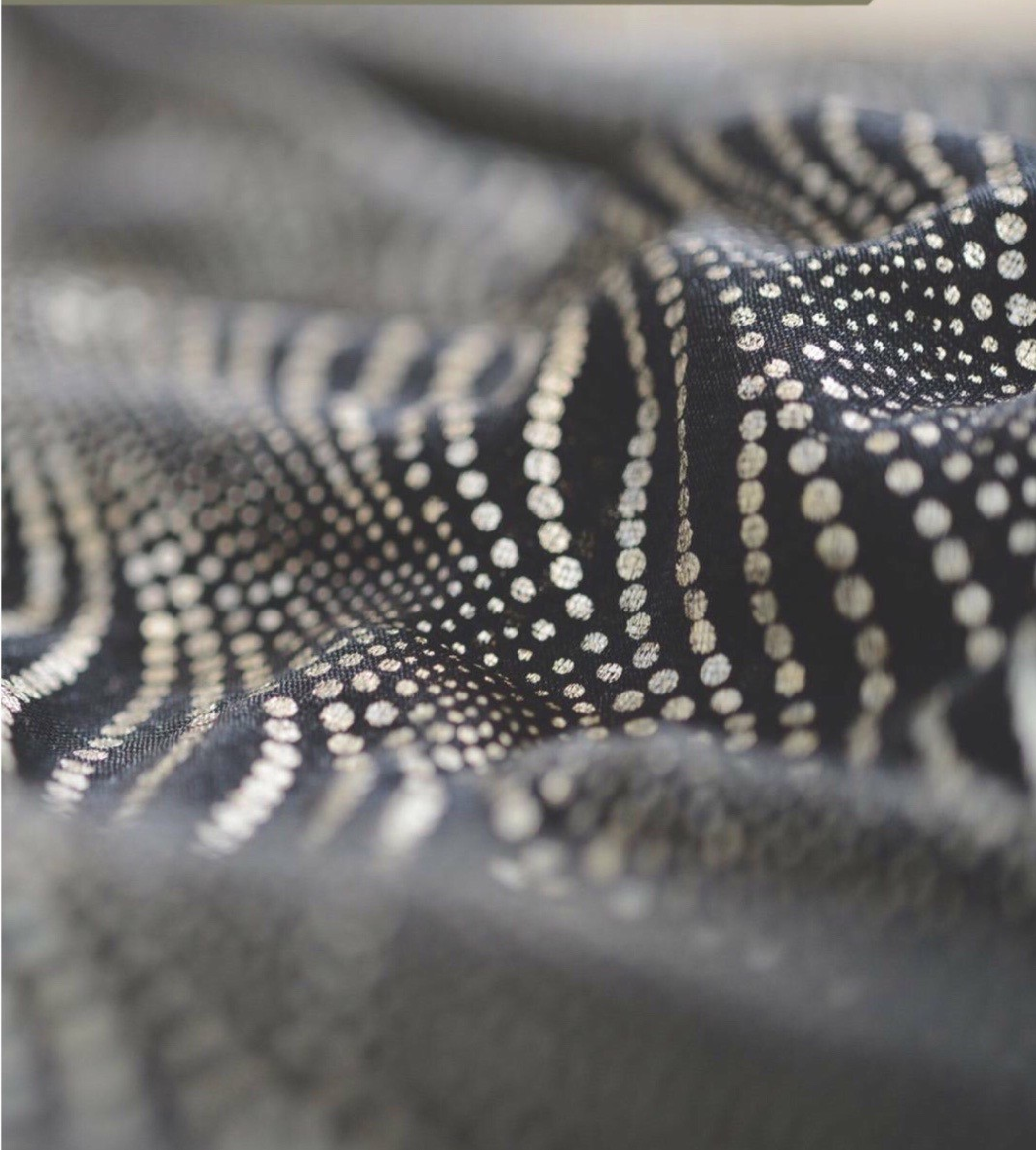
FIBER FABRIC & FASHION RESEARCH JOURNAL

วารสารวิจัยเส้นใย ผ้า และแฟชั่น

คณะอุตสาหกรรมสิ่งทอและออกแบบแฟชั่น มทร. พระนคร

ปีที่ 1 ฉบับที่ 2 กรกฎาคม - ธันวาคม 2564 ISSN 2773-8620 (Online)

Volume 1 No. 2 July - December 2021



วารสารวิจัยเส้นใย ผ้า และแฟชั่น

ชื่อวารสาร	วารสารวิจัยเส้นใย ผ้า และแฟชั่น (Online)
ISSN	ISSN 2773-8620 (Online)
ผู้พิมพ์	คณะอุตสาหกรรมสิ่งทอและออกแบบแฟชั่น มหาวิทยาลัยเทคโนโลยีราชมงคลพระนคร
วัตถุประสงค์	เพื่อเผยแพร่บทความวิจัย และบทความวิชาการทางด้านสิ่งทอและแฟชั่น ทั้งภายในและภายนอกมหาวิทยาลัย และส่งเสริมการเผยแพร่ผลงานวิชาการและวิจัยให้เป็นที่ยอมรับในแวดวงวิชาการ
ลักษณะวารสาร	เป็นวารสารอิเล็กทรอนิคแบบออนไลน์ (E Journal) ขนาด เอ 4
กำหนดการเผยแพร่	ปีละ 2 ฉบับ (ราย 6 เดือน) ฉบับที่ 1 มกราคม – มิถุนายน และฉบับที่ 2 กรกฎาคม – ธันวาคม เผยแพร่ในเวปไซต์ของคณะอุตสาหกรรมสิ่งทอและออกแบบแฟชั่น http://www.itfd.rmutp.ac.th/itfd2010/e-journal
เนื้อหา	มีเนื้อหาทางด้านวิชาการและวิจัยทางด้านสิ่งทอและแฟชั่น ประกอบด้วย - บทความวิชการและวิจัยทางด้านวิทยาศาสตร์ และเทคโนโลยี - บทความวิชาการและวิจัยทางด้านมนุษยศาสตร์
ภาษา	ไทย / อังกฤษ
ลักษณะบทความ	1. ต้องไม่เคยเผยแพร่ในวารสารอื่นใดมาก่อนหรือไม่อยู่ในขั้นตอนการพิจารณาเพื่อเผยแพร่ในวารสารอื่นๆ 2. ต้องเป็นผลงานวิจัยที่มีผลกระทบในวงกว้างที่ไม่ใช่งานวิจัยเพียงระดับสถาบัน
การส่งบทความ	ส่งบทความมาที่อีเมล์ rattanaphol.m@rmutp.ac.th ; kongkiat.m@rmutp.ac.th
สำนักงาน/ ติดต่อ	คณะอุตสาหกรรมสิ่งทอและออกแบบแฟชั่น มหาวิทยาลัยเทคโนโลยีราชมงคลพระนคร เลขที่ 517 ถนนนครสวรรค์ แขวงสวนจิตลดา เขตดุสิต กรุงเทพมหานคร 10300 โทรศัพท์ 02 665 3555 โทรสาร 02 6653545 มือถือ 08 6992 3305 08 7484 3723

FIBER FABRIC & FASHION RESEARCH JOURNAL

Name of Journal	FIBER FABRIC & FASHION RESEARCH JOURNAL (Online)
ISSN	ISSN 2773-8620 (Online)
Publisher	Rajamangala University of Technology Phra Nakhon, Faculty of Industrial Textiles and Fashion Design
Objective	To disseminate academic work in textiles and fashion disciplines and Promote the dissemination of academic and research works to be accepted in academic areas.
Type of journal	Online journal by website http://www.itfd.rmutp.ac.th/itfd2010/e-journal
Publication Frequency	2 issues per year (January-June) , (July –December)
Content	Academic and research content in textiles and fashion consists of • Academic and research articles in science and technology • Academic and research articles in the humanities
Language	Thai / English
Article Requirements	1. Authors should be noted that only original articles are accepted for publication. Neither the article submitted, nor a version of it has been published, or is being considered for publication elsewhere. 2. Submitted articles must be beneficial to the public.
Article Submission	Email: rattanaphol.m@rmutp.ac.th ; kongkiat.m@rmutp.ac.th
Office/ Contact	Rajamangala University of Technology Phra Nakhon, Faculty of Industrial Textiles and Fashion Design. No. 517, Nakhonsawan Road, Suan Chitladda Sub-district, Dusit District, Bangkok, 10300 THAILAND Email: rattanaphol.m@rmutp.ac.th ; kongkiat.m@rmutp.ac.th Tel. +66 (02) 665 3555 โทรสาร +66 (02) 6653545 Mobile +66 (08) 69923305; +66 (08) 74843723

วารสารวิจัยเส้นใย ผ้า และแฟชั่น

วารสารวิจัยเส้นใย ผ้า และแฟชั่น

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คำแนะนำในการเตรียมต้นฉบับบทความ

1. การเรียงลำดับเนื้อหาบทความ

1.1 ชื่อเรื่อง (Title) ภาษาไทยและภาษาอังกฤษควรสั้นกะทัดรัด และสื่อความหมายของเรื่องที่ทำอย่างชัดเจน

1.2 ชื่อ นามสกุลของผู้เขียน ใส่ทุกคน เป็นภาษาไทยและภาษาอังกฤษ ระบุสถานที่ทำงาน และที่อยู่สำหรับผู้นิพนธ์ประสานงาน (Corresponding Author) ให้ระบุหมายเลขโทรศัพท์ และไปรษณีย์อิเล็กทรอนิกส์ (E-mail)

1.3 บทคัดย่อ (Abstract) ภาษาไทยและภาษาอังกฤษเป็นเนื้อความสรุปสาระสำคัญของเรื่อง วัตถุประสงค์ วิธีการศึกษาผลการศึกษา และผลสรุป มีความยาวไม่เกิน 250 คำ มี 1 ย่อหน้า

1.4 คำสำคัญ (Keyword) ภาษาไทยและภาษาอังกฤษอย่างละ 3–5 คำ ไว้ท้ายบทคัดย่อแต่ละภาษา

1.5 เนื้อหา (Text) บทความวิจัยควรประกอบด้วย

- **บทนำ (Introduction)** บอกความสำคัญหรือที่มาของปัญหาที่นำไปสู่การศึกษา วัตถุประสงค์ และอาจรวมวรรณกรรมที่เกี่ยวข้อง (Literature Review)
- **วัสดุ อุปกรณ์และวิธีการวิจัย (Materials and Methods)** กล่าวถึงรายละเอียด การวิเคราะห์และทดลองที่กระชับและชัดเจน
- **ผลการทดลอง และการอภิปรายผล (Results and discussion)** บอกผลที่พบอย่างชัดเจน สมบูรณ์และมีรายละเอียดครบถ้วน รวมทั้งเป็นการประเมิน การตีความ และการวิเคราะห์ในแง่มุมต่างๆ ของผลที่ได้ว่าเป็นไปตามวัตถุประสงค์หรือไม่ มีความสอดคล้องหรือขัดแย้งกับผลงานของผู้อื่นอย่างไร ต้องมีการอ้างหลักการหรือทฤษฎีมาสนับสนุนหรือหักล้างอย่างเป็นเหตุเป็นผล
- **สรุปผลการวิจัย (Conclusion)** ส่วนนี้นำเสนอผลลัพธ์ของงานโดยการตีความสิ่งที่ค้นพบในระดับที่สูงกว่าการอภิปรายผล และอาจมีข้อเสนอแนะที่จะนำผลวิจัยไปใช้ประโยชน์

1.6 กิตติกรรมประกาศ (ถ้ามี) ระบุสั้นๆ ว่าได้รับการสนับสนุนทุนวิจัยและความช่วยเหลือจากที่ใดบ้าง

1.7 เอกสารอ้างอิง (References) การอ้างอิงในบทความใช้การอ้างอิงแบบตัวเลข เอกสารอ้างอิงท้ายบทความทุกฉบับจะต้องมีการอ้างอิงในบทความ มีการอ้างอิงที่ถูกต้องตามหลักวิชาการ ตามรูปแบบของ APA (American Psychological Association) รายละเอียดของเอกสารอ้างอิง ประกอบด้วย ชื่อผู้เขียน ชื่อหนังสือหรือชื่อของบทความ ชื่อของเอกสารที่พิมพ์ สำนักพิมพ์ หรือสถานที่พิมพ์ ปีที่ (ฉบับที่) พิมพ์ และเลขหน้าที่อ้างอิงทั้งนี้การเขียนให้เป็นไปตามรูปแบบของชนิดเอกสารที่อ้างอิง

1.8 ภาคผนวก (ถ้ามี)

1.9 ตารางและรูปภาพ ต้องมีความคมชัดและให้แทรกไว้ในบทความ มีคำอธิบายสั้นๆ แต่สื่อความหมายได้สาระครบถ้วนและเข้าใจ กรณีที่เป็นตาราง ให้ระบุลำดับที่ของตาราง ใช้คำว่า “**ตารางที่...**” และมี

คำอธิบายใส่ไว้เหนือตาราง กรณีที่เป็นรูปให้ระบุลำดับที่ของรูปใช้คำว่า “**ภาพที่...**” และมีคำอธิบายใส่ไว้ใต้รูป

2. คำแนะนำในการเขียนและพิมพ์

2.1 คำแนะนำทั่วไป บทความต้องมีความยาวไม่เกิน 9 หน้ากระดาษ A4 พิมพ์ด้วย Microsoft Word for Windows การตั้งค่าหน้ากระดาษ ขอบด้านบนและด้านล่าง 3 ซม. ด้านซ้ายและ ด้านขวา 2.5 ซม. พิมพ์ 1 คอลัมน์ การลำดับหัวข้อของเนื้อเรื่องให้ใช้เลขกำกับ บทนำเป็นหัวข้อหมายเลข 1 และหากมีหัวข้อย่อยให้ใช้เลขระบบทศนิยมกำกับหัวข้อย่อย เช่น 2.1 เป็นต้น ดูรายละเอียดเพิ่มเติมได้ที่ http://www.itfd.rmutp.ac.th/itfd2010/e-journal

2.2 แบบและขนาดตัวอักษร

- กรณีเป็นบทความภาษาไทย ใช้ตัวอักษรแบบ “TH Sarabun PSK” ชื่อบทความใช้ตัวอักษรขนาด 18 ตัวหนา ชื่อผู้เขียน บทคัดย่อและเนื้อความต่างๆ ใช้ตัวอักษรขนาด 14 ตัวปกติ ชื่อหัวข้อและหัวข้อย่อยใช้ตัวอักษรขนาด 14 ตัวหนา
- กรณีเป็นบทความภาษาอังกฤษ ใช้ตัวอักษรแบบ “Times New Roman” ชื่อบทความใช้ตัวอักษรขนาด 14 ตัวหนา ชื่อผู้เขียน บทคัดย่อและเนื้อความต่างๆ ใช้ตัวอักษรขนาด 12 ตัวปกติ ชื่อหัวข้อและหัวข้อย่อยใช้ตัวอักษรขนาด 12 ตัวหนา

3. เกณฑ์การพิจารณาบทความ

มีดังนี้ ความคิดริเริ่มสร้างสรรค์ คุณค่าทางวิชาการความสมบูรณ์ของเนื้อหาและโครงสร้าง ภาษาที่ใช้ ความชัดเจนของสมมติฐาน/วัตถุประสงค์ ความชัดเจนของการนำเสนอและการจัดระเบียบบทความ ความถูกต้องทางวิชาการ การอภิปรายผล และการอ้างอิงที่ถูกต้องตามหลักวิชาการ

บทความจะต้องได้รับการประเมินโดยผู้ทรงคุณวุฒิในสาขาวิชานั้นอย่างน้อย 2 คน ซึ่งกองบรรณาธิการอาจให้ผู้เขียนปรับปรุงให้เหมาะสมยิ่งขึ้นและทรงไว้ซึ่งสิทธิ์ในการตัดสินลงพิมพ์หรือไม่ก็ได้

Instructions to Authors

1. Order of an Article Content

1.1 Title both in Thai and in English must be concise and clearly convey what is done.

1.2 Name and Surname of the Author(s) in Thai and in English. Office address must be specified. Telephone number and e-mail address of corresponding author (if any) are needed.

1.3 Abstract in Thai and in English of not more than 250 words is compulsory. It must include essence, objectives, methodology, and findings of the research.

1.4 Keywords of 3–5 words are needed to be put below the abstract.

1.5 Text of the article should consist of the followings:

- Introduction: State background and objectives of the study. Literature review may be included.
- Materials and Methods: Concise and clear explanation of details, analysis, and experiment is required.
- Results and Discussion: Report the complete findings. Evaluation, interpretation, and analysis of the findings are to be made so as to show whether the research achieved the objectives or not, how it agrees with or contradicts to other research. Theories and principles are needed to support the discussion in a logical manner.
- Conclusion: This section presents the outcome of the work by interpreting the findings at a higher level of abstraction than the Discussion. Suggestions for making use of the findings may be included.

1.6 Acknowledgement (if any): Briefly identify and acknowledge fund sources and assistance.

1.7 References: **Numbering system is used for in-text references.** Every end-text reference must be referred to in the article. References must be properly written in conforming APA (American Psychological Association) format. Each reference consists of authors' name, book title or article title, document title, publisher, publishing year, (issue No.) and referenced page number depending on types of reference text.

