the highest strength was measured for sample 1 in the amount of 122.76 cN/mm, while the highest breaking elongation of 59.44% was measured for sample 3, which probably depends on the direction of production and the structure, that is, the orientation of the fibers in the structure of the non-woven composite, but also the components (matrix) used in the electrospinning process.

5. References

[1] De Luycker, E., et al.: Simulation of 3D interlock composite preforming, *Composite Structures*, **88** (2009) 4: str. 615-62, ISSN 0263-8223
[2] Yi, H. L.; Ding, X.: Conventional Approach on Manufacturing 3D Woven Preforms Used for Composites. *Journal of Industrial Textiles*, **34** (2004) : str. 39-50, ISSN 1528-0837
[3] Tsai, K. H.; Chiu, C. H.; Wu, T. H.: Fatigue Behaviour of 3D Multi-Layer Angle Interlock Woven Composite Plates, *Composites Science and Technology*, **60** (2000), str 241-248, ISSN 1879-1050.
[4] ISO 9073-3:2023 *Nonwovens - Test methods - Part 3: Determination of tensile strength and elongation at break using the strip method*

Tea Jovanović

Biography	She was born in 1993 in Metković and in 2012 graduated High school of Economics at the city of Ploče. In 2015, she completed undergraduate university studies at the University of Zagreb Faculty of Textile Technology in Zagreb, where she graduated in 2018. She is a third-year PhD student at the University of Zagreb Faculty of Textile Technology. She is currently employed as an office manager and member of subscription sales support.
Title of PhD thesis	The influence of the raw material composition and knitted fabric structure on its elastic properties subjected to static and cyclic loading
Mentor	prof. Željko Penava, PhD
Date or dissertation defense	

THE ANALYSIS OF WORK DURING KNITTED FABRIC STRECHING UNTIL RUPTURE

Tea JOVANOVIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, tea.jovanovic81@gmail.com

Abstract: *The force/extension diagram resulting from uniaxial tensile loading until the break of two samples of weft- knitted plated fabric, intended for the production of long-sleeve recreational shirts or winter undershirts, has been analysed. The core yarn used is a 20 tex cotton yarn, while the plating consists of a 44 dtex PA multifilament yarn. The force/extension curve is adequately described by a third or fourth-degree polynomial equation. By applying specific integrals and appropriate mathematical methods, the total and partial work during fabric elongation to rupture has been determined. The share of work until the end of the knitted fabrics elastic deformation ranges from 0,2 to 3,5% of the total work, and up to the beginning of plastic deformation, it ranges from 1,3 to 20 % of the total work.*

1. Introduction

Under the so-called static tensile loads on the dynamometer, knitted fabrics usually stretched transversally and/or longitudinally to break. Based on the analysis of the force/stretching diagram, it is possible to analyse the proportions of the work involved in stretching in the wale direction and in the course direction [1,2]. For certain applications, new knitting structures are always sought or yarns with new structural features and properties are used, and by harmonizing yarn and machine parameters and finishing, knitting structures and afterwards garments are made [3,4].

2. Experimental part

Two samples of weft- knitted plated fabric in two structures were designed: 1. partially plated 1+1 and 2. (fully) plated fabric, Tab. 1. The core yarn for knitting is a 20 tex cotton yarn, produced on a ring spinning machine, while the plating yarn is a 44 dtex f 10 PA multifilament yarn. In the partially plated 1+1 fabric, the PA yarn is interlaced every other row (90 % cotton, 10 % PA) with an area weight of 200 g/m^2. In the fully plated fabric, cotton and PA yarn (82 % pamuk, 18 % PA) with an area weight of 233 g/m^2 are woven into each row. Cut fabric samples for uniaxial tensile elongation until rupture were tested on a dynamometer tt. Statimat M – Textechno (sample width 50 mm, length 300 mm; distance between grippers of the dynamometer 100 mm and stretching speed 100 mm/min) [5].

3. Results and Discussion

Table 1: Determined polynomial equations and correlation coefficients for knitting patterns

Elongation course	in a partially plated 1+1 structure	in a (fully) plated structure
in the wale direction (transverse)	$F=0{,}0091\cdot\Delta L^3–0{,}232\cdot\Delta L^2+1{,}6142\cdot\Delta L$; r=0,99	$F=-0{,}7998\cdot\Delta L^4+9{,}5958\cdot\Delta L^3–20{,}18\cdot\Delta L^2+17{,}711\cdot\Delta L$; r=0,99
in the course direction (longitudinal)	$F=0{,}0138\cdot\Delta L^3–0{,}1946\cdot\Delta L^2+1{,}1237\cdot\Delta L$; r=0,99	$F=-0{,}5989\cdot\Delta L^4+7{,}1427\cdot\Delta L^3–12{,}249\cdot\Delta L^2+13{,}852\cdot\Delta L$; r=0,99

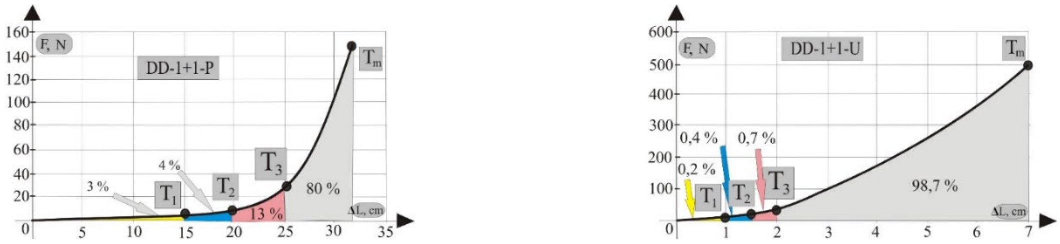
*Explanation of symbols: F – tensile force; ΔL – stretching, r - correlation coefficient

Fabric elongation in the wale direction is significantly greater than in the course direction and described by a III. degree polynomial function (Tab. 1), while knitted fabric elongation in the course direction is significantly less and described by a IV. degree polynomial function.

Table 2: Values of significant parameters and coordinates

Elongation course	Ti (elongation, cm; force, N)	Work below the force/extension curve (W, N·cm)
partially plated		
in the wale direction	T1 (15; 4,6), T2 (20; 13), T3 (25; 36) i Tm (33,8; 148)	899
in the course direction	T1 (1; 5), T2 (1,5; 10), T3 (2; 21) i Tm (7; 500)	1128
(fully) plated fabric		
in the wale direction	T1 (8; 3,8), T2 (15; 20), T3 (18; 37) i Tm (28,3; 189)	1199
in the course direction	T1 (1,3; 11), T2 (2,5; 50), T3 (3; 75) i Tm (8; 535)	1707

During elongation, the partially plated 1+1 knitted fabrics in the wale direction reaches an elongation to rupture of 338 %, with the maximum force approximately equal to the breaking force being 148 N (Fig. 1). The knitted fabric elongation in the course direction is significantly less, reaching only 70 %, with the highest force during stretching being considerably higher than that in the wale direction, at 500 N. For fully plated knitted fabrics, two yarns are interlaced in every row, resulting in a higher work input during stretching compared to partially plated 1+1 knitted fabric (Tab. 2). Due to higher knitted fabric density, elongation in the wale direction is 283 %, less than that of partially plated knit, which reaches 338 %. However, the breaking force is significantly higher, reaching 189 N. One of the goals of plating is to achieve a denser and firmer knitted fabric structure; hence, the fully plated knitted fabric has the highest recorded knitwear rupture force, reaching 535 N during stretching in the course direction.



a b

Figure 1: Force/stretching diagrams until rupture of untreated weft- knitted plated fabric 1+1 with shares of work input during knitted fabric stretching: a) transverse elongation, b) longitudinal elongation; ordinate – force F, (N), and abscissa, stretching ΔL, (cm)

The amount of work invested from the beginning to the top of the curve (from 0 to point T2) is only 7 % of the total share work invested (899 N·cm). From the top of the curve (point T2) to the beginning of plastic deformation (point T3), the work share invested is 13 % of the total work. After the beginning of fabric plastic deformation during elongation in the wale direction (from point T3), the results of the fabric elongation are no longer interesting during garment production. However, it should be noted that only 20 % of the work was used for elongation until the beginning of permanent deformation. The rest of the work is used during heavy load, causing the threads in the knitwear structure to break, thus creating holes in the knitwear, which impairs the appearance and the garment performance. The elongation in the course direction is significantly lower, so the work share invested until the beginning of plastic deformation (up to point T3) is only 1,3 %, and the other 98,7 % is spent to the beginning of plastic deformation.

4. Conclusions

The analysed fabrics are suitable for making long-sleeve shirts and produced in two similar basic plated structures that allow for different tensile properties in the wale (transverse) and course (longitudinal) directions. The amount of total work invested for stretching in the wale direction until the beginning of permanent deformation is 899 N·cm, while in the course direction is 1128 N·cm for partially plated of weft- knitted plated fabric. The share of work until the end of the knitted fabrics elastic deformation ranges from 0,2 to 3,5 % of the total work, and up to the beginning of plastic deformation, it ranges from 1,3 to 20 % of the total work.

5. References

[1] DIN 53835-2: 1981 *Testing of textiles; determination of the elastic behaviour of single and plied elastomeric yarns by repeated application of tensile load between constant extension limits*

[2] Penava, Ž. i sur.: Deformacijske karakteristike tkanine pri različitim smjerovima djelovanja jednoosnog vlačnog opterećenja, *Tekstil*, **70** (2021) 1-3, str. 1-11, ISSN 1849-1537

[3] Stojanović, S. i Geršak, J.: Tekstilne strukture namijenjene za sportsku odjeću, *Tekstil*, **68** (2019) 4-6, str. 55-71, ISSN 1849-1537

[4] Katić Križmanić, I. i Salopek Čubrić, I.: Tehnike kreativnog mišljenja u istraživanju materijala za povećanu udobnost u sportu, *Tekstil*, **69** (2020) 1-3, str. 45-53, ISSN 1849-1537

[5] EN ISO 13934-1:2013 *Textiles - Tensile properties of fabrics- Part 1: Determination of maximum force and elongation at maximum force using the strip method*

Ana Kalazić

Biography

Born in 1993 in Zagreb. After finishing the Tituš Brezovački High School in Zagreb, in the academic year 2012/2013 enrolled in the study of Accounting and Finance at the Faculty of Economics in Zagreb, where he obtained a professional bachelor's degree in business economics. In 2015/2016 enrolled in undergraduate studies in Textile Technology and Engineering at the Faculty of Textile Technology in Zagreb and in 2019/2020 graduated and obtained a master's degree in textile technology and engineering. In the period from 2020-2023. she works at the Faculty of Textile Technology in Zagreb as an expert associate on the IRI II project "*Development of multifunctional non-combustible fabric for dual purpose*", financed by the EU from the European Fund for Regional Development. In the academic year 2020/2021. enrolls doctoral study Textile Science and Technology at the Faculty of Textile Technology in Zagreb.

Title of PhD thesis

Study advisor

assist. prof. Snježana Brnada, PhD

Date or dissertation defense

THE INFLUENCE OF STRUCTURE ON THE SURFACE ROUGHNESS OF WOVEN FABRICS

Ana KALAZIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, ana.kalazic@ttf.unizg.hr

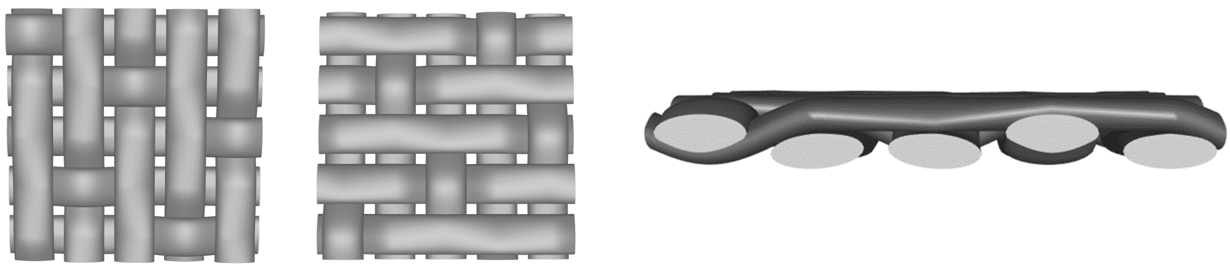
Abstract: *When making a purchase, customers often touch the fabric, and the impression the fabric leaves, along with other criteria, is a crucial factor in the decision-making process. Therefore, manufacturers make efforts to enhance the tactile properties of fabrics, attributing significant importance to them. Achieving the desired characteristics of the fabric involves careful selection of weaves, density, yarn fineness, raw materials, and design. Technological advancements encompass all stages, including fibre production and processing, yarn manufacturing, preparation for weaving, the weaving process, surface treatments, and shaping into the final product.*

1. Introduction

Technical textiles are omnipresent in today's human life, with virtually no industry branch left untouched by their application. The production of technical textiles is considered a highly successful sector within the textile industry, rapidly advancing and evolving. Technical textiles encompass a broad range of purpose-specific materials, including household fabrics such as those used for bed linens. These fabrics often combine cotton with polyester fibres, providing functionality and comfort. The properties of fibers are transferred to yarn characteristics and further improved through subsequent fabric treatments. Fabrics made from natural fibres offer increased comfort, breathability, and reduced allergic reactions, while synthetic fibers contribute to enhanced fabric strength [1,2]. In the analysis of fabric samples in this study, Fabric Touch Tester device (SDL Atlas) plays a significant role.

2. Experimental

In the experimental section of the study, samples of bed linen fabric were analysed. The samples were woven with 100 % cotton yarn in a satin weave (Figure 1).



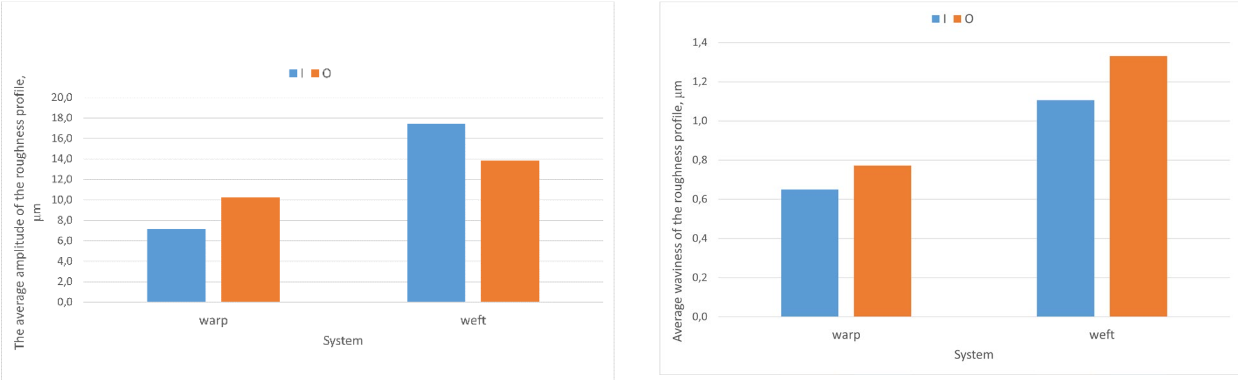
a b c

Figure 1: Simulation of the satin weave: a) Front; b) Back of the fabric, c) Yarn interlacing

Fabric samples were treated with a finishing agent and tested on the Fabric Touch Tester device (SDL Atlas). The focus of this research was on the analysis of roughness parameters (average amplitude profile of roughness and average waviness profile of roughness).

3. Results and Discussion

To assess the impact of finishing on surface roughness, data obtained from testing on the Fabric Touch Tester device (SDL Atlas) were analysed. A comparison was made between the average amplitude profile of roughness and the average waviness profile of roughness in the warp and weft directions on the face and back of the fabric [3,4].



a b

Figure 2: a) Average amplitude profile of roughness; b) average waviness profile of roughness

In the graph in Figure 2a, it is evident that the fabric in the warp direction on the front of the fabric has a higher average amplitude profile of roughness, while in the weft direction, it has a lower amplitude compared to the back side of the woven fabric in the same direction.
Regarding the average waviness (Figure 2b) of the roughness profile in both the warp and weft directions, there is a higher average waviness on the back side of the woven fabric in both tested directions.

4. Conclusion

According to the presented results, on the front of the fabric along the warp direction, larger amplitudes are evident compared to the back of the fabric in the same direction. This is influenced by the dominance of one yarn system on the front and another on the back of the fabric. The situation is reversed in the weft direction. Regarding the average waviness of the roughness profile on the front of the fabric, there are more frequent changes.
Due to the complexity of the woven fabric structure, it is necessary to consider and examine multiple arbitrary directions to obtain a comprehensive understanding of the fabric's roughness.

5. References

[1] Kovačić, S.; Schwarz, I. & Brnada, S.: *Tehničke tkanine*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, 978-953-7105-78-5, Zagreb (2020)
[2] Nawab, Y.; Hamdani, S.T.A. & Shaker, K: *Structural Textile Design: Interlacing and Interlooping.* CRC Press, 9781315390406, Boca Raton (2017)
[3] Akgun, M.: Assessment of the surface roughness of cotton fabrics through different yarn and fabric structural properties, *Fibers and Polymers*, **15** (2014), pp. 405-413
[4] Mao, N.; Wang Y.; & Qu, J.: Smoothness and roughness: characteristics of fabric-to-fabric self-friction properties, *The Proceedings of 90th Textile Institute World Conference,* The 90th Textile Institute World Conference, str. 125-134, ISBN: 978-1-5108-4079-9, Poznan, Poland, Travanj 2016, The Textile Institute, Manchester, United Kingdom (2016)

Franka Karin

Biography

Franka Karin was born in 1986 in Zagreb. In June 2012 she received the academic title: Master of Engineering in Textile Technology and Engineering at the University of Zagreb, Faculty of Textile Technology, major: Industrial Design of Clothing. Faculty of Textile Technology, major: Industrial Design of Clothing. Since October 2017, she has been working as an assistant at the University of Zagreb, Faculty of Textile Technology, Department of Textile and Clothing Design. In December 2017, she enrolled doctoral study Textile Science and Technology. She focused her research on sustainable design and methods for designing and manufacturing clothing according to the zero-waste concept.

Title of PhD thesis

Study advisor

assoc. prof. Blaženka Brlobašić Šajatović, PhD

Date or dissertation defense

DEVELOPMENT OF BASIC SILHOUETTES OF WOMEN'S CLOTHING ADAPTED TO THE FUNDAMENTAL SETTINGS OF SUSTAINABILITY IN FASHION

Franka KARIN

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, franka.karin@ttf.unizg.hr

Abstract: *The fashion industry bears a great responsibility for the generation of textile waste in the world and is one of the biggest polluters, which is why awareness of sustainable development has been raised. Sustainable development is important for production processes in order to preserve ecology and prevent the depletion of natural resources. Sustainable fashion takes into account the aspects of sustainable development and strives for an environmentally friendly design in production where fabrics are used rationally. The aim of the thesis is to investigate the current methods of the zero-waste concept and propose a new method in the process of designing and tailoring clothes that achieves maximum utilisation of the fabric in order to reduce or eliminate tailoring waste. The method is applied to basic silhouettes of women's clothing.*

1. Introduction

The zero-waste concept is a method developed in response to fast fashion, which has led to an excessive amount of textile waste and the need for new solutions due to the unsustainable practices of the fashion industry. With the zero-waste concept, textile waste is minimized or completely avoided in the design process and in the production of clothing. With the current approach to the design, modelling and tailoring of clothing, the waste from tailoring is 15 to 25 %. Such production is not sustainable because it pollutes the environment, uses cheap materials and poorly paid labour. The counterbalance to fast fashion is slow fashion, which is not subject to the rapid changes of fashion trends, but is based on traditional design and high-quality workmanship, which extends the life of the product [1,2]. The no-waste concept has gained importance in the fashion industry since the beginning of 2010 due to the environmental, economic and political climate. It is characterized as an experimental method that is ethically linked to ecology, with the aim of long-term sustainable production [3]. In the no-waste concept, the use of fabrics is thought through in advance so that the textiles are not wasted during production itself, for which the designers bear a great responsibility. Fashion designers Timo Rissanen and Holly McQuillan achieved the most significant results in clothing design based on the no-waste concept. They laid a good foundation for further research and experimentation [4].

2. Investigated methods of the zero-waste concept

The primary aim of the zero-waste concept is to make the best possible use of the material. What is important are the technical and aesthetic elements that allow the garment to fit into the dimensions of the fabric, which is not the case in current practice. In the tailoring process, it is necessary to consider the most favourable options for tailoring parts to avoid tailoring waste [5]. Designers Timo Rissanen and Holly Mcquillan have experimentally approached sustainable garment design under the guidelines of the zero-waste concept, with the aim of producing minimal or no waste. They mention two types of textile waste. They emphasize that in this method, five basic criteria must be met during the design process. These are: Aesthetics, fit, cost, what is left of the fabric and the possibility of production. The avoidance of textile waste must not compromise the aesthetics and fit of the garment [4]. Research to date has produced various innovative design solutions that have been successfully applied and achieved good results [6]. They approach design by applying innovative techniques in designing and tailoring garments, focusing on geometric and mathematical principles. In this way, they arrive at pattern pieces that make optimal use of the fabric and reduce waste. The methods mainly involve adapting pattern pieces to non-standard fabric widths, fitting pattern pieces in different directions, disregarding the warp direction and mainly knitting, resulting in voluminous garments with unrecognizable basic garment silhouettes of various shapes of women's clothing.

3. Research plan and methodology of the new proposed no-waste concept method

The field of sustainable fashion is constantly evolving and in accordance with this development, designers in their researched various methods tend to reduce waste in the fashion industry as a response to the environmental challenges of the fashion industry, which is known for its wasteful practices. The analysis of the studied methods of garment design using the no-waste concept revealed that the garments mostly do not conform to the basic silhouettes of women's clothing. Therefore, a new method of the no-waste concept is proposed for the design and construction of basic silhouettes that fulfils the five basic criteria of the design process. The basic criteria are: Aesthetics, fit, cost, fabric waste during cutting and production feasibility. The new method develops a process for obtaining basic cuts according to the zero-waste concept and adapting them to the basic silhouettes of women's clothing. The starting point for the process of creating basic cuts for basic silhouettes of women's clothing is a grid determined by the width of the fabric and the main body measurements, which are determined by mathematical expressions. The mathematical expressions define the areas of the pattern pieces and the length of the contours of the pattern pieces. For each individual basic silhouette of women's clothing, a basic pattern is created according to the basic construction and the new method. The cutting patterns are created on the computer and the resulting fabric utilization is calculated and compared. The basic cuts determined using the new method are modelled according to the selected design and the basic silhouettes of the women's clothing. Construction elements (eyelets, seams, pleats) are used in the waist and hip area, the shoulder length and the length of the garment in order to do justice to the fit of the garment and to emphasize the individual basic silhouette of the women's clothing.

3. Conclusion

The need to raise awareness of the importance of sustainable guidelines in fashion and to minimize textile waste has given rise to new methods in the context of sustainable development. The zero-waste concept is an example that requires continuous work and research to achieve good results in terms of sustainable fashion in the design and production process. With the methods of the zero-waste concept and the application of new technologies, it is possible to create garments that minimize or eliminate textile waste, while maintaining esthetic criteria and respecting the basic silhouettes of women's clothing, and in the long term to restore the reputation of the textile industry while respecting the environment.

