The 9th RMUTP International Conference on Science, Technology and Innovation for Sustainable Development
(Section: Textiles and Clothing Sustainability)

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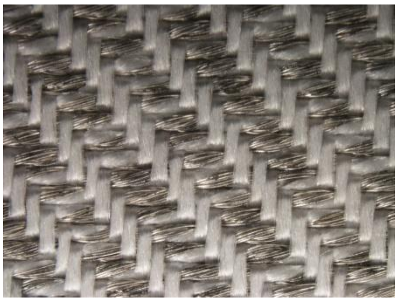

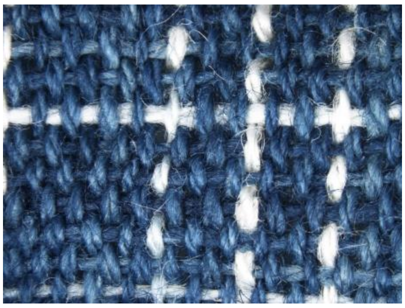
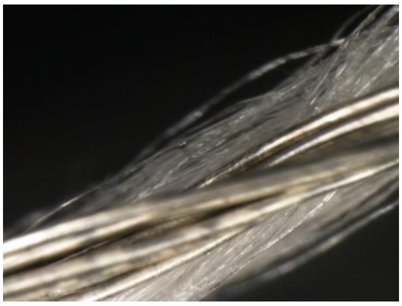


21 - 22 June 2018

The Sukosol hotel, Bangkok, Thailand

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Preface

This e-proceeding contains the accepted and presented paper at the The 9th RMUTP International Conference on Science, Technology and Innovation for Sustainable Development (Section: Textiles and Clothing Sustainability), held on 21 - 22 June 2018 at The Sukosol hotel, Bangkok, Thailand. The general purpose of this conference is to provide a forum for the presentation and discussion of the latest research and technology on all aspects of textiles and materials. The topics addressed in this proceeding span the entire spectrum of research to applications for textile technology and textile materials. This e-proceeding contains the accepted manuscripts from the areas of Textile Materials, Technology in Textile Industry, Textile Equipment, Apparel Design, Future Trends in Textile and Apparel Industry, Engineering Materials and Functional Materials, Engineering Education and Management.

We hope that you will enjoy the excellent work of our many authors and this proceeding brings you some new ideas and understanding of the magical textile and clothing technologies.

The organizing committee

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A STUDY ON LOW STRESS MECHANICAL PROPERTIES OF DENIM FABRIC FOR HAND EVALUATION

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Keywords-Denim, Handle Value, KES, Objective evaluation.

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.

1 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.

2 Materials and Methods

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

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.

2.1 Experimental 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.

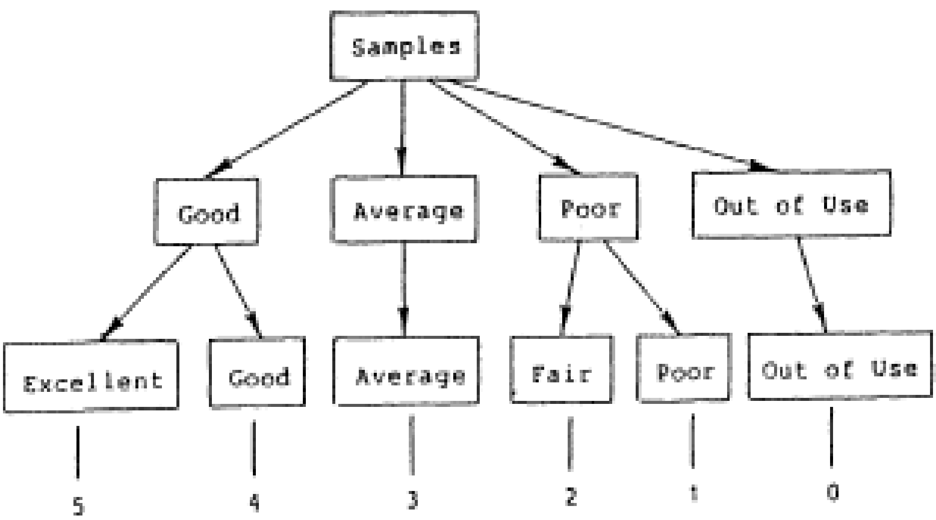

Fig.1 Procedure for subjective evaluation of Total Hand Value of Denim samples

Sample having following specifications is given highest rating among all 49 samples. The total sum of rating given by 18 panellists is 72.

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

3 Results 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

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).

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

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.

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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.

1. 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.

2. 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.

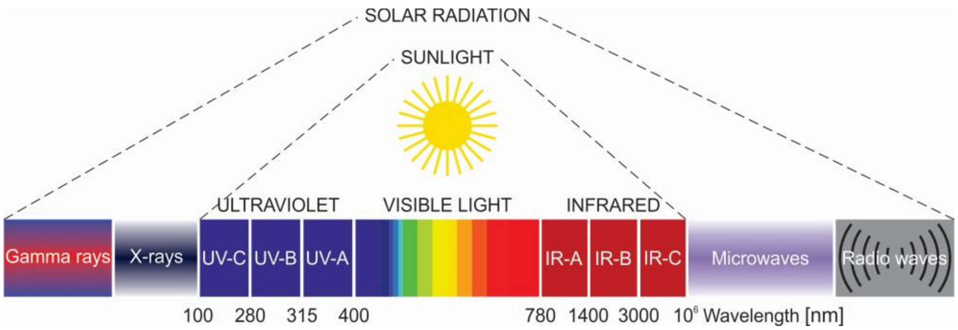

Figure 1: *Solar radiation and sunlight spectrum*

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.

2.1. 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].

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.

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].

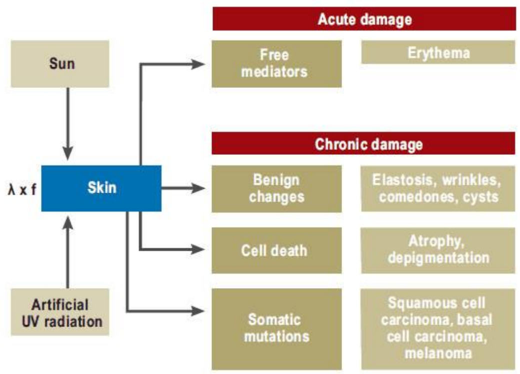

Figure 2: *Consequences of excessive UV exposure on human skin*

2.2. 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.

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 GHz – 100 THz

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

Figure 3: *The division of infrared radiation by CIE (left) and ISO (right)*

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.

2. 3. 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

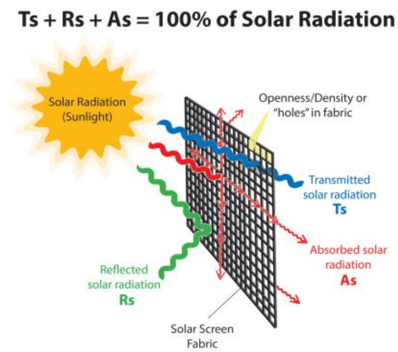

Figure 4: *Distribution of solar radiation when it reaches the fabric*

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.

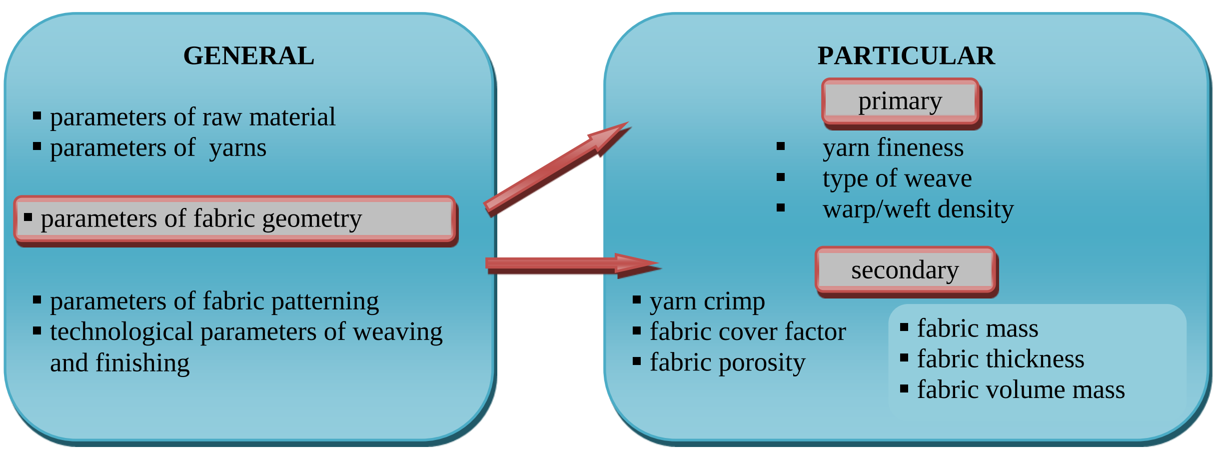

Figure 5: *Woven fabric constructional parameters having an effect on solar radiation*

3. 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, G_{lim} 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 between 10-16, 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.

5. Results 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.

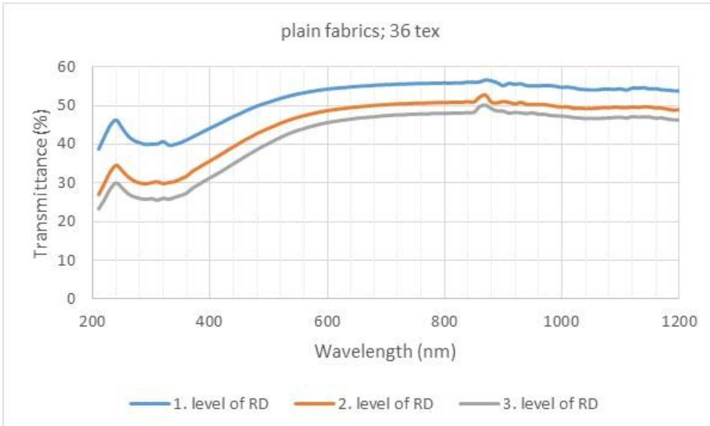

Figure 6: *Transmittance curves of plain-woven fabrics at different levels of fabric relative density as function of the wavelength*

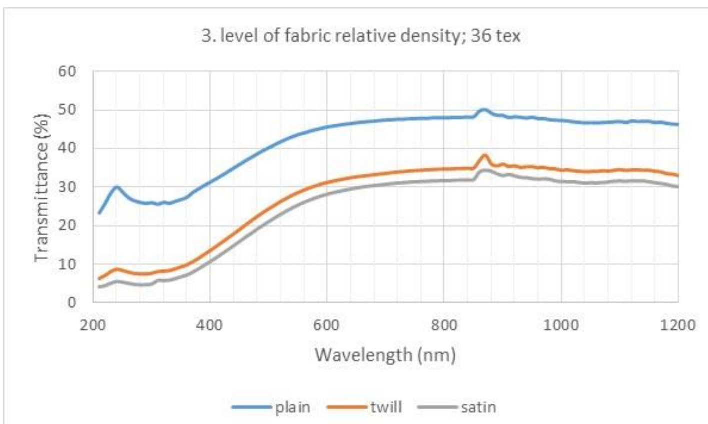

Figure 7: *Transmittance curves of woven fabrics by 3. level of fabric relative density at different type of weave as function of the wavelength*

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. 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.

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A STUDY OF WICKABILITY OF QUICK DRY INNER WEAR

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Abstract: Quick dry inner wear products become increasingly popular in the tropical regions with a hot and rainy climate. This study evaluated the quick dry property of three brands (Brand A: online brand; Brand B: general market and Brand C: youth market) inner wear for women available in the market via studying their wicking rates. It was found that Brand C products had satisfactory wicking ability as they claimed, whereas Brand A showed no quick dry property.

1. Introduction

Hong Kong features a tropical monsoon climate, and the weather is very humid and rainy with a relatively high temperature [1]. The humid weather usually causes the fabric harder to dry [2]. The wet fabric traps the moisture or sweat on the skin and affects the comfortability, especially for the non-breathable fabric, which may increase the risk of infection and hyperthermia [3,4]. Moisture movement is closely related to the thermal-psychological comfort, which can control the heat transfer since moisture is a good conductor for heat [5]. Therefore, the quick dry property for women's inner wear is very important, which can be evaluated by the wicking ability.

Nowadays, there are quite a lot of quick dry inner wears available on the market. The present study aims to investigate the quick dry performance of such products in Hong Kong market by comparing the wickability of three common commercial inner wears in different market position: Brand A: online brand; Brand B: general market and Brand C: youth market.

2. Experimental

2.1 Fabric samples

Three different brands (Brand A: online brand; Brand B: general market and Brand C: youth market) of quick dry inner wears for women were obtained in Hong Kong market. They were all made of 100% cotton with the quick dry technology as claimed, which could provide the good sensation while wearing in summer. The appearance and weave parameters for three brands were shown in Figure 1 and Table 1.

All samples were conditioned in the standard condition for at least 24 hours prior to wicking test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

(A)

(B)

(C)

Figure 1. *The fabric appearance and construction of three brands: (A); (B) and (C).*

Table 1. *Fabric weave parameters for three brands, A, B and C*

Brand	Wale/cm	Course/cm	Fabric density /cm^2	Fabric weight (g/m^2)	Fabric thickness/cm
A	11.9	20.5	243.9	80.5	0.0744
B	14.2	18.8	266.96	101.25	0.0717
C	13	17	221	73.75	0.0720

2.2 Wicking test

Wicking refers to the movement of moisture by capillary action due to spontaneous wetting, and it is affected by the interactions between fluid and textile material. Wickability is the ability of liquid transport along both the vertical and horizontal directions of fabric samples [6]. Both wicking directions were investigated according to the AATCC standard.