1.8 Appendix (if any)

1.9 Tables and Figures must be clear and inserted in the article. Brief explanation is needed to convey meaningful and understandable essence. For tables, identify the table number respectively followed by a brief explanation and put it above the table itself. For figures, identify the figure number respectively followed by a brief explanation and put it below the figure itself. (Tables and figures are requested to record in .jpg file in addition to the article file.)

2. Instructions for Writing and Typing

2.1 General Instructions: Each article must not be longer than 9 A4 pages. Microsoft Word for Windows must be used for typing. Page layout is as follows: Upper and bottom edges are 3 cm, left and right edges 2.5 cm., one column. Use numbering system for topic arrangement starting from 1. Introduction and so on. Use decimal system for sub-topics. For more information, see and download from http://www.itfd.rmutp.ac.th/itfd2010/e-journal

2.2 The Proper Use of Fonts and Sizes

- Thai language article: Use 18-point TH Sarabun PSK, single-spaced, boldface type for the title. The authors' name, abstract and contents are to be in 14-point size. Use 14-point boldface font size for the main and subtopics.
- English language article: Use 14-point Times New Roman, single-spaced, boldface type for the title. The authors' name, abstract and contents are to be in 12-point size. Use 12-point boldface font size for the main and subtopics.

3. Criteria for Article Consideration

Creativity, academic value, completeness of content and structure, language usage, clearness of objectives/hypotheses, content presentation and organization, academic accuracy, proper finding discussion and references are to be considered.

An article will be reviewed by at least two experts of the field. The editorial board has a privilege to ask the authors to improve their articles, and to decide whether submitted articles should be published or not.

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คณะอุตสาหกรรมสิ่งทอและออกแบบแฟชั่น มทร. พระนคร
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Drying Rate Evaluation of Men's Quick-Dry Sportswear

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Abstract

Drying rate and time are two important components for drying a fabric to evaluate the quick dry property. This study evaluated the quick dry properties of summer men's sportswear T-shits of different brands (Nike, Adidas, Laishilong and Columbia) by studying the drying rate. It was found that all the samples showed satisfactory drying rate. The fabrics of Adidas showed the highest drying rate, only 45 minutes required for drying, followed by Laishilong samples, while the poorest drying properties was seen in Columbia T-shirts.

Keywords: Drying rate, Sportswear; Quick dry property, Fabric structure

INTRODUCTION

Drying process means the removal of moisture remained in the fabric after squeezing or hydro-extraction. The amount of moisture in a fabric depends on the thickness, structure such as size and shape of pores of the fabric, and also the chemical interaction between the water molecules and the surface of that fabric [1]. The rate of drying is determined by the moisture content of the particular fiber, the drying temperature, the relative humidity (RH), and the velocity of the air in contact with the fiber [2].

The quick dry clothes refer to the fabric or garment will dry faster when compared with the wool or cotton materials under the same conditions of temperature and humidity. It does not mean that it will absorb the sweat but transferred the sweat to the surface of the clothes and make people feel dry on the side touch with human skin [3]. Most of quick dry fabric are made of synthetic fiber, which has lower water absorbing performance, higher air permeability and water proof performance [4].

Quick dry fabric is designed for the requirements of outdoor environment. It is easy to sweat when people are in outdoor activities. The quick dry clothes will make the sweat to evaporate into the air to keep your skin dry [5]. Some of them use the principle of similar characteristics of shape memory polymer, or microporous membrane principle, or the principle of difference between water molecules diameter and the diameter of air molecules. It will accelerate the evaporation of sweat and avoid the getting cold by heat loss [6].

Quick dry is an important property of sportswear and contributes to the prevention of heat loss, wearing comfort and light weight. This has made quick dry a common performance requirement for garments. Moisture from the fiber inside the infiltration of water can be quickly release, discharge and maintain in an excellent dry effect, which enables the fabric in an often dry and comfortable state. In this study, we aims to comparatively evaluate the quick dry properties of sportswear available in Hong Kong market by analyzing the drying rate behavior.

EXPERIMENTAL

Fabric samples

Four summer men's running T-shirts of different brands, i.e., Nike, Adidas, Laishilong and Columbia, were selected for this study. These running T-shirts were claimed and advertised that they can keep human body dry with excellent quick dry behavior when people are exercising. The samples are single and double jersey but with different colors, fiber types and content. Cotton and polyester are the major fibers, including the recycled polyester and spandex, used in the fabric samples. Detailed fabric specification was shown in Table 1.

Table 1. Specification of tested samples.

Item		Sample specification			
Brand		Nike	Adidas	Laishilong	Columbia
Composition		85% polyester 15% cotton	Front body: 61% polyester recycled and 39% polyester; Back body: 51% polyester and 49% polyester recycled	100% polyester	Shell face: 100% polyester; Side panel: 86% polyester and 14% elastane
Color		Grey	Black	Black	Blue
Fabric structure		Single Jersey	Double Jersey	Double Jersey	Double Jersey
Fabric weight (g/m^2)		130.61	128.41	142.76	77.74
Fabric thickness/mm		0.299	0.328	0.292	0.194
Fabric density	Wale/cm	With holes: 18 Without holes: 13.5	Front body:18 Back body:18	17.5	25
	Course/cm	With holes: 17 Without holes: 27.2	Front body:19 Back body:23	20	30

All samples before testing were conditioned with the temperature 20±2°C and relative humidity 65±2% for at least 24 hours. After conditioning, samples were used in physical testing and all the experiments were carried out under standard testing condition.

Surface morphology analysis

The surface morphology of sportswear samples was observed by the Digital Microscope (Leica DVM6, Hamburg, Germany).

Drying rate evaluation

Drying rate and time used for drying a fabric are two important factors to evaluate its quick dry properties, which may greatly affect the comfort of clothing. Drying ability is determined by the rate of moisture retention in fabric and time used for drying. Effectiveness of perspiration removal from skin to outer environment through evaporation can be demonstrated by drying rate of fabric. Drying measurement becomes crucial for the study of moisture management fabrics performance since a slow drying fabric may negatively affect the thermal comfort of a greatly active wearer who may excessively sweat. Therefore, drying rate testing was conducted to evaluate the drying ability and speed of fabric under standard atmosphere.

The testing procedures were set as below.

1. Fabric samples were cut into size of 5x5cm.
2. The specimens were weighted before wetting and recorded for further calculation.
3. As 1 gram is equivalent to 1 mL, same amount of water with the fabric weight was applied to fabric for 100% soaking.
4. The weight of fabric was measured every 5 minutes until 3 consecutive unchanged weights were recorded.
5. Step 4 and 5 were repeated until all specimens were measured.

The total time used for drying the wetted fabric to its original dried weight would be recorded. Also, the drying rate would be calculated for every 5 minutes as an interval in order to monitor the water retention percentage in the fabric per unit time. The equation was shown as follows.

For determining the drying rate of fabric, calculation of drying rate of fabric in each time shot is required and the equation used is:

$$(W_a - W_b)/T \times 100\%$$

Where, W_a = Weight after testing, fabric weight after wetting and drying again; W_b = Original Weight or Weight before test; T = Time (min).

RESULT AND DISCUSSION

Fabric appearance and structure analysis

The appearance and fabric structure of four samples were shown in Figure 1. Two samples, Nike and Adidas, were knitted by single jersey, while the other two samples, Laishilong and Columbia, were knitted by double jersey with specific techniques. The miss stitches were applied on the back body of Nike T-shirt to create the holes on the fabric. For the Adidas's T-shirt, there were two tensions of the double jersey applied on the front body of garment, thus to create subtle disruptive pattern. Its back body was knitted by plain single jersey but every three wales has constant tension and then one wale has different tension. The whole garment of the Laishilong's T-shirt was knitted by plain stitches. The fabric structure of Columbia's T-shirt was special knitted by every 5 wales of front loops with 1 wale of back loops. Also, every 5 courses plain stitches were knitted and followed with 1 course of tuck stitches. Therefore, the overall fabric structure of Columbia's T-shirt seems plaid pattern.

Figure 1. Appearance and fabric structure of fabric samples of different brands: Nike (A, a), Adidas (B, b), Laishilong (C, c) and Columbia (D, d).

Drying rate analysis

Drying rate and time are two important components for drying a fabric to evaluate the quick dry property. The drying rate was measured periodically every 5 minutes and the measurement was determined by the change in volume per unit time. The high drying rate means the fabric can become dried easily.

As shown in Figure 2, it can be seen that the fabric with holes of Nike took 1 hour to dry from the wetted fabric to its original dried weight (0.3305 g). For Laishilong fabric, it took 55 minutes for drying. Both front body and back body from Adidas took the shortest time for drying, which took 45 minutes. Only Columbia fabric took the longest time for drying that needs 80 minutes.

The periodical drying rates of the specimens were calculated every 5 minutes. All the fabric specimens have regular drying rate since the percentage of moisture retention are reduced constantly for every interval. When the fabric was nearly dried to its original weight, the change in the percentage of moisture retention becomes less and less. Figure 3 summarized the total drying rates of the specimens. The Columbia fabric has the highest total drying rate (54.028%) while the front body fabric from Adidas has the lowest total rate (43.739%). By contrast, other three specimens have similar total drying rates. The potential reason may be due to the fabric construction and fiber content.

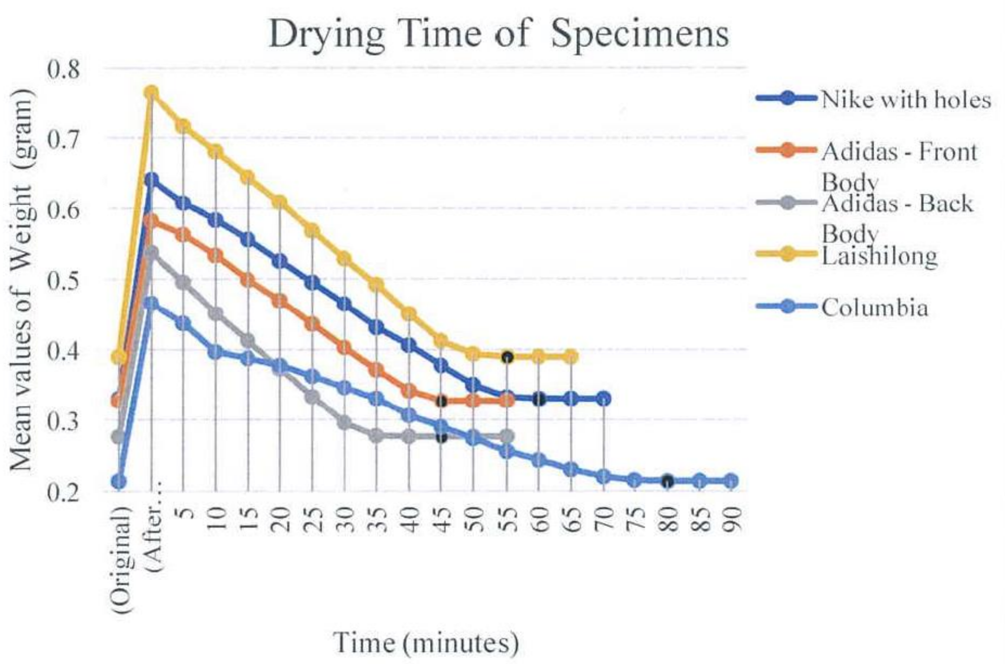


Figure 2. Drying time of samples.

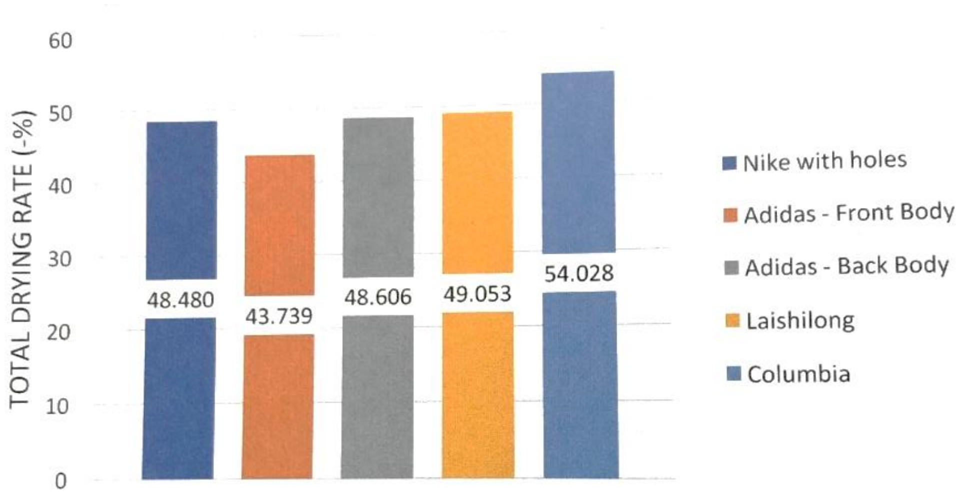


Figure 3. Total drying rate of samples.

Effect of fiber content on drying rate

Fiber content is one of the factors affecting the drying rate (the percentage reduced). Since polyester is the common fiber used in sportswear, only polyester and recycled polyester fiber were further studied here. Figure 4 shows the distribution of polyester content and total drying rate, which reflects a positive relationship of polyester content and total drying rate. The more polyester fibers used in the fabric, the higher drying rate reduced, which means more moisture dried.

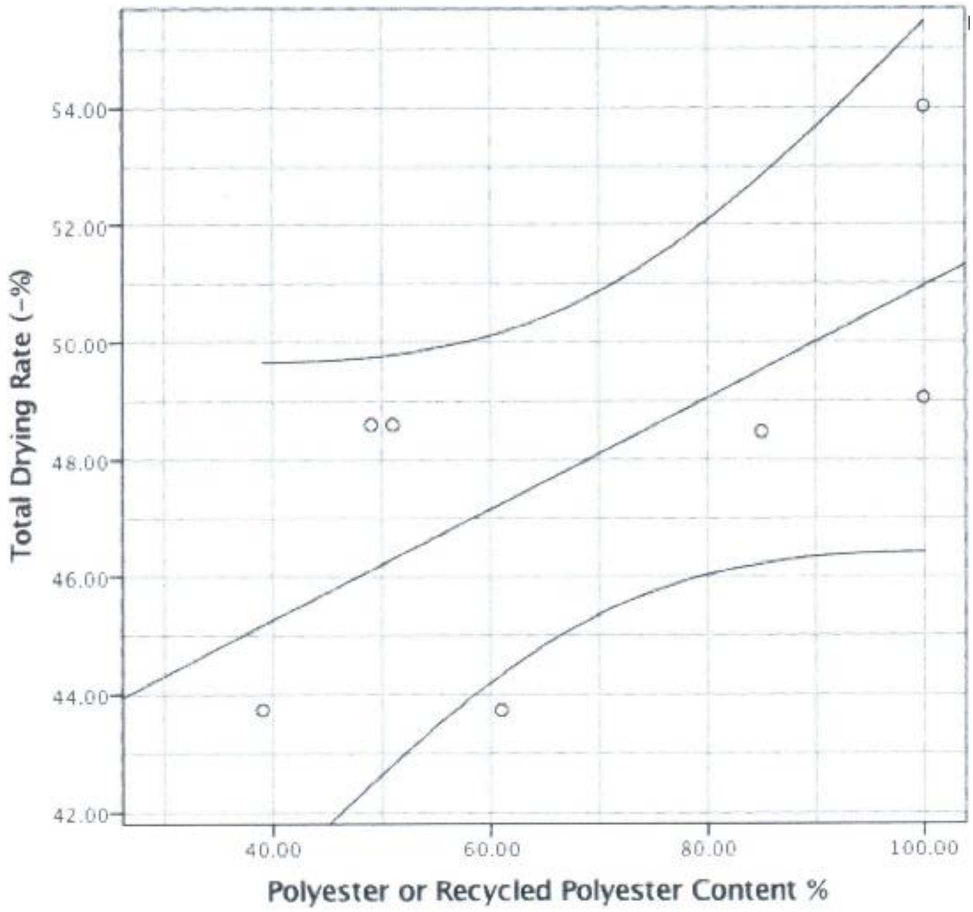


Figure 4. Relationship between polyester content and total drying rate.

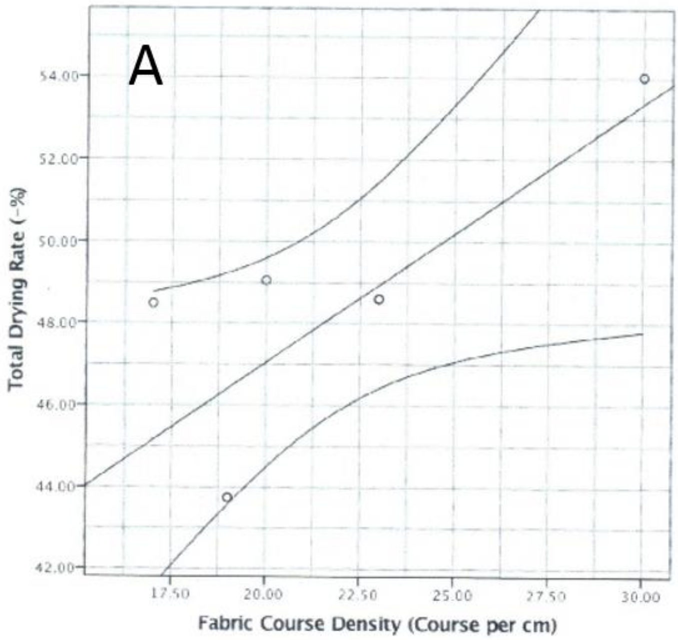
Effect of fabric density on drying rate

The correlation analysis (Table 2) shows that there was a significant correlation between the drying rate and fabric course density (*p* value = 0.042 < 0.005), and the relationship was strongly positive (*r* value =0.773>0.7). However, the relationship between drying rate and the fabric wale density was not significant but the correlation was strongly positive (r value =0.729>0.7). These relationship between drying rate and fabric density, both wale and course density, can be elaborated via Figure 5. The drying rate has directly proportional relationship with fabric course and wale density. This implies that the higher fabric course and wale density, the higher the drying rate reduced.