4. References

[1] McQuillen, H.: *Zero Waste design thinking*, University of Boras, ISBN: 978-91-88838-33-9, (2019)

[2] Niinimäki, K.: *Sustainable fashion: New approaches. Aalto University publication series*, Aalto ARTS Books, ISBN 9789526055732, Helsinki, Finland, (2003)

[3] Hsiou-Lien, C.; Davis Burns, L.: Environmental Analysis of Textile Products. *Clothing and Textiles Research Journal*, **24** (2006) 3, pp. 248-261, https://doi.org/10.1177/0887302X06293065

[4] Rissanen, T.; McQuillen, H.: *Zero-waste Fashion Design*, Bloomsbury Publishing, ISBN 9781350094833, London, New York, (2016)

[5] Baumgarten, L.; Wilson J., Carr F.: *Costume Close Up: Clothing Construction and Pattern*, 1750-1790. The Colonial Williamsburg Foundation, ISBN 10: 0896762262, Virginia, (1999)

[6] Hye-Won, L.: A systematic review of zero waste fashion construction techniques. *The 91st Textile Institute World Conference: Integrating Design with Sustainable Technology*, University of Leeds, July 2018, Leeds, UK, (2018)

Ines Katić Križmančić

Biography	Ines Katić Križmančić was born in 1965, in Zagreb. She completed her graduate studies at the Faculty of Textile Technology, the University of Zagreb and acquired the title Mag. ing. des. text. She enrolled doctoral study Textile Science and Technology in 2019/2020. She has over thirty years of experience in the textile industry working as a textile and fashion designer, technologist, and cluster leader. Her scientific interest is linked to the topic of innovative textile materials for enhancing the comfort of sportswear.
Title of PhD thesis	Development and characterization of football jersey materials to optimize comfort and durability
Mentor	prof. Ivana Salopek Čubrić, PhD
Date or dissertation defense	

PROPOSAL FOR A DESIGN SOLUTION OF FUNCTIONAL SPORTSWEAR BASED ON THE PARAMETERS OF KNITTED FABRICS

Ines KATIĆ KRIŽMANČIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, ikatickri@ttf.hr

Abstract: *The functions of clothing can be varied. There is a great emphasis on the simultaneous achievement of two features, protecting the body and improving body functions. In the textile market, there are permanent demands for the expansion of existing and the development of new innovative solutions. To reach these requirements as successfully as possible, scientists are continuously working on the development of new functional materials, especially in the sportswear segment, which is experiencing continuous growth. Therefore, in this paper, the properties of engineered knitwear were examined to create a proposal for the design of a sports garment.*

1. Introduction

During the process of designing clothes, the focus should first of all be on its purpose, and then on its aesthetic appeal. The design of functional clothing should at the same time provide answers to questions about body protection, safety, health, improving efficiency and improving body functions. The segment of functional clothing that continues to grow is sportswear. The effectiveness of sportswear is influenced by the thermodynamic, aerodynamic and hydrodynamic properties of the materials used and their combinations. Sportswear must be designed in such a way that it supports the athlete in sports activity, provides him with maximum support and provides maximum comfort and protection.

2. Experimental

In this paper, a set of five engineered knits ST1-ST5, weft knitted fabrics, made of polyamide yarn, was conducted. Within the experimental part, the knitting parameters and air permeability were investigated. The results of the tested properties are important for the perception of the comfort of the garment and provide guidelines for the development of proposals for the design of a women's sports top.

2.1. Methods

In the experimental part, the following properties were investigated: fibre fineness, loop density, thickness, mass per unit area and air permeability. Before testing, the samples were conditioned in a standard test atmosphere. The fibre fineness is determined using the mass system. The loop density is defined by the standard EN 1497:2008 [1]. The loop density was measured using a Dino-Lite PRO HR digital microscope. The thickness was determined and described by ISO standard 5084 [2], and the gauge brand DM-2000 was used for testing. The determination of the mass per unit area is defined by the HRN ISO 3801:2003 standard [3]. A precise analytical balance manufactured by Kern ALJ 220-4 was used for measurement. Air permeability was measured using the Air Tronic device, manufactured by Mesdan S.p.A. and the test is determined by the SS-NE ISO 9237-1995 standard [4].

3. Results and Discussion

One of the most important properties that affect the comfort of materials for making sportswear is related to knitting parameters and air permeability. The test results are shown and summarized in Fig. 1.

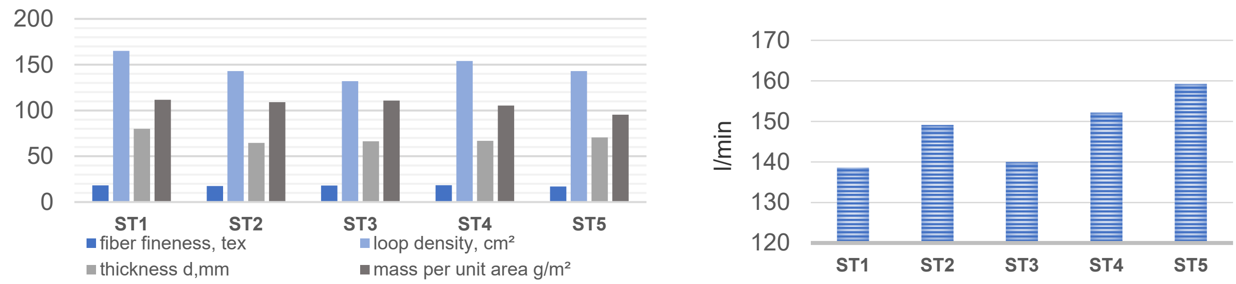


Figure 1. Comparative presentation of the measurement results in a) fibre fineness, loop density, thickness and mass per unit area of specimens ST1-ST5 b) air permeability for specimens ST1-ST5

Since the difference in the fibre's fineness of the selected knits is relatively small, the parameter that most significantly affects the mass per unit area and thickness of the knitwear is the loop density. Knitwear ST5, ST4 and ST2 with the smallest mass and thickness show the highest air permeability. The proposal for the design solution of the women's sports top, Fig. 2, was made concerning the investigated properties of the designed knitwear and the obtained results, absolute and regional rates of sweating of the female body during increased physical activity, which was mapped and published by Havenith et. al in their article [5]. The highest rates of sweating are found in the areas between the shoulder blades, the chest and the shoulders.

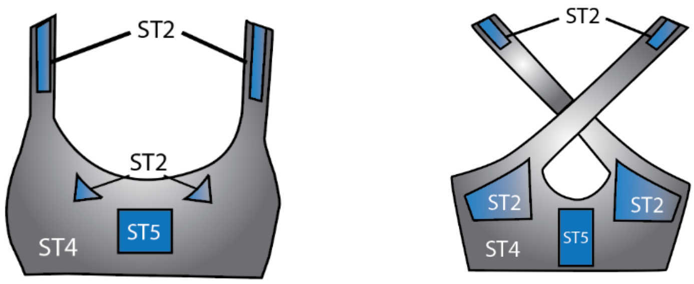


Figure 2. Proposal of the design solution of a women's sports top concerning the tested properties of specimens ST1-ST5

4. Conclusion

Of all the tested knitwear, specimen ST4 has the most optimal combination of all properties for making a women's sports top, while the ST5 and ST2 specimens are optimal for making parts of the top that rest on the skin in areas that show a high rate of body sweat generated during more pronounced physical activity. Further scientific efforts should be focused on studying many other parameters that can significantly affect the comfort and durability of women's sports tops.

Acknowledgement

This work was fully supported by the Croatian Science Foundation as part of the project IP- 2020-02-5041 Textile materials for increased comfort in sports – TEMPO, led by prof. Ivana Salopek Čubrić, PhD.

5. References

[1] BS EN 1497:2008 *Textiles - Knitwear - determination of the number of stitches per unit of wale and course*
[2] EN ISO 5084: *1996 Determination of the thickness of textile products*
[3] ISO 3801:2003 *Textiles - Fabrics - Determination of mass per unit length and mass per unit area*
[4] ISO 9237:1995 *Textiles - Determination of the permeability of fabrics to air*
[5] Smith, C. J.; Havenith, G.: Body Mapping of Sweating Patterns in Athletes: A Sex Comparison, *Medicine and Science in Sports and Exercise*, 44 (2012) 12, pp.2350–236

Ana Kiš

Biography	She was born in 1985 in Čakovec. She finished high school 'Mining and Chemical School Varaždin' and enrolled the Faculty of Chemical Engineering and Technology in Zagreb, where she graduated in 2010. After finishing her studies, she got a job at the company Čateks d.d. where she worked for 11 years. In 2018, she enrolled doctoral study Textile Science and Technology. Since 2021, I have been employed at the company Franck d.d. in the position of Quality Control Analyst until January 2022. In January 2022, I got a job at Vertiv Croatia d.o.o. to the position of Quality Suppliers Engineer.
Title of PhD thesis	Development of new thermoprotective woven fabrics structures with optimal ratio of thermal protection and comfort
Mentor	prof. Stana Kovačević, PhD
Date or dissertation defense	

INFLUENCE OF THE STRUCTURE OF 3D FABRICS ON RADIATION HEAT RESISTANCE AND THERMOPHYSIOLOGY PROPERTIES

Ana KIŠ

Vertiv Croatia d.o.o.., Oreškovićeva ul. 6n-2, Zagreb, akis@ttf.hr

Abstract: *The goal of the research is to investigate the influence of complex 3D fabric structures on radiation heat resistance (EN ISO 6942:2022) and water vapor resistance (EN ISO 11092:2014) - two important parameters for fabrics for thermal protective clothing. Six 3D fabric samples were woven from the same warp, with three weft densities and in two different weaves. The results showed that the 2pp sample gave the best results of heat resistance to radiation and water vapor resistance. The structure of the sample is responsible for these results, because the trapped air in the fabric's pore pockets, in addition to providing greater resistance to radiant heat, the resulting folds also give the fabric better physiological properties.*

1. Introduction

Different weave types result in different fabric structure parameters such as fabric thickness, surface mass and heat radiation protection. In the case of fabric resistance to heat radiation, a significant difference can be found between weaving structures, and in fact it has been proven that the best performance in terms of thermal protection is given by samples of a complex woven structure. Two-dimensional weave structures: plain weave, atlas weave and twill weave provide less resistance to thermal radiation [1]. 3D fabrics that have an emphasized third dimension (thickness), two fabrics are tied together with individual warps or weft yarns are created simultaneously creating a unique overall structure. They consist of two groups of yarns: warp, weft and interlaced warp or weft yarns, which occasionally join the upper and lower fabrics [2,3]. The cross-section of the 3D fabric labelled "pp" and "tp". The microscopic analysis of the samples discussed in the paper [4] shows that the upper fabric, which forms the face of the fabric of higher density aramid fibres, has a uniform surface. The lower density cotton and modacrylic lower fabric has a wrinkled surface, created by interweaving with the upper fabric. The surface folds of the fabric, created by weaving, create a gap between the fabrics that is filled with air. By increasing the density of the weft, the pleats become denser and more frequent, with less air volume, which affects the volume, thickness and weight of the fabric. The folds of pp fabrics are more pronounced when applied to tp samples. In this paper, it was investigated how such a structure of 3D fabrics affects two important parameters from the aspect of heat protection.

2. Experimental

Six 3D fabrics of the same base with three weft densities and in two different weaves (plain and twill) were used for the research. The yarn composition of the upper and lower fabric of the warp and weft is the same for all samples. Upper fabric: warp – 95 % M-aramid Conex NEO / weft – 5 % P-aramid Twaron. Bottom fabric: warp – 45 % Cotton Long Stapel Combed / weft – 55 % Modacrylic Sevel FRSA/L.

Table 1. Parameters of 3D fabric samples

Sample	Fabric	Weave upper / lower fabric	Density warp - weft (thread/cm)	The fineness of the yarn (tex)		Surface mass (g/m^2)	Thickness (mm)
				Warp	Weft		
1pp[1]	Upper	Plain weave	40 - 35	12,5×2	16,7×2	356	0,63
	Lower	Plain weave	20 - 17	12,5×2	25		
2pp	Upper	Plain weave	40 - 32	12,5×2	16,7×2	336	0,61
	Lower	Plain weave	20 - 16	17×2	25		
3pp	Upper	Plain weave	40 - 30	12,5×2	16,7×2	303	0,59
	Lower	Plain weave	20 - 14	17×2	25		
1tp[2]	Upper	Twill 3/1	40 - 35	12,5×2	16,7×2	316	0,61
	Lower	Plain weave	20 - 17	17×2	25		
2tp	Upper	Twill 3/1	40 - 32	12,5×2	16,7×2	293	0,58
	Lower	Plain weave	20 - 16	17×2	25		
3tp	Upper	Twill 3/1	40 - 30	12,5×2	16,7×2	287	0,58
	Lower	Plain weave	20 - 14	17×2	25		

3. Results and Discussion

Results are presented as radiant heat Q_c (EN ISO 6942:2022) and water vapor resistance R_{et} (EN ISO 11092:2014), tab. 2.

Table 2. Average values of the transmitted heat flow, Q_c (kW/m2) and values of resistance to water vapor, R_{et} (m^2Pa/W)

Sample	1pp	2pp	3pp	1tp	2tp	3tp
Qc (kW/m^2)	10,33	10,02	10,17	10,02	10,33	10,50
Ret (m^2Pa/W)	5,02	5,39	5,11	6,18	5,73	4,95

3D-fabrics 2pp and 1tp provided the highest resistance to radiant heat, transmitted heat flux 10,02 kW/m^2, although the surface mass of fabric 1tp is 6 % less than the surface mass of fabric 2pp. Sample 3tp provided the lowest resistance to radiant heat – Q_c = 10,50 kW/m^2 with a heat transfer factor of 0,5250. Water vapor resistance, R_{et} ranges from 4,94 m^2Pa/W for 3D fabric 3tp to 6,18 m^2Pa/W for 3D fabric 1tp. The lowest resistance to water vapor, R_{et}, had sample 3tp with 4,95, while the highest R_{et} was provided by sample 1tp with a value of 6,18 m^2Pa/W. The smallest value of R_{et} = 4,95 m^2Pa/W belongs to sample 3pt with the smallest surface mass of 287 g/m^2. What is interesting is that the next value R_{et} = 5,02 m^2Pa/W belongs to sample 1pp with the highest surface mass of 356 g/m^2. In general, samples of 3D fabrics with larger surface masses (1pp, 2pp, 3pp) in which the upper fabric is made of aramid fibers in the fabric and the lower fabric is made of modacrylic fibres also in the fabric have lower R_{et} values, i.e. they provide a smaller resistance to the passage of water vapor from 3D tp fabrics, which means that they are therefore more comfortable to wear. The correlation of fabric tp with surface mass shows (i.e., by reducing the surface mass of samples 1tp (316 g/m^2) – 2tp (293 g/m^2) – 3tp (287 g/m^2)), that the amount of heat flux Q_c is increases from 10,02 kW/m^2 – 10,33 kW/m^2 – 10,50 kW/m^2. The same correlation is not seen with pp 3D fabrics. Fabric 1pp, which has the highest surface mass of 356 g/m^2, has a Q_c of 10,33 kW/m^2. While samples 2pp and 3pp with lower surface mass provide better resistance to radiant heat, i.e. a better Q_c value of 10,02 kW/m^2, i.e. 10,17 kW/m^2.

4. Conclusion

If we look at the pp samples, the 2pp sample gave the best results, Q_c=10,02 m^2K/W. The lowest R_{et} value was given by sample 1pp with the highest density and surface mass, R_{et} = 5,02 m^2Pa/W. The just described structure of that sample is responsible for these results. Because the trapped air in the pockets of fabric pores, in addition to providing greater resistance to radiant heat, the resulting folds also give the fabric better physiological properties, better breathability, which means that the developed metabolic heat is more easily released into the environment.

Acknowledgement

The research was supported by the Croatian Science Foundation as part of projects IP-2018-01-3170 Multi-functional woven composites for thermal protective clothing (MF-WCOMPROTECT), led by prof. Stana Kovačević, PhD.

5. References

[1] Kiš, A.; Brnada, S.; Kovačević, S.: Influence of Fabric Weave on Thermal Radiation Resistance and Water Vapor Permeability, *Polymers*, **12** (2020) 3, pp. 1-15
[2] Bilisk, K.: New method of weaving multiaxis three dimensional flat woven fabric: Feasibility of prototype tube carrier weaving, *Fibers and Textiles in Eastern Europe*, **17** (2009), pp. 63-69
[3] Bilisik, K.: Multiaxis three dimensional (3D) woven fabric, In *Advances in Modern Woven Fabrics Technology*, IntechOpen: London, UH, 2011
[4] Kovačević, S.; Rogina-Car, B.; Kiš, A.: Application of 3D-Woven Fabrics for Packaging Materials for Terminally Sterilized Medical Devices, *Polymers*, **14** (2022) 12: 4952, pp. 1-15

Mateo Miguel Kodrič Kesovia

Biography

Mateo Miguel Kodrič Kesovia, born in 1987 in Dubrovnik. In 2006 he enrolled study of restoration and conservation at the University of Dubrovnik, where in 2012 he completed his Master. Part of his education took place at the Palazzo Spinelli Institute in Florence and at the Institute for Conservation and Restoration in Vienna. He specialized analysis and cataloging of historical textiles (CIETA) in 2011 in Florence. Since September 2013, he has been employed at the University of Dubrovnik and since 2021 as assistant professor. In 2014 he enrolled doctoral study at the Faculty of Textile Technology in Zagreb. He specialized textile restoration in 2017 at the renowned Abegg Stiftung in Switzerland. His scientific interests are interdisciplinary research in the field of history of textile technology, methods of reconstruction and reproduction, digitization of historical textiles.

Title of PhD thesis

Method of analysis and digitalization of technical documentation of historical damask fabrics in Dubrovnik region

Mentors

prof. Željko Penava, PhD prof. Katarina Nina Simončić, PhD

Date or dissertation defense

TYPOLOGY AND TERMINOLOGY OF HISTORICAL DAMASK FABRICS

Mateo Miguel KODRIČ KESOVIA

University of Dubrovnik, Branitelja Dubrovnika 41, mmkesov@unidu.hr

Abstract: *As part of the research subject withing doctoral thesis, detailed research was carried out regarding textile and technological characteristics of historical damasks from the area of Dubrovnik, with the aim of presenting the possibility of applying and processing data collected by modern methods of technical analysis and digitization of historical textile materials. One of the main challenges in the process of documentation and definition of the analysed fabrics is certainly the issue of professional terminology, which is not yet standardized and adapted enough at the national level to describe historical material. This work will present the recommended international categorization of damask structures as well as their representation on an examined sample size of 52 historical damasks preserved in the Dubrovnik area, dating from the 16th to the 20th century.*

1. Introduction

Damask (Italian: Damasco, French: Damas, German: Damast) is by definition a type of patterned fabric that contains only one system of warp threads and one system of weft threads. Patterns on damask are created by contrasting the warp and weft effects of the same or different weave structure, one of which forms a damask face, while reverse these effects are inverted [1]. The first forms of the damask technique appear in ancient China during the reign of the Han Dynasty (206 BC - 221 AD), but it will not become established until the Tang Dynasty (618 - 907 AD). Already from 2nd-3rd century, they also appear in the area of the Middle East, where the city of Damascus stands out among the main centers, after which this fabric typology will later get its name in Europe [2,3]. Historical damasks are most often hand-woven. It was only with the invention of the jacquard mechanism at the beginning of the 19th century that the limitations in the pattern were completely resolved and the number of effects increased [4]. By introducing additional brocade and/or lance wefts when patterning damask, a more richer décor is achieved on an already expensive and unique fabric typology [5,6].

2. Experimental

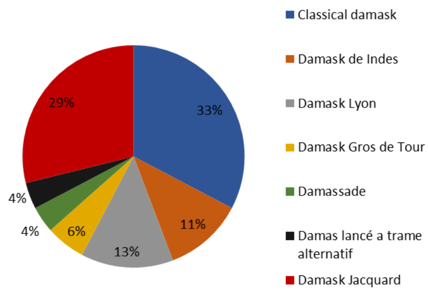
The research was carried out on mostly protected historical damasks from different parts of the Dubrovnik area: the textile fund of the Cultural and Historical Museum of Dubrovnik Museums, the collection of liturgical vestments from the Annunciation Church of the Blessed Virgin Mary on the island of Lokrum, the collection of textiles from the Church of Our Lady of Šunj on the island of Lopud, the collection of the Croatian Academy of Science and Art, and private collections. The samples were analysed as part of complete objects or as preserved fragments, dated from the 16th to the 20th century. The carried out technical analysis determined the construction parameters of the used yarns (type, thickness, fineness, twist direction and angle) and fabric structure (thickness, thread density and weave structure), as well as analysis of weaving errors. For this purpose, a combination of the classic method of structural analysis was used, using a precision magnifier for optical thread counting Fadenzähler "Print" (Baladéo Art.Nr: PLR000161) under a magnification of 10x, but also modern tools such as a digital microscope Dino Lite Pro AM413T5 (magnification up to x500) with the corresponding software Dino Capture 2.0 v.1.5.18A.

3. Results and Discussion

From a total of 52 analysed historical samples, it was determined that almost all types of damask are represented in the Dubrovnik area. As expected, no archetypes of early Chinese (twill) damasks from the Han and Tang dynasties have been recorded. The representation of the majority of damask typologies in the collections within Dubrovnik testifies to the richness and diversity of textile material in the area (Tab. 1). The PhD thesis presents a detailed overview of all damask typologies, knowledge on technique development and production technology through certain historical periods in order to precisely sistematize the historical examples from the Dubrovnik area and its surroundings. Missing typologies were also processed so that the historical context and insigts into the technique development could be fulfilled. The historical knowledge on of the weaving method and the sampling mechanism provides an insight into the technological aspect and individual typologies characteristics, which enables tentative dating or determination of the original origin of damask fabrics. However, it is also necessary to emphasize that certain techniques or typologies of damask could be represented in other countries as well, because technology, like art, freely migrated between different cultures and thus appeared in several places at the same time.

Table 1: Quantitative analysis of damask types on the analysed specimens from the Dubrovnik area

Damask typologies	Amount
Classical 5-end damask	17
Damask de Indes	6
Damask Lyon	7
Damask Gros de Tour	3
Damassade	2
Damas lancé a trame alternatif	2
Damask Jacquard	15
Total	**52**



4. Conclusion

A key procedure in the preservation of cultural assets is the preparation of thorough documentation that includes all relevant information of the object and remains permanently available for future generations to study and understand the cultural, sociological and technological aspects of the development of rich cultural heritage and society in general. Historical textiles are a very diverse and complex matter that requires interdisciplinary, specialized knowledge and skills for study and documentation. Most often, we are talking about textile fragments and objects without accompanying documentation, signatures or indications of the origin of their creation, which represents a great challenge for determining the context and grouping them with examples of similar physical, technical or aesthetic characteristics.
Given that historical fabrics - including damask - are defined on the basis of visual and textile-technological properties, it is of crucial importance to standardize and promote appropriate professional technical terms, suitable for describing and documenting historical textile materials. The terminology of weaves, textile structures, as well as specific effects present on fabrics must be determined according to strictly defined rules in order to avoid misinterpretation, misunderstanding or the use of commercial names.

Acknowledgment

I would like to thank my mentors for their long-term support, and all my colleagues in the fields of art history, textile technology and textile conservation-restoration who provided me with an insight into historical materials and collections, shared scientific information and literature, and regularly expressed their professional and constructive opinions on the relevance of this doctoral research for our profession.