2.2.1 Vertical wicking test

The vertical wicking was investigated according to the standard AATCC-197. The distance and time that distilled water travels along and through the fabric sample were recorded. The rate of distilled water spreading along the vertical direction of fabric determines the vertical wicking ability of the fabric sample. Vertical wicking performance was determined by vertical wicking rate, which can be calculated by Equation (1).

$$W = d/t \qquad (1)$$

Where
W is wicking rate (mm/s);
d is wicking distance (mm); and
t is the wicking time (s)

2.2.2 Horizontal wicking test

The horizontal wicking test was to evaluate the ability of liquid transport along horizontal direction of fabric. The horizontal wicking was investigated according to the standard AATCC-198. The distance and time that distilled water travels along and through the fabric sample were recorded. The rate of distilled water diffusing along the horizontal direction of the fabric samples determines the horizontal wicking ability of the fabric. Horizontal wicking performance was determined by horizontal wicking rate, which can be calculated by Equation (2).

$$W = \pi(¼)(d_1)(d_2)/t \qquad (2)$$

Where
W is wicking rate (mm^2/s)
d_1 is wicking distance in length direction (mm)
d_2 is wicking distance in width direction (mm); and
t is the wicking time (s)

3. Results and Discussion

The results reported in this study were based on the samples collected from the market in the period August 2016. Variation of results may occur if samples taken from different market locations and time. Wicking ability is critical for removing moisture and water vapor between the fibers by capillary movement. Excellent wicking ability helps quickly remove the moisture vapor of fabrics, showing better quick dry property, which is essential for inner wear.

3.1 Results of vertical wicking test

According to Equation (1), vertical wicking rate was obtained. If there was no distance measured in 30 minutes, the wicking rate was defined as 0. The test results were shown in Table 2.

The average values of vertical wicking in warp and weft are shown in Table 2. It can be clearly seen that the Brand C samples have the highest vertical wicking rates, both in wrap and weft directions (27.62 and 33.94 mm/s, respectively). A sharp decrease in the vertical wicking rate is observed for the Brand B samples, only 2.03 mm/s in the warp direction and 0.15 mm/s in the weft direction. However, the samples for Brand A fails to show any vertical wicking property, amazingly. Hence it is found that Brand A sample has the worst vertical wicking ability among three brands, while Brand C is the optimum sample with the best vertical wicking.

Table 2. *Vertical wicking ability test results for three clothing brands.*

	A			B			C		
Warp (mm)	0	0	0	76	68	75	145	144	145
Time to reach 20±1mm line (s)	300	300	300	41.93	48.43	85.74	5.1	5.6	5.0
Warp wicking rate (mm/s)	0	0	0	2.79	2.44	0.87	28.4	25.5	28.9
Average warp wicking rate (mm/s)	0			2.03			27.62		
Standard deviation	0			1.02			1.82		
Weft (mm)	0	0	0	52	42	50	117	118	116
Time to reach 20±1mm line (s)	300	300	300	357	372	247	3.18	3.47	3.74
Weft wicking rate (mm/s)	0	0	0	0.15	0.11	0.20	36.8	34.0	31.0
Average weft wicking rate (mm/s)	0			0.15			33.94		
Standard deviation	0			0.05			2.89		

3.2 Results of horizontal wicking test

According to Equation (2), horizontal wicking rate is determined. In this test, the time was recorded if the water can spread through the 100 ± 3mm circle, otherwise, it was not recorded. The test results are shown in Table 3.

Table 3. *Horizontal wicking ability test results for three clothing brands.*

Brand	Warp/Length (mm)	Weft/Width (mm)	Time (s)	Wicking rate (mm^2/s)	Average wicking rate (mm^2/s)	Standard deviation
A	43	26	300	2.93	2.82	0.61
	35	26	300	2.38		
	31	25	300	2.03		
	41	33	300	3.54		
	36	34	300	3.20		
B	60	46	300	7.23	10.02	3.00
	85	67	300	14.91		
	65	50	300	8.51		
	70	48	300	8.80		
	68	60	300	10.68		
C	153	101	20.82	582.9	844.82	457.93
	170	134	10.82	1653.6		
	140	100	14.52	757.3		
	148	104	20.98	576.2		
	150	105	18.91	654.2		

The averaged horizontal wicking rate values are shown in Table 3. Clearly, the wicking rate of Brand C sample is significantly higher than the other two brands, which means the optimal ability of the fabric to remove moisture. The value of wicking rate for Brand C sample is 766.7 mm^2/s, while this figure for Brand B is 10.02 mm^2/s. similarly. Brand C sample shows the lowest horizontal wicking rate, being only 2.8 mm^2/s.

3.3 Effect on fabric parameters on wickability

As discussed above, three brands samples shows different wicking properties, both for vertical and horizontal wicking, which may be related with the fabric weave parameters such as density, weight and the thickness. Next, the correlation between fabric weave parameters and wicking ability is discussed below.

As shown in Table 4, for the fabric density, p-value 0.38 was greater than 0.05, indicating that density might not be the essential factor affecting the wicking property. Likewise, for both fabric weight and thickness, it was observed that the p-value was also greater than 0.05. This reveals that fabric weight and thickness were not the leading factors in the wicking property.

Table 4. *Correlation between the fabric weave parameters and wicking properties.*

		Vertical wicking rate		Horizontal wicking rate
		warp	weft	
Pearson correlation (*R*-value)	Density	-0.83	-0.83	-0.86
	Weight	-0.64	-0.64	-0.68
	Thickness	-0.47	-0.47	-0.42
P-value	Density	0.38		
	Weight	0.56	0.56	0.52
	Thickness	0.69	0.69	0.73

4. Conclusion

This study investigated the wicking ability of three brands inner wear for women in Hong Kong market to assess their quick dry properties. It was found that Brand C products had satisfactory wicking ability as they claimed, whereas Brand A showed no quick dry property.

Acknowledgement

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AN ANALYSIS OF RELATIVE HAND VALUE OF QUICK DRY INNER WEAR

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Abstract: Hand feel properties are importance factor of quick dry inner wears. This study aims to evaluate the hand feel properties of women's quick dry inner wears in the market (Three brands were selected with different market position: Brand A: online brand; Brand B: general market and Brand C: youth market) by studying the relative hand value. The relative hand value was measured according to the standard of AATCC-202. Results analysis showed that Brand B was the optimal product in terms of resilience and smoothness, whereas the softness property for Brand C performed better.

1. Introduction

The typical climate in Hong Kong is humid with relatively high temperature [1]. The humid climate would cause fabric becomes difficult to dry [2]. The accumulation of sweat in fabric may have risk of infection and hyperthermia [3,4]. Therefore, quick dry garment is available in the market which may regulate the moisture transfer from the skin to maintain healthy body temperature [5]. There are quite a lot of quick dry inner wears available on the market but their hand feel properties do not reported much. Therefore, this study aims to investigate the hand feel properties of commercially available women's quick dry inner wear in which three brands are selected based on their market position.

2. Experimental

2.1 Fabric samples

Three brands of popular quick dry inner wears for women (Brand A: online brand; Brand B: general market and Brand C: youth market) were obtained in Hong Kong market. They were all made of 100% cotton with the quick dry technology as claimed, which could provide the good sensation while wearing in summer. The appearance and weave parameters for three brands were shown in Figure 1 and Table 1. All samples were conditioned in the standard condition for at least 24 hours prior to hand feel test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

(A)

(B)

(C)

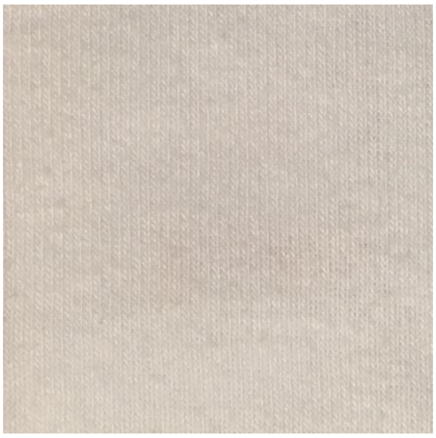

Figure 1. *The fabric appearance and construction of three brands: (A); (B) and (C).*

Table 1. *Fabric weave parameters for three brands.*

Brand	Wale/cm	Course/cm	Fabric density /cm^2	Fabric weight (g/m^2)	Fabric thickness/cm
A	11.9	20.5	243.9	80.5	0.0744
B	14.2	18.8	266.96	101.25	0.0717
C	13	17	221	73.75	0.0720

2.2 Relative hand value test

Relative hand value (RHV) is an index to show consumer's overall response when handling a fabric. It can be measured according to the standard AATCC-202 using the fabric evaluation system (PharbrOmeter, Nu Cyberteck Inc., California, USA). This system measures the "sensory perceptions" of various fibrous products and gives data including softness, smoothness and resilience.

3. Results and Discussion

3.1 Relative hand value (RHV) results

RHV can be used to predict the fabric quality manifestation. As stated in the standard AATCC-202, this index can be used to "predict the tactile sensations a human perceives when handling a fabric." The testing results of three brands of samples were shown in Table 2. Clearly, the lowest resilience value (65.83) was seen in Brand B sample, which means Brand B products has the best performance in resilience. The difference in the softness data among three brands is slight. Still, Brand C is the softest sample among three, with the lowest softness data 91.57. However, the smoothness data for Brand C products is the highest, up to 78.17, where this data of Brand B is 74.89. This indicates that Brand B product performs better in smoothness than the other two brands of samples.

Table 2. *Results of relative hand value.*

Brand	Relative hand value		
	Resilience	Softness	Smoothness
A	76.01	92.41	77.06
B	65.83	91.83	74.89
C	80.17	91.57	78.17

3.2 Effect of fabric characteristic on resilience

RHV values are closely related with the fabric characteristics such as fabric density, weight and thickness respectively. Figure 2(A, B, C) shows the correlation of resilience and fabric density, weight and thickness. It is clearly shown that a fabric with less dense, lighter and finer yarn tend to give a better performance on resilience. It was reported that the fiber diameter and thickness are the main factors affecting resilience of fabric. The smaller the diameter and thicker the fabric is, the better resilience performance it gets [6]. Finer yarn means lighter fabric and in this test results it matches the statement. Higher density fabric tends to withstand wear and distort since it has a better entanglement between yarns in order to increase the rigidity and dimensional stability the fabric. However, the thickness result fails to match with the statement. The possible explanation may be due to the large fluctuation of thickness between samples.

As discussed above, the fabric with less density, weight and thickness is conducive to the resilience properties. In this study, Brand B shows the best resilience among all samples.

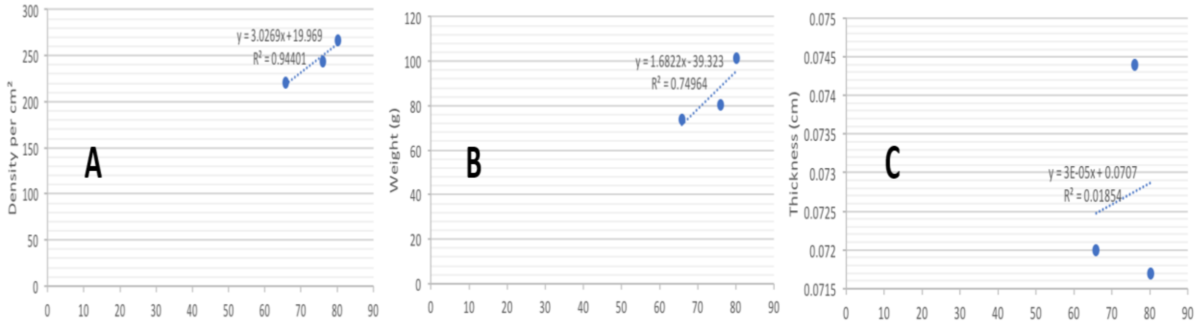

Figure 2. *Effects of fabric density (A), weight (B) and thickness (C) on the resilience.*

3.3 Effect of fabric characteristic on softness

It is pointed out that fabric softness is highly related with fabric thickness, fabric diameter and density [7]. Softness is the opposite of rigidity, and it decreases as the density increases. Figure 3(A) shows the positive relationship between softness and density, which indicates that the lower the density, the softer the fabric is.

The relationship of softness and weight is shown in Figure 3(B). It defines the softness increases with decreasing weight. Heavier weight indicates the fabric is made with coarser yarn which is yarn with larger diameter. Finer yarn provides a more compact structure which able to withstand bending. The ability to bend is highly correlated with softness. Hence, fine yarn tends to have better softness.

Figure 3(C) shows the most significant slope among three. From the slope tilt to the top, the correlation of softness RHV and thickness has a positive relationship. The smaller the RHV value the better performance the fabric can get. Therefore the thinner the fabric is, the softer it is. Softness is highly correlated with fabric compression properties [7]. Thinner fabric tends to withstand bending and compression while thick fabric is too bulky.

In the experiment, Brand C has the lowest density, lightest weight and relatively low thickness. It fits two characteristics out of three. Therefore, it is not surprising that Brand C has the lowest softness RHV which is 91.57. Brand B softness RHV is 91.83 only slightly higher than Brand C. Brand A has the worst performance in softness RHV since it has the relatively high density, heavy weight and the thickest.

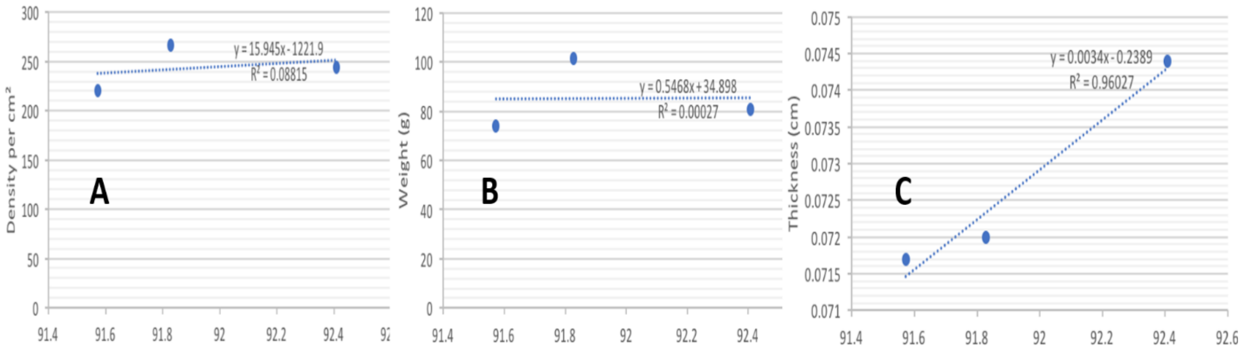

Figure 3. *Effects of fabric density (A), weight (B) and thickness (C) on the softness.*

3.4 Effect of fabric characteristic on smoothness

Figure 4(A, B, C) shows the relationship of smoothness and fabric characteristics. Fabric with higher density, light and thinner are found to be smoother. Finer yarn tends to be less hairiness that gives a smooth surface. The wales and course per cm of high density fabric would be higher and provide a smooth surface. Thinner thickness fabric indicates the finer yarn is used.