Table 2. Correlation analysis among drying rate and fabric density.

		Wale density	Course density
Drying rate	Pearson correlation	0.729	0.773*
	Sig. (2-tailed)	0.063	0.042

*correlation is significant at the level 0.05 level (2-tailed).



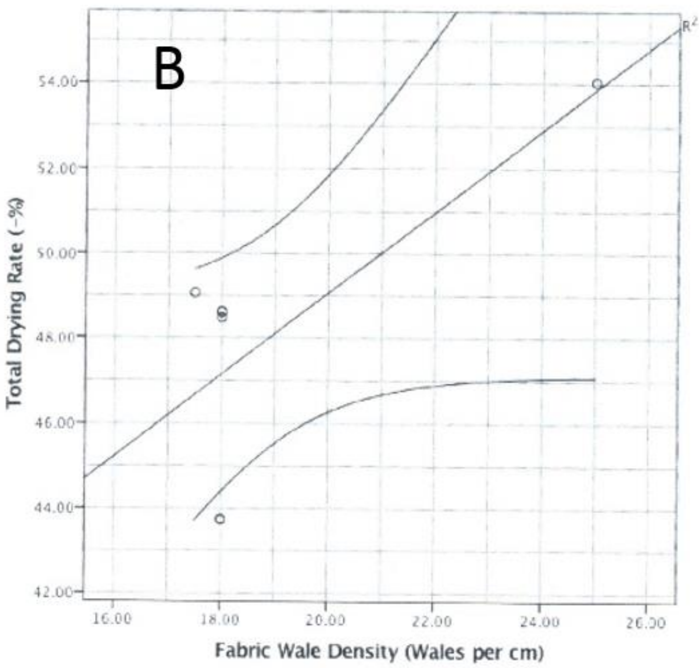


Figure 5. Relationship between drying rate and fabric course density (A) and wale density (B).

Effect of fabric thickness on drying rate

The effect of the fabric thickness on drying rate was different from that on polyester content and fabric density. This is because the relationship between fabric thickness and drying rate was in inverse proportion, as shown in Figure 6. This implies that the higher the fabric thickness, the lower the drying rate.

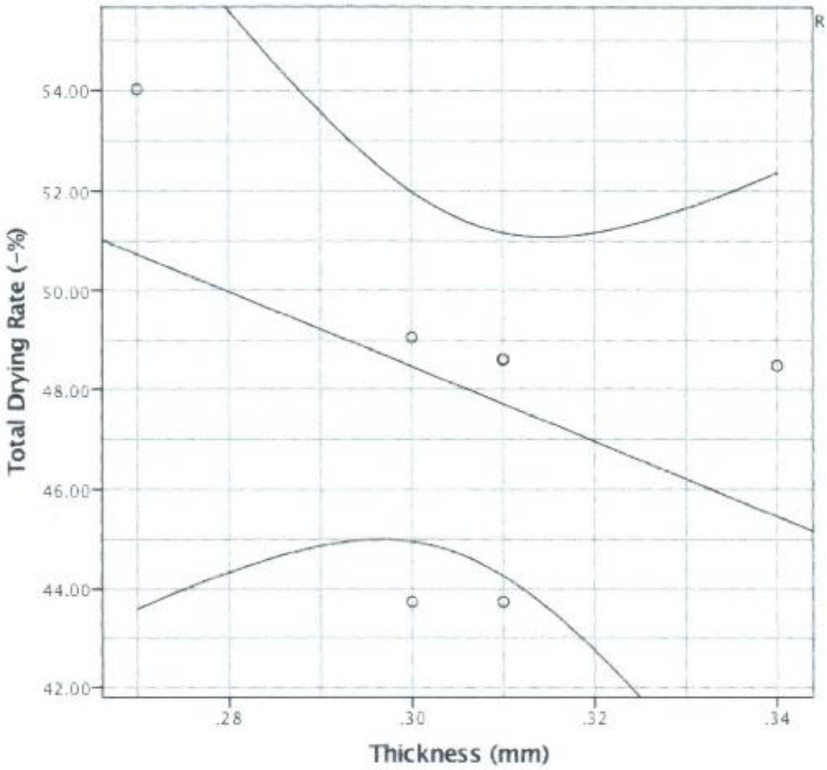


Figure 6. Relationship between drying rate and fabric thickness.

CONCLUSIONS

In this study, the quick dry properties of summer men's sportswear T-shirts of different brands available in Hong Kong market were comparatively evaluated by studying the drying rate. It was found that the fabrics of Adidas, both front body and back body, showed the highest drying rate, only 45 minutes required for drying, followed by Laishilong samples, whereas the Columbia T-shirts took the longest time for drying (80 minutes) and showed the poorest drying property.

REFERENCES

[1] Fangueiro, R., Filgueiras, A., Soutinho, F., and Meidi, X. (2010). Wicking behavior and drying capability of functional knitted fabrics. Textile Research Journal, 80(15), 1522-1530.
[2] Hassan, M. M., and Leighs, S. J. (2017). Quick dry ability of various quick drying polyester and wool fabrics assessed by a novel method. Drying Technology, 35(5), 585-592.
[3] Chen, D., Tan, L., Liu, H., Tang, F., Hu, J., and Li, Y. (2010). Fabrication of Fast-Absorbing and Quick-Drying Wool Fabrics with Good Washing Durability. ChemSusChem, 3(9), 1031-1035.
[4] Wang, F., Zhou, X., and Wang, S. (2009). Development processes and property measurements of moisture absorption and quick dry fabrics. Fibres & Textiles in Eastern Europe, 17(2), 46-49.
[5] Fourt, L., Sookne, A. M., Frishman, D., and Harris, M. (1951). The rate of drying of fabrics. Textile Research Journal, 21(1), 26-33.

[6] Hassan, M. M. (2014). Enhanced antistatic and mechanical properties of corona plasma treated wool fabrics treated with 2, 3-epoxypropyltrimethylammonium chloride. Industrial & Engineering Chemistry Research, 53(27), 10954-10964.

A Study on Low Stress Mechanical Properties of Denim Fabric for Hand Evaluation

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Abstract

Denim is widely used by every age of people all over the world. As the use of denim is increasing progressively, till now the handle properties of denim fabric not reported at significant level. In the present study, five commercial denim fabric samples were used. Denim samples, weighing from 8.5oz/sq.yds to 14.5 oz/sq.yds, were processed as per standard commercial procedure for denim finishing. These finished denim samples were tested on Kawabata Evaluation System (KES) for low stress mechanical properties. The results of KES values are used for calculation of Total Hand Value (THV) using equation for summer suit. The obtained result for THV using equation for summer suit for denim samples is in the range from 1.62 to 3.30.These values of low stress mechanical properties values given by KES, can be used to engineer the denim fabric for bottom wear.

Keywords: Denim, Handle Value, KES, Objective evaluation

INTRODUCTION

The fabric production is known for more than 6000 years. However, the investigation in the area connected with perception of textiles during their contact with a skin started about a hundred year ago [1]. Clothes, which are used in direct contact with the human body, are mostly made of fabrics of planar fibre construction, that is, they are manufactured for the most part from textiles. Needless to say, the quality of clothes directly affects both the human mind and body. For this reason, it is essential to have a system which allows us to accurately and thoroughly evaluate the qualities and use-value of textiles [2].The “handle” or “feel” and the “drape of fabrics” are of great importance, to the user of textiles in clothing and home furnishings, as well as to the textile designer and the textile finishing mill. There is no consumer who, when buying clothing, interior textiles or evaluating upholstery of a car, has not touched the product to see what it feels like. The first attempt to evaluate the handle of textile products date back to 1926, when Binns set the beginning of systematic subjective evaluation [3,4,5].After introduction of Objective evaluation method of fabric hand from the basic mechanical characteristics of fabric was developed by Kawabata and Niwa and the objective evaluation equations are widely used for various end use such as men's or women's suits, women's fine dresses, outer or inner wear knits, and developed new equations for bed sheets, disposable diapers, nonwovens, terry towels, etc. [3,6,7,8]. However, hand evaluation for denim fabric is not reported at significant level. In this paper, subjective and objective evaluation of denim fabric is carried out.

MATERIALS AND METHODS

Materials

In this present study 49 denim samples used for the evaluation. Denim samples were collected from various denim industries in India. Samples having different weight (7.6 to 14.5 oz/sq.yds.), different finishing treatment and different yarn properties were employed for the study.A panel of 18 judges from the industry and educational institutes performed the subjective hand evaluation.

Table 1. Denim samples.

Sample weight [Oz/sq. Yards]	No. of samples
7.6 to 10	5
10.1 to 12.5	34
12.6 to 14.6	10
Total	49

Methods

Samples were supplied to Panellists one by one and asked them to rank the samples according to the intensity of feeling on the scale of 0 to 5 (5 being the best) to be used as bottom wear. Sample having following specifications is given highest rating among all 49 samples. The total sum of rating given by 18 panellists is 72.

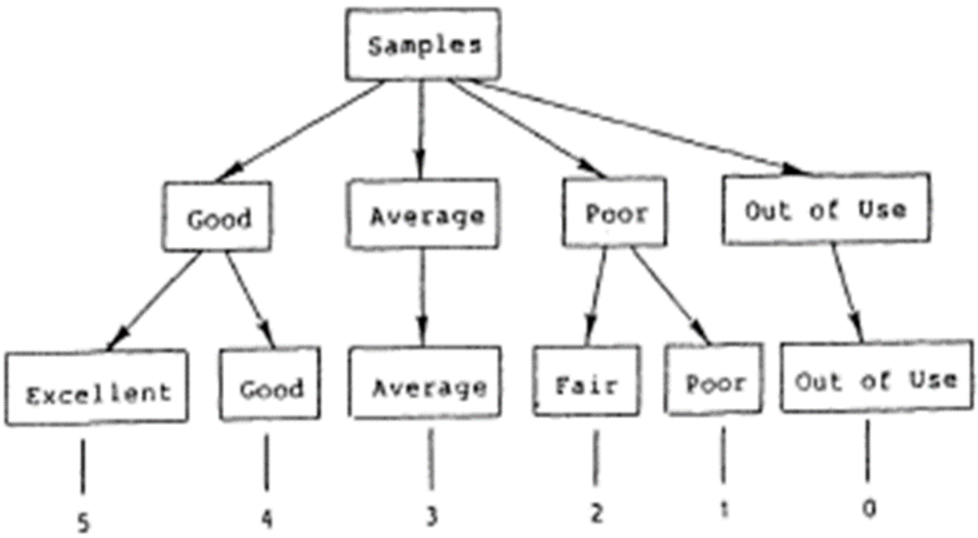

Figure1. Procedure for subjective evaluation of Total Hand Value of Denim samples.

Table 2. Properties of Highest Rated Denim Sample

Weight [Oz/sq. Yards]	10.38
EPI	72
PPI	60
Weave	3/1 RHT
Warp count	8.1^s Ring
Weft count	7.4^s OE

RESULT AND DISCUSSION

Significant test of variances was used to evaluate the level of agreement between each judge and the total mean of the remaining judges. Panellists tended to have a better degree of overall agreement among them which exhibited a higher percentage of significance, and therefore gave a higher level of overall agreement. For objective evaluation, KES-F system is used.

Table 3. Low Stress Mechanical Properties.

Tensile properties		
Linearity	LT	0.749
Tensile energy	WT [gf.cm/cm^2]	15.8
Resilience	RT [%]	43.13
Shear properties		
Shear stiffness	G[gf/cm.degree]	3.51
Hysteresis	2HG[gf/cm]	6.20
Bending Properties		
Bending rigidity	B [gfcm^2 /cm]	0.2730
Hysteresis	2HB[gfcm^2 /cm]	0.2833
Compression Properties		
Linearity	LC	0.349
Compressional energy	WC[gfcm^2 /cm]	0.301
Resilience	RC[%]	38.83
Surface Properties		
Coefficient of friction	MIU	0.207
Mean deviation of MIU	MMD	0.0249
Geometrical roughness	SMD[micron]	6.69
Weight	W[mg/cm^2]	35.36
Thickness	T[mm]	0.803

Table 4. Hand values for Winter suit (KN-101Winter).

Koshi	7.92
Numeri	3.93
Fukurami	5.30
THV (KN-301 Winter)	2.93

Table5. Hand values for Summer suit (KN-101Summer).

Koshi	8.68
Shari	5.33
Fukurami	4.85
Hari	8.68
THV (KN-301 Summer)	2.85

All the sixteen parameters describing fabric low stress mechanical properties were determined with four Kawabata instruments by prescribed procedure for sample which has been given highest mean rating by panellist. The details of KES-F test results are given in Table 3. Primary hand values and total hand values (THV) are calculated by using equations for summer suit (KN-101 Winter) and winter suit (KN-101 Winter).

CONCLUSIONS

Denim samples are evaluated for fabric handle by Subjective and objective evaluations. Following conclusions were obtained.

- Subjective evaluation of denim fabrics shows good agreement among panelists.
- Although the panelists has carried out subjective evaluations and given highest hand value rating for denim sample no.17, THV by objective evaluation for same denim sample is in the range of 3 by using summer and winter suit equations.
- Existing equation or primary hand values relations are not suitable for Denim fabric. Denim is no more a work wear fabric, however is one of the important material as for as clothing is concern and handle properties of denim is to be studied and new relationship of hand values is to be developed for denim.

REFERENCES

[1] Bajzík, V. (2015). Some approaches to objective evaluation of fabric hand. World Journal of Textile Engineering and Technology, 1, 48-58.

[2] Inoue, T., and Niwa, M. (2010). Hand evaluation and formability of Japanese traditional Chirimen fabric. International Journal of Clothing Science and Technology, 22(4), 234-247.

[3] Krasteva, D., and Kandzhikova, G. (2015). Objective Evaluation of the Handle of Woven Terry Fabrics. Journal of Textile & Apparel Technology & Management, 9(3), 1-15.

[4] Jung, C. S., and Koo, Y. S. (2014). Handle analysis of Cosmetic Textiles and its Correlation with Subjective haracteristics-Focus on puff textile. Fashion & Textile Research Journal, 16(2), 312-318

[5] Binns, H. (1926). The discrimination of wool fabrics by the sense of touch. British Journal of Psychology, 16(3), 237-247.
[6] Kawabatra, S. (1980). The standardization and analysis of hand evaluation. Osaka, The Textile Machinery Society Japan.
[7] Kawabata, S., Niwa, M., and Wang, F. (1994). Objective hand measurement of nonwoven fabrics: part I: development of the equations. Textile Research Journal, 64(10), 597-610.
[8] Matsudaira, M., and Kubo, M. (1996). Objective evaluation of hand for futon cloth. Journal of the Textile Machinery Society of Japan, 42(1-2), 23-35.

Q-max Test Analysis of Summer Cooling Towels

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Abstract

This study evaluated the cooling properties of summer cooling towels of different brands by Q-max analysis. It was found all the samples could provide a cooling effect at first contact after being wetted. The samples of Perfect Fitness showed the highest cooling effect followed by the N-rit samples, whereas Street samples had the poorest cooling effect. The reason may be explained by the yarn density, fabric structure and thickness.

Keywords: Q-max test, cooling towel, fabric weight, fabric thickness

INTRODUCTION

Nowadays, consumers are increasingly concerned on the high-functional textile products apart from the aesthetic features, demanding breathable, coolness touching and quick dry fabric and clothing in summer [1]. Due to the hot weather in Hong Kong and increasing demand of functional products, cooling products are popular in recent years, particular the cooling towels which could be bought from sports chain stores, street stores and online shops. Various brands of this product emphasize the cooling effect and excellent cooling sensations of the towel which helps body stay cool during summer and sports time.

Cooling towels' function is achieved by the evaporation of water. It is simple to activate the cooling towel. The step is to soak the towel with the water, wring the excess water, snap it and then just place it around the neck when doing sports or just using during hot days [2]. Repeat the above steps when the cooling effect is no longer obvious.

Evaporative cooling towels are said to offer cooling effect helping body stay cool for hours by quick moisture absorption and evaporation of the heat out of the towel by water. In the market, many brands have used different functional fabrics to develop the cooling towels and all the cooling effect is activated with water. The representative brands include Perfect Fitness, N-rit and Cooldyxm, etc. This study aims to comparatively evaluate the cooling properties of cooling properties of four types of cooling towel products using Q-max analysis.

METHODOLOGY

Fabric specimen

Four cooling towels were obtained from four different brands through chain stores, online shop or street store in Hong Kong and China market. These tested products have different fiber contents, fabric structure and thickness but all of them provide the cooling function with water. The present study aims to compare the product of chain store with online store and street store. The specification of each sample was shown in Table 1.

All samples were conditioned with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2% for 24 hours before testing

.