5. References

[1] Centre International d'Etude des Textiles Anciens: Vocabulaires techniques textiles – Français, CIETA., Lyon, 1997

[2] Banić, S.: Damast i vez iz druge polovine 15. stoljeća na misnom ornatu u Franjevačkom samostanu u Hvaru, *Ars adriatica*, **1** (2011), str 117-132, ISSN 1848-1590

[3] Schulz, V.-S.: Crossroads of Cloth - Textile Arts and Aesthetics in and beyond the Medieval Islamic World, *Perspective,* **1** (2016), ISSN 1777-7852

[4] Atasoy, N. et al: *IPEK – Imperial Ottoman Silks and Velvets*, Azimuth Editions Limited, ISBN 1898592195, Velika Britanija, (2001)

[5] Sonday, M.: Damask: Definition and Technique, *Riggisberger berichte 7 - Leinendamaste*, Schorta, R. (ur.), pp. 113-130, ISBN 10: 3905014122, Abegg Stiftung, Riggisberg, (1999)

[6] Kodrič Kesovia, M.M.; Penava, Ž.; Jemo, D.: The story of two historical textile fragments: Technical analysis and reconstruction of the lost textile pattern, *Textile Research Journal*, **91** (2021) 23–24, pp. 2859–2871, ISSN 0040-5175

Ivan Kraljević

Biography

Ivan Kraljević, born in 1991, enrolled Faculty of Textile Technology at University of Zagreb in 2010. He successfully completed the undergraduate study of TTE, course Engineering Design and Management of Textiles, with the topic Quality evaluation of leather for suitcases, and two years later the graduate study with the thesis Testing of the prints durability on semi processed bovine leather, under the mentorship of prof. Antoneta Tomljenović. In November 2016, he enrolled doctoral studyTextile Science and Technology. Since February 2016, he has been employed at the Jadran Hosiery as head of the knitting and sewing department. Scientifically, he participated in the research project IP-2016-06-5278 funded by the Croatian Science foundation. He has published nine co-authored scientific papers and one professional paper. His research interest is testing and quality control of new materials for the sock industry and leather.

Title of PhD thesis

Study advisor

prof. Antoneta Tomljenović, PhD

Date or dissertation defense

EVALUATION OF THE ABRASION RESISTANCE OF COTTON SOCKS

Ivan KRALJEVIĆ

Jadran Hosiery, Vinka Žganeca 2, 10000 Zagreb, ivan.kraljevic@ttf.unizg.hr

Abstract: *The abrasion resistance of fine, casual men's socks with the highest cotton content was tested, which were manufactured in full plating with multifilament texturized polyamide 6.6 yarns of different linear densities. The test procedure in accordance with EN 13770, method 1, was carried out using the Martindale abrasion tester.*

1. Introduction

Socks are knitted next to skin type garments worn on the feet, and cover the ankle and part of the calf [1]. They should maintain their quality throughout their lifetime and must meet high standards of abrasion resistance. Abrasion, which is an unavoidable problem, usually occurs on the heel and sole of the socks and causes holes or thinning of the knitted structure. Since the abrasion resistance of socks depends on their construction and the fibres used, it is very important to choose the right yarns for their production [2]. Men's casual socks are usually made of high cotton content to ensure softness and comfort and blended with polyamide to improve fit and durability. Therefore, this study evaluated the abrasion resistance of men's socks with the highest cotton content produced in full plating with polyamide 6.6 yarns of different linear densities. A test procedure according to EN 13770:2002, method 1 [3], was applied using a Martindale abrasion tester and samples were taken from the sole and heel.

2. Experimental

The investigation was carried out on five groups of calf length, fine, casual, black coloured men's socks of size (EU 42) made of a high cotton content (using single ring spun cotton yarn with a linear density of 29,4 tex) fully plated with texturized polyamide 6.6 multifilament yarns of different linear densities, designated as: 22 dtex f7 × 2, 33 dtex f10 × 2, 44 dtex f13 × 2, 78 dtex f23 × 2, 110 dtex f34 × 2. The plain single jersey pattern was used in for the foot and leg part, and a 1 × 1 rib structure was used for the cuff of the socks. The socks were produced in Jadran Hosiery using the Lonati E14 sock knitting machine with a cylinder diameter of 88,9 mm (3 ½'') and 168 needles and ironed at a temperature of 110 °C using a Cortese machine [4]. The characteristics of the men's socks, named according to the code of the PA 6.6 plating yarn used (CO/PA 22×2 – CO/PA110×2), are listed in Table 1, including the values for the weight of a sock, the mass per unit area, the thickness and the density parameters of the sock plain knits.

Table 1: Characteristics of five groups of cotton socks [4]

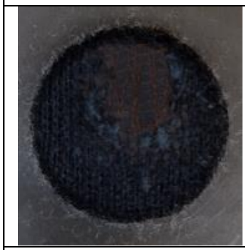
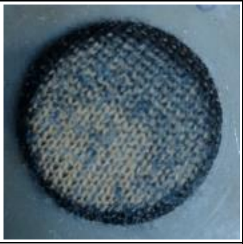
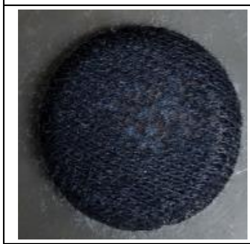
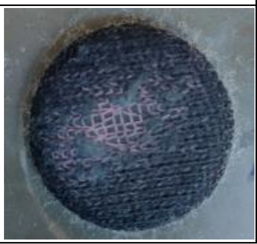
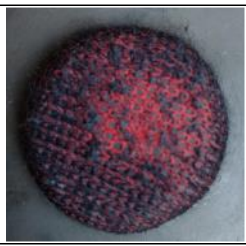
Sock sample	Weight of sock (g)	Mass per unit area (g/m^2)	Thickness (mm)	Wales/cm	Courses/cm
CO/PA 22×2	15,5	177,7	0,90	11	12
CO/PA 33×2	16,5	189,7	0,93	11	12
CO/PA 44×2	17,9	202,7	1,00	10	11
CO/PA 78×2	21,8	223,6	1,13	10	11
CO/PA 110×2	25,2	262,5	1,25	9	10

Prior to measurement, the sock samples were conditioned on a flat surface for at least 24 hours in a standard atmosphere with a temperature of 20 ± 2 °C and a relative humidity of 65 ± 4 %. The abrasion resistance of the sock plain knits was measured using the Mesdan-Lab Martindale abrasion and pilling tester according to EN 13770:2002, method 1, where the plain knit specimens were abraded against the reference wool abrasive fabric with a cyclic, planar motion in the form of a Lissajous figure. Two circular specimens with a diameter of 38 mm were taken from the heel and two from the sole of the socks. The endpoint was defined as the significant thinning (wear of the main spun yarns), which was periodically checked. The number of rubs until the endpoint was reached was recorded.

3. Results and Discussion

Increasing the linear density of polyamide 6.6. yarns used for plating of socks increases the weight of the socks as well as the thickness and mass per unit area of the sock plain knits, while the density of the knitted structure (number of wales and courses per centimetre) slowly decreases (Table 1). The results show that as the linear density of the plating polyamide 6.6 yarn increases, the number of abrasion rubs required to reach the endpoint also increases, as can be seen in Table 2, in which polyamide yarn of different colours used to differentiate five groups of tested socks is clearly visible.

Table 2: Abrasion resistance of the plain knits sampled from the heel and the sole of the socks

Sock sample, heel				
CO/PA 22×2	CO/PA 33×2	CO/PA 44×2	CO/PA 78×2	CO/PA 110×2
				
Number of abrasion rubs to reach the endpoint				
4000	6000	7000	8000	14000
Sock sample, sole				
CO/PA 22×2	CO/PA 33×2	CO/PA 44×2	CO/PA 78×2	CO/PA 110×2
				
Number of abrasion rubs to reach the endpoint				
4000	6000	7000	8000	12000

4. Conclusion

It has been established that the socks knitted from fully plated cotton with texturized polyamide 6.6 yarn of higher linear density show a significant thinning of the specimens by higher values of abrasion rubs, which is reflected in a higher abrasion resistance.

5. References

[1] Tomljenović, A. *et al*.: Usage Durability and Comfort Properties of Socks Made of Differently Spun Modal and Micro Modal Yarns, *Materials*, **16** (2023), 1684, ISSN 1996-1944

[2] Kraljević, I. *et al*.: The Abrasion Wear Resista*nce of Men's Socks, Proceedings of International Conference MATRIB 2021, Materials, Tribology, Recycling 2021*, Ćorić, D. *et al.* (Ur.), pp. 281-290, ISSN 2459-5608, Vela Luka, Croatia, 30.6.-2.7. 2021., Croatian Society for Materials and Tribology, Zagreb, (2021)

[3] BS EN 13770:2008 *Textiles - Determination of the abrasion resistance of knitted footwear garments*

[4] Tomljenović, A. *et al*.: Influence of Linear Density of Polyamide Plating Yarn on the Usage and Comfort Properties of Men's Cotton Socks, *Book of Abstracts from 22nd AUTEX World Textile Conference 2023*, Wang, L. (Ur.), pp. 43, ISBN 9783036414188, Melbourne, Australia, 26.-28.6.2023., Trans Tech Publications Ltd, Baech, Switzerland, (2023)

Anja Ludaš

Biography

Anja Ludaš was born 1993 in Zagreb. She received her master's degree in 2019 after graduating from the University of Zagreb Faculty of Textile Technology. She has been working on her PhD on doctoral study Textile Science and Technology since 2019 and is currently working as an assistant at the Department of Materials, Fibres and Textile Testing. She also participating in the research project of the Croatian Science Foundation IP-2019-04-6418 „*Laser synthesis of nanoparticles and applications*" and the Erasmus+ project Aequalis4TCLF Blueprint Project.

Title of PhD thesis

Study advisor

prof. Sanja Ercegović Ražić, PhD

Date or dissertation defense

MODIFICATION OF THE PROPERTIES OF MELT-SPUN RECYCLED PA 6 POLYMER FILAMENTS BY ADDITION OF BIOACTIVE SUBSTANCES AND NON-THERMAL PLASMA POST-TREATMENT

Anja LUDAŠ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, anja.ludas@ttf.unizg.hr

Abstract: *The process of chemical spinning of PA 6 polymer from the melt with the addition of bioactive substances (ZnO, TiO_2 and chitosan) will be optimized. Such treatments are more effective because the desired ingredient is spun directly with the polymer. The subsequent processing of the modified filament will be carried out by cold low-pressure plasma under optimized conditions, with the aim of achieving multifunctional properties and applications, while the basic properties of the material remain almost unchanged. The properties of the filament will be tested using reliable test methods.*

1. Introduction

The end of the 20th century saw the development of fibres with new properties as the fourth generation of fibres for highly demanding materials such as microfibers, biodegradable fibres, nanofibers and fibres with new structures and properties. The process of chemical spinning of fibres from the melt is one of the most common methods for the production of synthetic fibres due to its economical approach, the absence of solvents and the simplicity of the process. It is used whenever a thermostable melt with the required rheological properties can be produced from the polymer and the melt can be extruded through a die without major degradation of the polymer, forming a filamentary fibre. The most commonly used polymers for chemical melt spinning are polyamides, polyesters and (linear) polyolefins [1]. Polyamide 6 is often used for the production of fibres that are extremely strong, wear-resistant and sustainable, making them ideal for the production of various types of products for textile and technical applications. Bioactive substances such as zinc oxide (ZnO), titanium dioxide (TiO_2) and chitosan are used in the textile industry to improve the functionality of textile materials due to specific properties such as self-cleaning, dirt and water repellency, antistatic, UV protection and antibacterial effect [2, 3]. Parallel to the development of nanotechnology, advanced processes using environmentally friendly cold plasma technology are being developed to obtain textile materials with modified properties. Textile materials subjected to plasma treatment undergo physio-chemical changes in the surface layer (up to 100 nm), while the basic properties of the material remain almost unchanged [4].

2. Experimental

Recycled PA 6 polymer granules obtained by recycling fishing net waste (AquafilSLO) will be used to carry out the research. The research will be carried out in three phases: in the first phase, the parameters of the process of chemical spinning of synthetic fibers from the melt on the spinning device will be optimized depending on the thermal properties of the PA 6 polymer. The modification of the recycled PA 6 polymer with bioactive agents will be carried out on a laboratory twin-screw extruder for uniform mixing of polymer and additives, after which the modified filament will be chemically spun on a laboratory single-screw extruder with a filament spinning unit (Areka, Turkey). In the second phase, the amount of ZnO and TiO_2 nanoparticles and the bioactive agent chitosan as well as the ZnO particles obtained by green synthesis will be adjusted to the mass of the PA 6 polymer under optimized conditions to produce a filament with modified properties. In the third research phase, the obtained filaments will be modified with an environmentally friendly low-pressure plasma (LP-Nano LF-40kHz, Diener Electronic GmbH), which could contribute to the release of the active ingredient with the aim of achieving multifunctional properties, as its effect manifests itself through physicochemical changes in the surface layer of the substrate and the modification of the surface properties. In addition, given the nature of the gas and the way in which the active plasma particles act on the surface of the material, it is expected that the surface of the processed material will be roughened, improving the adhesive properties of the obtained material.

3. Results and Discussion

The characterization of the spun filaments without/with the addition of bioactive substances to assess the degree of modification and the uniformity of the respective processing will be carried out using standardized and instrumental analysis methods. The whiteness of the extruded polymer filament will be measured with a reflectance spectrophotometer, as is the yellowing. The morphological and chemical properties of the filaments will be analysed by scanning electron microscopy (SEM) with EDS analysis using a Prisma E microscope. Infrared spectroscopy with Fourier transformation will analyse possible changes in the functional groups and chemical bonds, i.e. to gain an insight into the relationship between the individual components in the sample. The thermal properties of the samples are analysed using differential scanning calorimetry. The analysis will also be carried out using an ICP device to extract or dissolve metal or mineral samples in order to analyse traces or concentrations of certain elements in the sample. The procedure for testing the antimicrobial efficacy of the processed samples will be carried out in accordance with the ISO 20645:2004 (qualitative test) and ISO 20743:2021 (quantitative test) standards against the target bacterial species and the genotoxic potential of the bioactive substances. The aging of the polymer filaments will be tested using the xenotest in accordance with the ISO 105-BO2+A1:2014 standard, with the filter changed to B04. Finally, the results will be carried out using reliable statistical tools to draw conclusions and evaluate the effectiveness of the modifications.

4. Conclusion

The main goal of this doctoral thesis is to investigate the possibility of incorporating ZnO and TiO_2 nanoparticles and the bioactive agent chitosan into recycled PA 6 polymer, the possibility of obtaining ZnO by green synthesis and the chemical spinning of the modified polymer from the melt. Subsequent processing of the resulting modified filament with low-pressure plasma under optimized conditions can contribute to the release of the active ingredient with the aim of achieving multifunctional properties and applications.

Acknowledgement

This work has been supported by Croatian Science Foundation through the project Laser synthesis of nanoparticles and applications (IP-2019-04-6418) led by assist. prof. Nikša Krstulović, PhD.

5. References

[1] Hufenus, R. et al.: Melt-Spun Fibers for Textile Applications, *Materials*, **13** (2020) 19, pp. 1-32, doi: 10.3390/ma13194298
[2] Ghaffari, S.; Mojtahedi, M. R. M. & Dastjerdi, R.: Comparison of the Morphological, Mechanical and UV Protection, Properties of TiO2/Polyamide 6 (PA6) and ZnO/PA6 Nanocomposite Multifilament Yarns, *Journal of Macromolecular Science, Part B: Physics*, (2015), pp. 1-38
[3] Piekarska, K. et al.: Chitin and Chitosan as Polymers of the Future—Obtaining, Modification, Life Cycle Assessment and Main Directions of Application, *Polymers,* **15** (2023) 793, pp. 1-31
[4] Ercegović Ražić, S. & Čunko, R.: Modifikacija svojstava tekstilija primjenom plazme, *Tekstil*, **58** (2009) 3, str. 55-74, ISSN 0492-5882

Maja Mahnić Naglić

Biography	Maja Mahnić Naglić is born in Slavonski Brod. At the University of Zagreb Faculty of Textile Technology, she completed the undergraduate study Textile Technology and Engineering in the field of Clothing Engineering in 2009, and in 2011 she gained master degree in the field of Industrial Clothing Design. Since 2012, she has been employed at the Faculty of Textile Technology as an external associate, and since 2015 as an associate assistant at the Department of Clothing Technology. She participates in teaching in the field of 2D/3D CAD/CAM systems for clothing computer design. In 2013, she enrolled doctoral study Textile Science and Technology. As a co-author she has published two chapters in scientific books, eight original scientific papers in journals cited in the WoS and Scopus databases, four original scientific papers in other journals and 17 original scientific papers in international conference proceedings.
Title of PhD thesis	Dynamic clothing behaviour under the influence of body biomechanics
Mentor	prof. Slavenka Petrak, PhD
Date or dissertation proposal defense	

DYNAMIC CLOTHING BEHAVIOUR UNDER THE INFLUENCE OF BODY BIOMECHANICS

Maja MAHNIĆ NAGLIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a
Zagreb, maja.mahnic@ttf.hr

Abstract: *Within the proposed doctoral research, a method for computer analysis of clothing fit in dynamic conditions will be developed. Body surface deformations and changes in body measurements in dynamic conditions will be analysed based on different female body types. Possibilities of connecting the 3D body scanning system with the process of 3D animation will be explored in terms of development of animated body models for 3D clothing simulation and dynamic fit testing of computer prototypes. With the aim of verifying the method and its applicability for computer 3D clothing design and fit testing in dynamic conditions, the deformation analysis of real clothing prototypes in targeted movements will be carried out.*

1. Introduction

The shape of human body and movement kinematics are the basis of research in the field of design and development of new clothing models. The development of computer technologies and CAD systems for 2D/3D clothing design enabled 3D simulation and fit analysis of computer prototypes, with the purpose of predicting the appearance and functionality of new clothing models in the development process. The clothing fit in static conditions refers to the fit of the garment to the human body shape, while the degree of fit depends on the garment type, the quality of the construction solution, and the type and mechanical properties of the textile material. The clothing fit in dynamic conditions refers to the fit of clothing on the body in motion, whereby the garment must not restrict the body's movement, nor must the movement cause excessive strain in the textile material from which the garment is made. High requirements are especially pronounced in the case of clothing for special purposes [1,2]. By integrating various 3D systems for human body shape and movements kinematics analysis into the process of computer 3D clothing design and development, a detailed analysis of the anthropometric and kinematic characteristics of the body and the application of their parameters in the process of developing new clothing models are enabled [3-6]. Research and computer analyses of clothing fit are based on the physical simulation of the clothing behaviour on 3D body model, which enables analysis of computer clothing prototypes surface geometry deformations, caused by the interaction with the body model and determined by the body clothing contact mechanics and defined parameters of the textile material physical and mechanical properties [7,8].

2. Experimental part

Within the experimental part, the analysis of changes in body measurements and dimensions of body surface segments in dynamic conditions, on different female body shapes types will be carried out. Based on the established results, the parameters for garment pattern modifications and analysis of computer 3D clothing prototypes, from the aspect of dynamic anthropometry, will be defined. Based on the scanned 3D body models, kinematic models and animation for the target set of movements will be developed and used for computer 3D simulation and garments fit analysis in dynamic conditions, Figure 1.

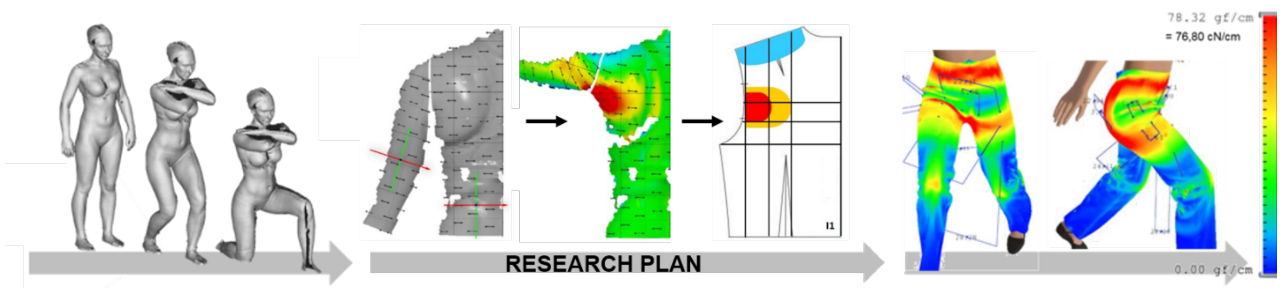


Figure 1: Doctoral thesis research plan

Based on the results of the computer 3D prototypes analysis, the relationship between the textile mechanical properties, pattern construction parameters and the biomechanics of the body in motion will be investigated. The possibilities of predicting the garment behaviour in dynamic conditions and verification of the developed method will be analysed based on the results of deformation analysis on real garment prototypes on bodies in motion.

3. Results

Based on the proposed research plan, a new method for the computer garment fit analysis in dynamic conditions will be developed, based on the 3D simulation of the garment mechanical behaviour on an animated scanned body models. Modelling the targeted mechanical properties and behaviour of the garment during 3D simulation on the body in motion will enable the analysis of the surface deformability of computer prototypes, and thus the analysis of stress on the critical zones of the garment. The doctoral thesis will result in a method that represents an innovative approach to the problem of assessing the fit of clothing on an individualized computer body models in motion.

4. Conclusions

The main goal of the doctoral thesis is to develop a method for computer analysis of the fit of clothing in dynamic conditions. In accordance with the aim of the research, the following hypotheses were set:

H1: Deformations of the body surface in motion depend on the structure and shape of the body, and by developing and applying mathematical models for adjusting kinematic points on the body and deformation of surface segments depending on a particular body type, a realistic animation of a scanned body model applicable for computer 3D simulation of clothing in dynamic conditions can be developed.
H2: By modelling the target mechanical behaviour of the textile material, garment simulation will enable deformability of the garment surface in correlation with the deformability of the body type model in the given movement.
H3: Based on the analysis of computer garment model geometry deformations in interaction with the body model in motion, it is possible to reliably evaluate the stress of the garment in dynamic conditions.

5. References

[1] Geršak, J. & Marčić, M.: The complex design concept for functional protective clothing, *Tekstil*, **62** (2013) 1/2, pp. 38-44, ISSN 0492-5882
[2] Lee, H. et al.: Ergonomic Mapping of Skin Deformation in Dynamic Postures to Provide Fundamental Data for Functional Design Lines of Outdoor Pants, *Fibres and Polymers,* **14** (2013) 12, pp. 2197-2201, ISSN 1229-9197
[3] Ashdown, S. et al.: Use of body scan data to design sizing systems based on targeted markets, *National Textile Center Annual Report,* **11** (2001) 4, pp. 1-5
[4] Petrak, S. & Rogale, D.; Mandekić-Botteri, V.: Systematic Representation and Application of a 3D computer-Aided Garment Construction Method, Part II Spatial transformation of 3D garment cut segments, *International Journal of Clothing Science and Technology,* **18** (2006) 3, pp. 188-199, ISSN 0955-6222
[5] Medved, V.: Kinematika i kineziologija lokomocije, U *Principi biomehanike,* Naklada Ljevak, ISBN 978-953-303-435-5, Zagreb, (2011), str. 463-496
[6] [6] Ma, Y.Y.; Zhang, H. & Jiang, S.W.: Realistic Modelling and Animation of Human Body Based on Scanned Data, *Journal of Computational Science & Technology,* **19** (2004) 4, pp. 529-537, ISSN 1000-9000
[7] Choi, K.J. & Ko, H.S.: Research problems in clothing simulation, *Computer-Aided Design*, **37** (2005) 6, pp. 585-592, ISSN 0010-4485
[8] Yeung, K.W.; Li, Y. & Zhand, X.: A 3D Biomechanical Human Model for Numerical Simulation of Garment-Body Dynamic Mechanical Interactions During Wear, *The Journal of Textile Institute,* **95** (2004), pp. 59-79, ISSN 0040-5000

Mislav Majdak

Biography	Mislav Majdak was born in 1995 in Zagreb. In the year 2020 he graduated from the university module Textile chemistry, material and ecology University of Zagreb, Faculty of Textile Technology. In 2021 he enrolled doctoral study Textile Science and Technology at University of Zagreb, Faculty of Textile Technology. The same year he was employed on a project Antimicrobial coating for biodegradable medicine materials, led by prof. Iva Rezić, PhD, PhD. He has successfully defended his PhD thesis topic „*Antimicrobial coatings with nanoparticles for biodegradable polymers and textile materials*“ on February 22nd, 2023.
Title of PhD thesis	Antimicrobial coatings with nanoparticles for biodegradable polymers and textile materials
Mentor	prof. Iva Rezić, PhD, PhD
Date or dissertation defense	

APPLICATION OF 3D TECHNOLOGIES FOR THE FABRICATION OF INDIVIDUALIZED SUPPORTIVE ORTHOSIS

Mislav MAJDAK

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb mislav.majdak@ttf.unizg.hr

Abstract: *3D technologies, such as 3D scanning, 3D modelling and 3D printing, enable the fabrication of individualized medical devices. In this paper, a summary of a complete fabrication of a supportive orthosis that could be used for a potential treatment of distal radius fracture was presented. The supportive orthosis was designed according to the contours of the forearm, which in turn made it an individualized device.*

1. Introduction

Fractures, especially forearm fractures (distal radius fractures) are one of the most common injuries. Thanks to the extensive research that was done on a large population of patients, it was concluded that forearm fractures are most common among prepubescent children (7 to 13 years) and older (60+) generation [1]. One of the methods, and most widely used methods, for successful treatment are conservative methods of treatment i.e., immobilization. These methods include the application of plaster, or polymer (fiberglass) casts [2]. Unfortunately, an unlikely chance of skin burns development, as well as compartment syndrome caused by an insufficient consideration of swelling, are the biggest flaws these casts may have on the patients wellbeing [3]. With the application of 3D technologies, such as 3D scanning, a fast and precise 3D model of a body or body part can be achieved. Further on, with the application of 3D modelling software, an individualized 3D object can be easily made, while with the use of 3D printing an automated fabrication of the same 3D object can be achieved [5]. Therefore, in this paper, a fabrication of an individualized supportive orthosis with the use of 3D technologies will be presented.