The smoothness of Brand B performs the best which is 74.89 RHV. The fabric characteristic of density and thickness match with the criteria of better smoothness performances. It has the highest density and thinnest thickness. The smoothness of Brand C performs the worst which is 78.17 in RHV value.

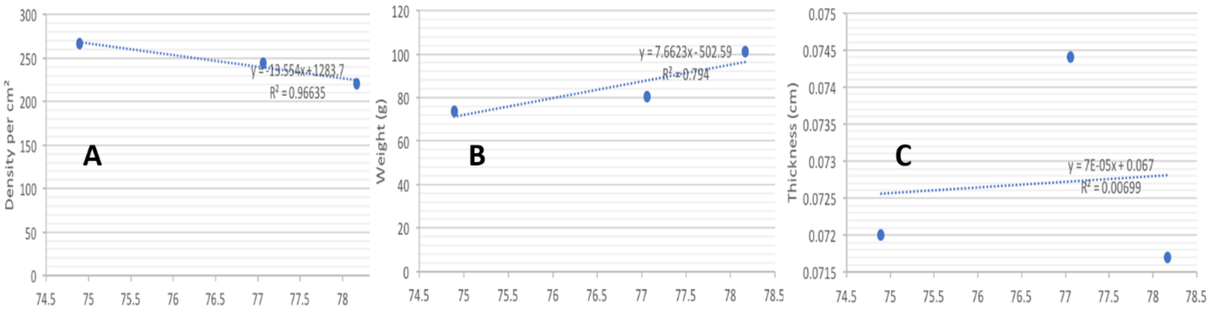

Figure 4. *Effects of fabric density (A), weight (B) and thickness (C) on the smoothness.*

In summary, Brand B shows the best performance on relative hand value result, especially in terms of resilience and smoothness. The softness for Brand C samples was the best performance.

4. Conclusions

This study investigated the relative hand properties of three brands of inner wears for woman in Hong Kong market according to the standard of AATCC-202. It was found that different product showed different advantage in relative hand value. For the resilience and smoothness, Brand B was the optimal choice, whereas Brand C was the softest sample among three samples.

Acknowledgement

This work is part of final year project submitted by Hin-heng, Lois Yim 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.

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DETERMINE THE THERMAL CONDUCTIVITY AND Q-MAX PROPERTIES OF QUICK DRY INNER WEAR

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Abstract: Thermal property is an importance factor of quick dry inner wears. This study aims to evaluate the thermal property of womens' quick dry inner wears in the market using three brands of different market position (Brand A: online brand; Brand B: general market and Brand C: youth market) by studying the thermal conductivity and Q-max value (warm/cool feeling). The thermal conductivity and Q-max values were measured according to the standard of KES-F7. Thermal conductivity analysis showed that Brand B was the optimal product, while Q-max results indicated that both Brand B and Brand A had the best product in terms of quick dry property.

1. Introduction

Hong Kong features very humid and relatively high temperature weather [1] and people sweating is often occurred during summer time in Hong Kong which makes the fabric difficult to dry [2]. During sweating, the fabric may get wet and the moisture trapped may cause uncomfortable feeling or may induce risk of infection and hyperthermia [3,4]. Thus, quick dry garment is found in the market to fit the need which would regulate the heat for the wearer. However, there is no much research on studying the thermal property of quick dry garment. Therefore, this study is aimed to investigate the thermal conductivity and Q-max (warm/cold feeling) of some brands of women's inner wear.

2. Experimental

2.1 Fabric samples

Three brands of popular quick dry inner wears for women (Brand A: online brand; Brand B: general market and Brand C: youth market) were obtained in Hong Kong market. They were all made of 100% cotton with the quick dry technology as claimed, which could provide the good sensation while wearing in summer. The appearance and weave parameters for three brands were shown in Figure 1 and Table 1.

All samples were conditioned in the standard condition for at least 24 hours prior to thermal conductivity test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

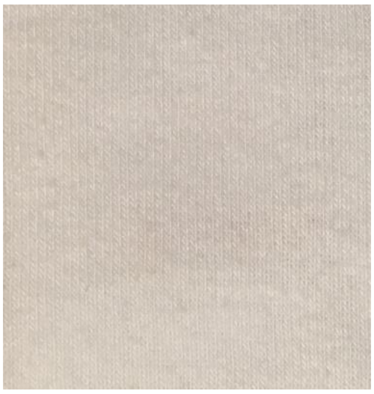
(A)	
(B)	
(C)	

Figure 1. *The fabric appearance and construction of three brands: (A); (B) and (C).*

Table 1. *Fabric weave parameters for three brands.*

Brand	Wale/cm	Course/cm	Fabric density /cm^2	Fabric weight (g/m^2)	Fabric thickness/cm
A	11.9	20.5	243.9	80.5	0.0744
B	14.2	18.8	266.96	101.25	0.0717
C	13	17	221	73.75	0.0720

2.2 Thermal conductivity measurement

Thermal conductivity refers to the ability of heat transfer through the fabric. In this study, thermal conductivity was measured according to the standard of KES-F7. Thermal conductivity of fabric can be calculated by using the Equation (1):

$$k = \frac{W \times D}{A \times \Delta T} \quad (1)$$

Where

k = thermal conductivity (W/cm · °C);

W = Data average;

D = average thickness of samples;

A = area of heat plate = 25 cm^2;

ΔT = Temperature difference = 9 °C.

To convert it into SI unit (W/mk):

$$K_{SI}\ (W/mk) = k \times 10^2$$

2.3 Q-max measurement (warm/cool feeling)

Q-max is the index of indicating the coldness and warmth feeling which affects the sensation of coldness or warmth of skin touching fabric. It is determined by the heat loss from the skin to the fabric.

3. Results and discussion

3.1 Thermal conductivity measurement

Thermal conductivity of three brands of samples is shown in Table 2. It can be clearly seen that the thermal conductivity of Brand A and Brand C was almost equivalent, both of which was significantly lower than that of Brand B. The thermal conductivity for Brand B was up to 0.082. The reason may be explained by the fabric weave parameters. Next, the correlation of fabric parameters and the thermal conductivity was explored to evaluate this hypothesis.

Table 2. *Thermal conductivity for three different samples measured.*

Brand	W	Average W	Thickness/cm	Average thickness/cm	K_{SI} (W/mk)
A	2.22	2.19	0.076	0.074	0.072
	2.19		0.076		
	2.22		0.074		
	2.15		0.076		
	2.17		0.070		
B	2.54	2.58	0.071	0.072	0.082
	2.55		0.072		
	2.64		0.072		
	2.52		0.071		
	2.64		0.063		
C	2.28	2.29	0.074	0.072	0.073
	2.27		0.075		
	2.27		0.075		
	2.38		0.070		
	2.27		0.066		

Figure 2(A) shows the positive correlation of thermal conductivity and density. It is shown that the thermal conductivity increases with increasing fabric density. Larger density indicates the fabric with more and larger pores. The pore of fabric is the main factor that affects thermal conductivity. Large pore is conductive to trap more air which is a great insulator of heat. Hence the fabric with large pore size tends to show better thermal conductivity.

Figure 2(B) shows the positive relationship between thermal conductivity and weight. The heavier fabric indicates the yarn with larger diameter was used. In this experiment, the results were opposite to the previous research. The coarse yarn may be the potential reason because it cannot be knitted into a dense and highly packed structure.

It was reported that thermal conductivity decreases with increasing fabric thickness [7]. The results in Figure 2(C) were consistent in this statement. Thicker fabric has a looser structure to trap air inside the spaces. As a result, the thicker fabric shows better thermal insulation and less thermal conductivity.

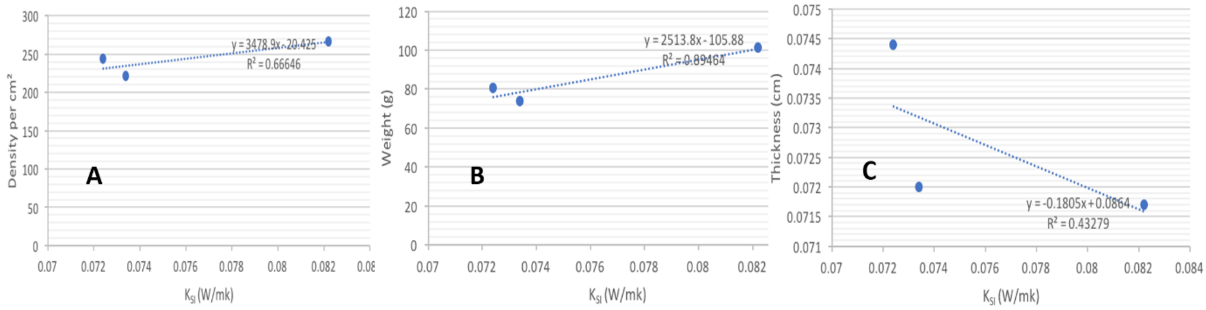


Figure 2. *Effects of fabric density (A), weight (B) and thickness (C) on the thermal conductivity.*

The higher the thermal conductivity value, the better thermal conductivity of the fabric. Brand B had the highest thermal conductivity while Brand A was the lowest. This indicates that Brand B was the most effective inner wear in terms of quick dry property, whereas Brand A products were the unsatisfactory choice.

3.2 Q-max measurement (warm/cool feeling)

Q-max can be directly determined by the machine, and the higher Q-max value means cooler initial touching feeling. The Q-max values of three brands of samples are 0.103, 0,103 and 0.092 for Brand A, Brand and Brand C respectively. As can be seen, Brand A and Brand B had the same Q-max value, whereas Brand C was the lowest sample with Q-max value. This indicates that both Brand A and Brand B performed better in terms of warm/cold feelings, which could be explained by their fabric parameters.

Figure 3(A) shows the positive correlation of Q-max and density. It means the Q-max of fabric increases with the increase of fabric density. The reason may be that the fabric with high density means high wales or courses per inch and has densely packed structure. A densely packed fabric can provide a smooth surface which increases the contact between fabric and skin. Therefore, heat can be easily transferred to the atmosphere from body and a cooler sensation can be caused when touching. Fabric thickness may be another factor affecting Q-max value. As shown in Figure 3(B), there is a positive correlation between Q-max and fabric thickness.

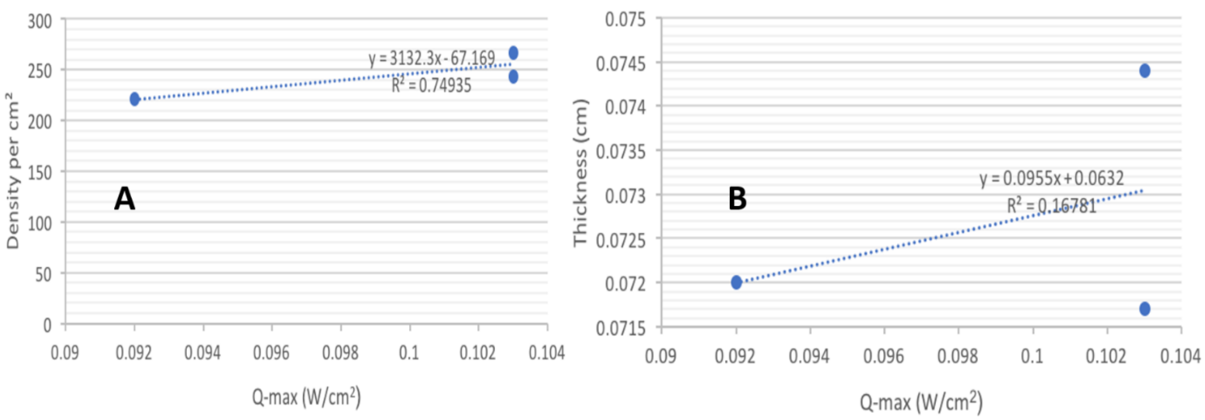


Figure 3. *Effects of fabric density (A) and thickness (B) on the Q-max value.*

The initial touch feeling indicated by Q-max is very important for summer inner wear because it provides a cool feeling while in contact with human skin. In this study, both Brand A and Brand B provides a cooler hand feel and were more suitable than Brand C to be worn in Hong Kong.

4. Conclusions

This study investigated the thermal conductivity and Q-max properties of three brands of inner wears for woman in Hong Kong market according to the standard of KES-F7. It was found that different product showed different advantage. From thermal conductivity analysis, Brand B was the optimal product due to its excellent heat transfer property, while Q-max results showed that both Brand A and Brand B were the optimal choice in terms of warm/cold feeling.

Acknowledgement

This work is part of final year project submitted by Hin-heng, Lois Yim 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.

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AN EXPERIMENTAL STUDY OF WATER VAPOUR TRANSMISSION

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Abstract: Water vapour transmission is an importance factor determining the quick dry property of inner wears. This study aims to evaluate the quick dry properties of womens' quick dry inner wears in the market (three brands were selected: Brand A: online brand; Brand B: youth market and Brand C: general market) by simulating of water vapour (sweat) transmission from skin surface to outer fabric surface. It was found that Brand B product was the optimal choice in terms of water vapour transmission.

1. Introduction

Humid and relatively high temperature is a common weather feature in Hong Kong during summer [1]. The sweating would influence the comfort properties of a garment during wear because the fabric is difficult to dry in a short period of time [2]. The moisture trapped in the fabric may cause health effect to the wearer [3, 4] and also affect the body temperature regulation [5]. Therefore, quick dry garments are launched to the market. In the quick dry products, the water vapour transmission (WVT) is a critical parameter in determining the quick dry property of inner wear. Nowadays, there are quite a lot of quick dry inner wears available on the market. The present study aims to investigate the quick dry performance of such products in Hong Kong market by comparing the WVT properties of three common commercial women's quick dry inner wears for different market position (Brand A: online brand; Brand B: general market and Brand C: youth market).