Table 1. Specification of tested samples.

Item		Sample specification			
Brand		Perfect Fitness	N-rit	Cooldyxm	Ice Towel
Composition		100% PVA	92% Polyester 8% Spandex	100% Polyester	100% Polyester
Size/cm		73×27	99×19.7	108×31	88×35
Type		Composite fabric	Knit	Knit	Knit
Fabric weight (g/m^2)		360.16	131.43	165.05	194.09
Fabric thickness/mm		1.95	0.40	0.61	0.62
Yarn linear density/ Tex		32.3	15.7	18.5	21.4
Fabric density	Wale/cm	7	18	18	17
	Course/cm	6	24	22	18

Surface morphology analysis

The surface morphology of fabric structure of selected brands samples were observed by the Digital Microscope (Leica DVM6, Hamburg, Germany).

Q-max test (KES-F7)

Q-max testing measures the instant warm or cool feeling of the fabric using KES-F7 Thermo Labo II. Q max value (peak heat flux) is evaluated by the heat transmission from the heat plate to the sample fabric, to imitate the sensation of fabric touched by hands and heat flow from human skin to the fabric. In this test, samples in dry and wet states were assessed. Higher q-max value indicates a cooler feeling.

First, KES-F7 Thermo Labo II was switched on and warmed up for about 10 to 15 minutes. The temperature in the water box should be circulated and kept at 20°C to 21°C. BT Box and guard temperature were set at 30°C and 30.4°C respectively. Then, the copper plate of T Box was put above the copper plate of BT Box to start heating to designed temperature. The fabric piece was placed on the sample base in which the side that contacts skin was place upward. Afterwards, the qm button was pushed while the temperature of the T Box reached 30.1°C, then the T Box was moved and placed on the tested fabric piece accurately. The qm digital reading on the monitor was then recorded. All steps were repeated until 5 sample fabrics from each brand in both dry and wet conditions were assessed.

RESULT AND DISCUSSION

Fabric morphology analysis

The appearance of the samples were observed by using the microscope LEICA M165C, and shown in Figure 1. Clearly, the appearance of four samples were different. The fabric structure of samples were shown in Figure 2. The sample of Perfect Fitness was made of composite fabric with 2 layers (Figure 2A). In first layer, there are small pores on the fabric surface whereas there is a plain weave structure in second layer. N-rit has mesh effects formed by interrupting the loop wales (Figure 2B). Cooldyxm's towel was constructed in two layers and mesh weft knit with hexagon pattern on surface, and Ice Towel was constructed of a mesh weft knit with honeycomb pattern and it had two layers.

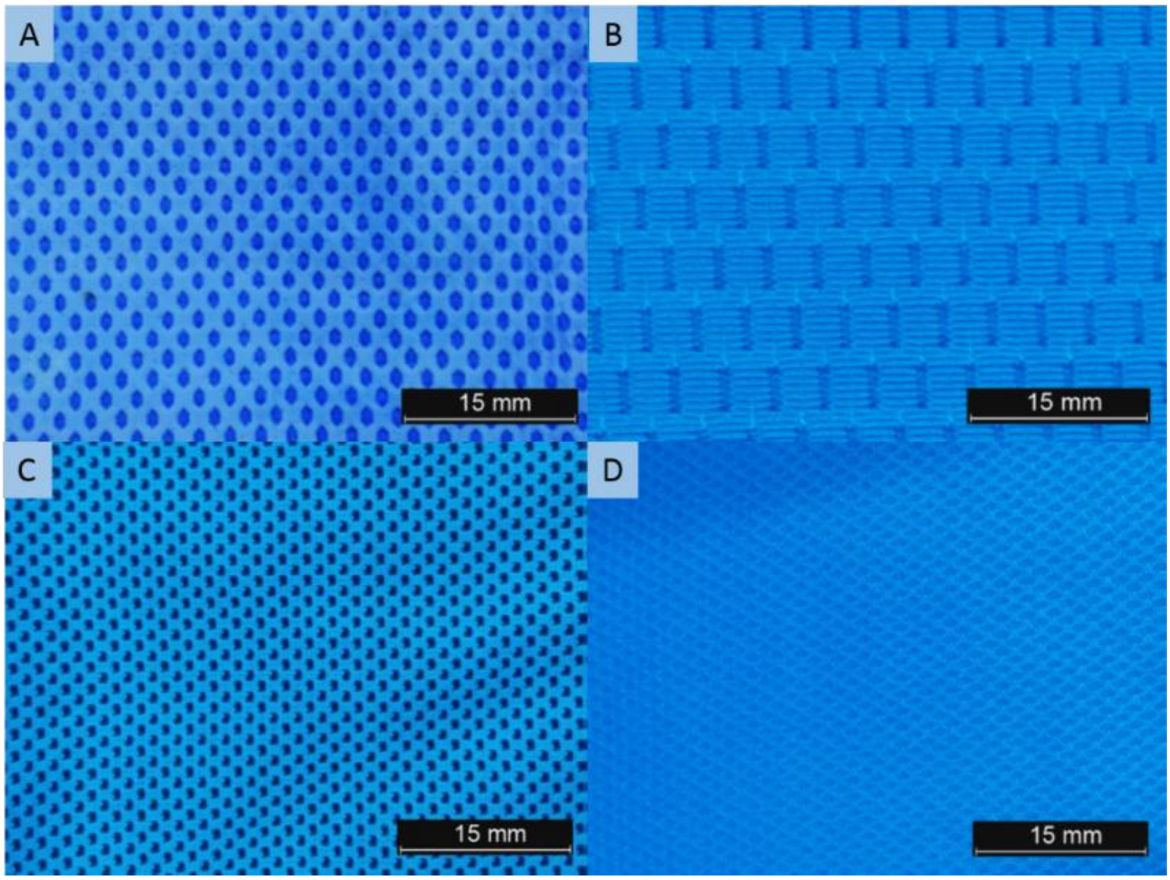

Figure 1. Fabric face appearance of samples of different brands: Perfect Fitness (A), N-rit (B), Cooldyxm (C) and Ice Towel (D).

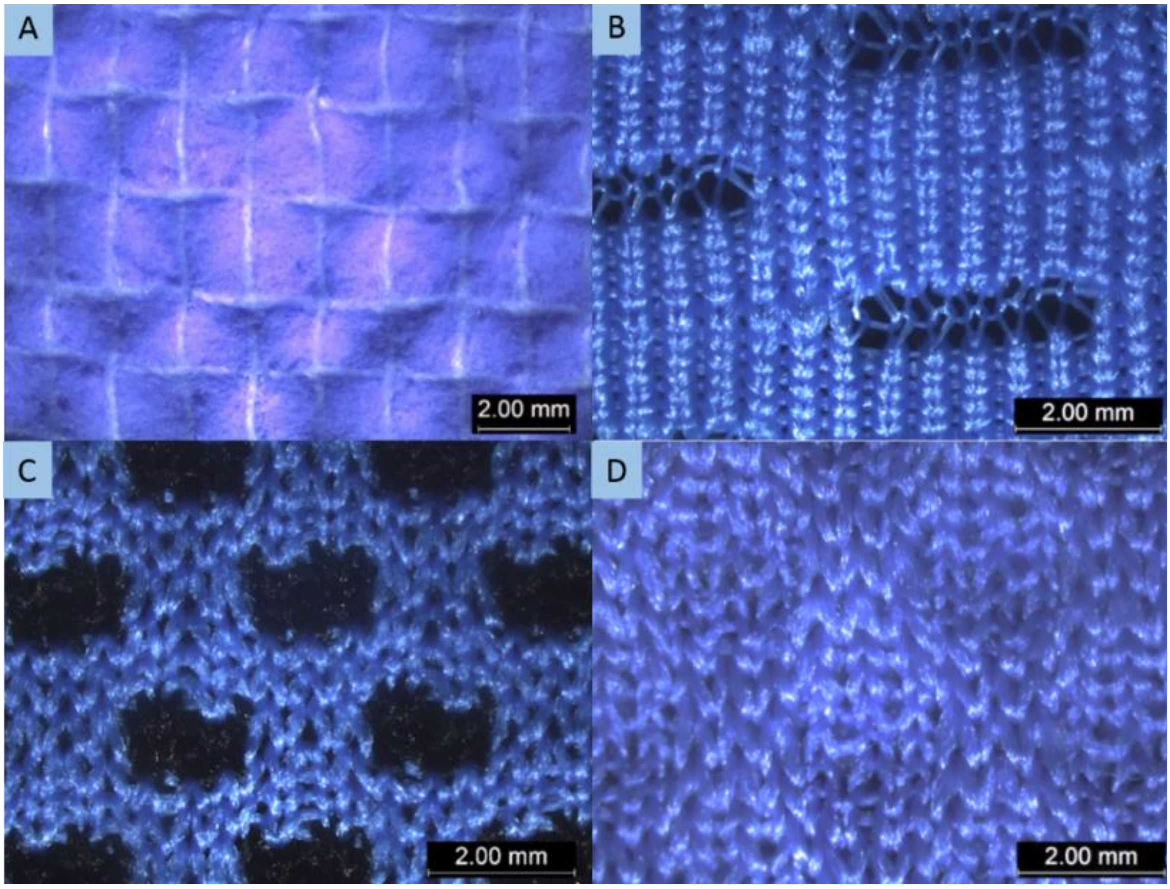

Figure 2. Fabric structure of samples of different brands: Perfect Fitness (A), N-rit (B), Cooldyxm (C) and Ice Towel (D).

Q-max test analysis

Based on the Q-max results in Figure 3, Perfect Fitness has the highest Q-max value of 0.164 and 0.381 $J/cm^2 \cdot sec$ in both dry and wet states respectively. N-rit has the second highest Q-max value which is 0.103 and 0.344 $J/cm^2 \cdot sec$, followed by Cooldyxm (0.088 $J/cm^2 \cdot sec$ in dry state and 0.301 $J/cm^2 \cdot sec$ in wet state) and Street (0.082 $J/cm^2 \cdot sec$ in dry state and 0.290 $J/cm^2 \cdot sec$ in wet state). The highest mean wet Q-max to the lowest is 0.381 $J/cm^2 \cdot sec$ to 0.290 $J/cm^2 \cdot sec$, and the difference is 0.09 $J/cm^2 \cdot sec$. If Q-max of the fabric is more than 0.140 $J/cm^2 \cdot sec$, it can be regarded as cool fabric which could provide instant coolness sensation. Since Q-max values of all four samples exceed 0.140 $J/cm^2 \cdot sec$ in wet state, they could provide a cooling effect at first contact after being wetted. Moreover, the sample of Perfect Fitness can provide the coolest instant sensation after wetting when compared to other three products since the higher the Q-max value, the cooler the touch feeling of the fabric with skins.

Relationship between Q-max in Dry and Wet States

Comparing dry and wet Q-max, it was found that all samples have higher Q-max value in wet state than that in dry state. This indicates that the sensation of all the towels was cooler after being wetted by water. As Hes & De Araujo [3] suggested that the greater cooling effect could be achieved by wet fabric due to the water content absorbed by the fabric, the towel in wet state can generate cooler touch feeling.

According to the correlation table from SPSS (Table 2), p-value is 0.000 (<α =0.005), this indicating that there is a significant correlation between dry Q-max and wet Q-max. As the R-value equals to 0.880 (r > 0.7, strong relationship), the relationship is strong and positive. Therefore, it can be concluded that the higher the dry Q-max value, the greater the wet Q-max value of the fabric, and the better the coolness sensation it can provide through contacting the skin directly.

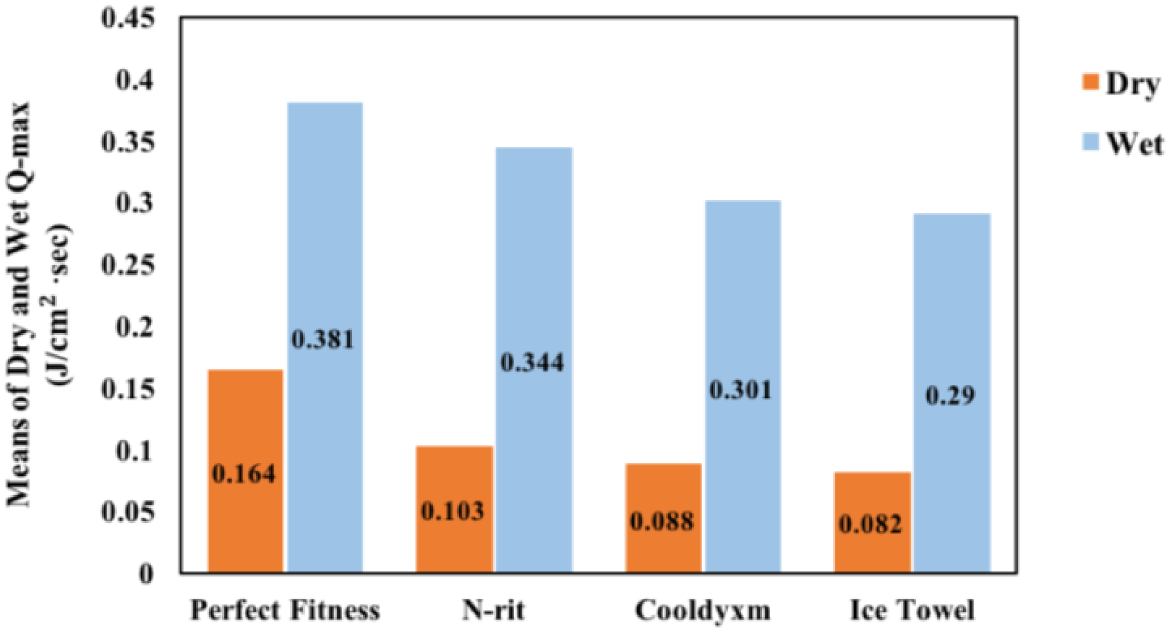

Figure 3. Mean value of dry and wet Q-max of four samples.

Table 2. Correlation between Q-max in dry and wet states.

		Dry Q-max (J/cm^2·sec)
Wet Q-max (J/cm^2·sec)	Pearson correlation	0.880**
	Sig. (2-tailed)	0.000

The relationship between dry Q-max and wet Q-max was shown in Figure 4. It can be found that wet Q-max values of the fabrics increase with the increase of dry Q-max, between which a positive linear relationship was shown. Wet fabric has higher coolness sensation than dry fabric, and it may be due to the evaporation of water in the wet fabric which can provide cooling effect to dissipate heat. It was also found that cooling effect was greater for wet fabric. The evaporation of sweat from skin would increase the surface area for evaporation and provide a greater skin cooling as shown in Figure 4.

The sample of Perfect Fitness has the highest dry Q-max, thus it also has the greatest wet Q-max value. Since the product of street shop has the poorest performance in dry Q-max, its average wet Q-max values are the lowest as well.

Relationship between water absorption and wet Q-max

Reischl & Goonetilleke [4] indicated that wet fabric with minimal amount of water can provide a greater instant cooling effect than the fabric with a large amount of water. However, this behavior is not suitable to apply to this project case. It was found that wet Q-max is not correlated to the amount of water absorbed by the fabric (Table 3).

Since p-value was 0.329 (>α = 0.05) and r-value equaled to 0.671, it is confident to prove that the amount of water absorption by the fabric was not correlated with the wet Q-max (Table 4).

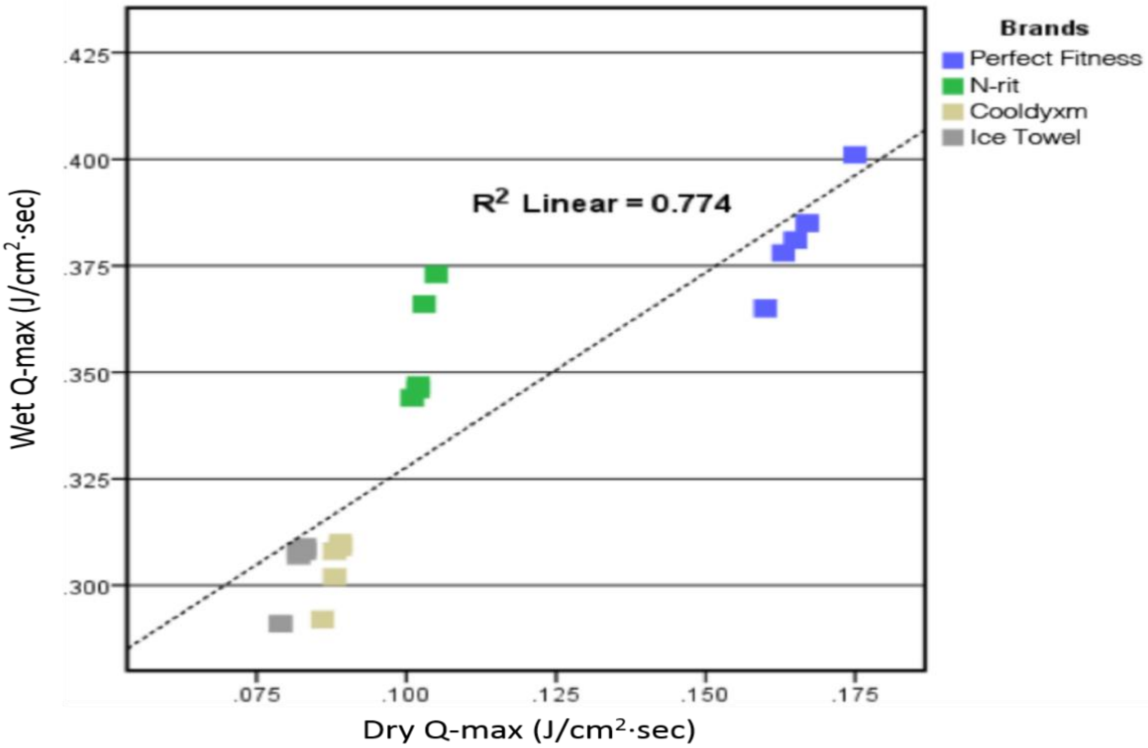

Figure 4. Relationship between dry Q-max and wet Q-max.