2. Experimental part

The process of orthosis fabrication was done in three steps; (I) 3D scanning; (II) 3D modelling; (III) 3D printing. Each of these steps is crucial for the successful fabrication of a medical device. In the first step, with the help of full-body 3D scanner *Vitus Smart* (Human Solutions GmbH) a digitalised mode of a forearm was obtained. Afterwards, along the forearm contours, a 3D model of an orthosis was made with the help of a 3D modelling software *Rhinoceros 3D* (TLM Inc.). Digitalised 3D forearm model, as well as a 3D orthosis model are presented in Figure 1.

a b

Figure 1: 3D models of: a) forearm made after the 3D scanning process, b) orthosis made with the use of 3D modelling software and presented in conjunction with a forearm model

Lastly, the 3D models were prepared for 3D printing with the use of *PrusaSlicer* (Prusa Research by Josef Prusa), where the printing parameters, that are shown in Table 1 were implemented.

Table 1: Printing parameters implemented with the use of PrusaSlicer

Layer height [mm]	Fill angle [°]	Print speed [mm/s]	Extrusion temperature [°C]	Bed temperature [°C]
0,3	45	60	215	60

Figure 2: A 3D printed model of an orthosis

3. Results and Discussion

3D technologies enable an effective fabrication of individualized medical devices, in this case an orthosis. The 3D scanning procedure was an effective and most of all a fast process that lasted 12 seconds. Moreover, thanks to the process speed, a painless acquisition of anthropometric measurements can be acquired. Furthermore, 3D modelling process was in itself easy, since it didn't require a specialized knowledge. Application of 3D modelling enabled a completely individualized design. Finally, it took 9 hours and 30 minutes to make two parts, or 19 hours if one 3D printer was used. Since plaster casts require 72 hours to completely dry [6], the printing time is acceptable.

4. Conclusion

Medical devices, such as orthosis are an invaluable for successful treatment and medical procedures. Although conventional orthoses are still widely used, their flaws can be resolved with the use of new and advanced technologies. Therefore, with the use of 3D technologies, a fast and effective fabrication of individualized medical devices that surpass aforementioned flaws can be achieved.

Acknowledgements

Research/PhD thesis was made as a part of research project ABBAMEDICA IP- 2019-04-1381 project leader prof. Iva Rezić, PhD, PhD financed by Croatian Science Foundation. Many thanks to assoc. prof. Slavica Bogović, PhD for the help with the fabrication of a 3D object.

5. References

[1] Patel, S., D.; Statuta, M., D. & Ahmed, N.: Common Fractures of Radius and Ulna, *American Family Physician,* **103** (2021) 6, pp. 345-354, ISSN 15320650
[2] Mauck, B., M. & Swigler, C., W.: Evidence-Based Review of Distal Radius Fractures, *Orthopedic Clinics of North America*, **49** (2018) 2, pp. 211-222, ISSN 0030-5898
[3] Szostakowski, B.; Smitham, P. & Khan, W., S.: Plaster of Paris – Short History of Coatings and Injured Limb Immobilization, *Open Orhtopedic Journal*, **11** (2017) 1, pp. 291-296, ISSN 1874-3250
[4] Najafabadi, D., F.; Rezaie, M., R. & Forghany, S.: The Validity and Reliability of a low-cost handheld 3D Scanner for Use in Orthotics and Prosthetics, *Journal of Rehabilitation Sciences and Research*, **7** (2020) 1, pp. 8-14, ISSN 19961944
[5] Rezaie, F.; et. al.: 3D Printing of Dental Prostheses: Current and Emerging Applications, *Journal of Composite Sciences*, **7** (2023) 80, pp. 1-24, ISSN 23065354
[6] Ekanayake, C. et. al: Revolution in orthopedic immobilization materials: A comprehensive review, *Heilyon*, **9** (2023) 3, pp. 1-24, ISSN 24058440

Paula Marasović

Biography	Paula Marasović was born in 1994 in Šibenik and completed her master's degree in Textile Technology and Engineering under the study programme Textile Design and Management at the University of Zagreb. She was a student assistant in courses Nonwovens, Technical Textiles, and Spinning. In 2018, she enrolled doctoral study Textile Science and Technology. From 2018 to 2019, she worked as a production planner at Kelteks Ltd. She contributed articles on culture and sustainable fashion to web portals. Since 2020, she has been a Textile & Leather Review editorial board member. Since 2021, she is a doctoral student on the project "*Development of biodegradable nonwoven agrotextiles from natural and renewable sources*." She authored seven cited scientific papers in WOS and Scopus and presented 16 papers at international conferences.
Title of PhD thesis	Development of Biodegradable Nonwoven Agrotextiles from Natural and Renewable Sources
Mentor	assoc. prof. Dragana Kopitar, PhD
Date or dissertation defense	

DEGRADATION OF NONWOVEN TEXTILES MADE FROM POLYMERS FROM RENEWABLE SOURCES EXPOSED TO EXTERNAL INFLUENCES

Paula MARASOVIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, paula.marasovic@ttf.unizg.hr

Abstract: *Nowadays, it is imperative to have ecological production, including production, but also the use and disposal of products, and this trend is particularly pronounced in the field of agrotextiles. In this study, the biodegradation of nonwoven textiles used in mulching, produced from hemp, viscose and PLA fibres, and their exposure to weather conditions in the field for 180 days were investigated. Results show significant changes in viscose mulch, reduced braking force in hemp, and slow biodegradation in PLA, emphasizing the need for sustainable raw materials, due to the different effects of weather conditions on physical-mechanical properties.*

1. Introduction

Mulching is a common practice in agriculture and horticulture, where most agrotextiles and mulches are produced from artificial materials derived from petroleum. The use of artificial mulching materials over time leads to their decomposition and accumulation in the soil, which adversely affects crop growth [1,2]. Numerous studies point to significant environmental pollution, with a positive trend in demand for environmentally friendly alternatives. Research supports the superiority of nonwoven mulches made of natural fibres and biopolymers, which improve soil conditions, increase crop yields and have a positive impact on the environment [3]. The paper examines the decomposition time of non-woven mulching textiles, produced from natural and renewable materials (hemp fibres, viscose and PLA) with the same production parameters. All mulches made of non-woven material showed effectiveness in mulching, and the research determined the decomposition time. The produced nonwoven mulches are an environmentally acceptable alternative to conventional agricultural films produced from low-density polyethylene.

2. Experimental

All nonwovens were produced in Renotex Ltd. factory, by the mechanical process on card and bonded with the needle punching process, with the same production parameters and the nominal mass per unit area of 400 gm^{-2}. As the same production parameters were used, the measured mass per unit area of nonwoven textiles made of hemp fibres is 470 gm^{-2}, viscose 410 gm^{-2} and polylactic acid (PLA) fibres 360 gm^{-2}. Nonwoven agrotextiles measuring 1,5 m x 1,5 m were placed on the field randomly, in blocks of four replication plots. The field conditions to which the samples were subjected (air temperature, relative air humidity, and rainfall) were monitored during the entire experiment. The samples were periodically removed after 30, 90, and 180 days from the day of placing on the field. Mass per unit area (EN ISO 9073-1:2023), thickness (EN ISO 9073-2:2021) tensile properties (EN ISO 9073-3:2023) and air permeability (EN ISO 9073-15:2007) were examined according to the current standards. Part of the samples was left in the field, and the influence of firld conditions is still being monitored, since the tested properties did not decrease by 90 %, as stated by the current norms for biodegradation testing.

3. Results and discussion

A linear decrease in the mass per unit area and thickness of the nonwoven textile is visible depending on the exposure time. After 180 days of exposure, the mass per unit area of nonwoven textiles made of viscose (24 %) and hemp (13 %) fibres decreased, while the mass per unit area of nonwoven textiles made of PLA fibres remained unchanged. The thickness of viscose (46,7 %) and hemp (6,2 %) nonwovens also decreased, while the thickness of PLA fibre nonwovens remained unchanged. The breaking force of all nonwoven textiles increased significantly, in both directions of production (MD and CD) after 30 days of exposure. After 90 days of exposure, the breaking force of nonwoven textiles made of hemp and viscose fibres decreases, while the breaking force of nonwoven textiles made of PLA fibres continues to increase. The air permeability of the nonwoven textile increased after 30 days of exposure, after which a trend of decreasing values was recorded, which is attributed to the change in the dimensions of the nonwoven textile, i.e. its shrinkage and expansion (decrease/increase in the initial dimension of the mulch). The results indicate considerable weather resistance of nonwoven textiles made of PLA fibres.

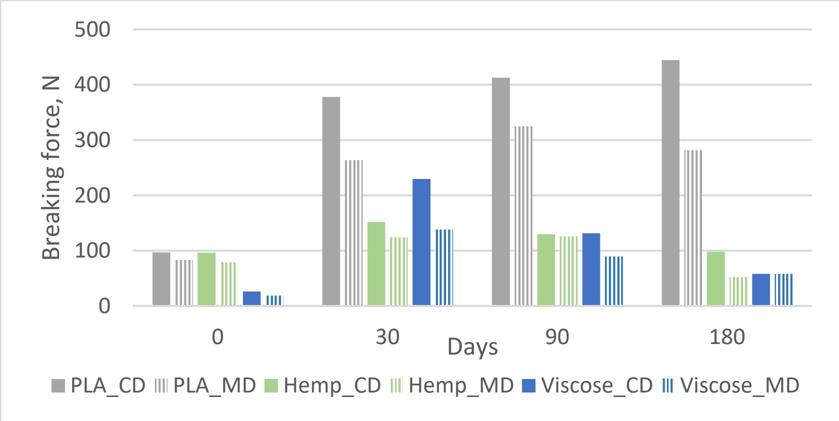


Figure 1. Change of nonwoven fabric breaking force in MD and CD during 180 days of exposing

4. Conclusion

The behaviour of nonwoven textiles produced from hemp, viscose and PLA fibres due to exposure to field conditions shows significant differences. After 180 days of exposure to field conditions, there is a visible difference in the reduction of mass per unit area and thickness of nonwoven textiles produced from viscose and hemp fibres. Nonwoven textiles made of PLA fibres show an increase in tensile properties compared to unexposed ones, which indicates a change in the structure of nonwoven textiles due to exposure to field conditions.

Acknowledgment

This research has been supported by the European Union from the European Structural and Investment Funds, the Operational programme Competitiveness and Cohesion, the European Regional Development Fund under the project KK.01.2.1.02.0270.

5. References

[1] Chen, Y., et.al. Microplastic pollution in vegetable farmlands of suburb Wuhan, central China, *Environmental Pollution*, **257** (2020), pp.113449, ISSN 1873-6424

[2] Weber, C.J. & Opp, C.: Spatial patterns of mesoplastics and coarse microplastics in floodplain soils as resulting from land use and fluvial processes, *Environmental Pollution*, **267** (2020), pp.115390, ISSN 1873-6424

[3] Liu, X., et.al. Development of natural fiber-based degradable nonwoven mulch from recyclable mill waste, *Waste Management*, **121** (2021), pp. 432–440, ISSN 0956-053X

Lela Martinaga

Biography	Lela Martinaga completed studies in Ecoengineering (Faculty of Chemical Engineering and Technology) and then enrolled doctoral study Textile Science and Technology at the University of Zagreb, Faculty of Textile Technology. From 2016. till 2022. she worked as a research assistant at the Department of Applied Chemistry of the same institution and studied biocatalytic processes of synthesis of metal nanoparticles and their application for the development of functional materials within the project of the Croatian Science Foundation. She has co-authored 11 scientific papers and 19 abstracts published in journals and conference proceedings, had four oral and ten poster presentations at conferences and was the immediate supervisor of five graduate and undergraduate thesis. She received a scholarship from the Republic of Austria for scientific training at the University of Natural Resources and Life Sciences (BOKU) in Vienna, Austria.
Title of PhD thesis	Enzymatic synthesis and characterization of metal and metal oxide nanoparticles and their application in improving functional properties of textile materials
Mentors	prof. Iva Rezić, PhD, PhD prof. Ana Vrsalović Presečki, PhD
Date or dissertation defense	

THE APPLICATION OF GLUCOSE DEHYDROGENASE IN THE SYNTHESIS OF GOLD NANOPARTICLES

Lela MARTINAGA

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, lela.pintaric@ttf.unizg.hr

Abstract: *The use of gold nanoparticles (Au-NPs) in the textile industry products can ensure many improvements in their antibacterial, UV protective, flame retardant and/or hydrophobic properties. In this research, synthesis of Au-NPs using oxidoreductive enzyme Glomerella cingulata glucose dehydrogenase (Gc GDH) as a bioreductant was conducted. The influence of reaction conditions on the synthesis of Au-NPs was studied and optimized, the reaction kinetics and the influence of gold (Au) ions on the reaction rate were determined. Results of the characterization of the synthesized Au-NPs using UV-Vis spectroscopy showed an average size of the NPs around 50 nm while the results of transmission electron microscopy (TEM) analysis showed that synthesized Au-NPs have a spherical shape and an average size of 2,83 nm and 6,63 nm after 24 h and 48 h of the reaction, respectively.*

1. Introduction

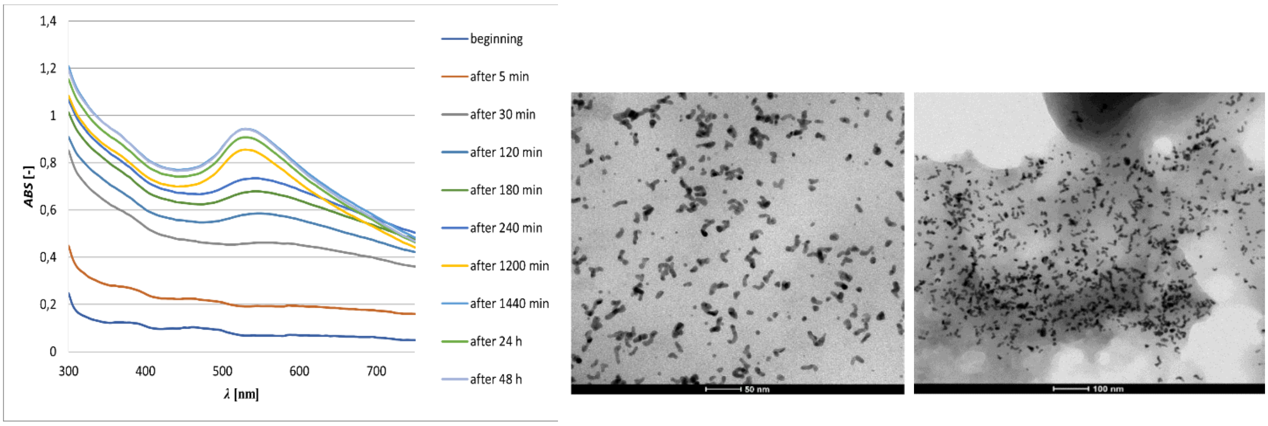
Green nanoparticle synthesis is a fast-developing branch of nanotechnology that uses environmentally friendly bioreductants such as agrowastes, plant extracts and enzymes for the synthesis of metallic NPs, ensuring an environmentally friendly, simple, cost-effective and relatively reproducible process [1]. Noble metal nanoparticles, whereas Au-NPs stand out can have unique physical, chemical, and biological properties that are highly dependent on their size and shape, that also determines their use in biomedicine, food, cosmetic and textile industry products, optical devices, biosensors, etc. [2]. In this research, an enzyme-mediated synthesis of Au-NPs by *Gc* GDH was investigated and optimised. The reaction kinetics was determined and mathematical model of the reaction was proposed. Synthesized Au-NPs were characterized using UV-Vis spectroscopy and transmission electrone microscopy (TEM).

2. Experimental

To determine the optimal reaction conditions for the enzymatic Au-NPs synthesis different concentrations of *Gc* GDH in a few reaction media with different pH values at various temperatures were tested. Enzymatic synthesis of Au-NPs was carried out by the addition of gold(III) chloride trihydrate ($HAuCl_4 \cdot 3\ H_2O$) in the glucose oxidation reaction catalysed by the *Gc* GDH in a batch reactor under the optimal reaction conditions: 0.1 M phosphate buffer pH 5,5, *Gc* GDH concentration 0,3 mg cm^{-3}, glucose concentration 1000 μM, $HAuCl_4 \cdot 3\ H_2O$ concentration 550 μM, 37 °C, without stirring, light and oxygen. Kinetics of the Gc GDH in the glucose oxidation was determined at the optimal reaction conditions using the initial reaction rate method by following the glucose concentration by high performance liquid chromatography (HPLC). Also, the impact of Au ions on the reaction rate was determined. Synthesized Au-NPs were characterized by recording spectras using UV-Vis spectrophotometer Multimode Plate Reader EnSpire (Perkin Elmer, USA) operating at a 5 nm resolution from 300-700 nm and using TEM analysis of samples resuspended in Milli-Q water placed on a carbon-coated copper grid and dried at room temperature on a FEI Tecnai G^2 Spirit instrument (Thermofisher Scientific, The Netherlands) operated at 160 kV.

3. Results and discussion

Results of the UV-Vis measurements tracked during 48 h of the reaction showed maximal absorbances at 525 – 530 nm after 24 h of the reaction indicating an average size of synthesized Au-NPs around 50 nm (Figure 1a) [3]. Enzyme kinetics in the above mentioned reaction was measured and described by single.substrate Michaelis-Menten kinetics. Impact of the Au ions on the reaction kinetics was also investigated and the significant influence of the Au ions on the reaction rate was found and described by the single-substrate Michaelis-Menten kinetics with competitive product inhibition. Based on kinetics measurements and control experiments that were carried out, it was concluded that synthesis of Au-NPs occurs due to the reduction of Au ions by glucose and amino acids integrated in the *Gc* GDH in synergy. According to the TEM analysis, synthesized Au-NPs have a spherical shape with and average size of 2,83 ± 2,40 nm after 24 h (Figure 1b) and 6,63 ± 3,03 nm after 48 h (Figure 1c) of the reaction, respectively, indicating that the particles agglomerated over time.



a b c

Figure 1: Results of the Au-NPs characterization: a) UV-Vis spectrum during 48 h of the synthesis; b) TEM image of Au-NPs synthesis after 24 h; c) TEM image of Au-NPs synthesis after 48 h

4. Conclusion

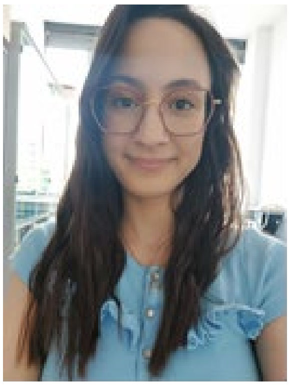
Based on the results of the reaction kinetics and mathematical model, reaction mechanism of the Au-NPs synthesis using *Gc* GDH was proposed and validated. Successful synthesis of Au-NPs was confirmed spectrophotometrically (maximum absorbances at 525 – 530 nm) and by TEM analysis (2,83 nm after 24 h, and 6,63 nm after 48 h of the reaction).

Acknowledgment

This research was supported by the Croatian Science Foundation projects (project manager prof. Iva Rezić, PhD, PhD) - "Young researchers' career development project - Training new doctoral students" (DOK-10-2015) and "Antibacterial coating for biodegradable medicine materials - ABBAMEDICA" (IP-2019-04-1381), and by the Scholarship of the Scholarship Foundation of the Republic of Austria (Undergraduates, Graduates, Postgraduates) awarded by the Austrian Agency for International Cooperation in Education and Research (cooperation prof. Iva Rezić, PhD, PhD and assist. prof. Roland Ludwig, PhD).

5. References

[1] Adelere, I. A.; Lateef, A.: A novel approach to the green synthesis of metallic nanoparticles: the use of agro-wastes, enzymes, and pigments, *Nanotechnology Reviews*, **5** (2016), pp. 567-587, ISSN 2191-9089
[2] Ahmed, S. et al.: Biosynthesis of gold nanoparticles: a green approach, *Journal of Photochemistry and Photobiology B: Biology*, **161** (2016), pp. 141-153, ISSN 1011-1344
[3] Zuber, A. et al.: Detection of gold nanoparticles with different sizes using absorption and fluorescence based method, *Sensors and Actuators B-Chemical*, **227** (2016), pp. 117-127, ISSN 0925-4005



Petra Mihovilović

Biography

Petra Mihovilović was born in Split in 1997. In 2019, she completed her undergraduate studies in Chemistry at the Department of Chemistry at the University of Zagreb Faculty of Science. She graduated from the same faculty in 2021 with a major in research-oriented chemistry (fields: analytical chemistry and biochemistry). In 2021, received the Medal of the Department of Chemistry for her outstanding academic success. In 2022, she is employed as an assistant at the Department of Applied Chemistry at the University of Zagreb Faculty of Textile Technology. In the same year, he enrolled doctoral study Textile Science and Technology. Her scientific interest is in materials engineering and the development of sustainable and environmentally friendly technologies for wastewater treatment with a special focus on the removal of microplastic particles released from textiles. In 2023 she collaborates on project IP-2020-02-7575 „*Assessment of microplastic shedding from polyester textiles in washing process*- InWashed-MP" funded by the Croatian Science foundation, led by prof. Tanja Pušić, PhD

Title of PhD thesis

Study advisor

prof. Branka Vojnović, PhD

Date or dissertation defense

DEVELOPMENT OF A SAMPLE PREPARATION METHOD FOR THE ANALYSIS OF MICROPLASTIC PARTICLES IN WASTEWATER FROM THE WASHING OF TEXTILES

Petra MIHOVILOVIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, petra.mihovilovic@ttf.unizg.hr

Abstract: *Microplastic pollution can be found in almost all ecosystems, which is why it is recognized as one of the most important environmental problems of our time. Textiles of synthetic origin are one of the main sources of microplastic (MP) particles, and MP particles have been shown to serve as a potential vector for the transfer of various adsorbed pollutants and pathogens. The diversity of emission sources and the complexity of the physio-chemical and biological properties of plastic material is reflected in the difficult, reproducible isolation and analysis of MP. Moreover, the ubiquitous distribution leads to numerous challenges in the control of background contamination. The PhD thesis will aim to develop and optimize a method for minimizing the matrix effect in laundry wastewater systems, followed by research on microplastic particles as a vector for contaminant transfer.*

1. Introduction

The continuous increase in production, unsustainable use and improper disposal of plastics has led to the emergence of a new type of pollutant known as microplastics. The term microplastic is used for smaller plastic fragments and refers to a particulate substance with dimensions smaller than 5 mm [1]. Environmental pollution caused by microplastics is an ecological problem for several reasons. Plastic materials with a complex chemical structure are less susceptible to degradation, and at the same time, under the influence of atmospheric conditions (solar radiation, water temperature and abrasion processes), fragmentation of plastic materials and leaching of potentially toxic additives into the aquatic environment occurs [2]. Fragmented particles with a larger specific surface area are a good adsorbent for various types of pollutants (dyes, heavy metals, pathogenic organisms), which eventually enter the food chain via aquatic organisms [3].