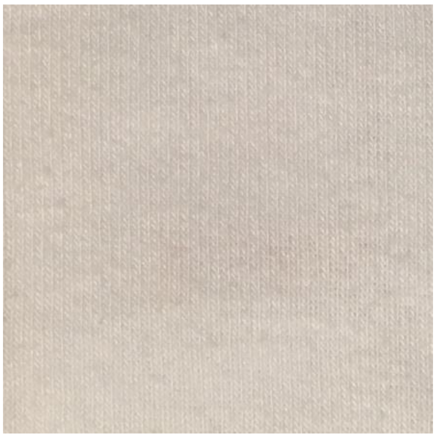
2. Experimental

2.1 Fabric samples

Three popular quick dry inner wears for women (Brand A: online brand; Brand B: general market and Brand C: youth market) were obtained in Hong Kong market. They were all made of 100% cotton with the quick dry technology as claimed, which could provide the good sensation while wearing in summer. The appearance and weave parameters for three brands were shown in Figure 1 and Table 1. All samples were conditioned in the standard condition for at least 24 hours prior to water vapour transmission test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

(A)

(B)



(C)

Figure 1*. The fabric appearance and construction of three brands: (A); (B) and (C)*

Table 1. *Fabric weave parameters for three brands.*

Brand	Wale/cm	Course/cm	Fabric density /cm^2	Fabric weight (g/m^2)	Fabric thickness/cm
A	11.9	20.5	243.9	80.5	0.0744
B	13	17	221	73.75	0.0720
C	14.2	18.8	266.96	101.25	0.0717

2.2 Water vapour transmission measurement

WVT directly affects the drying speed of fabric. This test was to measure the rate of water vapour movement under standard temperature and humidity via simulating the situation of water vapour (sweat) transmission from skin surface to outer fabric surface. The fabric next to skin was faced the wetter side in this experiment (Figure 2). After 24 hours, the weight difference was evaluated. The procedures to measure WVT were followed according to ASTM-E96 standard. WVT of fabric can be calculated by using the Equation (1):

$$\text{WVT} = \frac{G}{tA} \quad (1)$$

Where
WVT is water vapour transmission rate (g/h · m^2);
G is weight change (g);
t is 24 hours (h); and
A is the area of cup mouth, m^2.

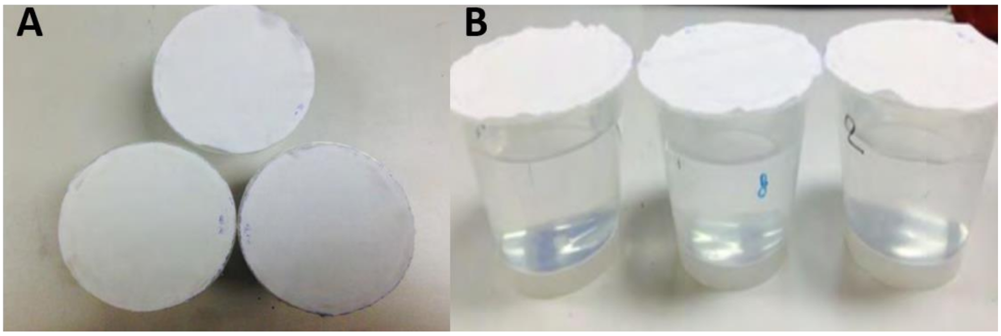


Figure 2. *Water vapour transmission test setting, (A) top view and (B) side view.*

3. Results and discussion

3.1 Water vapour transmission measurement

The higher the WVT value, the better water vapour transmission of fabric. WVT was measured according to the standard of ASTM-E96, as shown in Table 2. Clearly, Brand C has the highest water vapour transmission rate, up to g/h · m^2, while WVT of Brand A is the lowest. This indicates that Brand C products are the optimal choice in terms of quick dry property, which may be due to the fabric characteristics.

Table 2. *Results of water vapour transmission.*

Brand	Weight (g)	Weight after 24h(g)	Mean weight change (g)	WVT (g/h·m^2)
A	85.65	81.8	3.59	49.55
	80.1	76.77		
B	81.37	77.59	3.79	52.24
	82.03	78.24		
C	84.26	80.08	4.05	55.90
	85.92	82		

3.2 Effect of fabric characteristic on water vapour transmission

Figure 3(A) shows the positive relationship between fabric density and WVT. It means that the WVT increases as the fabric density increases. The high density of fabric samples means the highly packed structure, which may reduce the pore size. However, this statement did not match with the results shown in Figure 3(A). The positive explanation is that high density may affect the pore size and increase the quantity of pores. Therefore, more space allows the water vapour to transfer to the atmosphere.

Another influencing factor may be fabric weight. The heavier fabric means coarser yarn, which decreases the pore size and WVT. Compared to the normal and coarser yarn, fine fibers provide a larger surface area for WVT. Figure 3(B) shows the positive relation of WVT and weight. Clearly, WVT increases with increasing weight.

Figure 3(C) shows the negative correlation of WVT and fabric thickness, which means WVT decreases with increasing thickness. Thicker fabric takes longer and harder for the water vapour to transfer from skin to atmosphere compared to the normal fabric.

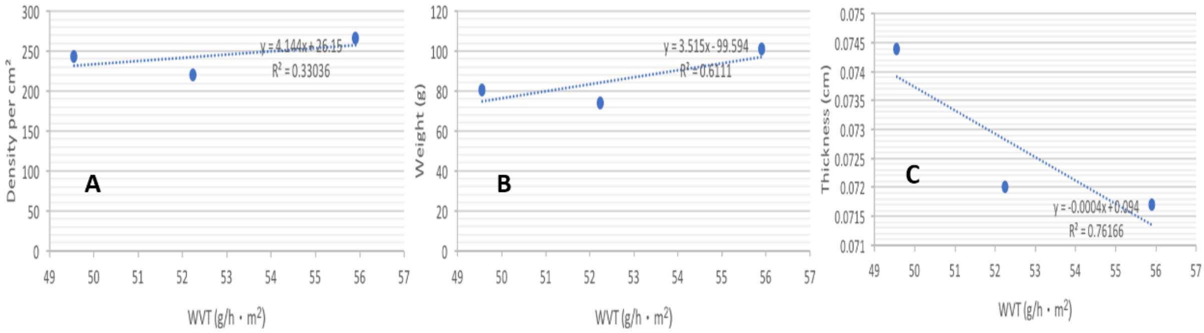


***Figure 3**. Effects of fabric characteristics: (A) density; (B) weight; and (C) thickness on WVT.*

WVT rate indicates the ability of water transmitting through fabric. This is a key factor affecting the comfortability of inner wear. WVT is mainly affected by the size and number of pores. Fabric density is highly correlated with the pores of fabric. High density would favour WVT. From the results above, Brand C was the best products, while Brand A has the worst performance in terms of WVT.

4. Conclusions

This study investigated the water vapour permeability properties of three brands of inner wears for woman in Hong Kong market. It was found that Brand C showed the best quick dry property because of the excellent water vapour permeability, while Brand A was the worst samples in terms of water vapour permeability.

Acknowledgement

This work is part of final year project submitted by Hin-heng, Lois Yim 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.

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AIR PERMEABILITY PROPERTY STUDY OF QUICK DRY INNER WEAR

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Abstract: Air permeability is an importance factor determining the quick dry property of inner wears. This study aims to evaluate the air permeability of women's quick dry inner wears in the market (Three brands were selected due to their different market position: Brand A: online brand; Brand B: youth market and Brand C: general market) by using the automatic air permeability tester. It was found that Brand B product was the optimal choice in terms of air permeability.

1. Introduction

Sweating is occurring in summer weather and the case in Hong Kong is very common due to very humid and relatively high temperature [1-4]. The sweating can help regulating the human body temperature [5]. However, sweat cannot be evaporated quickly under humid condition and stayed on the inner wear and skin. The excess heat needs to be transferred away from the skin to maintain healthy body temperature. Cooling is hence of high importance to avoid heat stroke. Air permeability is a critical parameter in determining the quick dry property of inner wear. Nowadays, there are quite a lot of quick dry inner wears available in the market. The present study aims to investigate the quick dry performance of such products in Hong Kong market by comparing their air permeability properties of three common commercial inner wears (Brand A: online brand; Brand B: youth market and Brand C: general market).

Experimental

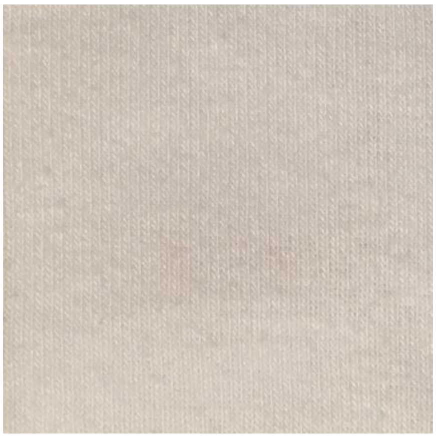
2.1 Fabric samples

Three women's quick dry inner wears Brand A: online brand; Brand B: youth market and Brand C: general market) were obtained in Hong Kong market. They were all made of 100% cotton with the quick dry technology as claimed, which could provide the good sensation while wearing in summer. The appearance and weave parameters for three brands were shown in Figure 1 and Table 1.

All samples were conditioned in the standard condition for at least 24 hours prior to wicking test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%. After conditioning, all experiments were carried out in a standard testing condition.

(A)

(B)



(C)

Figure 1. *The fabric appearance and construction of three brands: (A); (B) and (C).*

Table 1. *Fabric weave parameters for three brands.*

Brand	Wale/cm	Course/cm	Fabric density /cm^2	Fabric weight (g/m^2)	Fabric thickness/cm
A	11.9	20.5	243.9	80.5	0.0744
B	13	17	221	73.75	0.0720
C	14.2	18.8	266.96	101.25	0.0717

2.2 Air permeability measurement

Air permeability is an important factor which can affect the heat and moisture transfer [6]. It can be measured according to the standard of KES-F8-AP1.

3. Results and discussion

3.1 Air permeability results

The smaller value means better air permeability of fabric. Air permeability results are shown in Table 2. It can be clearly seen that the air permeability of Brand B is 0.05 KPa.s/m, which is lower than that of Brand A and Brand C. This indicates that Brand B has the best air permeability compared to Brand A and Brand C, which could be explained by the fabric characteristics of Brand B.

Table 2. *Results and calculation of air permeability.*

Brand	Air permeability (KPa.s/m)	Mean of air permeability (KPa.s/m)	Standard deviation
A	0.107	0.09	0.013
	0.075		
	0.095		
	0.087		
	0.078		
B	0.050	0.05	0.0075
	0.043		
	0.057		
	0.048		
	0.062		
C	0.110	0.12	0.022
	0.133		
	0.129		
	0.082		
	0.133		

3.2 Effects of fabric characteristics on air permeability

Figure 2(A) shows the negative correlation between fabric density and air permeability. This means that the lower the density is, the better the air permeability fabric gets. In a high density fabric, yarns are tightly packed. The space between yarns would be decreased, leading to smaller pore sizes. Air flow through the pores is the air permeability, which would be decreased because of the reduction of moving space [6].

The positive correlation between air permeability and weight is shown in Figure 3(B). The heavier fabric means higher air permeability value, resulting in poorer air permeability properties. Heavier weight indicates the coarser yarn was used. The fine yarn can achieve large pore size and high porosity, making the air easy to pass through. This provides a reason for the positive relationship between air permeability value and weight.

It is pointed out that air permeability decreases with increasing fabric thickness [7]. However, the result in Figure 2(C) does not match with this conclusion, which may be explained by the large difference of thickness among samples.

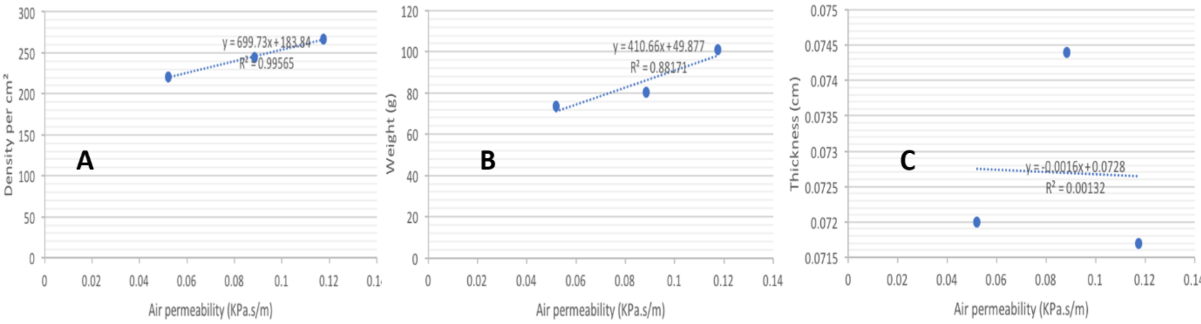


***Figure 2**. Effects of fabric characteristics: (A) density; (B) weight; and (C) thickness on air permeability.*

Air permeability affects the heat and moisture transfer of inner wear. In another word, it controls the heat and moisture comfort of inner wear. Therefore, it is an important factor controlling the effectiveness and comfortability of quick dry inner wear.

From the above discussion, better air permeability properties can be found in the samples with low density, lighter yarn and thicker fabric. Brand B has the least density and lightest weight which matches the discussion above. Also, it is thicker than Brand C which shows the highest density, heaviest weight and thinnest fabric. Therefore, Brand B has the best air permeability among all while Brand C has the worst.

4. Conclusions

This study investigated the air permeability properties of three brands of inner wears for woman in Hong Kong market. It was found that Brand B showed the best quick dry property because of the excellent air permeability property.

Acknowledgement

This work is part of final year project submitted by Hin-heng, Lois Yim 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.

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EVALUATION ON THE PROPERTIES OF ULTRAVIOLET RADIATION AND AIR PERMEABILITY OF COTTON T-SHIRTS

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Abstract: Cotton T-shirts from on-line shop and physical shop were selected for discussion. The final results showed that the quality of physical shop cotton T-shirt were better than on-line shop's counterpart. The average UPF of physical shop's T-shirt was 12.11 which is higher than that of on-line shop. This means that physical shop T-shirt may perform better than on-line shop counterpart in terms of blocking the sun-rays out and reducing the UVR exposure. The average air permeability of on-line shop was higher than that of physical shop, which means physical shop T-shirt had better air permeability property.