Table 3. Amount of water absorption of the fabrics (5×5 cm).

sample	Fabric weight/g		Water absorption/g
	Before wetting	After wetting	
Perfect Fitness	2.684	5.153	2.469
N-rit	0.863	2.008	1.145
Cooldyxm	1.037	2.259	1.222
Ice Towel	1.292	2.837	1.545

Table 4. Correlation between amount of water absorption and wet Q-max.

		Water absorption amount/g
Averaged wet Q-max (J/cm^2·sec)	Pearson correlation	0.880**
	Sig. (2-tailed)	0.000

The plot in Figure 5 shows the relationship between the water absorbed by the fabric and wet Q-max. Though the amount of water absorption of N-rit is the lowest, the wet Q-max value is the higher than Cooldyxm and Ice Towel, both of which can absorb more water than that of N-rit. Although it is shown that higher water content absorbed by the fabric may not lead to a cooler instant sensation for the skin, fabric with higher water absorption capacity could offer and maintain a longer cooling effect and sensation. This could be explained by the fact that more water held in the fabric and the longer time it requires to dry fabric, thus it can be seen that Perfect Fitness with the highest water absorption capacity could provide a prolonged cooling effect than other three products since the cooling is activated by the water absorbed in the fabric. The higher amount of water can allow more water evaporation for a longer period of time.

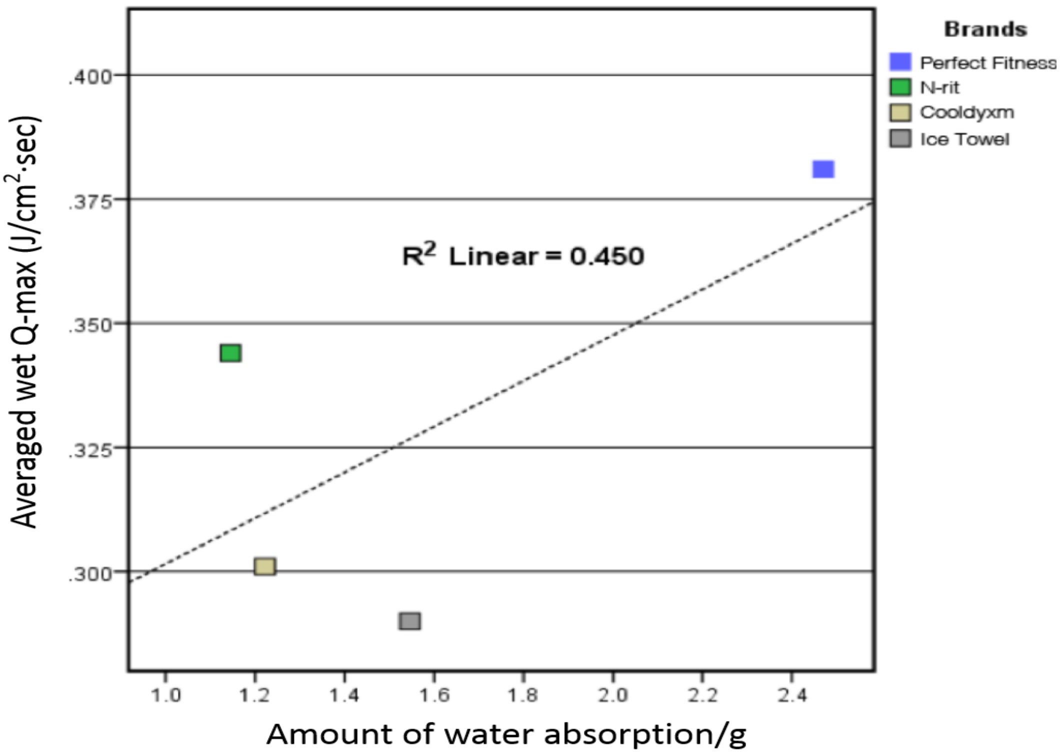

Figure 5. Relationship between water absorption and wet Q-max.

Relationship between Fabric Thickness and Wet Q-max

Selli and coworkers [5] indicated that fabrics with thinner outer layer would have higher coolness to touch. However, the correlation analysis showed that there is not significant correlation between fabric thickness and wet Q-max. From the correlation analysis (Table 5), as the p-value was 0.257 (>α = 0.05), it is confident to show that fabric thickness and wet Q-max were not correlated. The coolness of wet fabrics was independent of fabric thickness.

Table 5. Correlation between fabric thickness and wet Q-max.

		Fabric thickness/mm
Averaged wet Q-max ($J/cm^2 \cdot sec$)	Pearson correlation Sig. (2-tailed)	0.743 0.257

Figure 6 shows the linear relationship between fabric thickness and wet Q-max. Though the fabric of N-rit was the thinnest, the wet Q-max value was higher than that of Cooldyxm and Ice Towel, both of which were higher than that of N-rit. It still cannot conclude that the lower the thickness, the higher the wet Q-max as the thickest fabric of Perfect Fitness had the greatest instant coolness sensation. Although thick fabric could hold more water at its yarn interstice or fiber space when compared with thin fabric as the contact degree of water at yarn interstice is greater for thick fabric, the previous analysis shows that the wet Q-max was not correlated to the amount of water absorbed by the fabric. Thus the correlation between fabric thickness and wet Q-max cannot be proved based on the SPSS analysis.

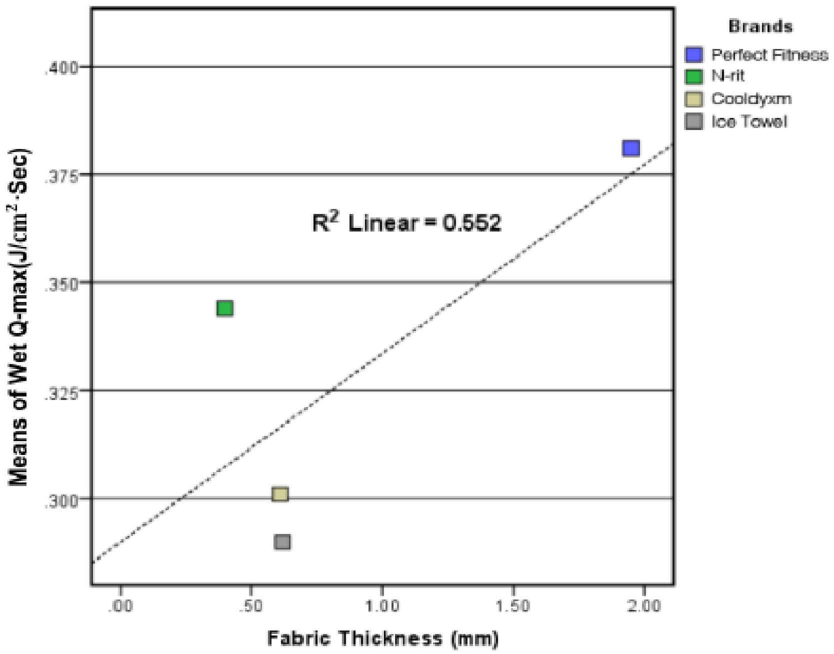

Figure 6. Relationship between fabric thickness and wet Q-max.

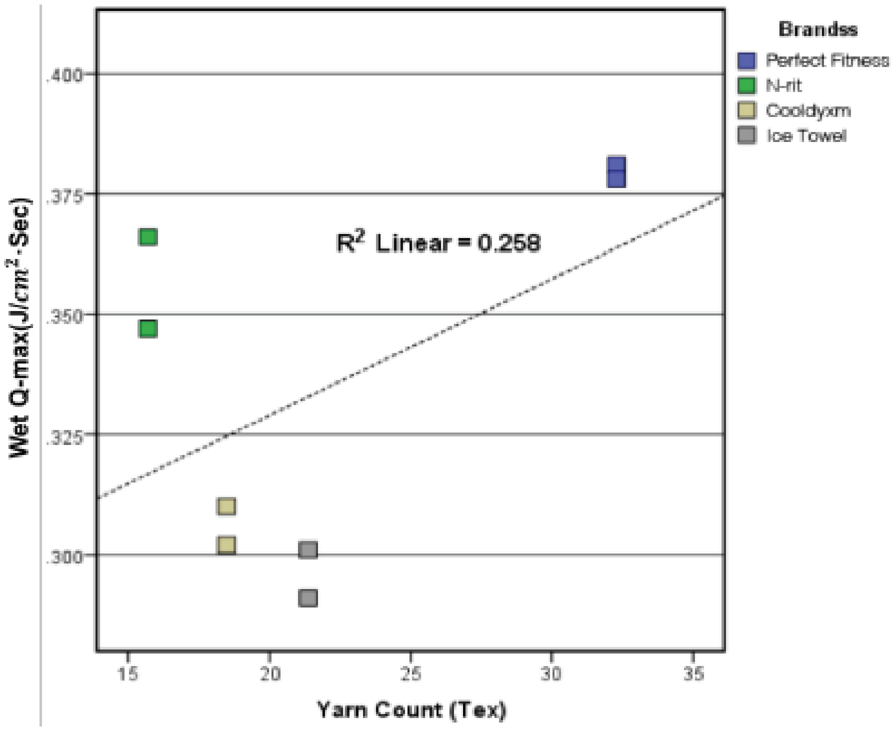

Figure 7. Relationship between yarn count and wet Q-max.

Relationship between yarn linear density and wet Q-max

Afzal et al. [6] found that an increase in yarn fineness would lead to a decrease in thermal absorptivity and the cool sensation. However, in this study, it was found that wet Q-max of the fabric was independent of the yarn count. From the correlation analysis (Table 6), as the r-value equaled to 0.508 and p-value was 0.199 (>α = 0.05), thus there was no correlation between these two variables. As can be seen from the graph (Figure 7), yarn count may not be the factor affecting wet Q-max as Perfect Fitness of coarsest yarn and N-rit of finest yarn are the two products with the highest wet Q-max values, thus yarn count may not be the factor affecting the instant coolness sensation.

Table 6. Correlation between yarn count and wet Q-max.

		Yarn count/Tex
Averaged wet Q-max (J/cm^2·sec)	Pearson correlation Sig. (2-tailed)	0.508 0.199

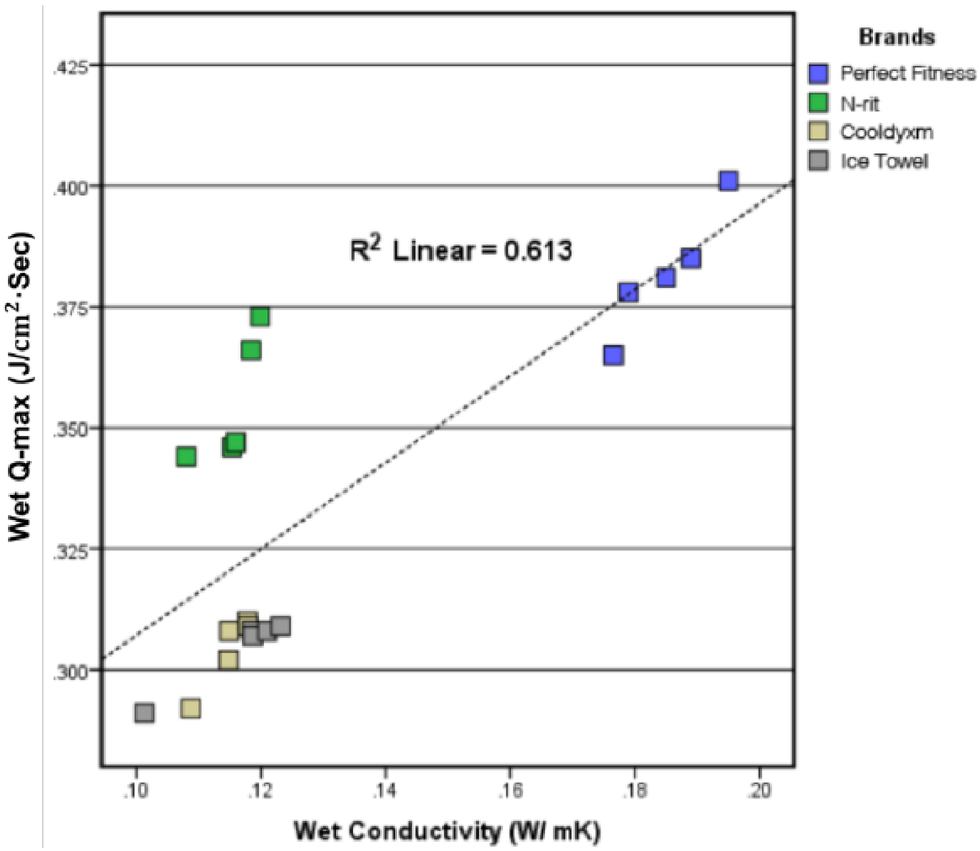

Figure 8. Relationship between thermal conductivity and wet Q-max.

Relationship between Thermal Conductivity and Q-max

Table 7 shows the correlation between thermal conductivity and Q-max. The p-value and the r-value were 0.000 (<α = 0.01) and 0.783 (r > 0.7, strong correlation) respectively, it is confident to prove that these two variables were positively and strongly correlated. From Figure 8, the plot shows the positive and linear relationship between thermal conductivity and Q-max. It can be seen that fabrics with higher thermal conductivity value would also have better Q-max performance and greater instant coolness of sensation, vice versa. Sample of Perfect Fitness has highest thermal conductivity and Q-max as well, which interprets that fabric with greater heat transfer ability and rapid rate of heat flow through the fabric would tend to have a feeling of coolness and higher Q-max value.

Table 7. Correlation between thermal conductivity and wet Q-max.

	Wet thermal conductivity(W/mK)
Averaged wet Q-max (J/cm^2·sec) Pearson correlation	0.783
Sig. (2-tailed)	0.000

One-way ANOVA analysis on wet Q-max values between the samples

From one-way ANOVA analysis (Table 8), as p-values was 0.000 (<α = 0.05), and the difference of mean of wet Q-max among Perfect Fitness, N-rit, Cooldyxm and Ice Towel was statistically significant at α = 0.05.

Table 8. One-way ANOVA of means of wet Q-max.

	Sum of squares	df	Mean square	F	Sig.
Between groups	0.022	3	0.007	64.771	0.000
Within groups	0.002	16	0.000		
Total	0.024	19			

Table 9. Multiple comparisons of means of wet Q-max.

(I) Brands	(J) Brands	Mean difference (I-J)	Std. Error	Sig.
Perfect fitness	N-rit	0.0268	0.00679	0.006
	Cooldyxm	0.0778	0.00679	0.000
	Ice Towel	0.0774	0.00679	0.000
N-rit	Perfect Fitness	-0.0268	0.00679	0.006
	Cooldyxm	0.0510	0.00679	0.000
	Ice Towel	0.0506	0.00679	0.000
Cooldyxm	Perfect Fitness	-0.0778	0.00679	0.000
	N-rit	-0.0510	0.00679	0.000
	Ice Towel	-0.0004	0.00679	1.000
Ice Towel	Perfect Fitness	-0.0774	0.00679	0.000
	N-rit	-0.0506	0.00679	0.000
	Cooldyxm	0.0004	0.00679	1.000

From the post-hoc comparison of Tukey HSD (Table 9), it shows that there was significant mean difference of wet Q-max of Perfect Fitness with N-rit (p-value =0.006), Cooldyxm (p-value =0.000) and Ice Towel (p-value =0.000) as the p-values were lower than α = 0.05. Also, N-rit was found to have significant mean difference of wet Q-max with Cooldyxm (p-value =0.000) and Ice Towel (p-value =0.000) as the p-values were lower than α = 0.05 while the mean difference of wet Q-max was not statistically significant for Cooldyxm and Ice Towel (p-value =1.000) as the p-value was larger than α = 0.05. Therefore, in term of wet Q-max, Perfect Fitness was statistically greater than N-rit, Cooldyxm and Ice Towel at α = 0.05 while the difference between Cooldyxm and Ice Towel was not significant, they have the same mean wet Q-max property.

CONCLUSIONS

In this study, the cooling properties of summer cooling towels of different brands available in Hong Kong market were evaluated by Q-max analysis. It was found that all the samples could provide a cooling effect at first contact after being wetted. The samples of Perfect Fitness showed the highest cooling effect followed by the N-rit samples, whereas Street samples had the poorest cooling effect. The reason may be explained by the yarn density, fabric structure and thickness.