A large proportion of the microplastic particles present in the environment are in the form of fibre fragments, which are mainly released during the machine washing of textiles. The laundry effluents are then discharged into wastewater treatment plants [4]. The tendency to release these particles depends on the properties of textile materials (texture and type of fabric, yarn and fibres) as well as on factors of the Sinner's circle in the washing process (use of detergent, washing temperature, duration of the process and mechanical agitation) [5]. As wastewater treatment plants are not fully adapted to the removal of MP particles, they represent the main entry point for particulate matter of synthetic origin into the aquatic environment.

One of the main topics of this doctoral thesis involves the methodology of sampling, isolation and characterization of microplastic particles. Numerous studies provide information on the amount of MP particles detected, but the applied methods of sampling, isolation, purification and identification of MPs vary widely, making a comprehensive interpretation and comparison of different studies results impossible. An additional complication in developing a standardized method for MPs monitoring is the wide range of concentrations, very diverse shapes (spherical shapes, irregular particles, fibres, films, foams), chemical composition (including conventional and biopolymers) and the degree of aging of the textile material. The particles can also contain various additives in their structure (antioxidants, light stabilizers, plasticizers, flame retardants, pigments, etc.) and adsorbed pollutants (persistent organic pollutants, antibiotics, metals, etc.) [6].

2. Experimental

The choice of the appropriate analytical technique for the isolation of MP particles depends primarily on the chosen methods for identification, characterization and quantification of the particles, but also on the complexity of the sample matrix. Considering the complexity of the laundry effluent matrix (high content of suspended solids and organic matter), a combination of several separation and extraction techniques is required. Density separation will be used to isolate microplastic particles from the matrix of laundry wastewater samples that contain a high proportion of suspended solids. For this purpose, solutions of different salts (NaCl, NaBr, NaI, ZnCl2, ZnBr2, etc.) will be used, which differ from each other in terms of solubility, density, toxicity and price. The density separation technique is ineffective for the removal of organic species from detergent suspensions (surfactants, builders, enzymes, etc.). Various reagents (e.g. acids, bases, oxidizing agents, etc.) and advanced extraction technologies (oil extraction protocol, microwave extraction, etc.) can be used to remove the organic matrix. As part of the optimization of the method for isolating microplastic particles, it will be examined whether the reagents used have a detrimental effect on the polymer particles (the particles must remain unchanged in terms of weight, volume, shape and colour). These effects will be determined by physical characterization of the isolated particles (digital microscope, SEM-EDX, etc.), which includes the determination of particle size, colour, shape and morphology. Chemical characterization by chromatographic and spectroscopic methods (pyro-GC/MS, FTIR, etc.) provides additional information about the change in the characteristic groups of the selected polymer material.

3. Results and discussion

In addition to analytical parameters such as accuracy, precision and selectivity in choosing the optimal methodology for sampling, processing and analysis of MPs, practical aspects such as time and cost of analysis, simplicity of the analytical technique and environmental impact of the chosen technique will be considered. Taking into account all possible sample preparation methods, preference will be given to a reagent that is compatible with the composition of the matrix, under the condition that the particles must remain unchanged in terms of weight, volume, shape and colour after treatment.

4. Conclusion

Environmental pollution by microplastics is one of the most important environmental issues today. This PhD thesis will contribute to the development of a consensus on sampling, sample preparation and analysis for the determination of MP in laundry wastewater systems, but also on the vector properties of the released particles. The choice of an individual pre-treatment method regarding the type of collected sample will influence the quality of the experimental data obtained. Only in this way it is possible to comprehensively compare the results of different research groups, to interpret the sources of these types of pollutants, their effects on living organisms, but also their future prevention.

Acknowledgment

HrZZ Croatian Science Foundation

This work has been supported by Croatian Science Foundation under the IP-2020-02-7575 „Assessment of microplastic shedding from polyester textiles in washing process“ InWaShed-MP, led by prof. Tanja Pušić, PhD.

5. References

[1] Zhang, C., Zhang, D.: Microplastics. U *Encyclopedia of Ocean Engineering*. Springer, ISBN 978-981-10-6963-5, Singapore, (2021)

[2] Liu, L. et al.: On the degradation of (micro) plastics: degradation methods, influencing factors, environmental impacts, *Science of the Total Environment*, **806** (2022) 151312

[3] Prata, J.C. et al.: Environmental exposure to microplastics: An overview on possible human health effects, *The Science of the total environment*, **702** (2020) 134455

[4] Bayo, J.; Olmos, S. & López-Castellanos, J.: Microplastics in an urban wastewater treatment plant: The influence of physicochemical parameters and environmental factors, *Chemosphere*, **238** (2020) 124593, ISSN 0045-6535

[5] Periyasamy, A. P. & Tehrani-Bagha, A.: A review on microplastic emission from textile materials and its reduction techniques, *Polymer Degradation and Stability*, **199** (2022) 109901, ISSN 0141-3910

[6] Ivleva, N. P.: Chemical Analysis of Microplastics and Nanoplastics: Challenges: Advanced Methods, and Perspectives, *Chemical Reviews*, **121** (2021) 19, pp. 11886- 11936

Marija Nakić

Biography	She was born in Široki Brijeg, where she completed primary and secondary school. She graduated from the University of Zagreb, Faculty of Textile Technology, specialising in textile and clothing design, and obtained a master's degree with a thesis on "Croatian ethno heritage in the Rama region". She is currently pursuing doctoral study Textile Science and Technology. She has worked as an interior designer in several companies in Herzegovina. She currently works in the International Relations Office at the University of Mostar.
Title of PhD thesis	Influence of the type of embedded materials and construction of clothing composites on the overall thermal properties of clothing
Mentors	assoc. prof. Željko Knezić, PhD assis. prof. Daniel Vasić, PhD
Date or dissertation defense	

DESIGN OF THE DUBROVNIK ŠUDAR REPLICA AND PERMANENT STORAGE OF ITS TECHNICAL FEATURES

Marija NAKIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, mnakic@ttf.hr

Abstract: *The research covers Croatian textile heritage through a detailed analysis of technical features of the female kerchief from the Kaštel region – the Dubrovnik šudar, as part of heavy, bourgeois and noble costumes, preserved in the museums of the Croatian coast. On the basis of the overall results of the research, a replica of the Dubrovnik šudar will be realized and a map will be created as a contribution to the preservation of textile heritage in Croatia. Digitization and permanent storage of the obtained research results will enable public access and familiarization with the Dubrovnik šudar as a valuable museum piece of textile heritage.*

1. Introduction

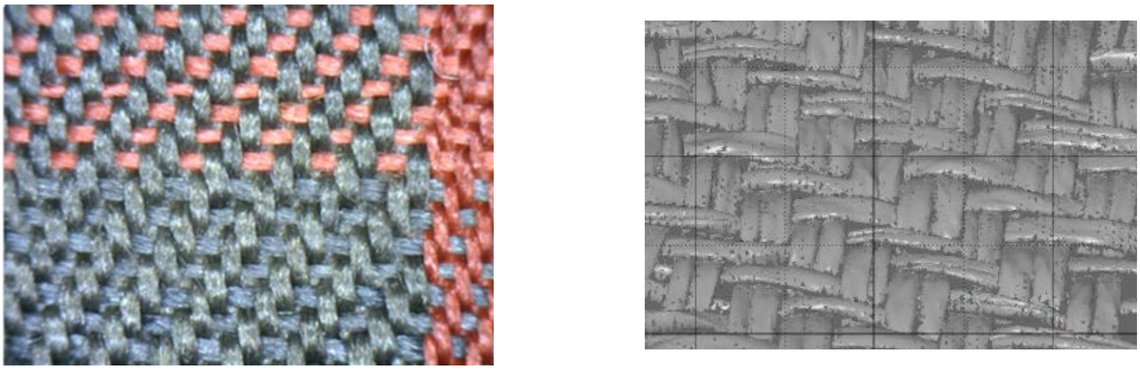
In the culture of women's attire on the Croatian coast, scarves played a significant role. As head coverings appear the following terms such as *rubac šudar, bevelaš, Dubrovnik šudar* and *blonda* [1]. Croatian handicraft distinguishes the production of everyday clothing made from coarser yarn and festive clothing made from very fine silk threads [2]. It is presumed that the scarves were called Dubrovnik *šudar* because of similarly woven scarves called *dumanjski ubručići*, which already existed in Dubrovnik, where the manufacturing of silk persisted for the longest time [3]. Recent research, in addition to digitization, brings new procedures for 3D virtual simulation of textile artifacts [4].

2. Experimental part

In this extended summary, the results of the surface analysis using the Dino-Lite Pro AM413T digital microscope and 3D scanning simulation are presented. Following the thorough analysis, the phase of crafting a replica of the Dubrovnik šudar ensued through decomposition and preparatory phases for weaving. A horizontal loom with four pedals, owned by the Museum of the town of Kaštela was restored for the purpose of weaving the replica. The preparatory phases and weaving took place both in the external and internal spaces of the museum to ensure that the replica-making process closely resembled the conditions of the original creation.

3. Results and discussion

Image 1 depicts a surface capture using a digital microscope and a 3D scanner simulation, showcasing the intertwining of the warp and weft. In the first snapshot, the harmony of the weave and colors is also visibly apparent.



a b

Figure 1: Sample images: a. digital microscope; b. 3D scanner simulation

Image 2 illustrates various phases necessary for creating a replica of the *Dubrovnik šudar* according to the concept of this doctoral thesis.

a b c

Figure 2: Making a replica of Dubrovnik šudar: a. sample; b. warping the foundation; c. equalizing tension before weaving

Through decomposition, the twill weave pattern was determined, as shown in Fig. 2a. In Fig. 2b, the warping of the warp is depicted, while in Fig. 2c, the equalization of the warp tension is shown before the start of weaving. The process of warping on horizontal looms requires consistent tension in the warp yarns, which is challenging to achieve for individuals without prior experience in such tasks. During the warping process, it is essential to ensure the formation of a proper cross of yarns, which is crucial for the arrangement of the warp. A complicating factor in the process itself was the warping of the green warp, due to its fineness being twice as great as that of the red yarn, required additional attention and effort. The yarn itself was not well-twisted, so during the warping process, it often happened that the green thread tangled and broke, further slowing down the entire procedure. The introduction of the warp into the reed was particularly challenging for the green warp yarn, as it frequently resulted in tangled yarns that had to be cut and spliced anew to pass through the reed. Equalizing the tension of the warp yarns before the weaving phase requires checking the yarns tension multiple times by gently running the outer part of the palm along the surface of the warp yarns. Subsequently, any loosened yarns are retightened, and, finally, tied into a loop. In the case of slackness in the yarns during the initial weaving phase, the loop can be untied again to ensure uniform tension.

4. Conclusions

Research focused on establishing new criteria for the preservation of textile heritage using modern technologies directly contributes to the scientific approach to preserving the historical textiles of the Croatian Coast. Evaluating textile heritage through the introduction of new methods and tools will enable the interactive transmission and nurturing of traditional knowledge, skills, and crafts to future generations in a contemporary manner.

Acknowledgement

The City Museum of Kaštela in Kaštel Lukšić, the Ethnographic Museum in Split, and the Textile Technology Faculty at the University of Zagreb, thank you for your assistance in the analysis of the samples.

5. References

[1] Ivančić, S., Acalija, S.: *Povismo i sukno: kaštelansko tradicijsko ruho*, Etnografski muzej Split & Muzej grada Kaštela, ISBN 978-953-6866-36-6 & 978-953-7276-37-9, Split (2015), str. 68-72

[2] Firšt Rogale, S.; Rogale, D. & Knezić, Ž.: Povijest izrade i proizvodnje odjeće u Hrvatskoj, In: *Godišnjak 2019 Hrvatske akademije tehničkih znanosti – Hrvatska tehnička i industrijska baština*, Akademija tehničkih znanosti Hrvatske, ISSN 1332-3482, Zagreb (2020), str.145-160

[3] Vojnović Traživuk, B.: Tekstilno rukotvorstvo u Dalmaciji, *Ethnologica Dalmatica*, **28** (2021), str. 19-49, ISSN 0353-9210

[4] Portalés, C. et al.: Interactive Tools for the Preservation, Dissemination and Study of Silk Heritage—An Introduction to the SILKNOW Project, *Multimodal Technologies and Interaction*, **2** (2018) 2, pp. 1-28, ISSN 2414-4088

Eanamul Haque Nizam

Biography	Eanamul Haque Nizam is currently employed as an assistant professor at Southeast University (Tejgaon, Dhaka, Bangladesh). He defended 2 master's degrees, receiving master's degree in fashion design and textile engineering at Wuhan Textile University (Hubei, Wuhan, China). His research interests include clothing size charts development, body morphology, new product development and fashion implementation in the textile sector. He has more than 13 years of teaching experience and one year of direct work experience in the industrial sector, and published more than 55 scientific and professional articles in magazines and two scientific books.
Title of PhD thesis	
Study advisors	prof. emer. Darko Ujević, PhD prof. Ayub Nabi Khan, PhD
Date or dissertation defense	

ANALYSIS OF ANTHROPOMETRIC DATA AND CLOTHING SIZE CHARTS DEVELOPMENT FOR THE MALE POPULATION IN BANGLADESH AGING FROM 21 TO 25 YEARS

Eanamul Haque NIZAM

Department of Textile Engineering, Southeast University, Tejgaon, and Dhaka, Bangladesh, eanamul.nizam@seu.edu.bd

Abstract: *The main aim of this doctoral thesis is size chart develpment for the Bangladeshi men's clothing market. In this study, a quantitative system was applied to conduct the research. The research was carried out on a sample of 459 male students aged between 20 and 25 years. The aforementioned group of students was measured for 25 key anthropometric points according to the ISO 3635, ISO 8559 and ISO 9407 standards in order to obtain the data necessary for the creation of an anthropometric system of clothing sizes. The obtained data were statistically processed according to the one-way ANOVA test ($F_{5,144}=0.0739$, $p\leq0.05$), Tukey's multiple comparison test (greater than 0.05) and the Shapiro-Wilk normality test (significance value of all data of the Shapiro-Wilk of the test is greater than 0.05 ($W\geq0.05$)) Research results support the development of clothing size chart. The analysis of the Pearson correlation coefficient shows that the measurements of students at the age of 20 are not significant for creating a clothing size chart in accordance with ISO and EN norms. Therefore, according to the obtained results, clothing size chart were made for the age groups from 21 to 25 years for the male population of Bangladesh. Research has shown that body height is important for the division into size body classes, and a division was made for each age into three classes (S, M and L) in order to obtain appropriate clothing size charts for clothing production.*

1. Introductions

Anthropometry is a research method of anthropology dealing with the human body dimension identification and verification in order to quantitatively characterizing the morphological (morphological anthropometry) and physiological (physiological anthropometry) features of the human body, which differ for different populations [1]. Anthropometry examines how these measurements change depending on factors such as age, race, gender, and nationality. Anthropometric data and formulas are used in medical and forensic research [2]. Therefore, it can be said that anthropometry is one of the key fields in science that provides information about the health status of the population. Although it is not always possible for the product and the user to match perfectly, the incorporation of anthropometric data into ergonomic design ensures a safe and simple relationship between the product and the user, which contributes to high work efficiency and productivity. Developed countries have been conducting anthropometric measurements for decades [3]. However, the anthropometric data for the male population of Bangladesh has not been determined so far. Bangladesh population has about 160 million people, making it the eighth most populous nation in the world [4]. The age span of 21 to 25 years is considered as the youth population and about 43 % of the population belongs to this age group in Bangladesh. The research of the doctoral thesis is based on the selection of the male population of students in the age span of 21 to 25 years, for which the clothing size chart was created necessary for the clothing production on the basis of 25 anthropometric dimensions taken.

2. Experimental

Sample: Students aged 20-25 (n=459) were selected for anthropometric measurements. Due to financial constraints, it was not possible to measure a larger number of students.
Body measurements: 25 anthropometric dimensions were measured on the subjects, which are necessary for creating a system of clothing sizes for clothing production. The International Organization for Standardization (ISO) issued a series of standards at the end of the 70s in the last century as a recommendation, which form the basis for uniform clothing labelling system for the whole world. Later, with the publication of the ISO 3635, ISO 8559 and ISO 9407 standards, the foundations were laid for defining the human body dimensions to serve as basis for the clothing industry as well as for the anthropometric measurements implementation.
Analysis of anthropometric data: The software Minitab 17.1 Statistical Package for Windows was used to analyse the study data after the anthropometric survey. The normality test was used to determine whether the collected data fit a normal distribution. The data for each measurement had a normal distribution, as expected. ANOVA analysis was then used to determine differences between different age (21-25 years). Relationships between different body dimensions were examined using Pearson's correlation coefficients. The system of clothing sizes was developed based on the obtained results [5].

3. Results and Discussion

The measured anthropometric data were used as the basis for the descriptive analysis, which showed that the mean values of body height for the male population of students ranging from 20 to 25 years are as follows: 169,81; 168,06; 168,47; 170,59; 168,93 and 165,55 and all measurements follow a normal distribution. Average and standard deviation, variance (CV%) and squared values were also calculated. Most of the anthropometric measurements showed high standard deviation (SD), which points to high variability of results and necessity to perform a t-test. The significance value greater than 0.05 according to Shapiro-Wilk normality test, referred to the normal distribution, while the significance value less than 0.05, point to results significantly deviating from the normal distribution. Linear regression analysis was also used to process the obtained data, where relationships between an unknown or dependent variable and a known or independent variable are obtained using a linear equation for quantitative modelling. Results obtained by those statistical methods were used to create new clothing size charts.

4. Conclusions

The research of the doctoral thesis is based on the selection of the 25 anthropometric dimensions measured in the male population of 459 students, with the age span ranging from 21 to 25 years, and afterwards the clothing size chart was created as basis for the clothing production. The obtained anthropometric data were statistically processed using software Minitab 17.1 Statistical Package for Windows, ANOVA test, Tukey's multiple comparison test and Shapiro-Wilk's normality test and divided into three classes (S, M, L). The resulting clothing size charts are the basis for the production male clothing ranging from 21 to 25 years in Bangladesh.

5. References

[1] Ujević, D., et al.: Hrvatski antropometrijski sustav, Tekstilno-tehnološki fakultet Sveučilišta u Zagrebu, Zagreb, (2006), str. 224

[2] *Body Measurements (Anthropometry), National health and nutrition examination survey III*, Westat, Inc. 1650 Research Boulevard Rockville, MD 20850, October 1988, *Acessed:* https://wwwn.cdc.gov/nchs/data/nhanes3/manuals/anthro.pdf

[3] Abeysekera, J. D., & Shahnavaz, H. Body size variability between people in developed and developing countries and its impact on the use of imported goods. *International Journal of Industrial Ergonomics*, **4** (1989) 2, pp. 139-149

[4] *Division of Bangladesh*, *Available at*: https://en.wikipedia.org/wiki/Divisions_of_Bangladesh, Acessed: 2023

[5] Ujević, D., Rogale, D., Hrastinski: *Tehnike konstruiranja i modeliranja odjeće*, Tekstilno-tehnološki fakultet, (2000)

Željka Pavlović

Biography

Željka Pavlović was born in 1987, in Zabok. After completing primary school in Samobor, she enrolled in the School of Economics, Trade, and Hospitality, graduating in 2005. From 2005 to 2012, she studied at the University of Zagreb Faculty of Textile Technology, where she graduated with a thesis on "Performance Properties of Short Socks," supervised by Prof. Zlatko Vrljičak. She worked at the Jadran Hosiery Factory for 3.5 years as a technologist. In 2015, she became an assistant at the University of Zagreb Faculty of Textile Technology, at the Department of Textile Design and Management. In 2016, she enrolled doctoral study Textile Science and Technology at the Faculty of Textile Technology. Her areas of special interest include sock design and production, as well as the analysis of the operation of knitting machines.

Title of PhD thesis

Thermophysiological properties of knitted fabrics as a function of the knitting process and structure

Mentor

prof. Vesna Marija Potočić Matković, PhD

Date or dissertation defense

ANALYSIS OF STRUCTURAL PARAMETERS OF KNITTED FABRICS

Željka PAVLOVIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, zeljka.pavlovic@ttf.unizg.hr

Abstract: *The knitting process and fabric structure significantly influence the properties of textiles, playing a crucial role in their comfort and performance. The importance of studying structural characteristics is emphasized. The knitting process and fabric structure are key factors in shaping thermal insulation, breathability, and the ability to maintain an optimal temperature in contact with the body. Through careful adjustment of these elements, innovations in the textile industry are achieved, creating materials that provide optimal thermal comfort in various conditions.*

1. Introduction

The focus of this research is the analysis of the key parameters of textile samples and their key role in achieving the comfort of textile materials [1]. Structural parameters such as horizontal and vertical density, yarn consumption in a loop, thickness and area and volume mass significantly influence the quality of textile materials [2]. By analysing these parameters, not only their mutual correlations are explored, but also a deeper understanding of their role in the creation of comfortable textile products. The comfort of clothing, often evaluated by the subjective impression of the wearer, has a strong connection with the physical characteristics of textiles [3]. Horizontal and vertical density can affect the breathability and flexibility of the knit, while the thickness of the knit can play a key role in thermal insulation [4]. The yarn consumption in a loop can influence the breathability of the material, while the surface and volumetric mass reflect the density and volume of the knit [5]. The study of these parameters therefore becomes a fundamental step towards the optimization of textile materials in order to achieve optimal comfort [6]. Through the analysis, mutual relationships are not only identified, but also the importance of each individual parameter is confirmed in the context of creating textiles that meet high standards of comfort, thereby improving the overall user experience.

2. Experimental

Circular double-needle knitting machine with a gauge of E17 was used for sample production. The working methodology encompasses an in-depth analysis of knitted fabric structural parameters to better comprehend their characteristics. The samples are weft, double-jersey, made with single yarns of fineness 20 tex. Yarns produced through various spinning technologies, including ring, rotor, air-jet, and SIRO, were utilized, incorporating different fibres such as cotton, viscose, lyocell, modal, micromodal and polyester. In the finishing process, the fabrics were washed at a temperature of 110 ºC with 0,05 % NaOH for 110 minutes. After washing, the fabrics underwent dyeing and were subsequently dried at 120 ºC, with a material passage speed of 0,15 m/s through the dryer. The analysis includes key elements such as horizontal and vertical density, yarn consumption in the loop, fabric thickness, surface and volumetric mass. This approach provides a thorough examination of the structural characteristics of the fabrics, identifying their interrelationships, thus laying the foundation for a detailed understanding of the correlation analysis results presented below.