1. Introduction

On-line shopping is a form of electronic commerce which allows consumers to directly buy goods from a seller over the Internet using a web browser. It has gained great development since it appeared in 1994, and now it has become very popular around the world [1, 2]. However, the quality of the products, e.g., textile products, is the major issue facing on-line shopping. Consumers are unlike to distinguish the normal products and counterfeit articles due to lack of necessary expertise. Solar rays, despite having some beneficial effects, can be harmful for human health. Ultraviolet (UV) protection provided by clothing or fabrics depends on several factors, including fiber type, yarn structure, fabric construction, density, thickness and colour [3, 4]. It was reported that the physio-chemical nature of fiber and fabric cover are the key parameters determining the UV protection property of fabrics [5]. Likewise, air permeability is also an important property of fabrics which depends on many parameters such as fabric structure, the number of warp and weft yarns per centimeter, the amount of twist in yarns, etc [6]. The present study aims to compare the properties of UV-protection and air permeability of fabric samples obtained from on-line and physical shops.

2. Experimental

2.1 Fabric samples

Two summer cotton T-shirt samples were obtained from on-line shop and physical shop. Two samples were white in colour and single jersey in structure. The specifications of two brands of samples were shown in Table 1. All samples were conditioned in the standard condition for at least 24 hours prior to wicking test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

Table 1. *Fabric specifications.*

Items	On-line shop	Physical shop
Fiber composition and content	Cotton 100%	Cotton 100%
Fabric construction	Single jersey	Single jersey
Colour	white	white
Fabric thickness/mm	0.704 mm	0.671mm
Fabric weight (g/100 cm^2)	1.650	1.698

2.2 Ultraviolet radiation test

Ultraviolet radiation is a kind of electromagnetic radiation that emitted by the sun, which can be divided into UVA, UVB and UVC. UVA is a kind of hazardous agent that can deeply penetrate in our body and damage our DNA. UVB is also a hazardous agent that can damage our body by the burning ray and eventually cause cancer. UVC is an agent that has already been blocked by the ozone layer, and thus does not exist in the earth. Therefore, only UVA and UVB were analyzed and discussed in this study. The property of blocking ultraviolet radiation of samples were evaluated according to the standard of AATCC Test Method 183. Each sample was cut into 2 specimens with the size 50×50 mm. The specimens were measured by CARY 300 spectrophotometer.

2.3 Air permeability test

Air permeability is a key property related to moisture and heat transfer, which can be used to evaluate the breathability of fabrics. KES-F8, the air permeability tester, was used to test the air permeability of samples. The KES-F8 was designed to measure the air permeability of a wide range of samples from high permeability to low permeability. The air permeability was determined by the rate of airflow, as stated in Equation (1):

$$R = KV = \Delta P/V \qquad (1)$$

Where
R = air resistance (kPa.s/m);
ΔP = pressure difference (kPa);
V = air velocity (m/s); and
K=constant of specimen.

3. Results and Discussion

3.1 Ultraviolet radiation analysis

Ultraviolet protection factor (UPF) is measure of UVR protection by a fabric. UPF ratings are determined by testing fabric in a laboratory in accordance with AATCC Test Method. The higher the UPF value, the greater the protection from UV radiation. The fabric rated above UPF 30 provides good protection against UV radiation, but 50+ is recommended.

The UVR transmission spectra (T %) over textiles were measured in the range of 280-400 nm with 2 nm interval. UV protection factor (UPF), blocking in UVA (315-400 nm) region and blocking in UVB (280-315 nm) region were all detected and the results are shown in Table 1. As can be clearly seen, the average ultraviolet protection factor (UPF) ratings of both samples are not categorized as good ratings. The average UPF of physical shop's cotton T-shirt was higher than on-line shop's (12.11>8.27), which means that physical shop's cotton T-shirt performs better than on-line shop's in terms of blocking the sun rays out to reduce the UVR exposure.

Table 2. *Results of UV test of physical shop (P) and on-line shop (O) cotton T-shirt.*

No.:	UPF		T(UVA) Av/% 315-400nm		T(UVB) Av/% 280-315nm		T(UVR) Av/% 280-400nm	
	P	O	P	O	P	O	P	O
1	11.51	8.41	3.70	5.56	9.20	12.58	5.20	7.46
2	11.11	8.55	4.00	5.33	9.62	12.41	5.53	7.24
3	12.35	8.57	3.60	5.26	8.64	12.25	4.97	7.15
4	11.66	8.19	3.67	5.97	9.16	12.97	5.16	7.85
5	11.60	10.23	3.93	3.92	9.24	10.22	5.37	5.64
6	11.17	9.46	4.19	4.54	9.57	11.11	5.64	6.32
7	14.62	6.99	2.83	6.28	7.20	15.16	4.02	8.70
8	15.89	7.35	2.72	6.19	6.63	14.42	3.78	8.42
9	14.77	8.79	2.77	4.89	7.15	11.91	3.97	6.80
10	9.86	8.61	2.57	4.87	10.90	12.16	6.29	6.86
11	10.80	8.68	4.08	5.14	9.93	12.09	5.67	7.03
12	10.04	6.48	4.55	7.14	10.71	16.42	6.22	9.65
Avg.	12.11	8.27	3.55	5.42	9.00	11.97	5.15	7.43

Exposure to sunlight is of high importance for human bodies to maintain metabolism process and protect from many harmful pathogens. However, this may also cause skin diseases such as premature aging, allergies, sunburn, and even skin cancer. To avoid ultraviolet radiation, a wide range of methods have been adopted to enhance the UV protection property of fabrics, i.e., UV-protective textile materials. The higher UV transmission value means lower UV protection. As can be seen from Table 2, the UV transmission of on-line shop cotton T-shirt was higher than physical shop's, indicating that on-line shop's sample performs worse than physical shop's. This could be explained by the different fabric thickness, density and the knitting structure. The finishing process provides another major reason why both samples showed different UV protection properties.

3.2 Air permeability analysis

Air permeability is an important factor which can be used to indicate the breathability of a fabric. The rate of airflow passing perpendicularly is adjusted to obtain a prescribed air pressure differential between the two fabric surfaces through a known area of fabric. From this rate of airflow, the air permeability of the fabric is determined. Table 3 shows the results of air permeability of both samples.

Table 3. *Result of air permeability test of physical shop's and on-line shop's cotton T-shirt.*

No.:	Air permeability (kPa • s/m)					
	1	2	3	4	5	Average
Physical shop	0.077	0.075	0.066	0.07	0.071	0.072
On-line shop	0.107	0.087	0.085	0.081	0.082	0.088

The lower value means better air permeability. It can be clearly seen that the average air permeability of on-line shop sample is slightly higher than physical shop, which means that physical shop's cotton T-shirt has a smaller permeating resistance and is superior in air permeability.

Heat losses are highly affected by the air exchange between the clothing microenvironment and the external environment. Clothing ventilation is a key measurement of the comfort of T-shirts. The present study investigates the effect of air permeability on the ventilation of fabrics. The ventilation of clothing may be linked with the wind, the air layer width, movement, holes of clothes, posture and the suppleness of fabrics. Meanwhile, the area and shape of the interstices between yarns are influenced by the yarn crimp and weave. When the twist increases, the density and the circularity of yarns are also increased. Then, the yarn diameter and the cover factor are reduced and the air permeability increased. The open of the fabric may occur by the extension of yarn as mentioned above, and it may result in the increase of the free area, thus leads to an increase in the air permeability. The increase of yarn twist may also reduce the air permeability by allowing circular yarns to be packed tightly and closely together with the woven structure.

4. Conclusion

In this study, the properties of ultraviolet radiation and air permeability of cotton T-shirts obtained from on-line and physical shops were fully investigated. It was found that the quality of physical shop cotton T-shirt performed better than on-line shop counterpart in terms of blocking the sun rays out and the air permeability. In contrast, on-line shop provides a convenient shopping way and shows a great development potential in future.

Acknowledgement

This work is part of final year project submitted by Man-wai Chan 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.

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EVALUATION ON THE DURABILITY OF ON-LINE AND PHYSICAL SHOP COTTON T-SHIRTS

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Abstract: Cotton T-shirts were obtained from on-line shop and physical shop for comparison and discussion on their durability. The final results showed that the quality of physical shop cotton T-shirt was better than on-line shop counterpart. The average warp and weft dimensional changes of on-line shop T-shirt were higher than that of physical shop, whereas physical shop's T-shirt had lower twist level that of on-line shop after repeated washing. This indicates that physical shop T-shirt performed better in dimensional change and skewness change.

1. Introduction

Textile construction is a term referring to the fiber, yarn and fabric dimensions and is of high importance for the initial properties of textile which influences the functionality during use [1]. The wear life of fabrics is complex because of the many different factors of fabric construction over a variety of structural levels [2]. Dimensional stability refers to the ability of a fabric to resist a change in its dimensions. Garments made from fabrics without dimensional stability may change shape after laundering, which is undesirable for wearers [3, 4]. A fabric can exhibit either reversible or irreversible shrinkage during laundering and pressing process. A wide range of factors may affect dimensional stability of fabrics, including fiber type, yarn structure, fabric construction [5]. However, the quality of the textile products, e.g., the durability property, is one of the major issues facing on-line shopping. The present study aims to investigate the quality properties of common textile products, T-shirts, by comparing the on-line shop and physical shop products in terms of durability properties, such as dimensional changes due to repeated laundering.

2. Experimental

2.1 Fabric samples

Two summer cotton T-shirt samples were obtained from on-line shop and physical shop. Two samples were white in color and single jersey in structure. The specifications of two brands of samples were shown in Table 1. All samples were conditioned in the standard condition for at least 24 hours prior to wicking test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

Table 1.*Fabric specifications.*

Items	On-line shop	Physical shop
Fiber composition and content	Cotton 100%	Cotton 100%
Fabric construction	Single jersey	Single jersey
Color	white	white
Fabric thickness/mm	0.704 mm	0.671mm
Fabric weight (g/100 cm^2)	1.650	1.698

2.2 Durability test

Sweating is a daily happened issue during summer and the laundering, a vigorous process involving mechanical agitation and detergent, is unavoidable. Moreover, tumble drying significantly affects the dimensional stability of a fabric as the material is wet at the beginning of the drying process and undergoes agitation. The shrinkage and dimensional change may occur during repeated laundering. In this study, the durability was evaluated in accordance with the standard method of AATCC Test Method 150.

2.2.1 Dimensional changes

Dimensional changes of garments after home laundering were tested. According to the standard AATCC Test Method 150, the dimensional changes of garment specimens after washing can be determined by the measurement of benchmarks applied on the garment before laundering (Figure 1).

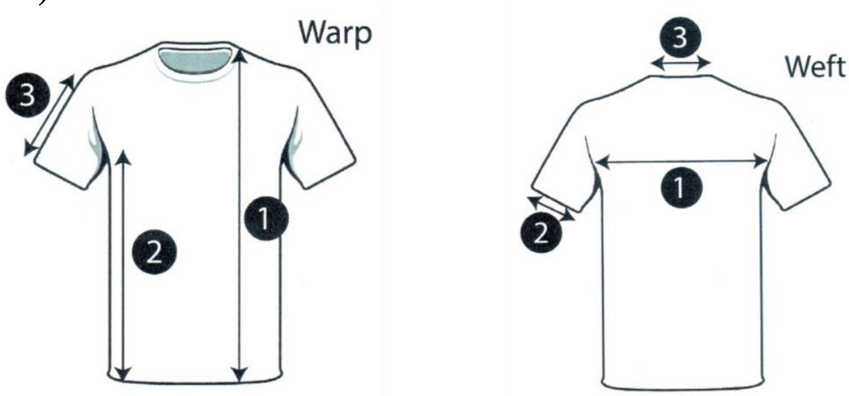

Figure 1. *Benchmarks for dimensional change test on T-shirt (warp and weft).*

2.2.2 Skewness change

Skewness change in fabric and garment twist due to automatic home laundering was measured according to the standard method of AATCC Test Method 179. According to the standard, the determination of the skewness change was subjected to the repetition of home laundering procedures. The measurement of the change was measured by using the benchmarks before laundering. Each garment was considered as a specimens. Use the fabric pen to draw reference line YZ across the width of the whole specimen panel. The YZ line was 75 mm above the bottom of the T-shirt. Then draw benchmark parallel to line YZ 500mm directly above the point A (Figure 2). The procedure was the same with the above dimensional changes of garments after home laundering test.

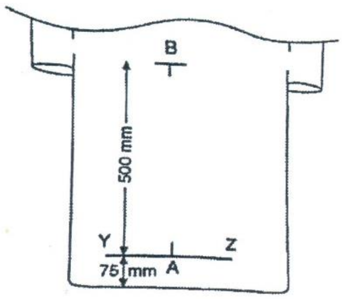

Figure 2. *Benchmarks for skewness test on T-shirt.*

3. Results and Discussion

3.1 Dimensional changes

The AATCC standard references was used to create a standard condition for testing the dimensional stability of the specimens. In order to simulate the home laundering, ballast was added to make a total load of 1.8 kilograms. The dimension of both samples before and after washing was shown in Table 2. It can be clearly seen that the dimension changed significantly after washing for both physical shop and on-line shop samples.

The dimension of physical shop T-shirt is significantly decreased from the first to the fifth washing cycle, especially in warp direction. In the contrast, the dimension in weft direction seems unchanged after several washing cycles. This indicates that washing cycles have a greater effect on the warp than the weft. Likewise, for the on-line shop sample, the dimension change is also observed after various washing cycles, especially in weft direction. It is worth noting that the warp direction of on-line shop sample remains unchanged from the third to fifth washing cycle. The dimensional change for on-line shop cotton T-shirt in both warp and weft direction are higher than physical shop's cotton T-shirt.

Table 2. *The length in specific benchmarks of physical shop (U) and* physical shop *(T) cotton T-shirt (unit: mm).*

Item		Initial		1st washing cycle		3rd washing cycle		5th washing cycle	
		U	T	U	T	U	T	U	T
Warp	1	794	740	726	649	706	649	697	643
	2	508	465	476	433	468	433	459	433
	3	219	175	198	165	194	160	194	160
Dimensional change/%		/	/	7.96	9.64	10.06	10.00	11.24	10.00
Weft	1	527	476	503	422	503	415	503	410
	2	186	174	179	146	179	142	179	140
	3	449	444	445	388	443	385	443	380
Dimensional change/%		/	/	3.01	12.85	3.18	14.13	3.18	15.22

3.2 Skewness change

Additionally, for the skewness tests, physical shop cotton T-shirt was twisted in 1.5 cm, while the figure for on-line shop sample was 5.1 cm. This indicates that physical shop sample performs better in dimensional stability. The possible explanation may consist in the structure of plain single jersey, which may cause a large percentage of distortion and highly unbalanced structure. However, as seen from Table 2, both samples have the same fiber content and fabric construction, but are different in the fabric thickness and weight, which may be another reason why physical shop had better dimensional stability. Besides, both physical shop and on-line shop T-shirt must have been subjected to the finishing process, which may also exert influence on the dimensional stability.