REFERENCES

[1] Hong Kong Trade Development (2017). Council clothing industry in Hong Kong. Retrieved from http://hong-kong-economy-research.hktdc.com/businessnews/article/Hong-Kong-Industry Profiles/Clothing-Industry-in-Hong-Kong/hkip/en/1/1X47J8XF/1X003DCL.htm.
[2] Ezshopex (2017). Ending cooling towel. Retrieved from http://ezshopex.com/endura-cooling-towel.html
[3] Hes, L., and de Araujo, M. (2010). Simulation of the effect of air gaps between the skin and a wet fabric on resulting cooling flow. Textile Research Journal, 80(14), 1488-1497.
[4] Reischl, U., and Goonetilleke, R. S. (2016). Fabric Cooling by Water Evaporation. Journal of Fiber Bioengineering and Informatics, 9(4), 237-245.
[5] Selli, F., and Turhan, Y. (2017). Investigation of air permeability and moisture management properties of the commercial single jersey and rib knitted fabrics. Textile and Apparel, 27(1), 27-31.
[6] Afzal, A., Ahmad, S., Rasheed, A., Ahmad, F., Iftikhar, F., and Nawab, Y. (2017). Influence of fabric parameters on thermal comfort performance of double layer knitted interlock fabrics. Autex Research Journal, 17(1), 20-26.

Demand Factors of Natural dyes of SMEs/ OTOP and Start-Up Entrepreneurs for Textile Product Development

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Abstract

This qualitative research aimed to study demand factors of using natural dyes for SMEs/OTOP and Start-Up entrepreneurs. The data were collected from survey, i.e. demand, development guidelines and problems of using natural dyes including problems from natural dye material sourcing. The subjects of this research were SMEs/OTOP and Start-Up entrepreneurs that used natural dyes. The research tool was an interview. The interview data were analyzed by using program in order to obtain the important topic for development and improvement of natural dye properties to reach user's requirements. Moreover, the feature benefits of natural dye applications were concerned. The interview results indicated that the demands factors, i.e. limited factors of natural dye using, required properties of natural dyes and also development guidelines of dyes for entrepreneurs maximum benefits.

Keywords: SMEs, OTOP, Start-Up, Entrepreneur, Natural dye

INTRODUCTION

Dyes are an important factor which attracts consumers' interests to purchase products. At present, there have been an increasing number of dyes, both synthetic and natural dyes, used in goods production. In general, synthetic dyes are popularly used because of their easy availability in ready-to-apply form, simple application process, consistency of shades, and better fastness properties. However, Current Green and environmental awareness have again revived such interests in natural dyes causing a high demand. A number of entrepreneurs are looking for an opportunity to develop natural dyes for both national and international competitions. [1]

The word 'natural dye' covers all the dyes derived from the natural sources like plants, animal and minerals. [2] Most natural dyes or raw material were found easily from by One Tumbon One Product: (OTOP) or SMEs because they are locally available. [3] However, using natural dyes to make products is not easy for a start-up entrepreneur. Besides, finding the source of local raw material is rather tough to access. It is difficult to apply natural dyes, and there are not many Start-Up entrepreneurs using them. Moreover, Traditional textile production techniques are complicated and slow, and the current environment, both physical and operational, is changing rapidly. There are several challenges and limitations associated with the use of natural dyes. [3] Thus, this research aimed to study the factors of demands in using natural dyes for SMEs/OTOP and Start-Up entrepreneurs as guidance for the development of natural dyes used in textile dyeing.

MATERIALS AND METHODS

This qualitative research using the data from review of the related literature and interview was divided into 3 steps.

Step 1: Literature review

The research articles related to natural dyes were studied so as to find out the problems, demand, and research development. The obtained details were used as guidance for the interview questions that were check by the experts to improve the language accuracy and content accuracy. The corrected interview questions were then administered by the researchers.

Step 2: Data collection

The data were collected on demand, development guidelines and problems of using natural dyes including problems from natural dye material sourcing.

Primary data: The data were collected by entrepreneurs for the scope of the content. The researcher interviewed the entrepreneurs by discussing ideas and opinions on the solutions to the problems and the development of natural dyes. In the interview, the researcher used semi structured interview guide. The question were open-ended for the entrepreneur to freely give comment.

The sample used in the study

The samples obtained by purposive sampling method were divided into 2 groups.

1.1 Ten groups of OTOP/SMEs entrepreneurs using natural dyes or synthetic dyes

1.2 Ten groups of Start-Up are entrepreneurs who were interested in natural dyes

Step 3: Analysis Data

1. The data collected from the interviews were recorded and carefully transcribed

2. The data from the transcription were categorized for the requirements of the guidelines and the problems of using natural dye using program.

3. All of the above data were analyzed according to the purpose of relationship analysis using descriptive analysis.

RESULT AND DISCUSSION

The OTOP/SMEs and Start-Up entrepreneurs were interviewed about natural dyes, and the interview data were analyzed by using program.

1. Problems in using natural dyes

The analysis of the interviews regarding the problems of using natural dyes was divided into 4 aspects as follows:

1.1 Problems of production and using natural dyes

The analyzed data from the interviews on the problems of production and using natural dyes of entrepreneurs indicated problems of complex production, i.e. time consuming, many steps and difficulties and retention of dyes as shown in Table 1.

Table 1. Problems of production and using natural dyes.

Problems of production and using natural dyes	Number of references	Interview examples
time consuming	22	*"It takes a lot of time for extract, filter, and dyeing process."*
many steps and difficulties	13	*"The process of natural dyeing is complicated and needs skills and experiences."*
retention of dyes	4	*"The dyes cannot be extracted because they can be moldy."*

1.2 Problems of properties of natural dyes

The analyzed data from the interviews on problems of properties of natural dyes of entrepreneurs indicated problems with basic properties, i.e. uncontrollable shades, low washing fastness, irreproducibility and light colors as shown in Table 2.

Table 2. Problems with properties of natural dyes.

Problems with properties of natural dyes	Number of references	Interview examples
uncontrollable shades	23	*"Dyeing with primary colors is difficult because of the source of raw materials from different sources resulting in the undesired colors."*
low washing fastness	16	*"Natural dyes were faded away easily and turned pale after washed many times."*
irreproducibility	15	*"It is difficult to reproduce shades by using natural dyes."*
light colors	4	*"The colors of dyeing are light, and the depth of colors is difficult to make."*

1.3 Problems with package of natural dyes powder

The analyzed data from the interviews on problems with package of natural dyes powder of entrepreneurs indicated the problem with lack of standard for natural dyes powder as shown in Table 3.

Table 3. Problems with the package of natural dyes powder.

Problems with the package of natural dyes powder	Number of references	Interview examples
lack of standard	2	*"The natural dyeing does not reach its standard in terms of durability, so it cannot be exported to another country."*

1.4 Problems of services

The analyzed data from the interviews on problems of services indicated problems of rare materials, high costs, and difficulty of shipment as shown in Table 4.

Table 4. Problems of services.

Problems of services	Number of references	Interview examples
rare materials	29	*"The material from plants is rare."*
high costs	8	*"It is expensive. If we buy little material, we can produce few products."*
difficulty of shipment	4	*"Sources of material are too far and too difficult to drive to buy."*

2. Demands using natural dyes of entrepreneurs

The analysis from the interviews regarding the demands using natural dyes was divided into 5 aspects as follows:

2.1 Demands of production and using natural dyes

The analyzed data from the interviews on demands of production and using natural dyes of entrepreneurs indicated demands of easy production, i.e. easy use, time reduction process and temperature reduction as shown in Table 5.

Table 5. Demands of production and using natural dyes.

Demands of production and using natural dyes	Number of references	Interview examples
easy to use	15	*"It should be immediate for us to use without an extraction process."*
time reduction process	15	*"The process periods should be reduced and prompt to be used."*
temperature reduction	5	*"The most of dyeing process is in high temperature. I want natural dyes which should be dried in low temperature for saving cost."*

2.2 Demands properties of natural dyes

The analyzed data from the interviews on demands properties of natural dyes of entrepreneurs indicated demands basic properties, i.e. color fastness to washing, color control, color fastness to light and reproducibility as well as demands additional properties, i.e. pastel color, variety of colors, UV protection and fluorescent as shown in Table 6.

Table 6. Demands properties of natural dyes.

Demands properties of natural dyes	Number of references	Interview examples
demands basic properties		
color fastness to washing	38	*"The color fastness to wash should be improved."*
color control	16	*"We should maintain the shade of dyeing depending on customer demands."*
color fastness to light	14	*"The light is not pale."*
reproducible	9	*"The color is repeatable."*
demands additional properties		
pastel colors	8	*"Pastel color shade should be the specification."*
variety of colors	7	*"A variety of colors is needed."*
UV protection	5	*"The main thing is UV because people are very concerned with the sun."*
glowing properties	2	*"If there are special properties that glow, it will be very exciting."*

2.3 Demands package of natural dyes powder

The analyzed data from the interviews on demands package of natural dyes powder of entrepreneurs indicated demands package of natural dyes powder, i.e. test results that confirm the performance and easy-to-use guide as shown in Table 7.

Table 7. Demands package of natural dyes powder.

Demands package of natural dyes powder	Number of references	Interview examples
test results that confirmed the performance	15	*"There must be an experimental evidence that confirms the standard of color fastness to washing and the durability of colors."*
easy-to-use guide	4	*"There should be a package that tells you how to make it easy to use."*

2.4 Demands of services

The analyzed data from the interviews on demands of services indicated demands low prices, easy to find and a trial as shown in Table 8.

Table 8. Demands of service.

Demands of services	Number of references	Interview examples
low prices	4	*"We want natural dyes with low prices."*
easy to find	2	*"It should be easy to find raw material in the market."*
a trial	2	*"There should be a dyeing trial before use."*

2.5 Demands form of ready-to-use natural dyes

The analyzed data from the interviews on demands form of ready-to-use natural dyes indicated demands form powder, pellet and gel packs as shown in Table 9.

Table 9. Demands form of ready-to-use natural dyes.

Demands form of ready-to-use natural dyes	Number of references	Interview examples
powder	15	*"Natural dye in powder form is interesting, because it is not easily seen in the market as people normally extract it by themselves."*
pellet	2	*"The pellet is better because we do not have to weigh it."*
gel packs	2	*"It's like Japanese detergent that throws it down. It's water-soluble and ready to use."*

The interview result implies that most of the problems of using natural dyes were 1) Problems of production and using natural dyes. Time consuming was referred (56.41%) more than production process and retention of dyes as shown in table 1. 2) Problems of properties of natural dyes. Uncontrolled shades were the most referred (39.65%). Its percentage of references is higher than the low washing fastness, irreproducibility, and light color as shown in table 2. Praphaisri Roopdee's and Wichain Voraputhaporn's research [4] also mentioned about uncontrolled shades. When material was dyed, extraction dyes were not satisfactory. In addition, Wichet Chankhonghom, Uthai Eksaphang, and Wut Wattanasin [5] said villagers who produce and use natural dyes have a dyeing problem. Each dye gives an unequal depth of shade. The different between natural dyes and synthetic dyes is the depth of shade. Synthetic dyes had an ability to control the depth of shade as same as the primary color. In terms of demands of using natural dyes, the aspects were 1) Demands of production and using natural dyes. The advantage is easy to use and reduce time in process were the most referred (42.85%) which were higher than temperature reduction as shown in table 5. 2) Demands of properties of natural dyes as shown in table 6. It's obvious that demands of basic properties were color fastness to washing which were the most referred at 49.35%. Demands additional properties were pastel color which were the most referred at 36.36%. All the results regarding problems and demands of quality natural dyes were consistent to *Suree* Phutrakul et al. [6]. Her finding was conducted to gather information, problems, and demands from the manufacturers, which needed to be modified to promote natural dyeing. The problem is the product quality. Researchers need to find information for research and development of high quality natural dye products acceptable to consumers and advantage for entrepreneurs. The simple, convenient, and low cost process has a variety of shades and color fastness equivalent to synthetic dyes.

The problem and demands of using natural dyes lead to the development of natural dyes in ready-to-use. The results showed that the powder form was the most demanding. Therefore, many production and problems in regard to equipment costs were extremely high in investment with high cost of production. As a result, natural dye powder was expensive. The quality control was required by such entrepreneurs. According to the research report of Kamjorn Saecheong [7], dye powder from marigold petals and natural dye powders were also problematic in terms of sticking together solid and sticky when absorb the moist in the air.

CONCLUSIONS

Demands factors of using both OTOP/SMEs and Start-Up entrepreneurs consist of 5 factors:

1. Production and using natural dyes factors. The process is rather complex and includes many steps; raw materials to extraction, filtration and dyeing. Therefore, easy use and step reduction of production are needed.

2. Properties of natural dyes factors. Natural dyes are low washing fastness. It gets pale easily, which leads to poor quality of products. Therefore, the entrepreneurs' most requirement was color fastness to washing in order to increase the quality of the product. In addition, additional properties were pastel color that was difficult to control color. This color is so required because it helps make an easier process. Another pastel color is a basic color that can be used with many customers.

3. Service factors are low in prices with high profits.

4. Package factors that are the most required by entrepreneurs were confirmed test result of the performance of natural dyes in order to make the entrepreneurs believe and feel more confident.

5. Ready-to-use natural dyes that is the most required by entrepreneurs is powder form as it is convenient and easy to use.

ACKNOWLEDGEMENT

This work was supported by Textile technology and innovation management research unit, Textile Science Department, Agro-Industry Faculty, Kasetsart University.

REFERENCES

[1] Saxena, S., and Raja, A. S. M. (2014). Natural Dyes: Sources, Chemistry, Application and Sustainability Issue," In Muthu, S. S. (Ed), Roadmap to sustainable textiles and clothing-Eco-friendly raw Materials, Technologies, and Processing Methods, (pp.37-80). Singapore, Springer Publisher.

[2] Samanta, A. K., and Konar, A. (2011). Dyeing of textiles with natural dyes. In Kumbasar, E. A. (Ed), Natural Dyes, (pp. 29-56). Zagreb, Intech Publisher.
[3] Stone, A. P. (2009). An Investigation of Isan textiles at the village level in North-Eastern Thailand with particular reference to design and manufacturing strategies. Doctoral Dissertation, Canberra, University of Canberra.
[4] Roopdee, P. and Voraputhaporn, W. 2012. Guidelines for the conservation of indigenous handicrafts weaving,natural dyeing of cotton, The women group of Ban Muang, Moo 2, Tambon Pronsawarn, Na Chalual district, Ubon Ratchathani province. Journal of Srivanalai Vijai, 2(4): 49-58.
[5] Chankhonghom, W., Eksaphang, U., and Wattanasin W. (2011). A study of dyestuff production for cloth and yarn dyeing by villagers in Songkhla province. Journal of Humanities and Social Sciences. 6(1), 219-231.
[6] Phurakul, S., Leawchaiphan, S., Siangsai, S., Jerasotigune, A., Butpetcharat, T., Saiyud, A., Wichai, S., Chanthonsatian, S. (2000). Development of natural dyes in upper North region (Research report). Bangkok: The Thailand Research Fund (TRF).
[7] Saecheong, K. (2001). Dye powder from marigold. Master Thesis, Bangkok, Kasetsart University.

Investigation of the Environmental Performance of Fashion Products on Purchase Intention

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Abstract

Environmental performance of product is one type of environmental knowledge, therefore it would affect the consumers' green purchasing intention. Accurate and verifiable eco-labels provided environmentally conscious consumers environmental information, which is beneficial for green consumption. In this study, we conducted survey on the relationship between environmental performance of fashion product and purchase intention. The target group was select with age ranged from 18-28. The survey results indicated that there is a direct relationship between environmental performance of products and purchase intention in fashion area.

Keywords: Consumer, Environmental performance, Purchase intention, Fashion products

INTRODUCTION

In past years, environmental performance and knowledge of production, distribution and consumption of apparel in consumers' aspect has drawn many attentions. Environmental knowledge is defined as factual information that individuals have about the environment, the ecology of the planet, and the influence of human actions on the environment/ecology [1]. According to Morris [2], accurate and verifiable eco-labels provided environmentally conscious consumers environmental information, which is beneficial for green consumption in order to its environmental performance. Therefore, in this study, we will investigate the relationship between environmental performance of products and purchase intention in fashion area of Hong Kong.

MATERIALS AND METHODS

Hypothesis

A significant and positive relationship exists between environmental performance of products and purchase intention.

Survey

Questionnaire survey was conducted and two groups of questions, environmental performance of products (Performance) [3] and purchase intention (Purchase) were asked. The questions were listed below and the questions were measured on 6 point Likert-type scale, in which 1 represents strongly disagree and 6 represents strongly agree. The target group was with the age ranged 18-28.

<u>Questions on environmental performance of products [3]</u>

Performance 1: I like the idea of green products.
Performance 2: I consider about buying environmentally friendly products.
Performance 3: I concern about social and environmental impacts of the products in fashion industry.
Performance 4: Environmental performance of product is important to me.
Performance 5: Environmental performance of products plays an important role in the consumers' purchasing decisions.
Performance 6: Environmental performance of products influences my purchase decisions.

<u>Questions on purchase intention</u>

Purchase 1: Green image of the brand is one of my evaluation criteria when making purchase decision.
Purchase 2: I am willing to be inconvenienced in order to take actions that are more environmentally friendly.
Purchase 3: I am willing to pay more for clothing for social responsibility business.
Purchase 4: It is important to me that the products I use do not harm the environment.
Purchase 5: I consider the potential environmental impact of my actions when making many of my decisions.
Purchase 6: Performance of the brand is one of my evaluation criteria when making purchase decision.

Data Analysis

SPSS (Statistical Package for Social Science) v.20 was used for data analysis.