3. Results and Discussion

Understanding the correlation relationships between structural parameters is crucial for a better understanding of the fabric's structural characteristics and their impact on the material's ultimate performance. The results of the correlation analysis of horizontal density, vertical density, yarn consumption in the loop, fabric thickness, surface and volumetric mass are presented. In Tables 1 and 2, the correlation connection of the examined parameters is displayed. The correlation between fabric thickness and density clearly demonstrates a strong connection, with correlation coefficients ranging between 0,79 and 0,90. Changes in fabric thickness closely follow variations in density, emphasized by the association with vertical density. On the other hand, the correlation of fabric surface mass with other examined parameters varies. A less pronounced connection is observed with yarn consumption at -0,32, indicating an inverse relationship where an increase in yarn consumption results in a decrease in fabric surface mass. Additionally, a moderate correlation is noted between fabric surface mass and thickness. This information suggests a certain proportionality between fabric thickness and surface mass, although not as pronounced as in the case of thickness and density.

Table 1: Correlation relationship between structural parameters of raw knitted fabric samples

	Horizontal density	Vertical density	Yarn consumptio n	Thickness	Surface mass	Volumetri c mass
Horizontal density	1					
Vertical density	0,622271	1				
Yarn consumption	0,075104	-0,5108	1			
Thickness	0,904658	0,790334	0,021117	1		
Surface mass	0,545635	0,762054	-0,32587	0,675223	1	
Volumetric mass	-0,32403	0,052977	-0,46435	-0,29496	0,500809	1

Table 2: Correlation relationship between structural parameters of finished knitted fabric samples

	Horizontal density	Vertical density	Yarn consumptio n	Thickness	Surface mass	Volumetri c mass
Horizontal density	1					
Vertical density	0,712179	1				
Yarn consumption	0,118394	0,023309	1			
Thickness	0,928206	0,854205	0,199231	1		
Surface mass	0,896468	0,869061	0,175782	0,949657	1	
Volumetric mass	-0,81935	-0,77165	-0,30072	-0,94374	-0,84162	1

Significantly higher correlations among parameters were observed in finished fabrics compared to raw ones. Extremely high correlation values, ranging from 0,85 to 0,92, stand out between the thickness of finished fabric and density, indicating a very strong connection between these parameters. Additionally, the most pronounced connections were noticed between the thickness of finished fabric and surface mass, with a remarkable correlation coefficient of 0,94.

4. Conclusion

From the given data, it can be concluded that there is a significant correlation among the examined parameters, both in the case of raw and finished fabrics. Specifically, thickness and density exhibit a strong connection (ranging from 0,79 to 0,90) in raw fabrics. Moreover, a robust correlation is observed between the thickness of finished fabric and density (0,85 to 0,92), as well as between thickness and surface mass of the fabric (0,94). On the other hand, less pronounced connections are noticed between surface mass and other parameters.

5. References

[1] Li, L.: The science of clothing comfort, *Textile Progress*, **31** (2001), 1–2, pp. 1–135, ISSN 1754-2278
[2] Vrljičak, Z.: *Pletiva*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 9789537105792, Zagreb, (2019)
[3] Oglakcioglu, N. et al.: Thermal comfort properties of some knitted structures, *Fibres and Textiles in Eastern Europe*, **15** (2007) 5-6, pp. 94–96, ISSN 1230-3666
[4] Stanković, S. B. et al.: Thermal properties of textile fabrics made of natural and regenerated cellulose fibers, *Polymer Testing*, **27** (2008) 1, pp. 41-48, ISSN 1873-2348
[5] Ogulata, R.T. et al.: Investigation of porosity and air permeability values of plain knitted fabrics, *Fibres and Textiles in Eastern Europe*, 82 (2010), 5, pp. 71–75, ISSN 1230-3666
[6] Fabbri, K.: *Indoor Thermal Comfort Perception*, Springer International Publishing, ISBN 978-3-319-18651-1, Švicarska, (2015)

Marijana Pavunc Samaržija

Biography

Marijana Pavunc Samaržija in 2012 completed graduate studies Textile Technology and Engineering (sections Textile Chemistry, Materials and Ecology) at the University of Zagreb Faculty of Textile Technology. Since 2013 till 2020 she was working at the University of Zagreb Faculty of Textile Technology (Department of Materials, Fibres and Textile Testing) as an assistant and from 2021 she was employed as a lecturer. From the beginning of her scientific work, her research interests are directed to textile fibres, fibre reinforced composites, recycling of textile materials, conservation, and restoration of textiles.

Title of PhD thesis

Study advisor

prof. Edita Vujasinović, PhD

Date or dissertation defense

LIFE CYCLE ASSESSMENT OF FIBRE REINFORCED COMPOSITES – CHEMICAL REYCYLING OF BIOCOMPOSITES

Marijana PAVUNC SAMARŽIJA

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, marijana.pavunc@ttf.unizg.hr

Abstract: *In a world, where environmental protection awareness is rapidly increasing, it is crucial to focus on waste reduction through recycling and reusing recycled materials, but this can be challenging, especially when it comes to composite materials. The challenge arises from the heterogeneous nature of composite materials and that the obtained recycled components often have a lower quality. In this paper, the possibility of chemical recycling of biocomposites with an emphasis on green chemistry was investigated.*

1. Introduction

Contemporary composite materials have become crucial in many industries such as automotive, aerospace, construction, and others due to their unique properties. However, their rapid development, which began at the beginning of the 21st century, brought with it a number of challenges, particularly from an ecological standpoint. One of these challenges relates to their disposal, since they are mostly heterogeneous materials primarily made from synthetic polymers and highly resistant to various environmental impacts. In the context of growing environmental issues such as global warming, ozone layer depletion, water and air pollution, excessive utilization of non-renewable resources, and various problems related to waste disposal, the governments of many countries have begun to adopt increasingly strict legal regulations relating to environmental protection. Current and future legislation on waste management and environmental protection requires from industry to ensure that all engineering materials used in the construction of products such as cars, aircraft, wind turbines, etc., are recyclable and/or properly disposed at the end of their life cycle [1, 2]. Therefore, in recent years, scientists and engineers have increasingly focused on finding environmentally friendlier and/or biodegradable materials suitable for composite manufacturing, while at the same time these materials will have equal or superior properties as traditional petroleum-based materials without harmful impact on the environmental. Thus, biocomposites, i.e. composites based on biodegradable polymers reinforced with natural fibres, primarily plant-based, such as flax, hemp, jute, sisal, etc., are receiving increasing attention [3]. Biocomposites are often described as environmentally friendly materials capable of biodegradation at the end of their life cycle (e.g., through composting). However, although composting is an important aspect of sustainability, the latest trends focus on preservation of raw materials, i.e. their recyclability and their potential use in new products, which contributes to the waste reduction and the promotion of a circular economy [4].

2. Experimental

The possible ways of composite recycling are mechanical, thermal, chemical, and biological, whereby chemical recycling is often classified as the process that might be capable of fully recovering fibrous raw material in its original form for reuse in a new product. This paper deals with possible methods for chemical recycling of randomly oriented Spanish broom fibres (fibres length: 2 to 5 mm) reinforced polylactic acid (PLA). Chemical recycling of these biocomposites was performed using distilled water (hydrolysis), acetone, ethanol, and dichloromethane (solvolysis) as solvents for the matrix, which at the same time have no effect on the fibre, enabling the separation of individual components of this heterogeneous composite system.

3. Results and Discussion

Figure 1 shows fibres separated after removing the matrix with the used solvents. Although the fibres retain their basic morphological characteristics (length, thickness, surface etc.), considering the life cycle analysis of Spanish broom fibres reinforced composite, a need to analyse the economic viability and cost-effectiveness of particular solvent used in this research was raised:

- Dichloromethane (CAS number 75-09-2) - highly volatile organic solvent; requires special facilities; potentially negative impact on humans and environment,
- Acetone (CAS number 67-64-1) - highly volatile organic solvent; flammable; requires special facilities; potentially negative impact on humans and the environment,

- Ethanol (CAS number 64-17-5) - volatile organic solvent; flammable; requires special facilities and additional thermal energy (heating up to 40 °C, 10 min); less danger to humans,
- Distilled water (CAS number 7732-18-5) - widely available solvent; requires thermal energy (heating up to 100 °C, 10 min); without danger to humans and environment.

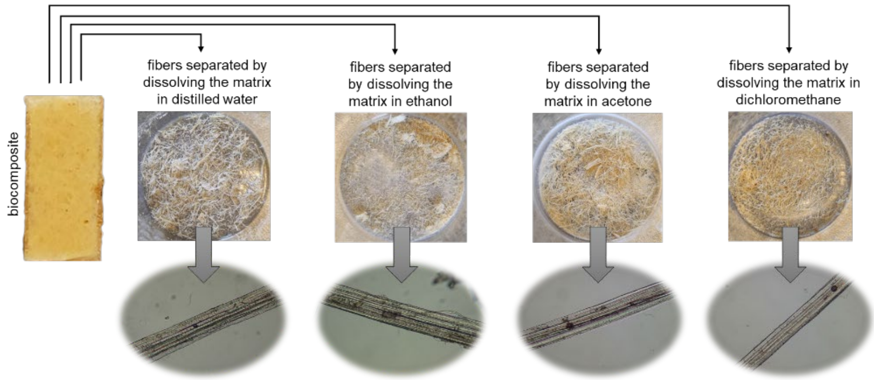


Figure 1: Fibers separated after removing the matrix

4. Conclusion

In accordance with the life cycle philosophy, presented results and considerations indicate effectiveness of using distilled water in the process of chemical recycling (hydrolysis) of biocomposites made from Spanish broom fibres and PLA matrix.

5. References

[1] Korniejenko, K. et al.: Tackling the Circular Economy Challenges - Composites Recycling: Used Tyres, Wind Turbine Blades, and Solar Panels, *Journal of Composites Science*, **5** (2021) 9, pp. 1-18, ISSN 2504-4777

[2] Shanmugam, V. et al.: Circular economy in biocomposite development: State-of-the-art, challenges and emerging trends, *Composites Part C: Open Access*, **5** (2021) 100138, pp. 1-16, ISSN 2666-6820

[3] Vujasinović, E. & Pavunc Samaržija, M.: Biokompoziti – materijali budućnosti, U *Održivi razvoj biokompozita i biogoriva iz obnovljivih izvora energije*, Sveučilište u Zagrebu Tekstilno-tehnološki fakultet, ISBN 978-953-8418-09-9, Zagreb (2023.), str.113-152

[4] Morici, E. et al.: Recycled (Bio)Plastics and (Bio)Plastic Composites: A Trade Opportunity in a Green Future, *Polymers*, **14** (2022) 10, pp. 1-24, ISSN 2073-436

Antonija Petrov

Biography

Antonija Petrov was born in 1993 in Zagreb. In 2017, at the University of Zagreb Faculty of Textile Technology, she completed her undergraduate study in Textile Technology and Engineering, majoring in Textile Design and Management. She completed the graduate study of Textile Technology and Engineering in 2019 and earned the title of Master of Engineering in Textile Technology and Engineering. She is currently employed as an assistant at the research project of the Croatian Science Foundation "*Textile materials for increased comfort in sports* - TEMPO, IP-2019-04-1381", led by prof. Ivana Salopek Čubrić, PhD. As part of her career development, the doctoral student enrolled doctoral study Textile Science and Technology as part of the Project for the development of careers of young researchers - training of new PhDs: "*Aspects of the application of thermography in the evaluation of the thermophysiological comfort of sports clothing* – ATLETO, DOK-2021-02-4746", led by assoc. prof. Goran Čubrić, PhD, where she steers her scientific interest in the application of infrared thermography to evaluate the comfort of sports clothing.

Title of PhD thesis

Study advisor

assoc. prof. Goran Čubrić, PhD

Date or dissertation defense

APPLICATION OF THERMOGRAPHY IN THE EVALUATION OF THERMOPHYSIOLOGICAL COMFORT OF SPORTSWEAR

Antonija PETROV

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, antonija.petrov@ttf.unizg.hr

Abstract: *The comfort of sportswear is crucial for optimal sports performance. Through careful design planning and material selection, functional heat and moisture management is achieved, enabling the maintenance of heat balance during physical activity. Materials for sportswear should transfer heat efficiently and facilitate heat loss through sweat evaporation to ensure the necessary comfort during sports activities. Fast fluid transfer through absorption together with efficient drying ability prevents condensation of sweat on the skin and ensures a dry and comfortable temperature. Infrared thermography provides valuable data on thermophysiological comfort by analysing the dynamic changes in skin temperature during physical activity. This data enables more precise adjustment of the materials to achieve optimum comfort during various sports activities.*

1. Introduction

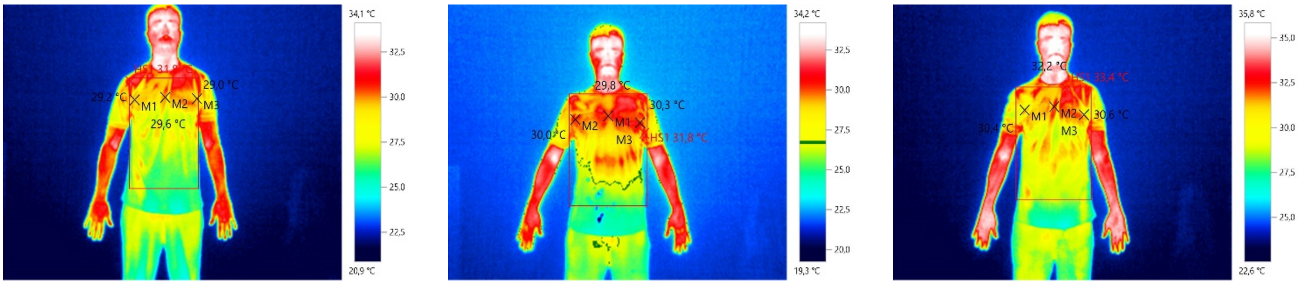
Throughout history, clothing has been the key to protecting the body from external influences, and sportswear has become very promising and dynamic with enormous innovations [1]. The global sportswear market is growing, driven by the increasing popularity of sports as a profession and the need for high-quality clothing that provides comfort and protection from harsh environmental conditions [2]. Sportswear can be divided into two basic groups: professional sportswear, which is suitable for peak physical performance, and leisurewear, which offers comfort, style and versatility [3]. Artificial fibres from synthetic polymers such as polyester, polyamide and elastane dominate in the production of sportswear due to their advantages such as quick drying, light weight and elasticity [4]. An important focus in the development of sportswear is comfort, which can have a significant impact on an athlete's performance. Methods for measuring comfort include objective (thermal mannequins, hot plate, water vapor permeability) and subjective methods (surveys and questionnaires) [5]. Infrared thermography (ICT) in sport provides non-invasive insights into athletes' body temperature during activity, which can be useful for analysing temperature changes. Nevertheless, ICT researchers often focus on the detection of sports injuries and pay less attention to researching the comfort of sportswear using this method [6]. Given the distinct lack of comfort research using ICT, there is a need to expand this area. Research with infrared thermography contributes to a better understanding of how this method can optimize the comfort and performance of sportswear under different conditions during physical activity.

2. Experimental

The application of infrared thermography in sports and sportswear provides important insights into the performance of athletes and the comfort of clothing during physical activity. For research within the doctoral thesis, knitwear intended for the production of sports jerseys will be used, investigating their physical and mechanical characteristics such as surface mass, thickness, density and tensile properties. The research also includes determining the surface roughness and porosity of the material. In addition, properties that influence the comfort of athletes will be analysed, in particular water vapor permeability, which is important for thermophysiological comfort. The research will focus on infrared thermography to detect temperature changes in athletes during certain sports activities.

3. Results and Discussion

The changes in skin temperature in football players after intensive activities are a reaction of the body to the exertion. After physical exertion, the body generates additional heat due to increased metabolic activity, which leads to an increase in skin temperature (Figure 1b). This increase in temperature can be accompanied by increased sweating as the body attempts to cool itself through the sweating process in order to maintain an optimal temperature. In addition, a further increase in skin temperature was observed after a rest period of 10 minutes (Figure 1c). This could indicate that metabolism and subsequent heat dissipation continue during the recovery phase, even though the intensity of the activity has decreased. If clothing is not effective in managing moisture and heat, sweat may be trapped against the skin, hindering the natural cooling process. High quality sportswear should allow efficient moisture transfer and quick drying to prevent sweat build-up, contributing to comfort during and after physical activity. These characteristics can help maintain a stable skin temperature and keep athletes comfortable during different phases of activity and recovery.



a b c

Figure 1: Examples of thermograms: a) before activity b) after activity c) after 10 minutes of rest

4. Conclusion

Analysis of temperature changes in athletes with the help of infrared thermography provides valuable information about thermophysiological comfort during sports activities. The expansion of research of this type enables further improvement of sportswear to achieve optimal comfort and performance of athletes.

Acknowledgment

This work has been fully supported by Croatian Science Foundation under the project IP-2020-02-5041 "Textile Materials for Enhanced Comfort in Sports - TEMPO", led by prof. Ivana Salopek Čubrić, PhD, and under the project DOK-2021-02-4746 „Young researchers' career development project - Training of new doctoral students - ATLETO", led by assoc. prof. Goran Čubrić, PhD.

5. References

[1] Dolez, P.; Vermeersch, O.: Izquierdo, V.: *Advanced Characterization and Testing of Textiles*. Elsevier, 1st Edition, (2018)
[2] Faheem, A. et al.: Recent Developments in Materials and Manufacturing Techniques Used for Sports Textiles, *International Journal of Polymer Science*, (2023), pp. 1-20
[3] Elmogahzy, Y.E.: Performance Characteristics of Traditional Textiles: Denim and Sportswear Products, U *Engineering Textiles*, 2nd Edition. Elsevier, 978-0-08-102488-1, (2019), pp. 319-346
[4] Guru, R.; Kumar, A.; Kumar, R.: Functional Textile for Active Wear Clothing, In *Textiles for Functional Applications,* IntechOpen (2021)
[5] Ziemele, I.; Šroma, I.; Kakarane, A.: Comfort in sportswear, *Key Engineering Materials*, **762** (2018), pp. 402-407
[6] Marins, J. C. B. et al: Applications of infrared thermography in sports. A review, *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, **15** (2015) 60, pp. 805-824

Luka Savić

Biography

Born in 1988 in Zagreb, Croatia. Graduated from the University of Zagreb, Faculty of Textile Technology, after completing a 4-month Erasmus+ professional internship at the University of Oxford in 2019. From 2019 to 2021, he worked as an assistant in the field of electrospinning on a research project at the University of Oxford. He is currently working as an assistant at the University of Zagreb, Faculty of Textile Technology, and is pursuing a doctoral degree in Textile Science and Technology. He volunteers as the vice president in the associations Penkala and Upcikliči. His scientific research interest is focused on the electrospinning process and the production of nanofibers for use in medicine (aided growth of tissues and nerve cells), and his teaching interest is in technical textiles and medical textiles, which is also his field of research.

Title of PhD thesis

Study advisor

assoc. prof. Maja Somogyi Škoc, PhD

Date or dissertation defense

ELECTROSPUN ELECTROACTIVE BIOPOLYMERS FOR THE PURPOSE OF OBTAINING CONDUCTIVE FIBERS

Luka SAVIĆ

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, luka.savic@ttf.unizg.hr

Abstract: *Electrospun, electroactive, and conductive polymers are being studied with the aim of innovative applications for medical textiles. The focus is on researching their potential in promoting cell proliferation and differentiation, which plays a crucial role in regenerative medicine. The goal is to develop textile materials that could serve as a basis for advanced therapeutic applications, including treatment and tissue regeneration.*

1. Introduction

Electroactive/conductive polymers (EAP/ECP) have shown promising results as medical textiles for tissue and neural engineering [1,2]. The application of current through electrospun electroactive textile micro/nano filament fibres yields promising outcomes for cell cultivation, where electrical stimulation aids in faster and more efficient cell growth on textile supports. Due to their electrical conductivity, textiles made from electroactive polymers are excellent for mimicking the actual bodily environment where cells are electrically stimulated for growth [3]. In medical textiles, fabrics made from electroactive polymers are extremely useful due to their ability to conduct electricity, simulating the bodily environment where cells grow with electrical stimulation.

All body cells, not just nerves and muscles, produce and respond to electrical signals. In the human body, bioelectric circuits created by electrical impulses direct cell activities towards specific anatomical locations [4]. Electrospinning stands out as an ideal method for producing new electroactive non-woven textiles that mimic the extracellular matrix. In medical research, it is necessary to further explore electrospun electroactive polymers, both biodegradable and biologically non-degradable, for use in treating various diseases, such as rare motor neuron diseases, Alzheimer's disease, neuromuscular scoliosis, spinal muscular atrophy (SMA), and spinal cord injuries [5].

Polymers such as polypyrrole (PPy), polyaniline (PANI), polythiophene (PT), polyvinylidene fluoride (PVDF), and poly(vinylidene fluoride-trifluoroethylene) (P(VDF-TrFE)) are particularly promising due to their electroconductive properties. The integration of EAPs with cells is key to developing textile composites from organic and inorganic materials that are functionally intertwined.

2. Experimental

The possibility of using electroactive and electrically conductive polymers for medical applications is being explored, with the goal of developing new medical textiles. In planning and conducting the research, general knowledge from the field of scientific work will be utilized.

A hypothesis will be set, followed by various research phases. The obtained results will be analysed and processed for the purpose of realization and confirmation of the hypotheses, which will be re-examined after multiple reviews of available literature and contact with various domestic and foreign research groups.

The processing and morphology of new textile materials will be carried out using reliable and standardized measurement techniques (FTIR-ATR, SEM-EDS, AFM, DSC/TGA, various microbiological tests, etc.) to assess their effectiveness. The methods and processes used will ensure the repeatability of results.

Appropriate mathematical and statistical procedures will be used to ensure a certain reliability in processing, analysing, and evaluating the obtained results.

The research plan includes the following sections:

I Acquisition of Equipment and Chemicals

1. Equipment for electrospinning has been acquired and is awaiting its location to be determined by the academic advisor.
2. The selection and procurement of the most suitable polymers that will serve as the bio-component and electroactive component have been completed.
3. The solvent needed for polymer processing has been determined and acquired.

II Optimization and Validation of Electrospinning Process Parameters
1. Testing solution concentrations for optimal electrospinning.
2. Determining optimal parameters for electrospinning.
3. Testing the obtained textile materials - tensile testing, microbiological testing, electrical conductivity testing, thermal testing of fibres, degradation studies.
4. Consulting with other institutions on conducting research.

III Post-Processing and Application Uses
1. Post-processing of spun textile materials.
2. Testing textile materials and the possibilities of their application uses.

3. Conclusion

The scientific contribution of this doctoral dissertation will be realized in both theoretical and practical terms. Electroactive and electrically conductive polymers will be developed, researched, and tested as new textile materials – medical textiles for use in medicine.

4. References

[1] Kumar, D.; Sharma, R.C.: Advances in Conductive Polymers, *European Polymer Journal*, **34** (1998) 8, pp. 1053-1060, ISSN 0014-3057
[2] Zhang, X. et al.: Electroactive Electrospun Nanofibers for Tissue Engineering, *Nano Today*, **39** (2021): 101196, ISSN 1748-0132
[3] Chen, C. et al.: Electrical Stimulation as a Novel Tool for Regulating Cell Behavior in Tissue Engineering, *Biomaterials Research*, **23** (2019) 25, pp. 1 – 12, ISSN 1226-4601
[4] Levin, M.; Pezzulo, G.; Finkelstein, J.M.: Endogenous Bioelectric Signaling Networks: Exploiting Voltage Gradients for Control of Growth and Form, *Annual Review of Biomedical Engineering*, **19** (2017), pp. 353–387, ISSN 1523-9829
[5] Picciani, P. et al.: Advances in Electroactive Electrospun Nanofibers, *Available at:* https://doi.org/10.5772/23229, *Acessed*: 15.12.2023.