4. Conclusion

In this study, the properties of durability of cotton T-shirts obtained from on-line and physical shops were fully investigated. It was found that the quality of physical shop cotton T-shirt performed better than on-line shop counterpart in terms of dimensional stability. In contrast, on-line shop provides a convenient shopping way and shows a great development potential in future.

Acknowledgement

This work is part of final year project submitted by Man-wai Chan 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.

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COMPARATIVE STUDY OF MOISTURE MANAGEMENT AND THERMAL CONDUCTIVITY PROPERTIES OF COTTON T-SHIRTS BETWEEN ON-LINE AND OFF-LINE SHOPS

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Abstract: Cotton T-shirts from on-line and off-line shop were selected for this study and their moisture management and thermal conductivity properties were compared. The final results showed that both off-line shop and on-line shop cotton T-shirts had moisture management properties. However, off-line shop's cotton T-shirt was better than on-line shop's counterpart, indicating the wear comfort of off-line shop T-shirt was better. Meanwhile, the thermal conductive property of on-line shop T-shirt performed worse than on-line shop. This indicates that off-line shop's T-shirt is more suitable for daily usage during summer.

1. Introduction

Liquid moisture property is of high importance for textile which significantly influences the wearer's perception of moisture comfort sensations [1]. Water vapor carries heat away from the body as it evaporates from the interface between skin and fabric. In the garment-skin microclimate, absorption and transportation of sweat through and across the fabric are related to sensorial comfort of garments [2]. The liquid moisture management performance of fabrics results from complex properties including their absorbent capacity, absorption rate, and evaporation [3]. Thermal conductivity is another property greatly affecting the wear comfort of fabrics, which is related to fiber type, yarn property, fabric structure and finishing treatments, etc. [4]. On-line shopping is a form of electronic commerce which allows consumers to buy goods directly from a seller over the internet, which makes the shopping very easy and convenient. However, the quality of the products in the on-line shops is a major issue of common concern, especially for the textile goods. The present study aims to investigate the properties of common textile products, T-shirts, by comparing the on-line shop and off-line shop products in terms of the liquid moisture management and thermal conductivity.

2. Experimental

2.1 Fabric samples

Two summer cotton T-shirt samples were obtained from on-line shop and off-line shop. Two samples were white in color and single jersey in structure. The specifications of two brands of samples were shown in Table 1. All samples were conditioned in the standard condition for at least 24 hours prior to wicking test with the temperature at 20 ± 2°C and the relative humidity at 65 ± 2%.

Table 1.*Fabric specifications.*

Items	On-line shop	Off-line shop
Fiber composition and content	Cotton 100%	Cotton 100%
Fabric construction	Single jersey	Single jersey
Color	white	white
Fabric thickness/mm	0.704 mm	0.671mm
Fabric weight (g/100 cm^2)	1.650	1.698

2.2 Liquid moisture management properties test

A very large amount of perspiration is released by body during summer which can significantly influence the wear comfort of a fabric. The sweat can be transferred through two ways, i.e., absorption of the garment and evaporation. Thus, the absorption and transfer of moisture is a key factor for the fabric to maintain the thermal comfort. In this study, the liquid moisture management properties of textile fabric were evaluated in accordance with the standard AATCC Test Method 195.

2.3 Thermal conductivity test

Thermal conductivity refers to the heat retention ability of a material, which is of high importance for textile fabric governing the thermal comfort. In this study, KES-F7 test was conducted to measure the thermal conducting properties of the T-shirt samples.

3. Results and Discussion

3.1 Moisture management analysis

The yarn that made from cotton has the capability to withdraw moisture content from the skin because of the hydrophilicity of cotton cellulose. The soaking up ability of cotton is 8%, and this is adequate to remain the skin of human dry and comfortable even in high perspiration situation. The softness of the yarn structure is also a key to improve the comfort feeling.

The results of liquid moisture management for both off-line shop and on-line shop cotton T-shirt samples are shown in Table 2. As can be clearly seen, on-line shop has better OWTC, while the OMMC for off-line shop is higher than that of on-line shop. OMMC refers to the ability to indicate the overall ability of the sample to manage the liquid moisture. Generally speaking, the higher the value of OMMC, the better the moisture management ability. This indicates that off-line shop is superior in the moisture management.

Additionally, the wetting time for on-line shop sample was higher than that of off-line shop's, for both top and bottom parts, which means off-line shop sample has a faster spreading speed. This matched with the results of spreading speed, as shown in Table 2. For the max wetted radius, the top and bottom part of off-line shop sample is equal, whereas the top part for on-line shop was slightly higher than the bottom part.

It is worth noting that for the absorption rate, the top part of on-line shop sample was far lower than that of the bottom, which means the moisture spread directly and penetrate through the fabric. However, the off-line shop sample saw a comparable absorption rate for both the top and bottom.

According to Table 2, the spreading capability of off-line shop cotton sample in the top and bottom was between fair and good. In the contrast, the spreading capability of on-line shop sample was between poor and fair. This indicates that off-line shop sample performed better than on-line shop's in the spreading capability. In summary, both of off-line shop and on-line shop samples have satisfactory overall moisture management because they are knitted in the same fabric structure and fiber content.

Table 2. *Results of moisture management of* off-line shop *and on-line shop cotton T-shirt.*

		On-line shop	Off-line shop
Wetting time (sec)	top	7.75	4.74
	bottom	4.16	2.98
Absorption rate (%/sec)	top	10.42	31.91
	bottom	42.44	35.92
Max wetted radius (mm)	top	18	16
	bottom	15	16
Spreading speed (mm/sec)	top	1.33	8.00
	bottom	2.16	2.65
One-way transport capability (OWTC)		620.47	539.04
Overall moisture management capability (OMMC)		0.69	0.71

3.2 Thermal conductivity analysis

The results of thermal conductivity for off-line shop and on-line shop samples are shown in Table 3. Clearly, according to Table 3, the bulkiness of on-line shop sample is higher than that of the off-line shop sample, while the fabric density of on-line shop sample is lower than that of the off-line shop's. Cotton is kind of fiber that could conduct more heat and achieve a higher conductivity. The lower value of thermal conductivity means that the fabric cannot transfer the heat energy quickly and trap the energy in the cloth. When the thermal conductivity coefficient is low and the thermal resistance is high, swelter occurs because heat is trapped.

Table 3. *Results of thermal conductivity of off-line shop and on-line shop cotton T-shirt.*

	Average power loss (W)	Average thickness (mm)	Average thermal conductivity (W/mK)	Average fabric density g/cm^3)	Average fabric bulkiness(cm^3/g)
Off-line shop	1.97	0.67	0.0520	0.25	4.30
On-line shop	1.78	0.71	0.0506	0.23	3.94

In addition, from Table 3, the fabric thickness for on-line shop sample is slightly lower than that of off-line shop, while the off-line shop sample has a higher fabric density. Likewise, the higher fabric bulkiness is seen in the off-line shop sample. More importantly, off-line shop has a slightly higher thermal conductivity than On-line shop. This means that on-line shop's cotton T-shirt was less thermal conductive and thus the heat loss was lower. To conclude, off-line shop cotton T-shirt seems more suitable for daily use during summer to maintain comfort.

4. Conclusion

In this study, the properties of moisture management and thermal conductivity of cotton T-shirts obtained from on-line and off-line shops were fully investigated. It was found that the quality of off-line shop cotton T-shirt performed better than on-line shop counterpart in terms of moisture management and thermal conductivity. In contrast, on-line shop provides a convenient shopping way and shows a great development potential in future.

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EFFECT OF PLASMA PRE-TREATMENT ON THE DYEABILITY OF SILK FABRIC WITH METAL-COMPLEX DYE

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Abstract: Plasma technology is an effective way to modify the physicochemical properties of silk fabric. This study was a preliminary study to explore the dyeability of silk fabric with metal complex dyes after treated with plasma technology, which may improve the processability and broaden the application of silk fabric. This study investigated the optimal plasma treatment condition and evaluated treated silk fabric in terms of wettability, surface modification and dyeability. It was found that plasma treatment can enhance the wettability and dyeability of silk fabric via the formation of hydrophilic functional groups in the structure of silk fiber.

1. Introduction

Silk is one of the most popular protein fiber and has become the symbol of royalty in ancient times because of its unique properties like wearing comfort, soft handle, good air permeability and elegant appearance [1]. Silk fiber is constructed with two different protein-based layers-fibroin in an inner layer and a sericin coating in an outer layer. Fibroin is the structural protein of silk fiber, whereas sericin is the water soluble proteinaceous glue that serves to bond the fibers together [2]. Silk processing from cocoons to the finished clothing materials consists of a series of steps, such as reeling, weaving, degumming, dyeing or printing, and finishing. Acid dyes are commonly used for the dyeing of silk fabrics. Nevertheless, the properties of silk fiber are often influenced by acids which are generally used as the additives and auxiliaries in the dyeing process [3]. Moreover, the color fastness to wash is usually unsatisfactory. Thus, surface modifications of silk fiber, such as plasma treatment, is often used to address these questions.

Plasma modification is one of the effective ways for the surface treatment of textile materials, since plasma treatment could modify the chemical and the physical properties of the surface of the textile materials without affecting the original bulk properties of the textile materials [4]. Plasma treatment provides possibilities to refine a textile material surface, enabled by the adjustment of parameters like gas flows, power, pressure and treatment time [5]. Plasma treatment of textile material surface causes not only a modification during the plasma exposure, but also leaves active sites at the surfaces which are subject to post-reaction. It has been proved that the hydrophobic characteristic of silk can be promoted with the aid of plasma treatment [6]. The present study is to investigate the application of plasma treatment in the surface modification of silk fiber dyed with metal complex dyes.

2. Experimental

2.1 Fabric specimen pretreatment

Before carrying out the plasma treatment, the silk fabric was scoured with acetone around for 10 minutes to remove the impurities. Next, the fabric was placed in the standard condition (temperature 21±1°C, relative humidity 65±2%) for 24 hours for drying. Finally, cut the silk fabrics into 10 cm x10 cm^2 for further experiments.

2.2 Plasma treatment

The plasma generator Atomflo™ 400 series (Surfx Technology, US) was used for plasma treatment in this study. The gases used for the plasma treatment were helium and oxygen. The operation of plasma treatment was controlled by a controller. The flow rate of helium was 30.5 L/min, and the flow rates of oxygen were 0.3, 0.4, and 0.5 L/min. The discharge power was 150W. The jet-to-substrate distances were 3, 4, and 5mm and the moving speed of fabric was fixed at 1 mm/s, 5 mm/s and 10 mm/s. The detailed condition for plasma treatment was shown in Table 1.

Table 1. *Summary of the condition and parameters used in the plasma treatment.*

Condition	Helium flow rate (L/min)	Discharge power (W)	Oxygen flow rate (L/min)	Moving speed (mm/s)	Jet-to-substrate distance (mm)
I	30.5	150	0.3	1	3
II	30.5	150	0.4	5	4
III	30.5	150	0.5	10	5

2.3 Dyeing experiment

Metal complex dye was used in this experiment. The untreated and treated samples were cut into 5 x 5 cm for this dyeing test. Next, two dyebaths were prepared at 50°C. Then, two samples (treated and untreated) were put into the dyebaths (2% of dyestuff; and 8% of sulfuric acid, w/w) and the temperature of the baths was risen to 100°C within 30 minutes. After that, the samples were boiled for 45 minutes and then were rinsed and dried.

2.4 Evaluation of silk fabric treated with plasma

2.4.1 Wettability analysis

In this study, drop test was conducted to evaluate the wettability of silk fabric after plasma treatment according to AATCC 79-2010, which is the standard determining the water absorbency of yarns, fabrics and garments. The untreated fabric was acted as the control sample.

2.4.2 Dyeing evaluation

The dyeability of the treated and untreated silk fabrics were evaluated by spectrophotometer (DataColor) (with illuminatnt D65 and standard observer of 10˚) in order to obtain the CIE L*, a*, b* as well as ΔE values.

3. Results and Discussion

3.1 Wettability analysis

The results of wettability property of silk fabric after plasma treatment are shown in Figure 1. As can be seen, the untreated silk samples show excellent water repellency with the formation of contact angle (Figure 1(A) and 1(B)), whereas after plasma treatment, the wettability of silk fabrics are significantly improved (Figure 1(C) and 1(D)). This indicates that plasma treatment provides an effective strategy to improve the hydrophilcity of silk fabric. However, different parameters for plasma treatment such as jet-to-substrate distance and gas flow rate have different effects on the wettability of silk fabric.

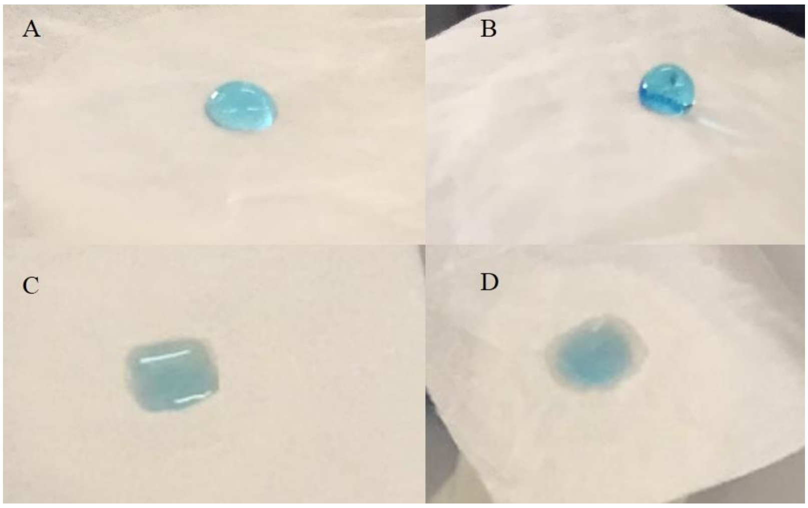

Figure 1. *Photographs of silk fabric, untreated samples (A) face; (B) back; and treated samples (C) face; (D) back.*

As shown in Figure 2, the distance of jet-to-substrate can greatly influence the effectiveness of plasma treatment. High distance leads to poor effectiveness of plasma treatment, which was same with the increase in the jet movement speed. This can be explained by the relationship between jet movement speed and plasma treatment duration. As the jet movement speed increases, the treatment duration is decreased. Although a long duration does not mean a better performance, a more significant modification of the fabric surface can occur. It provides enough time for the plasma species to penetrate into the fabric and cause a morphological change. Therefore, the treatment duration is required to be concerned and controlled carefully because it plays an important role in plasma treatment.