RESULT AND DISCUSSION

Survey

Total 206 questionnaires were collected within three weeks in social media platform and after screening and eliminating invalid questionnaires, 199 valid questionnaires were finally collected for further analysis.

Descriptive Statistics

Table 1 and Table 2 show the descriptive statistics on environmental performance of products and purchase intention respectively. Table 1 presents the mean and standard deviation of variable of environmental performance of products in which the mean of three out of six questions are higher than 4 and others are nearly 4 (the slightly agree) [3]. It indicates that environmental performance of products is most important information to be provided for he consumer. Table 2 shows the mean and standard deviation of variable of purchase intention where the mean of six questions are nearly 4 (the slightly agree). “I am willing to pay more for clothing for social responsibility business” has the highest mean of 4.181. It indicates that the effects of green marketing impacts on purchase intention.

Table 1. Descriptive statistics on the environmental performance of products. [3]

Questions	Mean	Standard Deviation	N
Performance 1	4.628	0.923	199
Performance 2	4.080	1.084	199
Performance 3	4.080	1.075	199
Performance 4	3.975	1.089	199
Performance 5	3.910	1.219	199
Performance 6	3.869	1.130	199

Table 2. Descriptive statistics on purchase intention.

Questions	Mean	Standard Deviation	N
Purchase 1	3.940	1.0524	199
Purchase 2	4.065	1.0592	199
Purchase 3	4.181	0.9414	199
Purchase 4	4.156	1.0640	199
Purchase 5	3.950	1.0719	199
Purchase 6	4.000	1.0636	199

Reliability Analysis

Table 3 shows the reliability results. There are six questions on environmental performance of products for measurement. The value of Cronbach’s Alpha is 0.852 (which is within the accepted range of 0.7-0.95). Therefore, the results of environmental performance of products have a great reliability and the scale has high consistency. It could be suitable to have further analysis. In addition, there are six questions on purchase intention where the value of Cronbach’s Alpha is 0.912 (which is within the accepted range of 0.7-0.95). Therefore, the results of purchase intention have a great reliability and the scale has high consistency. It could be suitable to have further analysis.

Table 3. Reliability test results.

Item	Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items
Environmental performance of products	0.852	0.847
Purchase intention	0.912	0.912

Correlation Test

Environmental performance of products and purchase intention are the two variables included in the hypothesis. From Table 4, it shows the result on hypothesis. The significance level of two variables is 0.000 showed in the Correlations Table which is less than 0.05 (A significance level of 0.05 reflects a 95% confidence interval). The value of Pearson correlation value is 0.788 at 0.01 significance level in which is highly close to 1. It indicates that there is positive relationship between environmental performance of product and purchase intention. Therefore, hypothesis is supported by correlation result.

Table 4. Correlation between environmental performance of products and purchase intention.

		Purchase mean
Performance mean	Pearson Correlation	0.788**
	Sig. (2-tailed)	0.000
	N	199

**Correlation is significant at the 0.01 level (2-tailed).

Simple Linear Regression Analysis

Environmental performance of products and purchase intention are the two variables in hypothesis. The null and alternative hypothesis would be shown as below:

H0: Environmental performance of products has no linear relationship with purchase intention.
H1: Environmental performance of products has linear relationship with purchase intention.

Table 5. ANOVA Table of H1[a].

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	92.962	1	92.962	323.108	0.000[b]
	Residual	56.679	197	0.288		
	Total	149.642	198			

a. Dependent Variable: Purchase mean
b. Predictors: (Constant), Performance mean

Table 6. Coefficant Table of H1[a].

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Standard Error	Beta		
1	(Constant)	0.655	0.193		3.399	0.001
	Performance mean	0.830	0.046	0.788	17.975	0.000

a. Dependent Variable: Purchase mean

From ANOVA Table in Table 5, the p-value of the F test was 0.000 which is less than 0.05 (i.e. rejects the H0 that regression coefficient is zero). The environmental performance of products has significant linear relationship with purchase intention at a significance level of 0.05. Moreover, the Coefficient Table in Table 6 shows the p-value of t test for the environmental performance of products associated with purchase intention is 0.000 which is less than 0.05. Thus, it could claim that environmental performance of products has linear relationship with purchase intention at a significance level of 0.05.

Table 7. Model Summary Table of H1.

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.788[a]	0.621	0.619	0.53639	0.621	323.108	1	197	0.000[a]

a. Predictors: (Constant), Performance mean

According to the Model Summary Table in Table 7, the coefficient of determination R^2 (R Square) is 0.621. It shows that 62.1% of the variation in the environmental performance of products could be interpreted by the variable of purchase intention. There is 62.1% of coefficient determination and the overall linear relationship of the model is also considered by significant value (p-value of F test and t test<0.05). The hypothesis is supported.

CONCLUSIONS

The relationship between the environmental performance of products and purchase intention was investigated in this study. The results showed that there is a significant positive relationship between the environmental performance of products and purchase intention. In other words, the environmental performance information of products provided would drive higher purchasing intention in the apparel industry. This supports the previous literature [4] which believed that the effectiveness of eco-information would be higher when it included products' environmental information which impacts on purchasing intention.

ACKNOWLEDGEMENT

This work is part of final year project submitted by Cheby Yuen-ting Chow in partial fulfilment of the requirements for BA (Hons) degree in the Institute of Textiles and Clothing, The Hong Kong Polytechnic University. Authors would thank the financial support from The Hong Kong Polytechnic University for this work. Authors gratefully acknowledge the help of Rajamangala University of Technology Phra Nakhon for supporting this research.

REFERENCES

[1] Arcury, T. A., and Johnson, T. P. (1987). Public environmental knowledge: A statewide survey. The Journal of Environmental Education, 18(4), 31-37.
[2] Morris, J. (1997). Green goods? consumers, product labels and the environment. London: IEA Environment Unit.
[3] Kan, C. W., Chow, C.Y., and Sujarittanonta, L. (2021). Examining the environmental performance of fashion products associated with eco-label. Fiber Fabric & Fashion Research Journal, 1(1), 46-50.
[4] D'Souza, C., Taghian, M., Lamb, P., and Peretiatko, R. (2007). Green decisions: demographics and consumer understanding of environmental labels. International Journal of Consumer Studies, 31(4), 371-376.

IR and UV Protective Function of Woven Fabrics

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Abstract

Nowadays, it is well known that exposure to ultraviolet radiation can have harmful effects. These effects include mainly sunburn (erythema) and tanning (pigment darkening), as well as premature aging of the skin, suppression of the immune system, damage to the eyes, and skin cancer. Currently, between 2 and 3 million cases of non-melanoma skin cancer and 132 000 cases of melanoma skin cancer occur globally each year. Fabric is the most basic and one of the best means of sun protection, however not all fabrics offer sufficient UV protection. In hot weather conditions, the use of UV-resistant materials is not enough. At the same time, a thermophysiological wear comfort is also desired, so clothing should be made from fabrics that protect the body against penetration and absorption of infra-red radiation. The proposed paper describes the influence of fabric constructional parameters on IR and UV radiation transmittance.

Keywords: IR, Sportswear, UV Protective, Woven, Fabric

INTRODUCTION

Fabrics are produced in order to fulfill different performance properties, which are essential for their end-usage application. In general, they should have enough durability, comfort, aesthetic appeal, easy maintenance, and they should support our health and protect us against potentially hazardous substances [1]. During the last several decades, people have become more aware of the negative effects that too much exposure to ultraviolet radiation has on human health. These effects include mainly sunburn (erythema) and tanning (pigment darkening), as well as premature aging of the skin, suppression of the immune system, damage to the eyes, and skin cancer [2-5]. Skin cancer, including melanoma and non-melanoma skin cancer, represents the most common type of malignancy in the white population. Cumulative epidemiologic data from Europe, Canada and the United States indicate a continuous and dramatic increase in incidence during the last decades. The highest incidence rates have been reported in New Zealand with 50 cases per 100,000 persons and Australia with 48 cases per 100,000 persons (59 for males and 39 for females in 2011), followed by the US (21.6 new cases per year per 100,000 in 2012) and Europe (13.2 and 13.1 new cases per year, per 100,000 for men and women, respectively) [6]. Currently, between 2 and 3 million cases of non-melanoma skin cancer and 132 000 cases of melanoma skin cancer occur globally each year. As the ozone layer is depleting, the atmosphere is losing its natural protective capability, and therefore more and more solar UV rays reach the Earth’s surface. The people that are most prone to this risk are those that spend large parts of the day outdoors (workers). Fabric is the most basic and one of the best means of sun protection, however not all fabrics offer sufficient UV protection. In hot weather conditions, the use of UV-resistant fabrics/clothing is not enough. At the same time, a thermophysiological wear comfort is also desired, so clothing should be made from fabrics that protect the body against penetration and absorption of infra-red (IR) radiation, but also allow moisture to evaporate from the body into the environment. At first glance, these two project demands appear to be in a contradiction. As such, there is a growing need to develop an optimal type of fabric structure that could offer sufficient protection against both UV and IR radiations. First and foremost, the basic knowledge regarding the influence of fabric constructional parameters on UV and IR protection properties should be fully understood at the very beginning, in order to develop the material itself, which will then offer sufficient or optimal UV and IR protection. The proposed paper describes this influence of fabric constructional parameters on IR and UV protection levels of woven fabrics and shows the results of the research focused on the influence of the woven fabrics' constructional parameters, e.g. type of weave and fabric relative density (as primary constructional parameters), on IR and UV radiation transmittance of 100% cotton woven fabrics.

SOLAR RADIATION – SUNLIGHT

The Sun emits different electromagnetic waves, however only three main components of solar radiation reach the Earth's surface: ultraviolet radiation (UV radiation), visible light radiation (light), and infrared radiation (IR radiation) (Figure 1). These electromagnetic waves refer to sunlight, which is filtered through Earth's atmosphere.

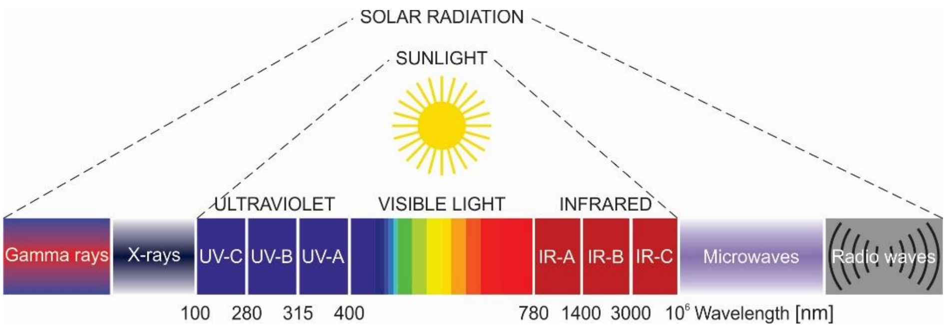

Figure 1. Solar radiation and sunlight spectrum

According to the CIE the spectral distribution of solar radiation at the surface of the Earth contains about 6.1 percent of ultraviolet light consisting of 0.5 percent of UVB (290-320 nm) and 5.6 percent of UVA (320-400 nm), 51.8 percent of visible light (from 400-780 nm), and 42.1 percent infrared light (from 780 nm to 1 mm) [7, 8]. Solar irradiance on the Earth's surface, e.g. the power per unit area received from the Sun, depends on the tilt of the measuring surface, the height of the Sun above the horizon, and atmospheric conditions. When the direct sunlight is not blocked by clouds, it is experienced as sunshine, e.g. a combination of bright light and radiant heat. The visible portion of the sun is visible to the human eye, whereas the IR and UV portion of the sun is not visible. We cannot feel the UV radiation, while the IR radiation can be felt as thermal radiation.

UV radiation and its effect on human health

The natural source of UV radiation is the Sun, which emits different types of electromagnetic radiation with different wavelengths and energies. UV radiation has wavelengths shorter than that of visible region, but longer than that of the soft X-rays, in the range of 10 nm to 400 nm, and energies from 3 eV to 124 eV. The UVR spectrum is further subdivided into near UV (400 - 300 nm), middle UV (300 – 200 nm) and vacuum UV regions (200 – 10 nm) by physicists, or into UVA (400 – 315 nm), UVB (315 – 280), UVC (280 – 100 nm) and UVD (100 - 10 nm) regions by biologists. The artificial sources of UV radiation are different types of lamps for phototherapy, solariums, industrial/work place lightening, industrial arc welding, hardening plastics, resins and inks, sterilisations, authentication of banknotes and documents, advertising, medical care, etc. UV lasers are also manufactured to emit light in the ultraviolet range for different applications in industry (laser engraving), medicine (dermatology, keratectomy) and computing (optical storage). Lamps and lasers emit UVA radiation, but some of them can be modified to produce UVB radiation as well.

There are significant differences between the UVA, UVB and UVC radiation regarding their effects on human health (Table 1). UVA radiation is also known as the glass-transmission region, while ordinary glass blocks over 90% of the radiation below 300 nm and allows the radiation above 350 nm to pass through. UVA radiation is believed to contribute to premature ageing and wrinkling of the skin, because it damages collagen fibres and destroys vitamin A in the skin. It penetrates deeply under the skin but does not cause sunburn, only sun tanning. Sun tan is a defence mechanism of the skin. Brown pigment melanin absorbs UVA radiation and dissipates the energy as harmless heat, thus blocking the UV from damaging any skin tissue. Today, it is also well established that UVA radiation can generate highly reactive chemical intermediates, which indirectly damage the DNA, and in this way induces skin cancer. UVA is the main cause of immunosuppression against a variety of infectious diseases (tuberculosis, leprosy, malaria, measles, chicken pot, herpes and fungal disease), rather than UVB, but its effects are also positive (type 1 diabetes, multiple sclerosis, rheumatoid arthritis). UVB radiation is known as sunburn region and has been implicated as the major cause of skin cancer, sunburn and cataracts. It damages the fundamental building element – DNA directly at the molecular level as well as collagen fibres and vitamin A in the skin [9].

Because of the ozone layer, indeed only UVA and UVB reach the Earth’s surface; 95 percent of natural UV radiation is in the UVA range. The biological reactions induced by UV radiation are complex. Because of the absorption spectrum of the skin, UVA – even though it has less energy than UVB – penetrates deeper and causes not only epidermal damage but also dermal changes. Nonetheless, UVB has the most carcinogenic effect. UVA enhances the carcinogenic effect through immunosuppression and by inducing the formation of reactive oxygen species (ROS). These in turn damage deoxyribonucleic acid (DNA), cell membranes and enzymes. The end result is damage to the epidermal keratinocytes and the dermal connective tissue (Figure 2). The negative effects of UV radiation on the skin depend on the type, duration and intensity of the UV exposure, and can lead to acute erythema (sunburn), or with cumulative exposure, to chronic actinic damage (extrinsic photoaging) [10].

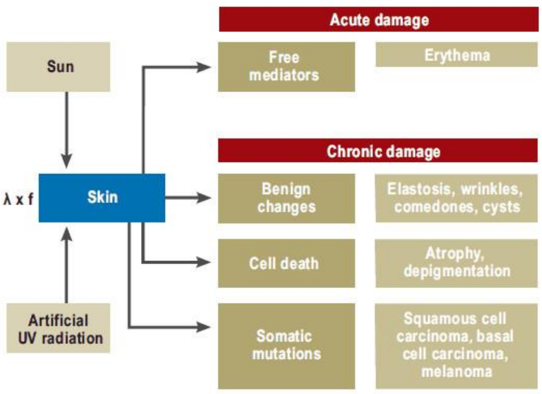

Figure 2. Consequences of excessive UV exposure on human skin

Table 1 Main differences between UVA, UVB, and UVC radiation

UVA radiation	UVB radiation	UVC radiation
λ = 400-315	λ = 315-280	λ = 280-100
Energy: 3.10-3.94 eV	Energy: 3.94-4.43 eV	Energy: 4.43-12.4 eV
Mean energy: 340 kJ/mol	Mean energy: 400 kJ/mol	Mean energy: 810 kJ/mol
Intensity: 27 W/m^2	Intensity: 5 W/m^2	Intensity: -
It has 1.7 times bigger mean energy than visible radiation.	It has 2 times bigger mean energy than visible radiation.	It has 4.1 times bigger mean energy than visible radiation.
Its intensity represents the 7,9% of solar radiation.	Its intensity represents the 1,5% of solar radiation.	-
Damages collagen fibres and accelerates skin ageing.	Damages collagen fibres and accelerates skin ageing.	Damages collagen fibres and accelerates skin ageing.
Destroys vitamin A.	Destroys vitamin A. Initiates vitamin D-production.	Destroys vitamin A.
Responsible for tan.	Responsible for deeper tan of longer duration. Responsible for sunburn.	Responsible for sunburn.
Indirectly destroys DNA and contribute to skin cancer.	Directly destroys DNA and causes skin cancer.	Directly destroys DNA and causes skin cancer.
Suppresses immune system protection by some diseases or have positive effect by others.	Has negative or positive effect on immune system.	-
Penetrates the skin.	Dangerous to the eyes.	Dangerous to the eyes.

IR radiation and its effect on human health

Infrared radiation (IR) is electromagnetic radiation with longer wavelengths than those of visible light, and is therefore generally invisible to the human eye, but people can still feel it as heat. The IR spectrum is subdivided into IRA, IRB, and IRC region by The International Commission on Illumination (CIE), or into NIR, MIR, FIR region by ISO 20473.