Vanja Šantak

Biography

After graduation at University of Zagreb Faculty of Textile Technology in 2003 he began his professional career. The first job position was an office administrator in the Birokorekt d.o.o. His ability to adapt to various tasks was highlighted during his tenure at Orka Zagreb d.o.o., Esotehna d.o.o., Color Trade d.o.o., and Orka Lab d.o.o. He gained a great experience as the Sales Manager at Interallis Chemicals d.o.o. from 2011 to 2013, in sales and technology. Currently, he is a Sales Engineer at NTI d.o.o., specialist in water technologies and the official distributor of Solenis chemicals.

Title of PhD thesis

Study advisor

prof. Tanja Pušić, PhD

Date or dissertation defense

OZONE-ASSISTED WASHING PROCESS OF TEXTILES

Vanja ŠANTAK

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, vsantak@ttf.hr

Abstract: *Ozone in washing process of textiles, due to its high oxidation potential, represents an advanced alternative to existing washing processes, contributing to hygiene, efficiency, and sustainability. This study will analyse the effect of the ozone-assisted washing process on various types of textiles to objectively evaluate its adaptability, flexibility, and sustainability. The primary and secondary effects, as well as disinfection, will be analysed using standard, conventional, and advanced methods to determine the advantages and disadvantages of the ozone-assisted washing process compared to existing processes.*

1. Introduction

Ozone (O_3), a powerful oxidant, is recognized as a key tool in the textile washing industry, offering revolutionary benefits in hygiene and environmental sustainability. First applied in the washing industry in the late 20th century, ozone soon became a desirable alternative to traditional washing methods due to its ability to effectively remove microorganisms and reduce water and energy usage. Its application ranges from hospital bed linens to hotel towels, where the disinfecting efficiency of ozone is of paramount importance. Recent research highlights that ozonized washing not only ensures deep cleaning and disinfection but also reduces energy and water consumption, thus contributing to the ecological sustainability and reducing the carbon footprint of the washing industry [1-3]. In the context of increasing global environmental concerns, ozonized washing represents a key technology in the pursuit of greener and more sustainable approaches in the textile industry. Additionally, ozone has proven extremely effective in removing various types of dirt and pathogens, including viruses and bacteria, making it an ideal solution in the context of current and future public health challenges. Its ability to adapt to different types of fabrics, such as cotton, polyester, and blends, further confirms its wide applicability and flexibility in various industry segments. In this paper, we will explore how ozonized washing can transform traditional washing methods, with a special focus on its ecological benefits, efficiency, and adaptability to different types of fabrics and stains.

2. Experimental

In this part of the research, we focus on examining the effectiveness of ozonized textile washing at different temperatures 20 °C, 40 °C, and 60 °C. We use standardized EMPA cloths with specific standard impurities to ensure consistency and reliability of results. The approach allows for detailed monitoring of the effectiveness of dirt removal and assessment of the impact of ozonized washing on different types of fabrics - polyester, cotton, and their blends. The experiment includes a detailed analysis of the effectiveness of removing different types of stains, including organic and inorganic compounds, and assessing the preservation of fabric quality after washing. In addition, water and energy consumption in the washing process will be monitored to determine the ecological efficiency of the method. Special attention will be paid to the impact of different temperature regimes on the effectiveness of ozonisation. Previous research shows that temperature plays a key role in the stability and effectiveness of ozone, and thus in the quality of the final washing result [4,5]. This experiment will contribute to a deeper understanding of how temperature affects the interaction between ozone and fabrics, which is crucial for optimizing the washing process.

3. Results and Discussion

Although the experimental part of the research has not yet begun, based on the available literature we can anticipate potential results and discuss them. Previous research has shown that ozonized washing at lower temperatures (20 °C, 40 °C) can be equally effective or even better in removing impurities compared to traditional high-temperature washing methods. Ozonized washing is expected to show a reduction in energy and water consumption, in line with current trends towards more sustainable and environmentally friendly practices. Additionally, the analysis of the impact of ozonized washing on different types of fabrics can provide insight into its adaptability and flexibility in various applications. For example, washing polyester fabrics may require a different approach compared to cotton or blends. Also, ozonized washing is expected to show a high level of disinfection, which is of particular importance in the context of current health and hygiene standards.

4. Conclusion

Based on the review of available literature and the anticipation of experimental results so far, it can be concluded that ozonized textile washing offers significant advantages over traditional methods. This technology not only improves hygiene standards but also contributes to ecological sustainability through reduced water and energy consumption. The adaptability of ozonized washing to different types of fabrics and washing temperatures is expected to open up new opportunities for improving the textile washing industry, particularly in terms of reducing the ecological footprint and improving public health standards. This paper represents an important step towards understanding and optimizing the use of ozone in textile washing practice.

5. References

[1] Owen, L.; Shivkumar, M. & Laird, K.: The Stability of Model Human Coronaviruses on Textiles in the Environment and During Health Care Laundering, *mSphere*, **6** (2021) 2, 6:e00316-21, ISSN 2379-5042
[2] Rice, R.G.; Magnanti, J. & Washbrook, T.: The CaroMont Health Ozone Laundry System: Energy Savings, Improved Laundered Product Qualities and Return on Investment at Gaston Memorial Hospital, Gastonia, *NC,* Ozone: Science & Engineering, **35** (2013) 5, pp. 399-419, ISSN 0191-9512
[3] Neral, B.: Kvaliteta pranja u kućanskom stroju za pranje s ozonatorom, *Tekstil*, **65** (2016) 7-8, str. 241-251, ISSN 0492-5882
[4] Neral, B.: Efficiency and Ecological Impacts of Household Ozone Laundering, *International Scientific Journal Science. Business. Society*, **2** (2017) 2, pp. 54-57, ISSN 2367-8380
[5] Valls, C., Cusola, O., Roncero, M. B. Evaluating the potential of ozone in creating functional groups on cellulose, *Cellulose*, **29** (2022), pp. 6595-6610, ISSN 0969-0239

Ana Šaravanja

Biography

Ana Šaravanja was born in 1998 in Zagreb, Croatia. In 2021 she graduated from the University of Zagreb Faculty of Textile Technology (TTF), majoring in Textile Chemistry, Materials and Ecology. She is the winner of the Dean's Award for Achievement during the undergraduate and graduate study of Textile Technology and Engineering. In 2021 she enrolled doctoral study Textile Science and Technology, and was employed as an assistant on the "*Young researchers' career development project – training of doctoral students*" (DOK-2021-02-6750) by the Croatian Science Foundation. She is researcher at project "*Assessment of microplastic shedding from polyester textiles in washing process*" InWaShed-M (IP-2020-02-7575), financed by the Croatian Science Foundation.

Title of PhD thesis

Study advisor

assoc. prof. Tihana Dekanić, PhD

Date or dissertation defense

INFLUENCE OF AGEING ON THE PROPERTIES OF POLYESTER FABRICS DURING WASHING

Ana ŠARAVANJA

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, ana.saravanja@ttf.unizg.hr

Abstract: *Polyester fabrics are subjected to changes in their properties due to the influence of various environmental factors, which affect not only their performance characteristics but also the ecosystem in general. In this research, the effect of simulated ageing under laboratory conditions on the properties of polyester fabrics as well as effluents filtrates and filter cake after the washing process was monitored.*

1. Introduction

Textiles are among the most important environmental pollutants as they tend to release microfibres, and the washing process is considered one of the main causes [1]. The washing of synthetic textiles has been identified as a source of primary microplastics, MP, entering wastewater treatment plants [2-4]. Considering the mentioned problem of the presence of MP in the environment, the PhD research will focus on monitoring the influence of artificial ageing on the properties of standard polyester (PES) and polyester-cotton (PES/P) fabrics, as well as the effects of artificial ageing (duration, type and radiation intensity) on the release of MP and microfibres in the washing process with standard and innovative process. In this study, the effect of artificial ageing on standard PES fabrics was investigated through the processes of controlled ageing and washing and by analysing aged fabrics, effluents, filtrates and filter cakes.

2. Experimental

Standard PES fabric (PES_N) with a mass per unit area 150 g/m^2, warp and weft yarn density of 27,7/20,0, in plain weave, supplied by Centre for Testmaterials BV Employees, CFT, was used.,. Fabrics dimension 30x20 cm were subjected to artificial ageing simulation in the Xenotest device, SDL Atlas, at different time intervals of light exposure (5, 10, 15, 20, 30, 40, 60, 75 and 85 hours (H)). To gain an insight into the behaviour of PES fabrics during ageing, the standard EN ISO 105-B02+A1:2013 was used. Carboxyl groups (-COOH) were determined in the sample by the methylene blue absorption method, which is based on the methylene blue absorption and spectrometric monitoring of the absorption of the filtrate, whereby the dye interact with the acidic carboxyl groups of the fibre. The PES fabrics were additionally subjected to the washing process in the Rotawash system, SDL Atlas, in accordance with EN ISO 6330:2012, using the standard ECE A detergent, bath ratio of 1:7, at a temperature of 60 °C for 30 minutes in 10 cycles. At the end of the washing process, the effluents were collected for further physio-chemical analysis and characterisation of the effluents, filtrate and filter cake in terms of MP release, microfibre and particle content. Fourier transform infrared spectroscopy (FTIR) was used to characterise the filter cake and polyester fabrics before and after artificial ageing and the washing process. A polyethersulfone membrane filter from Sartorius with a pore size of 0,2 µm was used for the detection and separation of the effluents into filtrate and filter cake, and the gold tile was used for the specific detection of PES microfibrils from the filter.

3. Results and Discussion

The results of previous research as part of the doctoral thesis have shown that the properties of PES fabrics change when exposed to sunlight: photo-oxidative degradation due to the slow diffusion of oxygen into the polymer which changes the physical properties of the fabric (roughness, loss of gloss, stiffness),), as well as a decrease in strength and weakening of mechanical properties, while at the molecular level, oxidation of the polymer chain at the C-H bond, cleavage of ester bonds and formation of new carboxyl groups (–COOH) occur. Fig. 1 shows the results of the determination of -COOH groups with methylene blue, which show that the amount of -COOH groups is proportional to the exposure time. After artificial ageing, the amount of -COOH groups per g of sample increases, while the amount does not change for samples aged for 15 hours or longer and remains constant regardless of the duration of light exposure.

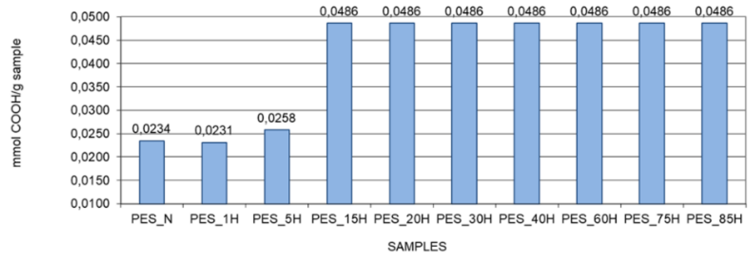
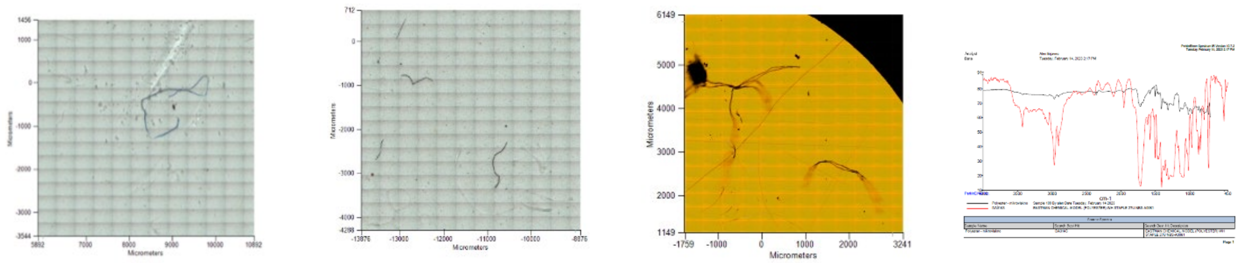


Figure 1: Graphic representation of the amount of –COOH groups per g of sample

Figure 2 shows an isolated example of a filter cake of a standard fabric (PES_N) and after 85 hours of illumination (PES_85H), the released fibres and an FTIR spectrum as evidence of released PES fibres from a fabric subjected to artificial ageing and washed according to a standard procedure.



a b c d

Figure 2: Microscopic images of the samples: a) filter cake of PES_N; b) filter cake of PES_85H; c) Fibre on a gold substrate; d) FTIR spectrum of the PES fibre

4. Conclusion

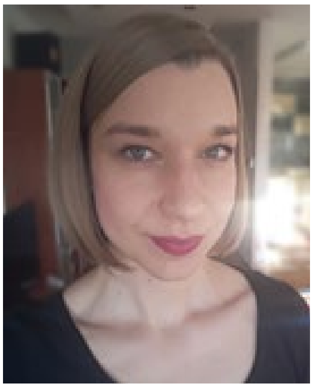
The results show that ageing influences the properties of PES fabrics. The amount of –COOH groups, increases during ageing and washing of polyester fabrics. By analysing the effluent from the washing process, fibril segments originating from the PES fibre were detected on the surface of the filter, which was confirmed by FTIR spectroscopy.

Acknowledgement

The work of doctoral student Ana Šaravanja has been supported in part by the "Young researchers' career development project – training of doctoral students", DOK-2021-02-6750, of the Croatian Science Foundation. This work has been supported in part by Croatian Science Foundation under the project IP-2020-02-7575, InWaShed-MP.

5. References

[1] Čorak, I. i sur.: Enzimi za hidrolizu poliestera, *Tekstil*, **68** (2019) 7-9, str. 142-151, ISSN 0492-5882
[2] Haap, J.: Analytical approach for the detection of micro-sized fibers from textile laundry, In: *Proceedings of the International Conference on Microplastic Pollution in the Mediterranean Sea*, Springer, ISBN 978-3-319-7179-6, Cham, (2018), pp. 73-79
[3] Bule, K. i sur.: Mikroplastika u morskom okolišu Jadrana, *Kemija u industriji*, **69** (2020) 5-6, str. 303-310, ISBN 978-953-6894-70-3
[4] Hernandez, E; Nowack, B. & Mitrano, D. M.: Polyester textiles as a source of microplastics from households: a mechanistic sturdy to understand microfiber release during washing, *Environmental science & technology*, **51** (2017) 12, pp. 7036-7046, ISSN 1520-5851



Marijana Tkalec

Biography

Marijana Tkalec was born in Čakovec in 1986. After graduation from the University of Zagreb Faculty of Textile Technology in the field of Textile technology (Clothing and Textile Design and Engineering), she worked in textile industries as a textile and fashion designer and engineer. She has received several awards for her work in the field of textile design. In 2017 she enrolled doctoral study Textile Science and Technology at the Faculty of Textile Technology. She currently works as an assistant at the University of Zagreb Faculty of Textile Technology.

Title of PhD thesis

Study advisor

prof. Martinia Glogar, PhD

Date or dissertation defense

THE INFLUENCE OF THE SURFACE TOPOGRAPHY OF THE TEXTILE SUBSTRATE ON COLOUR CHARACTERISTICS IN REPRODUCTION BY DIGITAL PRINTING

Marijana TKALEC

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
Zagreb, marijana.tkalec@ttf.unizg.hr

Abstract: *The topographic characteristics of textile materials inevitably affect the perception of fabric texture and the appearance of colour on fabric surface. In order to explain the complexity of different textile materials and colour appearance, the paper analyses this phenomenon – the reproduction quality and colour appearance on fabric printed with digital Inkjet technology, depending on the construction and structural characteristics, i.e. texture of the textile fabric. The samples were digitally printed on Tx2-1600 Mimaki digital printing device with reactive dyes, previously pre-treated in a bath of a specific solution. All the results are presented through colouristic analyses, based on colour and colour differences objectification. The objective values of the parameters: lightness L*, Chroma C* and hue h° show a significant influence of the structure and characteristics of the substrate on colour reproduction, and significant changes are obtained, which are also confirmed by the colour differences evaluation. A microscopic analysis of the prints was carried out with a Dino-Lite Premier AM-7013MZT digital microscope. The results confirm the influence of the substrate structure on the colour characteristics.*

1. Introduction

Digital Inkjet is a graphical multicolour image reproduction technology, originally developed for homogeneous, uniform surface structures such as paper. Textiles as a unique, heterogeneous, three-dimensional form is having its own surface irregularities which causes droplet deformation and a greater depth of ink droplet penetration. Previous research refers to the influence of surface textile texture on the appearance of colour [1-6]. It confirms the significant influence of texture on the visual perception of colour, as well as on the results of instrumental evaluation, but the quantity and quality of this effect is not yet fully understood. The research presented in this paper also analyses the interdependence of the reproduction quality and appearance of the colour printed with digital Inkjet technology, depending on the construction and structural characteristics of the textile fabric. The aim of the research is to contribute to the understanding of the fundamental mechanisms of the interaction of dyes, colour and textile substrates.

2. Experimental

Samples of textile fabrics with a raw material composition of 50 % cotton and 50 % PA were used in the research. The samples were purposefully produced by the Čateks factory, using identical yarns, but varying in construction characteristics, which resulted in fabrics of different structures and textures: Plain 1/1, Twill 1/2 Z and Atlas 1/5. In the following experimental work, Inkjet digital printing of the samples was carried out (previously pre-treated in a bath of a specific solution); after printing the samples were air-dried and then fixed by steaming. Analysis of microscopic imaging with a DinoLite microscope and spectrophotometric measurement of the colour characteristics by remission spectrophotometer DataColour 850, with measuring aperture size 2,5 cm and measurement geometry d/8° was performed on the samples.

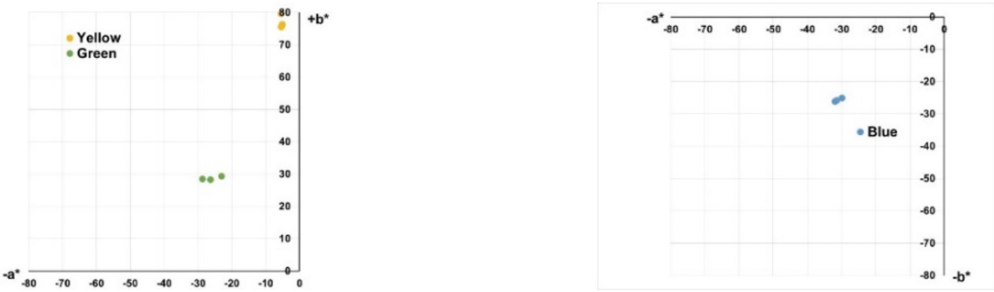
3. Results and Discussion

Figure 1 shows the prints on the selected fabrics, after fixing by steaming, washing and drying.

a b c

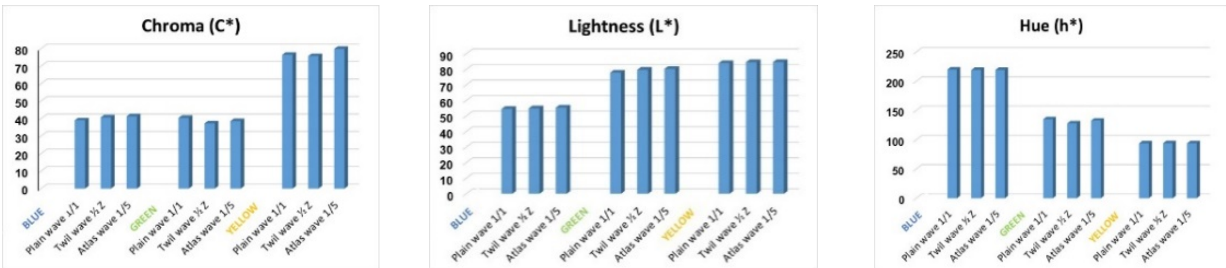
Figure 1: Digital InkJet prints on selected fabrics: a) Plain weave 1/1) b) Twil weave 1/2 Z) c) Atlas weave 1/5

The strong influence of the substrate is immediately noticeable, and there are visible differences in the quality of colour and pattern reproduction due to the structure of the substrate. The occurrence of printing ink spillage and the impossibility of keeping individual design elements within the given contours is observed. Spectrophotometric measurements of the colour characteristics are shown in Figure 2 as a placement of colours in a*/b* colour space, and in Figure 3 as comparative histograms showing lightness (L*), Chroma (C*) and hue (h°) change for printed colours due to different substrate structures. The presented results of the analysed colours indicate the influence of the structure and topographic characteristic on colour.



a b

Figure 2: Results of spectrophotometric measurement: values of the printed samples placed in a*/b* colour space



a b c

Figure 3: Results of spectrophotometric measurement: values of parameters of Lightness (L*), Chroma (C*) and Hue (h°)

4. Conclusion

The research presented in this paper confirms the complexity of interaction of colour and the structure of the textile substrate. The obtained results of the objective values of the parameters lightness L*, Chroma C* and hue h° show a significant influence of the structure and characteristics of the substrate on colour reproduction, and significant changes are obtained, which are also confirmed by the colour differences evaluation. The results confirm the influence of the substrate structure on the colour characteristics. In the digital printing process, a deeper understanding of these specifics is needed, in order to enable the optimization of process parameters and the prediction of possible errors and shifts in the colour characteristics of the print.

5. References

[1] Moussa, A. et al. : Colour change as a result of textile transformations, *Coloration Technology*, **124** (2008), 4; pp. 234-242, ISSN 1478-4408

[2] Gorji Kandi, S., Tehrana, M. A., Rahmatib, M.: Colour dependency of textile samples on the surface texture, *Coloration Technology*, **124** (2008) 6; pp. 348-354, ISSN 1478-4408

[3] Huertas, R., Melgosa, M., Hita, E.: Influence of random-dot textures on perception of suprathreshold color differences*, Journal of the Optical Society of America*, **23** (2006) 9; pp. 2067-2076, ISSN 1520-8540

[4] Xin, J. H., Hui-Liang S., Chuen C. L.: Investigation of Texture Effect on Visual Colour Difference Evaluation, *Color research and Application*, **30** (2005), 5; pp. 341-347, ISSN1520-6378

[5] Bae, J. H., Hong, K. H., Lamar, T. M.: Effect of Texture on Color Variation in Inkjet-Printed Woven Textiles, *Color Research and Application*, **40** (2015), 3; pp. 297-303, ISSN 0361-2317

[6] Yang, H. et al.: Influence of cotton fabric structure on ink droplet spreading and color performance, *Journal of Textile Research*, **40** (2019), 7; pp. 78-84, ISSN 0253-9721

Irena Topić

Biography

Irena Topić was born in 1983 in Zagreb and works as an art teacher. In 2011, she graduated with a bachelor's degree in costume design at the University of Zagreb, Faculty of Textile Technology (TTF), and in 2013 with a university degree in fine arts at the Academy of Fine Arts. From 2004 to 2006, she worked as a field surveyor on the Croatian Anthropometric System (HAS) project led by Prof. emeritus D. Ujević. She first worked at TTF as an assistant (2011 - 2017), and later as an external associate (2018 - 2021). During her career, she completed numerous professional trainings: at the CFPIC Institute, Felgueiras, Portugal (Tied Shoe project, headed by emeritus professor A. M. Grancarić), at the Faculty of Textiles, Leather and Industrial Management, "Gheorghe Asachi", Iaşi, Romania, and at the Cité des Arts, Paris. She participated in the project Knowledge for footwear (K4F).