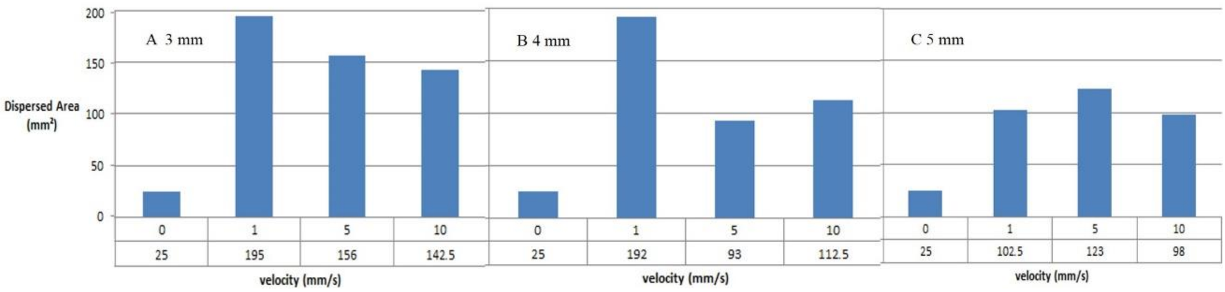

Figure 2. *Wettability of silk fabric treated under different jet movement speeds. The jet-to-substrate distance was 3 mm (A), 4mm (B) and 5mm (C); the oxygen flow rate was 0.3 L/min.*

In terms of surface wettability modification, the best plasma treatment condition found in this study was as follows: 0.3 L/min oxygen flow rate; 3 mm jet-to-substrate; and 1 mm/s jet movement speed. The silk fabric for dyeing would be treated with plasma under this condition.

3.2 Dyeability evaluation

Table 2. *CIE values of plasma treated silk sample and the control dyed with acid dyes.*

Samples	L*	a*	b*	ΔE
Untreated sample	72.02	2.31	36.09	0.65
Treated sample	70.88	2.65	36.99	
Difference (treated - untreated)	-1.15	0.34	0.90	

Table 2 shows that the CIE L*, a* and b* values for plasma treated silk fabric are changed after dyed with metal-complex dye, and ΔE, an objective index used to describe the difference between two colors, is 0.65. This shows that the effect of plasma treatment was obvious on the dyeability of silk fabric.

The L* value of untreated sample is larger than the plasma treated sample which means the lightness of plasma treated sample is lower. This is related to the color uptake of the fabric. As the surface modification of the plasma treated fabric is completed, its dye uptake (with final color) should be better than the untreated fabric. Based on this difference, it absorbs more light to express its color; hence, the light reflected from its surface is reduced and the brightness is also reduced.

With regard to a* and b* values, they represent the difference on red/green axis and yellow/blue axis, respectively. Both a* and b* value of untreated fabric were lower than that of treated sample, indicating that the redness and yellowness of silk fabric become higher after plasma treatment.

4. Conclusion

This study optimized the treatment condition of plasma technology in the surface modification of silk fabric. The treated silk fabric was evaluated by analyzing the wettability, surface modification and dyeability. It was found that plasma treatment is fairly effective to enhance the wettability and dyeability of silk fabric.

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EVALUATION OF THERMAL CONDUCTIVITY PROPERTY OF SOCKS

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Abstract: Socks fabrics seem a minor clothing in apparel categories but are indispensable item for daily activities for users. The function of socks is either for heat insulation of body temperature in cold weather or heat releasing to keep thermal neutral for foot in hot weather. Socks with good quality are conducive to prevent foot disease or smelly odor from foot. The wearing comfort of socks can be affected by the fabric properties of thermal transfer. The present study aims to investigate the relationship between the fabric parameters and thermal conductivity property of knitted socks fabric. The physical test on commercial socks fabric was carried out in standard condition atmosphere. It was found that the thermal conductivity of fabric was positively proportional to yarn count and thickness.

1. Introduction

Socks fabrics seem a minor clothing in apparel categories but are indispensable item for daily activities for users. The function of socks is either for heat insulation of body temperature in cold weather or heat releasing to keep thermal neutral for foot in hot weather [1-4]. Socks with good quality are conducive to prevent foot disease or smelly odor from foot. The wearing comfort of socks can be affected by the fabric properties of thermal transfer [5]. Therefore, the thermal conductivity property is of high importance for textile products, especially for socks. The present study aims to investigate the relationship between the fabric parameters and physical properties of knitted socks fabric.

2. Experimental

2.1 Fabric specimen

Men Supima socks were provided by an apparel company in this study and their specifications were shown in Table 1. Before testing, the socks were conditioned at 20±2°C and relative humidity of 65±2% for at least 24 hours.

2.2 Thermal Conductivity Evaluation

The thermal conductivity of socks samples was measured by KES-F7 Thermal Labo tester based on the Kawabata Evaluation System for Fabric. The thermal conductivity K can be calculated according to equation (1).

$$K = \frac{W \times D}{A \times \Delta T} \text{ (W/cm°C)}$$

Where
D = sample thickness (cm);
W = power value (W);
A = Area of the heat plate ($25 cm^2$); and
ΔT = Temperature difference (10°C)

Table 1. Details of the Supima cotton socks.

	Sample 1	Sample 2	Sample 3
Pictures			
Names	MEN SUPIMA COTTON WIDE RIB SOCKS	MEN SUPIMA COTTON CHECKED LINKS SOCKS	MEN SUPIMA COTTON PIQUE SOCKS
Types	Crew sock	Crew sock	Crew sock
Length (cm)	25 - 27	25 - 27	25 - 27
Color	Grey	Grey	Grey
Yarn count (Tex)	37.418	39.160	39.654
Thickness (mm)	1.33	1.44	1.59
Fiber Composition (%)	Supima cotton: 68 Nylon: 28 Polyester: 2 Spandex: 2	Supima cotton: 75 Nylon: 21 Polyester: 2 Spandex: 2	Supima cotton: 83 Nylon: 13 Polyester: 2 Spandex: 2
Fabric types in socks	Cuff: 1 x 1 Rib Instep & leg: 6 x 2 Wide Rib Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Checked patterns Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Moss stitch Sole, toe & heel: Single jersey

3. Results and Discussion

3.1 Thermal Conductivity Analysis

The thermal conductivity of the three samples was shown in Figure 1. It can be clearly seen that sample 3 has the highest thermal conductivity, whereas sample 1 showed the lowest thermal conductivity, for both instep and sole parts. This indicates that the thermal conductivity was positively related to the cotton content.

It is noteworthy that the thermal conductivity for sole part was higher than that of instep part, for all three samples. This could be explained by the fabric structure – 6 x 2 wide rib fabric in instep part and single jersey in sole part. Pac et al. [7] indicated the temporary thermal properties can be greatly influenced by the fabric structure. The thermal conductivity is affected by the combination of the fibrous materials and thermal conductivity of air. Figure 2 shows that the technical back of 6 x 2 rib is not plain and has wide empty space, in which air can be enclosed between fabric and skin. The thermal conductivity of air is generally 0.024 - 0.025W/mk in around 293K, lower than liquids and solids. This provides an explanation for the good thermal insulation of instep part due to enclosed air.

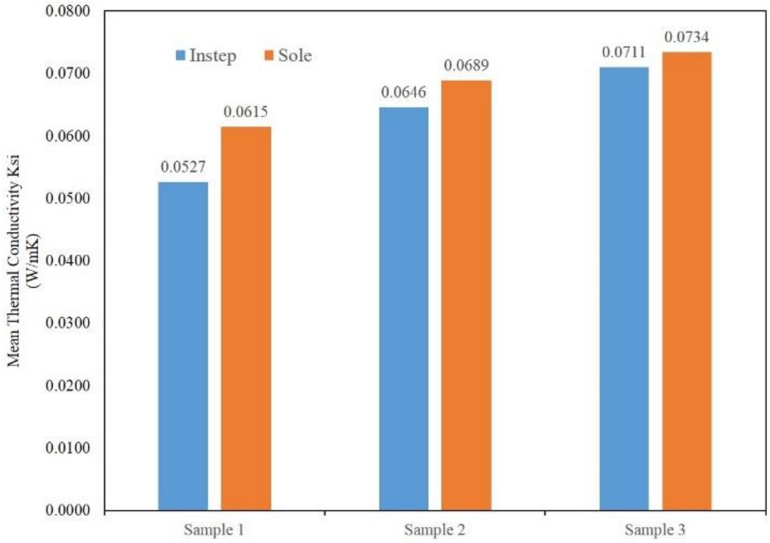

Figure 1. *Thermal conductivity of three samples*

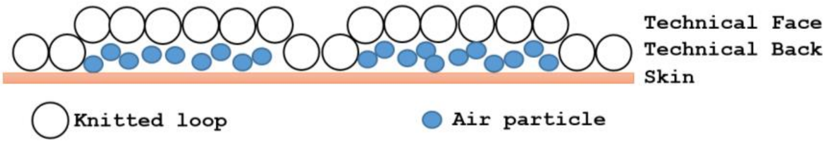

Figure 2. *Air trapped between instep fabric and skin.*

The air enclosed between fabric and skin seems as a heat insulator to reduce the flow of heat in conduction. The efficiency of heat transfer by conduction is lower due to long distance of movement of air particles for energy transfer. In addition, the air enclosed between fabric and skin is relatively static, heat transfer by convection is inhibited. Heat energy is difficult to release from body to outer environment because of fabric structure with trapped air. This explains why the thermal conductivity of sample 1 instep fabric was lower than other five fabric samples.

The similar situation is seen in sample 2 due to the similar fabric structure (Single knits fabric). This means heat energy was transferred from body with high temperature to fabric with low temperature directly and effectively. Overall, the greatest performance of thermal conductivity is sample 3.

3.2 Effect of fiber composition on the thermal conductivity

The thermal conductivity of fabric is usually influenced by the fiber composition. The Supima cotton content of sample 1, sample 2, and sample 3 was 68%, 75% and 83% (w/w), respectively, while the nylon content of three samples was 28%, 21% and 13% (w/w), respectively. Figure 3 shows the relationship between Supima cotton and thermal conductivity.

Clearly, R^2 value (0.9686) shows a strong positive linear relationship between the Supima cotton content and the thermal conductivity. This means that the thermal conductivity can be increased by increasing the content of cotton of the fabric.

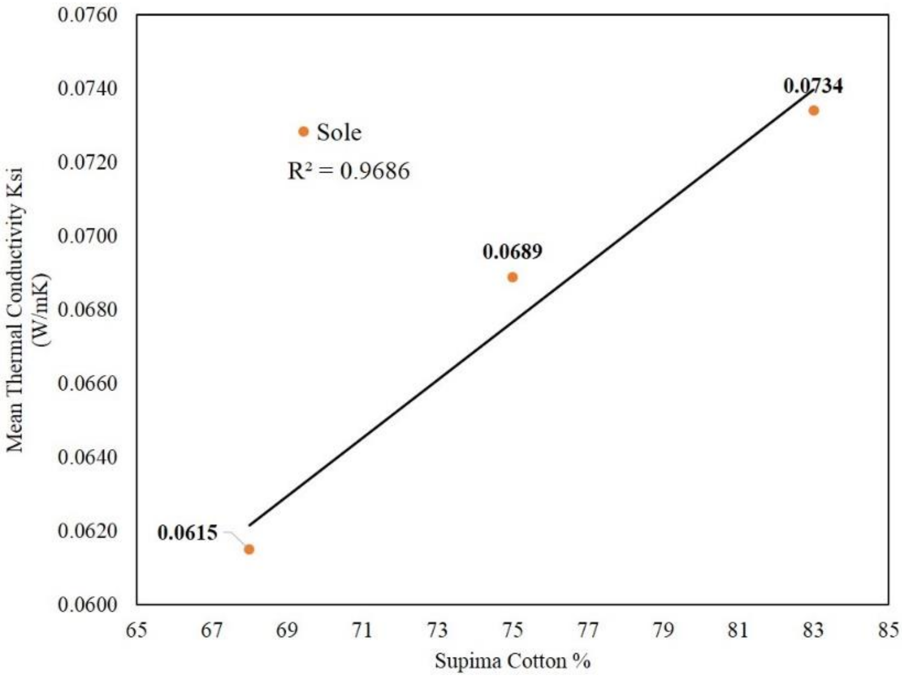

Figure 3. *Relationship between Supima cotton % and thermal conductivity in sole fabrics.*

The thermal conductivity of cotton and nylon are 0.0597W/mK and 0.25W/mK, respectively. Even though the thermal conductivity of cotton is lower than nylon, fiber proportion of Supima cotton was over 60% in three samples. The experimental value of thermal conductivity for three samples was close to that of cotton. This indicates that to select low conduction fibrous materials provides a way to achieve high heat insulating property of fabric because heat transfer can be reduced.

The correlation analysis in Table 2 shows the relationship between the thermal conductivity and the Supima cotton percentage. The *p*-value was 0.000 ($p<0.05$) and *r*-value was 0.978 (close to 1). Therefore, there is sufficient evidence to indicate the relationship (strong and positive) between Supima cotton and thermal conductivity. It can be concluded that the higher the Supima cotton proportion, the higher the thermal conductivity is.

Table 2.*Correlation between Supima cotton % and thermal conductivity in sole fabric.*

		Supima cotton (%)
Thermal Conductivity Ksi (W/mk)	Pearson Correlation	0.978**
	Sig. (2-tailed)	0.000

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

3.3 Effect of fabric thickness on the thermal conductivity

Fabric thickness shows linear correlation with the yarn density in plain knitted fabric. Figure 4 shows the relationship between the fabric thickness and the thermal conductivity. The R^2 value of sole fabrics is 0.9481 (close to 1) and showed the strong positive linear relationship.

Clearly, the finer the yarn count, the lower the thickness is. It means the fabric with high thickness has increased thermal conductivity.