Research shows that more than 90 percent of full solar radiation spectrum is in the VIS – IR range. Within IR radiation, roughly 30 percent of the total solar energy is IRA, which penetrates deeply into the human skin. In the last decade, several researches have indicated that not only has UV radiation some negative effects on human health, but VIS and IR radiation appear to have such effects as well, particularly near-infrared radiation (IRA radiation, 760-1440nm). While IRB and IRC radiation does not penetrate deeply into the skin, more than 65 percent of IRA reaches the dermis and alter the collagen equilibrium of the dermal extracellular matrix, thus influencing the photo-ageing process (formation of coarse wrinkles, uneven skin pigmentation, loss of elasticity, disturbance of skin barrier functions) [11]. Therefore, effective sun protection should not exclusively focus on UV, but also include protection against IRA.

Abbreviation	Wavelength	Frequency
IR-A	700 nm – 1400 nm	215 THz - 430 THz
IR-B	1400 nm – 3000 nm	100 THz - 215 THz
IR- C	3000 nm – 1 mm	300 THz - 100 THz

(a)

Designation	Abbreviation	Wavelength
Near - Infrared	NIR	0.78 – 3 μm
Mid - Infrared	MIR	3 – 50 μm
Far - Infrared	FIR	50 – 1000 μm

(b)

Figure 3. The division of infrared radiation by CIE (a) and ISO (b)

Distribution of solar radiation through the fabric

When solar radiation reaches textile material in the form of woven, knitted or compound fabric, there are several possible pathways (Figure 4): it can be transmitted, absorbed, or reflected by the fabric [12]. Part of the radiation is already reflected or scattered by the fibrous material at the fabric surface, part is absorbed by the fibrous material and converted into heat. Another part of the radiation passes directly through the pores between the yarns in the fabric and between the fibres in the yarns (direct transmission) or indirectly through the fibrous material (indirect transmission). Several factors have an important role by determining the effectiveness of fabric to protect us against solar radiation. In the case of woven fabric, these factors can be grouped as shown in Figure 5.

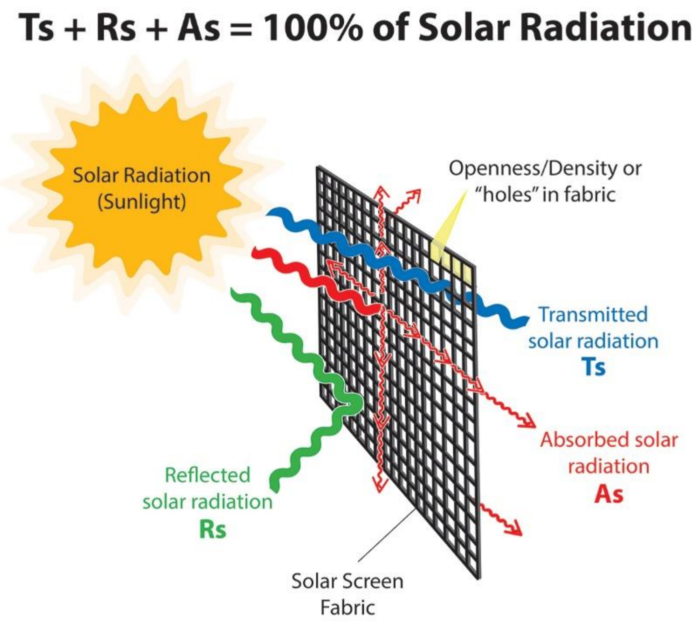

Figure 4. Distribution of solar radiation when it reaches the fabric

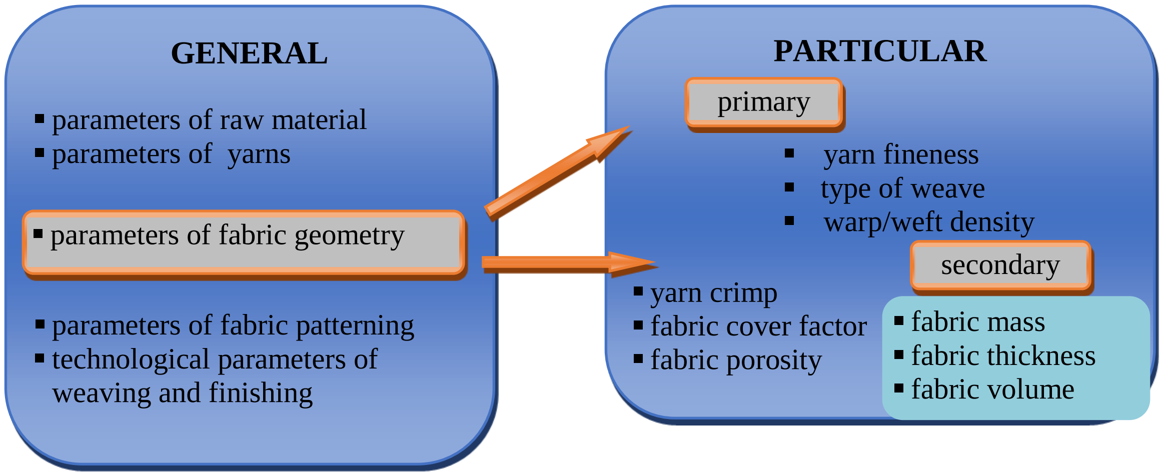

Figure 5. Woven fabric constructional parameters having an effect on solar radiation

MATERIALS AND METHODS

The woven fabrics were engineered according to Kienbaum's setting theory (Table 2) and manufactured using Picanol weaving machine. All woven fabrics were made from 100% cotton carded yarns with following constructional parameters: fineness: 36 tex, number of twist: 630 z, yarn diameter: 0.236 mm, volume coefficient: 6.606, bulk density of fibers: 1.5, yarn packing factor: 0.55, yarn flexibility factor: 0.8, yarn volume mass: 0.825 g/cm^3. It should be noted that samples where in a raw state in order to eliminate the influence of finishing treatments on solar radiation-protective function of fabrics. The basic fabric density was the same for all samples (4.645 threads per cm). The fabric relative density was calculated according to Equations 1-5:

$$t = \sqrt{t_1 \cdot t_2} \qquad (1)$$

$$t_1 = \frac{G_1}{G_{\lim}} \cdot 100 \quad t_2 = \frac{G_2}{G_{\lim}} \cdot 100 \qquad (2)$$

$$G_{\lim} = g \cdot V \cdot \sqrt{\frac{1000}{T}} \qquad (3)$$

$$g = 5{,}117 \cdot \sqrt{\rho_{fib} \cdot i} \qquad (4)$$

$$V = \frac{1.732 \cdot R}{R + \frac{a \cdot (2.6 - 0.6 \cdot z)}{f} \cdot 0.732} \qquad (5)$$

wherein t is fabric relative density or fabric tightness in percentages, G is actual density in threads per cm, Glim is limit density of fabrics with the same threads and the same weave parameters in warp and weft directions, in threads per cm, g is basic density in threads per cm, V is weave factor, T is yarn fineness in tex, , ρ_{fib} is bulk density of fibers in gcm^{-3}, i is yarn packing factor, R is number of threads in weave repeat, a is the number of passages of yarn in one weave repeat from face to back and vice versa, z is the smallest weave shift, and f is yarn flexibility. Subscripts 1 and 2 denote warp and weft yarn, respectively.

Table 2 The constructional parameters of tested woven samples

Fabric Code	Yarn Fineness (Tex)	Type of Weave	Warp Density (ends/cm)	Weft Density (pick/cm)	Level of Fabric Relative Density	Fabric Relative Density (%)
1	36	plain	19.9	9.6	I	62
2	36	plain	20.8	12.0	II	71
3	36	plain	20.8	16.4	III	83
4	36	twill	26.4	12.7	I	63
5	36	twill	27.1	16.0	II	72
6	36	twill	26.9	21.7	III	83
7	36	satin	29.9	12.9	I	58
8	36	satin	29.6	16.5	II	65
9	36	satin	29.9	23.6	III	79

Testing samples of different weaves – namely plain (10-01 01-01-00), twill (20-02 02-01-01), and satin (31-01 04-01-02) were prepared at three levels of fabric relative density: 55% - 65% (minimum), 65% - 75% (average), and 75% - 85% (maximum). The warp density of tested samples was around 20, 27, and 30 threads/cm for plain, twill and satin fabrics, respectively. The weft density of fabrics was set between10-16, 13-22, and 13-24 threads/cm for plain, twill and satin fabrics, respectively. Afterwards, the warp and weft densities were measured again in accordance with the ISO 7211-2. For measuring UV and IR transmittance, an UV/VIS/NIR spectrophotometer Lambda 900 was used in the range between 210 and 1200 nm. The device was equipped with a double beam optical system and two detectors with an integrating sphere unit (60 mm with Spectralon coating), which is able to evaluate the total spectral transmittance of the scattering material. A photomultiplier tube (PMT) detector was used for the UV (and visible) region and a low-temperature sulfide lead (PbS) detector for the NIR region. By using a spectrophotometer, the percent transmittance of solar radiation (both direct and diffuse), was measured at wavelength intervals of 10 nm in the 210-1200 nm spectral range.

RESULT AND DISCUSSION

Figures 6 and 7 present the results of solar radiation transmission through tested cotton woven fabrics over the wavelength between 200-1200 nm.

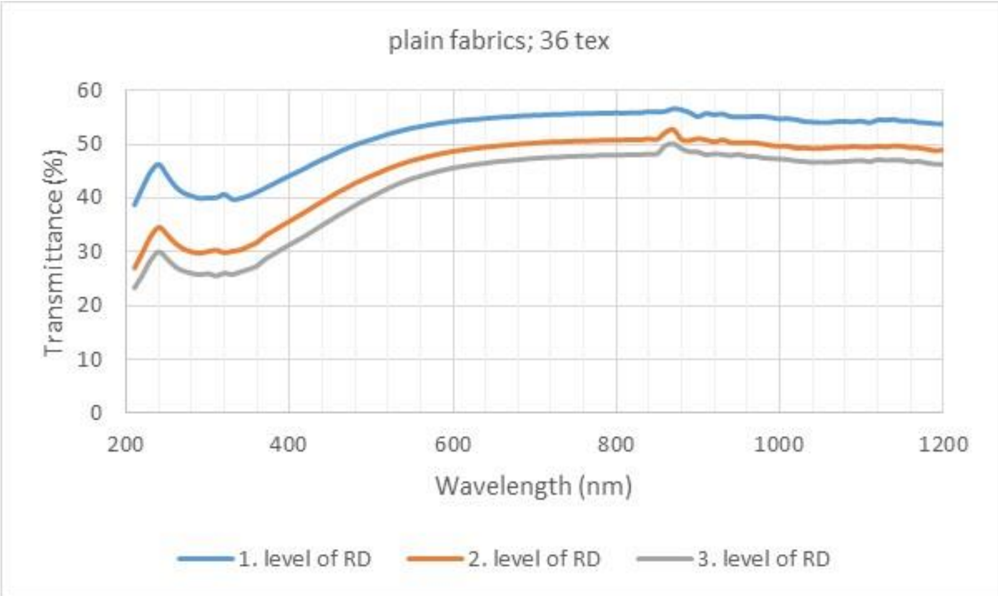

Figure 6. Transmittance curves of plain-woven fabrics at different levels of fabric relative density as function of the wavelength

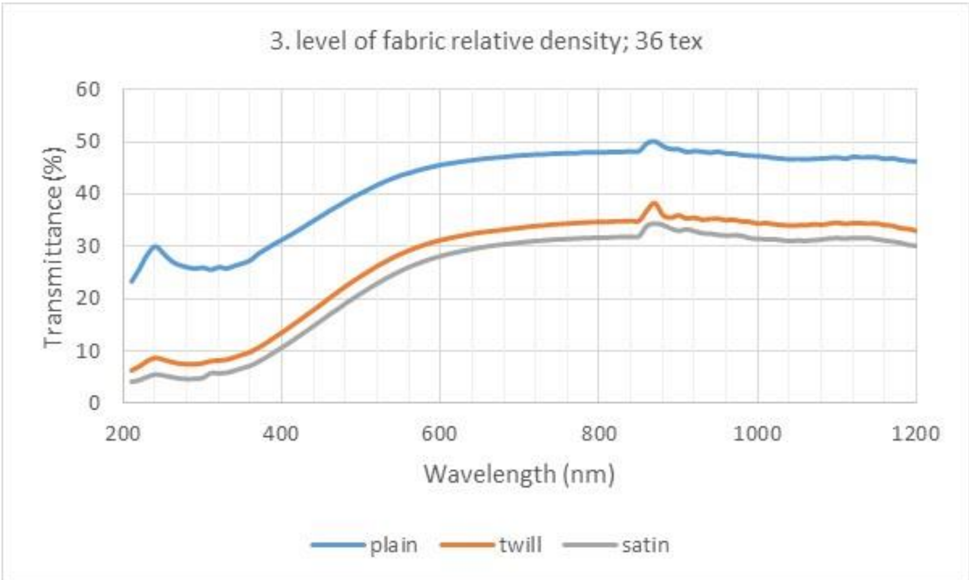

Figure 7. Transmittance curves of woven fabrics by 3. level of fabric relative density at different type of weave as function of the wavelength

The transmission of UV radiation through plain-woven fabrics was lower than IR transmission at all levels of fabric relative density. The maximal UV transmittance was 46.2% (at 240 nm), 34.7% (at 390 nm) and 30.6% (at 390nm) while the maximal IR transmittance was 56,5%, 52.6% and 50.2% (all at 870 nm) at 1., 2. and 3. level of fabric relative density, respectively. The similar conclusions are valid for twill and satin fabrics regarding the level of fabric relative density (fabric tightness). UV an IR transmittance decrease with the higher level of fabric relative density. Higher fabric relative density means lower open area (open porosity), thus resulting in less space for direct transmission of UV radiation through the open pores of woven fabric (pores between the yarns in the fabric). The UV/IR transmittance may also occur through the pores between the fibers in the yarns and through the fibers itself, but the open porosity (fabric tightness/fabric relative density) is considered to have bigger influence. If we compare the results regarding the type of weave, we can conclude (Figure 7) that satin fabrics allow less solar radiation to go through the fabric than twill and plain fabrics at the same level of fabric relative density. We should have in mind that satin fabrics have higher ends/picks by the same level of fabric relative density, and consequently lower open area.

CONCLUSIONS

The average warp/weft density was 18.6/24.3/26.8 for plain, twill and satin fabrics at 3. level of fabric relative density, respectively. The maximal UV transmittance was 30.5%, 12.6% and 9.7% (all at 390 nm), while the maximal IR transmittance was 50.2%, 38.3% and 34.3% at 3. level of fabric relative density for plain, twill and satin fabrics, respectively. Similar conclusions can be made for fabrics at 2. and 3. level of fabric relative density.

REFERENCES

[1] Hatch, K. L. (1993). Textile science. New York, West Publishing Company.
[2] Cesarini, J. P. (2001). Impact of ultraviolet radiation on humans. Indoor and built Environment, 10(5), 310-316.
[3] Ferrini, R. L., Perlman, M., & Hill, L. (1998). American College of Preventive Medicine practice policy statement: skin protection from ultraviolet light exposure. American journal of preventive medicine, 14(1), 83-86.
[4] Gies, P. H., Roy, C. R., Toomey, S., & McLennan, A. (1998). Protection against solar ultraviolet radiation. Mutation Research/Fundamental and Molecular Mechanisms of Mutagenesis, 422(1), 15-22.
[5] Reichrath, J. (2007). Sunlight, skin cancer and vitamin D: What are the conclusions of recent findings that protection against solar ultraviolet (UV) radiation causes 25-hydroxyvitamin D deficiency in solid organ-transplant recipients, xeroderma pigmentosum, and other risk groups?. The Journal of steroid biochemistry and molecular biology, 103(3-5), 664-667.
[6] Apalla, Z., Lallas, A., Sotiriou, E., Lazaridou, E., & Ioannides, D. Epidemiological trends in skin cancer. Dermatology Practical & Conceptual. 2017; 7 (2): 1–6.
[7] CIE (Commission Internationale de l'Eclairage): Solar spectral irradiance, CIE Technical Repor (1989), Table 4, Global solar irradiance at sea level No.85.
[8] Zabetakis, A. (2002). Textiles for protection against solar UVR, weather conditions and fire. In Dragčević, Z. (Ed), The International Textile Clothing & Design Conference: Magic World of Textiles, pp. 152-157, Zagreb, Faculty of Textile Technology, University of Zagreb.
[9] Dubrovski, P. D. (Ed.). (2010). Woven fabric engineering. BoD–Books on Demand.

[10] Fartasch, M., Diepgen, T. L., Schmitt, J., & Drexler, H. (2012). The relationship between occupational sun exposure and non-melanoma skin cancer: clinical basics, epidemiology, occupational disease evaluation, and prevention. Deutsches Ärzteblatt International, 109(43), 715.
[11] Schroeder, P., Calles, C., Benesova, T., Macaluso, F., & Krutmann, J. (2010). Photoprotection beyond ultraviolet radiation–effective sun protection has to include protection against infrared A radiation-induced skin damage. Skin pharmacology and physiology, 23(1), 15-17.
[12] How solar screen Ssades work (2018) Retrieved from https://insolroll.com/how-solar-screen-shades-work.

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