Title of PhD thesis

Study advisor

prof. emeritus Darko Ujević, PhD

Date or dissertation defense

THE IMPACT OF BODY PROPORTIONS IN THE CLOTHING CONSTRUCTION PROCESS FOR OVERWEIGHT PERSONS

Irena TOPIĆ

University of Zagreb, Faculty of Textile Technology, Prilaz baruna Filipovića 28a,
irena.topic@ttf.hr

Abstract: *Researching body proportions can contribute to new and more quality methods of clothing construction and modelling for overweight men and women. Within the doctoral thesis, the goal is to scientifically determine the trend in obesity among adult women and men population in the city of Zagreb, which will serve as basis for improvement in clothing construction procedures and everyday clothing designing. In addition, deviations concerning obesity increase will also be established in adult men and women population differing from the Croatian technical report from 2012, which was carried out within the STIRP HAS project. The goal of the doctoral thesis is to determine the relevant criteria for the selected population and to enable the proposal of new body types, and the improvement of the construction and designing processes of clothing for daily use, based on the results of the anthropometric measurements conducted on the selected male and female population.*

1. Introduction

Anthropometric measurements have been carried out since 1900, with the aim of improving and developing the body sizing systems and classifying different body types. Researchers' approaches and measuring methods have changed and improved due to development of anthropometric instruments. The body proportions determine the conformity and mutual relation of individual body measurements. Study within this doctoral thesis will be based upon the anthropometric measurements in overweight men and women population, and deviations from the average body shape. New and better methods of clothing construction and modelling for people suffering from obesity can be used to research the specific body proportions. The aim of the study is to increase the life quality and health protection of overweight persons. Body proportions of overweight persons suffering from obesity can be determined by systematic anthropometric measurements.

2. Experimental

The measurement for the purposes of the doctoral thesis will be carried out at the KBC Zagreb, by random selection (arrival criterion) of participants who meet the criteria for determining obesity in the male and female population. Participants aged form 18 to 65 years, with a body mass index (afterwards referred to as BMI) >30kg/m^2, with a waist circumference greater than 88 cm in women, and a waist circumference greater than 102 cm in men, will be included in this study. The study will include two groups: 50 women and 50 men. The exclusion criteria are: corticosteroid therapy involvement or being diagnosed with the Cushing's disease (Cushing's syndrome). After the review of the survey questionnaires and statistical data analysis, the personal preferences will be determined, as well the state of comfort while wearing and potential difficulties experienced while choosing suitable clothes. Anthropometric measurements within the doctoral thesis will be carried out using a set of anthropometric instruments: an anthropometer with one and/or two legs, a measurement tape, one-sided and/or two-sided goniometer, sliding caliper, measuring tape for determining the circumference of the neck and a digital scale.

The research is carried out in four phases:
1st phase: preparation of the research plan, review of published literature, development of cooperation with other scientific and research institutions and manufacturing companies.
2nd phase: calibration of the research equipment, compiling survey questionnaires and forms, and anthropometric measuring of the participants: 57 measurements for women and 54 for men.
3rd phase: conducting tests and anthropometric measurements during the ambulatory endocrinological examination (KBC Zagreb).
4th phase: mathematical-statistical anthropometric measurements data processing, defining new body types, addition of existing clothing sizes charts and potential application in clothing construction and design.

3. Results and Discussion

The results of anthropometric measurements that will be carried out by this research will tend to determine the trend of changes in body proportions in people suffering from obesity (women with a waist circumference greater than 80 cm and men with a waist circumference greater than 102 cm), which will enable establishment of new body types. This work will contribute to the development and establishment of guidelines for making of new standards and clothing sizes charts in the countries members of the European Union. Body proportions determine the conformity and mutual relation of individual body measures, in the specific case obesity in women and men and/or deviations from the average build, whereby the existence of non-conformity when designing and constructing clothing for daily use can be accurately determined.

4. Conclusion

Based on the conducted research and obtained results, relevant criteria will be determined in women and men population suffering from obesity in the Republic of Croatia, which will enable the proposal of new body types in accordance with established deviations from the average body shape. This will enable an objective scientific comparison, as well a comparison with the population in other countries, EU member states and beyond. It is also planned to establish a cooperation with other European institutes, which also monitor the trends of increasing obesity in women and men. Thereby, the basis for the production of men's and women's clothing for everyday use will be made, as well higher protection in the area of lower back part. Application of study results will contribute to further development of clothing size charts, the new technical report creation customized for the men and women population suffering from obesity and thus the overall improvement of clothing construction, design process and clothing production for everyday use.

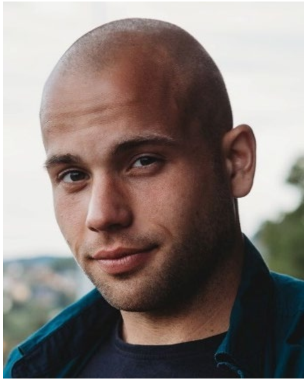
5. References

[1] Ujević, D. et al.: Osnove antropometrije ljudskog tijela i osvrt na razvoj sustava određivanja veličina za odjeću, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 113-124

[2] Hrastinski, M.et al.: Problematika sustava određivanja veličina i tržište, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 132-137

[3] Ujević, D., Doležal, K., Brlobašić Šajatović, B.: Hrvatski antropometrijski sustav, U: *Inovacijska kultura i tehnologijski razvoj*, Hrvatsko društvo za sustave, Zagreb, (2009), str. 133-137

[4] Ujević, D.: Hrvatski antropometrijski sustav – stanje, realizacija, primjena, U: *Hrvatski antropometrijski sustav: Podloga za nove hrvatske norme za veličinu odjeće i obuće*, Zrinski d.d., Zagreb, (2006), str. 16-23



Juro Živičnjak

Biography

Juro Živičnjak was born in Zagreb in 1995. He obtained the title of master engineer of textile technology and engineering at the University of Zagreb Faculty of Textile Technology in 2018, where he enrolled doctoral study Textile Science and Technology and where he has been working as an assistant within the Department of Materials, Fibres and Textile Testing since 2019. His scientific interests is in the field of testing the properties of various textile and leather. As a researcher, he was involved in the realisation of the project IP-2016-06-5278 funded by the Croatian Science foundation and has co-authored seven scientific papers, one technical paper and four book chapters.

Title of PhD thesis

Study advisor

prof. Antoneta Tomljenović, PhD

Date or dissertation defense

IMPROVING THE METHODOLOGY FOR ASSESSING THE PROPENSITY OF KNITTED FABRICS TO SURFACE CHANGES AFTER EXPOSURE IN THE PILLING BOX

Juro ŽIVIČNJAK

University of Zagreb Faculty of Textile Technology, Prilaz baruna Filipovića 28a, Zagreb, juro.zivicnjak@ttf.unizg.hr

Abstract: *The laboratory tests for testing the pilling propensity of knitted fabrics are designed to realistically and quickly simulate the pilling process, but also the appearance of fuzzing and matting, there occurrences are individually observed and evaluated in accordance with the textual description provided in the standard EN ISO 12945-4:2020. The grade describes occurred intensity of surface change (from 5 - unchanged appearance to 1 - greatly changed appearance), which observers assign based on subjective visual evaluation of the pretreated and initial samples. Since only the assessment of pilling can be carried out with the application of suitable 2D photographic rating standards, this study investigated the possibility of improving the methodology for assessing the resulting surface changes by using a digital camera and taking appropriate photographs of the surface of the tested knitted samples which can be assessed.*

1. Introduction

The knitted fabric propensity to surface changes is graded after a laboratory simulation of use in accordance with the standardised methods EN ISO 12945-1, 2, or 3:2020. The piling box method and the modified Martindale method are most commonly used methods [1]. In this study, the pilling box method was selected and the influence of the standardised speed (60 rpm) and the number of chamber revolutions (7200, 10800 and 14400) on the occurrence of surface changes in selected samples of circular weft double jersey knitted fabrics made of single viscose yarns (CV) was observed [2, 3].

2. Experimental

The pretreatment of knitted samples is performed in a cork-lined box by randomly tumbling and abrading of samples placed on polyurethane tubes on cork lining. Four fabric samples are simultaneously tested in the box, with two being sewn in the machine and two in the cross machine direction of the knitted fabric. In accordance with the EN ISO 12945-1:2020 standard, the samples are visually assessed after removal from the tube (Figures 1 a and 2 a), which allowed the entire surface of the sample to be compared with a 2D photographic rating standards (Figure 2 c), but at the same time prevents further treatment of the same sample.

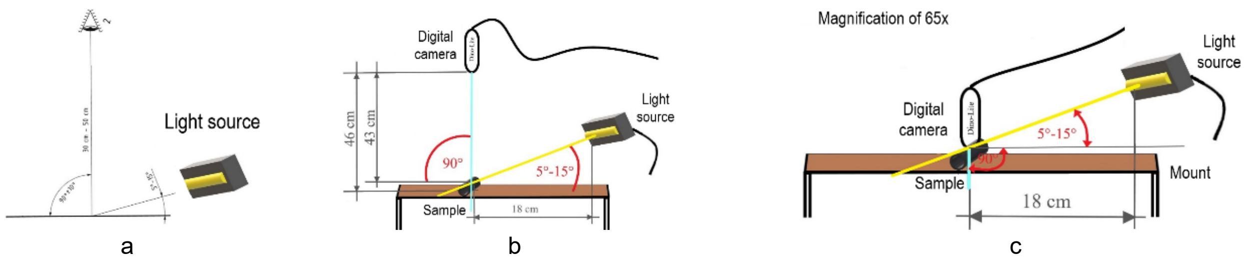
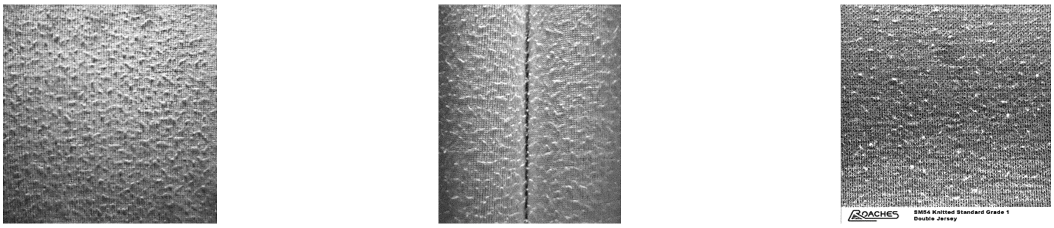


Figure 1: Schematic illustration: a) direct visual assessment of the sample surface, b) taking a photo of the entire sample (for the assessment of pilling) and c) taking a photo of part of the sample (for the assessment of fuzzing)

A digital microscope camera (Dino-Lite AM 413 ZT) was used to improve the evaluation methodology after pre-treatment in the piling box. The camera connection to a computer allowed the observer to take and save photos of the tested sample surface, which can then be assessed. Therefore, for the pilling assessment, two photos of single sample surface placed on single polyurethane tube were taken in natural size (Figure 1 b) and placed next to each other (Figure 2 b). To assess the occurrence of fuzzing, for which there are no comparable 2D photographic rating standards, the camera was positioned on the surface of the test sample and photos were taken at 65x magnification (Figure 1 c). The appearance of fuzzing is then observed as a blurring under which the knitted structure, i.e. wales and courses of knitted fabric, are difficult to distinct. In this case, the entanglement of fibres (pilling) is excluded.



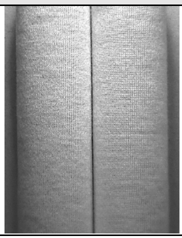
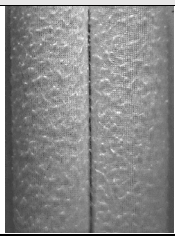
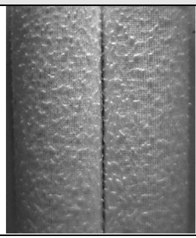
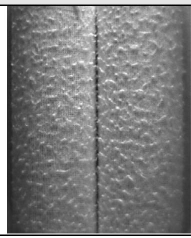
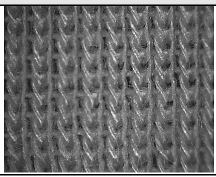
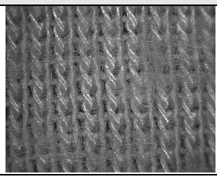
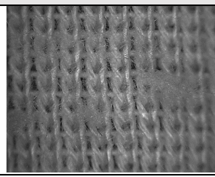
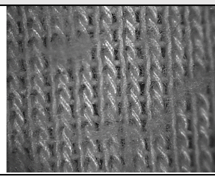
a b c

Figure 2: Images of CV knitted fabric surface appearance in actual size after 14400 box revolutions: a) sample removed from the polyurethane tube (surface area 121 cm^2) and b) sample on the polyurethane tube (surface area 66 cm^2); c) appearance of the 2D photographic rating standard for pilling (rating 1)

3. Results and Discussion

By testing it was determined that the same assessment of the knitted sample propensity to pilling is achieved by direct visual inspection of the sample surface and indirect inspection of photographs of the sample surface (without tube and on the tube). The assessment of fuzzing can be more precisely determined on the photograph with the magnification of 65x (Table 1).

Table 1. Surface appearance of the tested CV knitted sample on the tube after 7200, 10800, and 14400 box revolutions

Pilling	0	7200	10800	14400
Sewn in machine direction				
Grade	5	1	1	1
Fuzzing	0	7200	10800	14400
Sewn in machine direction Magnification: 65x				
Grade	5	2	2	4

4. Conclusion

By improving the methodology for assessing surface changes, it is possible to assess and analyse the degree of pilling and fuzzing on the same knitted samples during multiple consecutive assessments without the need of their removal from the polyurethane tube.

5. References

[1] Jasinska, I.; Stempien, Z.: An alternative instrumental method for fabric pilling evaluation based on computer image analysis, *Textile Research Journal*, **84** (2014) 5, pp.488-499, ISSN 1746-7748

[2] Eldessouki, M.; et al.: Integrated Computer Vision and Soft Computing System for Classifying the Pilling Resistance of Knitted Fabrics, *Fibres & Textiles in Eastern Europe*, **22** (2014) 6 (108), pp. 106-112, ISSN 1230-3666

[3] Telli, A.: The Relationship Between Subjective Pilling Evaluation Results and Detecting Pills and Textural Features in Knitted Fabrics, *Fibers and Polymers*, **21** (2020) 8, pp. 1841–1848, ISSN 1875-0052

Franka Žuvela Bošnjak

Biography

Franka Zuvela Bosnjak was born in 1978 in Split. She earned Master of Engineering in 2003 at the University of Zagreb Faculty of Textile Technology. In 1999 she was recognized as best student and in 2000 she received Rectors award for her scientific work. After 13 years working in the industry, she was empolyed as an assistant at University of Zagreb Faculty of Textile Technology, and since 2022 as lecturer in Study Unit in Varaždin. After employment, she enrolled doctoral study Textile Science and Technology with special interest in leather. Areas of scientific interest are research into the structures and properties of different types of leather and the preparation and processing of leather.

Title of PhD thesis

Study advisor

prof. Sandra Flinčec Grgac, PhD

Date or dissertation defense

ECOLOGICAL AND ECONOMIC ASPECTS OF THE APPLICATION OF ZEOLITE IN LEATHER PROCESSING WITH ANTIMICROBIAL PROTECTION

Franka ŽUVELA BOŠNJAK

University of Zagreb Faculty of Textile Technology, Hallerova aleja 6, Varaždin, franka.zuvela.bosnjak@ttf.unizg.hr

Abstract: *Considering the wide application of bovine leather in clothing, footwear and other branches of industry, there is a great need to improve the processing and finishing of leather. Legislative directives impose strict rules and regulations related to environmental protection. For this reason, the possibility of replacing an environmentally unfavorable fungicidal agent with zeolite was considered in the paper. In addition to the ecological aspect, it was investigated whether there is an economic profitability of applying zeolite, as well as testing the effectiveness of the antimicrobial protection of leather treated with zeolite.*

1. Introduction

For many years, the leather industry used chemicals such as organomercurials and chlorophenates, which are forbiden due to the high level of danger to the environment and people during exposure. In recent decades, they have been replaced with chemicals effective and more favorable for the environment such as: 2-(thiocyanomethylthio)benzothiazole (TCMTB), 3-iodopropynylbutylcarbamate (IPBC), n-octylisothiazolinone (OIT), diiodomethyl-p-tolylsulfone (DIMTS), and some phenols. Although this generation of biocides is more acceptable, the environmental impact is still significant. Zeolites, considering their chemical composition, can contribute to effective antimicrobial protection and as such can successfully replace the mentioned biocides. Without the use of biocides, damage to the leather caused by microorganisms occurs. The necessity of applying biocides is to prevent damage to the leather due to the action of microorganisms that otherwise can cause stains, non-uniformity in further processing, grain damage, changes in physical parameters which correlates with subsequent direct and indirect costs during leather finishing. The aforementioned changes on the leather represent a danger to the health of workers, which points to the necessity of application of high-quality antimicrobial protection [1-3].

2. Experimental

Process of soaking, liming, deliming and pickling was carried out in conventional industrial conditions. The amount of agents is dosed according to the weight of water. Water ratio is 50 % by weight of pickled hides. The leather sample was processed for 2 hours at a temperature of 30 °C in a bath with the following composition: Citric acid (Sigma Aldrich, St. Louies, USA), 70 gdm^{-3}; Zeolite 5A 65 gdm^{-3} and wetting agent Felosan RG-N (CHT, Swicerland) 1 gdm^{-3}. Processing was carried out in a Mathis turbomat P4502 laboratory device. After processing, antimicrobial tests were performed according to EN ISO 20645:2018 on the following strains: *Staphylococcus aureus* (*S. aureus*), *Escherichia coli* (*E. coli*) and *Candida albicans* (*C. albicans*) [4]. The processing recipe was used for profitability calculations as stated in the paper. Pickled hides that gets damage in the form of mold and fungus as a result of being stored on the grain side undergoes a washing process before further processing (tanning). The hide is washed in water ratio of 200 % by weight of hides. In bath is added surfactant 0,15 % Borron SAF (TFL, Germany) at 30 °C for 60 minutes. After the drain, clean water is poured in, 0,15 % Formic acid (Ivero, Croatia) and 0.15 % fungicide Busan 1401 WB (Buckman, Belgium) are added.

3. Results and Discussion

The above recipe was used to perform cost analysis. The total calculated costs do not include all variable costs (electricity and other overhead costs related to the production process) nor fixed costs (certain workers' salaries), only direct variable costs that define the processes. The total cost of the materials used in the treatment of leather with zeolite for 1000 kg of pickled leather is €149,85, the duration of the treatment is 120 minutes, while the amount of water used is 500 l.

For washing the leather after the appearance of mold and stains due to storage, the total costs of the materials used for 1000 kg of pickled leather are €205,87, the process lasts 135 minutes, and 2000 l of water is used.

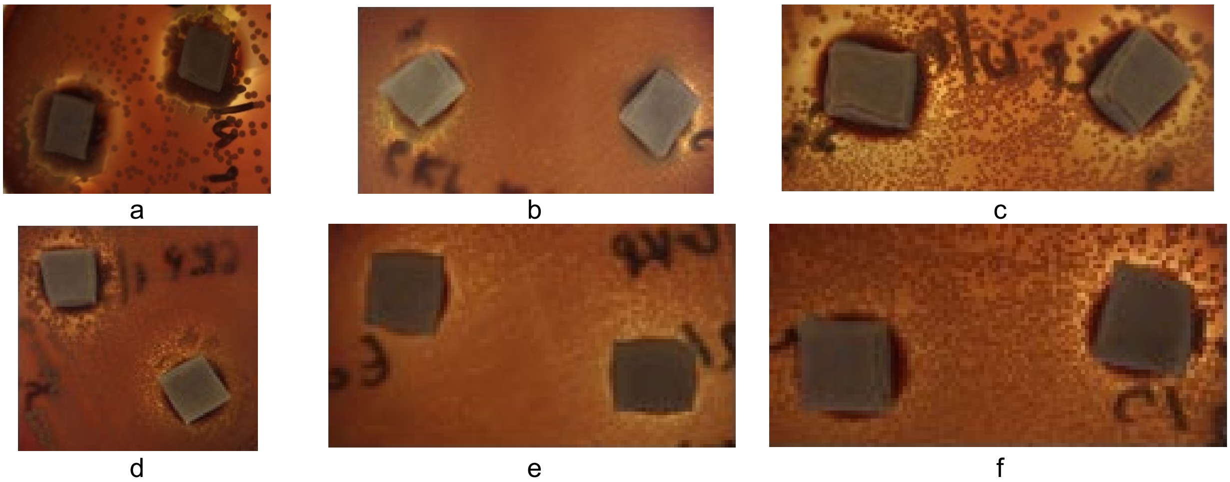


Figure 1: Pickled untreated bovine leather, the grain side a) CA, b) EC and c) SA and treated with zeolite: e) CA, f) EC and g) SA

The results show that pickled leather treated with zeolite has a certain resistance to the mentioned microorganisms. It can be seen that the samples treated with zeolite create additional antimicrobial protection against the gram-positive bacteria *Staphylococcus aureus*, the gram-negative bacteria *Escherichia coli* and the fungus *Candida albicans* compared to the results of the untreated pickled samples (Figure 1).

4. Conclusion

It can be concluded that there is an economic and ecological benefit of treatment with zeolite to protect the leather from microbes and mold. The advantage is visible through reduced water consumption of up to 80 % compared to the mold and fungus removal process. Use of additional chemicals is avoided, which greatly contributes to environmental protection. Considering the process of leather production and finishing, the reduction of time processing and the improvement of working conditions are clearly visible. The variable cost structure presented is determined under the ceterion *paribus condition* based on fixed wholesale prices for the unit of measure and the individual resources used. The zeolites in leather processing have cumulative economically justifiable costs. From the point of view of cost analysis, there is financial profitability, which can positively affect business efficiency and increase revenues.

5. References

[1] Žuvela Bošnjak, F.; Flinčec Grgac, S. & Maršić, K.: Economic efficiency of leather treated with zeolite after the picking process, *Zbornik radova International textile clothing & design conference*, Dragčević, Z.; Hursa Šajatović, A.; Vujasinović, E. (Eds.), pp. 291-294, Dubrovnik, October 2022, University of Zagreb Faculty of Textile Technology, ISSN 0955-6222
[2] Zugno, L. et al: Fungal Growth on Wetblue: Methods to Measure Impact on Leather Quality, *Journal of the American Leather Chemists Association,* **106** (2011) 1, pp. 1-17, ISSN 0002-9726
[3] Birbir, M. et al: Mold strains isolated from unfinished and finished leather goods and shoes. *Journal of the American Leather Chemists Association,* **89** (1994) 1, pp. 14-19, ISSN 0002-9726
[4] EN ISO 20645:2018 *Textile fabric – Determination of antibacterial activity – Agar diffusion plate test*

dr. sc. dr. sc.
TZT dr. sc. dr. sc. TZT TZT
sc. TZT TZT dr. sc. TZT dr. sc. dr. sc.
TZT dr. sc. dr. sc. TZT TZT TZT
sc. TZT dr. sc. TZT dr. sc. dr. sc.
dr. sc. dr. sc. TZT TZT TZT
TZT dr. sc. TZT TZT dr. sc. TZT
TZT dr. sc. TZT dr. sc. TZT dr. sc.
TZT dr. sc. TZT TZT dr. sc. TZT
TZT dr. sc. dr. sc. TZT dr. sc.
sc. TZT TZT TZT dr. sc. dr. sc.
TZT dr. sc. dr. sc. TZT dr. sc. dr. sc.
TZT dr. sc. TZT TZT dr. sc. TZT dr. sc.