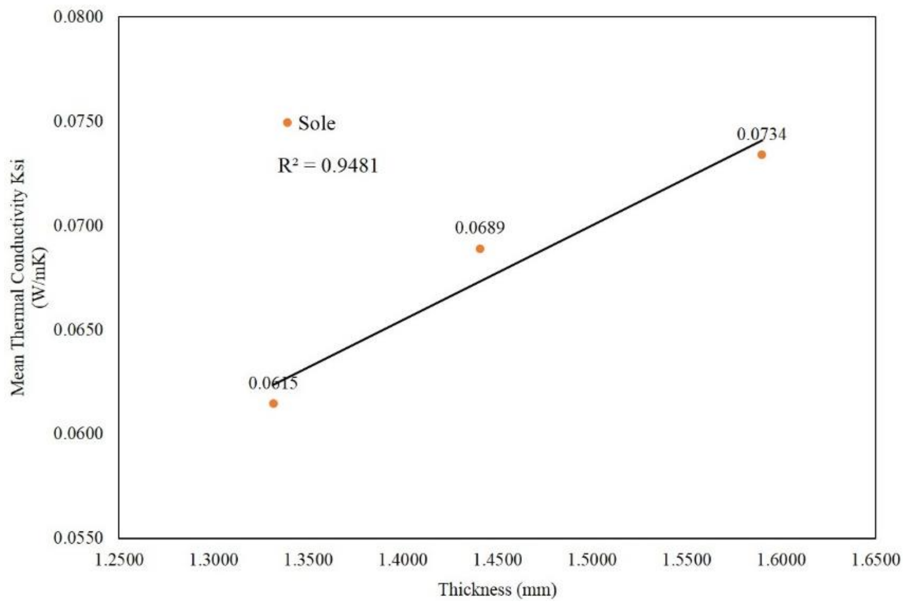

Figure 4. *Relationship between thermal conductivity and thickness.*

The correlation analysis in Table 3 showed the *p*-value was 0.000 ($p<0.05$) and *r*-value was 0.970 (positive and close to 1). Therefore, there is sufficient evidence to show significantly positive correlation between the thickness and thermal conductivity. Decrease in the fabric thickness causes reduction in the thermal conductivity.

Table 3. *Correlation between thickness and thermal conductivity.*

		Thickness (mm)
Thermal Conductivity Ksi (W/mk)	Pearson Correlation	0.970**
	Sig. (2-tailed)	0.000

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

3.4 Effect of yarn count on the thermal conductivity

The effect of yarn count on the thermal conductivity was shown in Figure 5. Clearly, a positive relationship was observed between the yarn count and the thermal conductivity, and the R^2 value of sole fabrics was 0.9711. This means increasing the yarn count helps to increase with the thermal conductivity increases. Since the thickness and thermal conductivity have positive relationship, it may be inferred that yarn count and thermal conductivity show positive linear relationship.

The correlation analysis in Table 4 showed the *p*-value was 0.000 ($p<0.05$) and *r*-value was 0.981 (positive and close to 1). Therefore, there is sufficient evidence to show significant correlation between the yarn count and thermal conductivity. It could be explained by the fact that the lower the yarn count, the lower the thermal conductivity is. The previous research found that the fine textile yarn may decrease the thermal resistance and thermal conductivity.

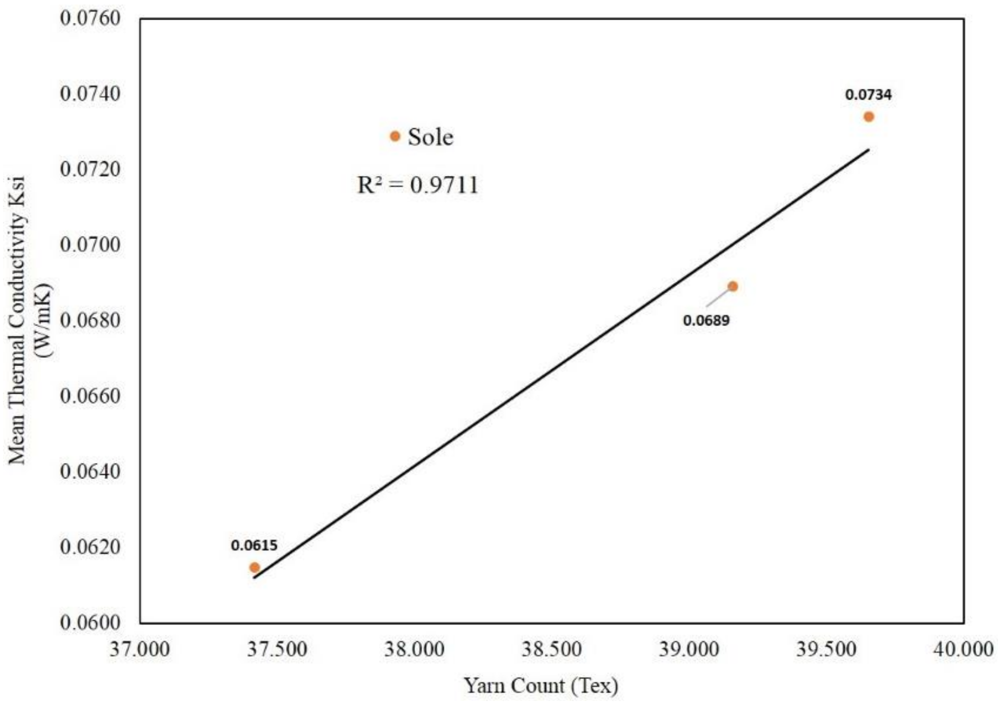

Figure 5. *Relationship between Thermal conductivity and yarn count in sole fabrics.*

Table 4. *Correlation between yarn count and thermal conductivity.*

		Yarn Count (Tex)
Thermal Conductivity Ksi (W/mk)	Pearson Correlation	0.981**
	Sig. (2-tailed)	0.000

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

4. Conclusion

In this study, we investigated the relationship between the fabric parameters and physical properties of knitted socks fabric. It was found that the cotton proportion of fabric can greatly affect the thermal conductivity of socks. High content of cotton of socks fabric tends to increase the thermal conductivity. The fabric thickness and yarn count were also found to be positively related with the thermal conductivity.

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A STUDY OF THE AIR PERMEABILITY OF SOCKS

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Abstract: Socks are the clothing preserving the foot in thermal neutrality and preventing foot from blister generating. The development of socks has been diversified like the type, materials, and function, etc. Socks with good quality are conducive to prevent foot disease or smelly odor from foot. The wearing comfort of socks can be affected by the fabric properties of air permeability. The present study aims to investigate the relationship between the fabric parameters and air permeability of knitted socks fabric. The ventilation of socks fabric was measured by the KES-F8 automatic air permeability tester. It was found that the air permeability of fabric was negatively proportional to the content of cotton, yarn count and thickness, before washing. Meanwhile, washing was found to increase the air permeability.

1. Introduction

Wear comfort of textile products is an important factor determining consumer satisfaction for selecting clothing. However, the climate of some Asian countries is very humid and hot. Sweating occurs easily to keep thermal balance of body. The humid weather usually causes the fabric harder to dry [1]. The wet fabric traps the moisture or sweat on the skin and affects the comfortability, especially for the non-breathable fabric, which may increase the risk of infection and hyperthermia. Moisture movement is closely related to the air permeability of textile fabrics, which can control the heat transfer [2]. Therefore, the air permeability property is of high importance for textile products, especially for socks.

Socks are the clothing preserving the foot in thermal neutrality and preventing foot from blister generating. The development of socks has been diversified like the type, materials, and function, etc. [3]. Socks with good quality are conducive to prevent foot disease or smelly odor from foot. The wearing comfort of socks can be affected by the fabric properties of air permeability [4]. The present study aims to investigate the relationship between the fabric parameters and air permeability of knitted socks fabric.

2. Experimental

2.1 Fabric specimen

Three samples of Men Supima socks were bought from an apparel company and their specifications were summarized in Table 1. The socks were conditioned at 20±2°C and 65±2% relative humidity for at least 24 hours prior to testing.

Table 1. Details of the Supima cotton socks.

	Sample 1	Sample 2	Sample 3
Pictures			
Names	MEN SUPIMA COTTON WIDE RIB SOCKS	MEN SUPIMA COTTON CHECKED LINKS SOCKS	MEN SUPIMA COTTON PIQUE SOCKS
Types	Crew sock	Crew sock	Crew sock
Length (cm)	25 - 27	25 - 27	25 - 27
Color	Grey	Grey	Grey
Yarn count (Tex)	37.418	39.160	39.654
Thickness (mm)	1.33	1.44	1.59
Fiber Composition (%)	Supima cotton: 68 Nylon: 28 Polyester: 2 Spandex: 2	Supima cotton: 75 Nylon: 21 Polyester: 2 Spandex: 2	Supima cotton: 83 Nylon: 13 Polyester: 2 Spandex: 2
Fabric types in socks	Cuff: 1 x 1 Rib Instep & leg: 6 x 2 Wide Rib Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Checked patterns Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Moss stitch Sole, toe & heel: Single jersey

2.2 Air Permeability

The air permeability is related to heat loss and moisture evaporation. The fabric with low air permeability tends to be more breathability and permeability. The ability of air permeability of the textile fabrics can be measured by the KES-F8 automatic air permeability tester based on the Kawabata Evaluation System for Fabric. The result can be analyzed by comparing all the samples. Five data of each sock sample was converted to mean value for comparison. The smaller the value, the higher the air permeability of fabric is.

3. Results and Discussion

3.1 Air permeability

The KES-F8 air permeability tester was used to measure the air resistance of the fabrics and the results were shown in Figure 1. It can be clearly seen that sample 1 has the highest air permeability value, whereas this value for sample 3 is the lowest in the instep part. Interestingly, sample 1 has the lowest air permeability value, which of sample 3 is the highest in the sole part, however. This may be closely related to moss stitch fabric structure, the rough surface of which is easily permeable to air. The effects of fabric structure is discussed in detail in the ensuing paragraphs.

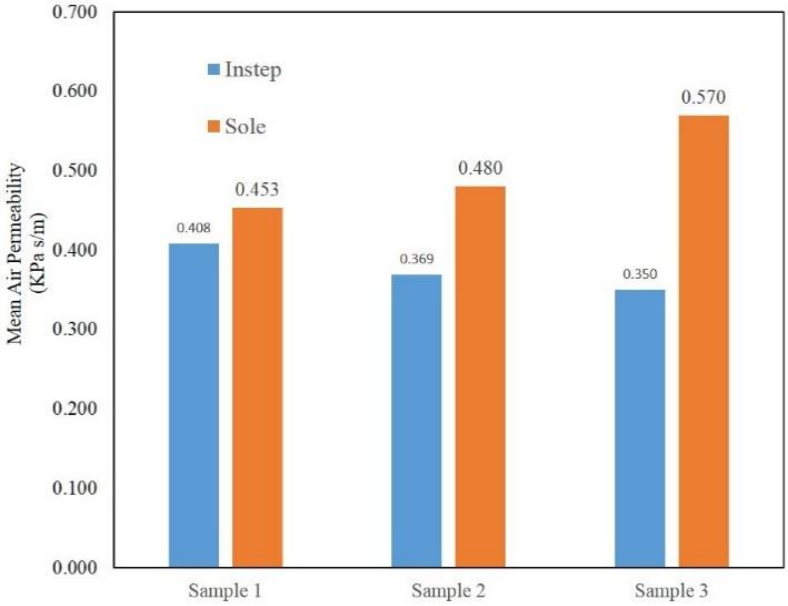

Figure 1. *Air permeability of three samples*

3.2 Effect of fiber composition on the air permeability

Fiber composition may greatly affect the air permeability of fabrics. Figure 2 shows the relationship between air permeability and supima cotton proportion in the sole fabrics. The R^2 value is 0.9329 (close to 1) and shows a strong positive linear relationship with almost perfectly fit of data. This means the fabric with high content of the Supima cotton shows high air resistance but low air permeability.

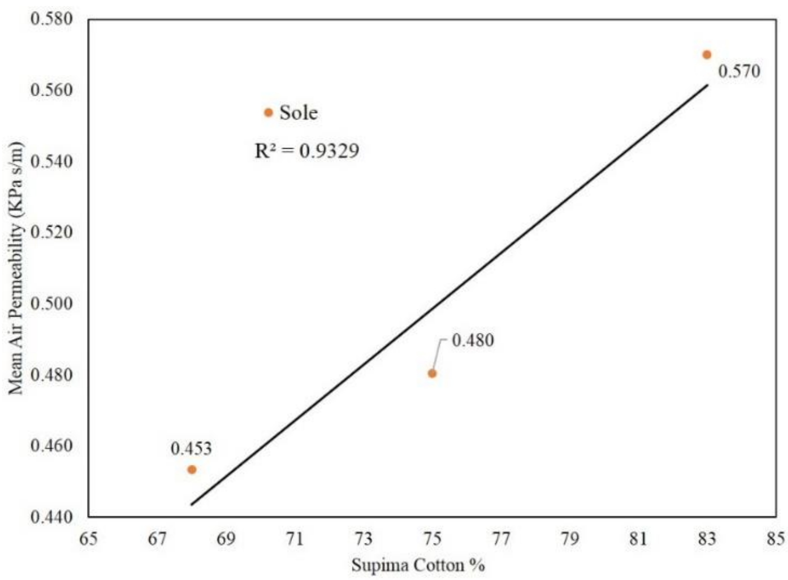

Figure 2. *Relationship between air permeability and Supima cotton % in sole fabrics.*

The correlation analysis between the air permeability and Supima cotton percentage is shown in Table 2. The *p*-value is 0.000 ($p<0.05$) and *r*-value is 0.962 (close to 1). This indicates that there is a significant correlation between Supima cotton proportion and the air permeability. The lower the Supima cotton content, the higher the air permeability is. The possible reason may be due to the hydrophilicity of Supima cotton, which has high moisture regain to absorb moisture vapor in air. The yarn diameter may be increased after swelling due to absorbing moisture, leading to decrease of porosity and poor air permeability.

Table 2. *Correlation between Supima cotton % and air permeability.*

		Supima cotton %
Air Permeability (KPa s/m)	Pearson Correlation	0.962**
	Sig. (2-tailed)	0.000

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

3.3 Effect of yarn count on the air permeability

Figure 3 shows the relationship between air permeability and yarn count in sole fabrics. The R^2 value was 0.66968 (close to 0.5) and showed the positive linear relationship. This means that the fabric with high yarn count had good air resistance but poor air permeability.

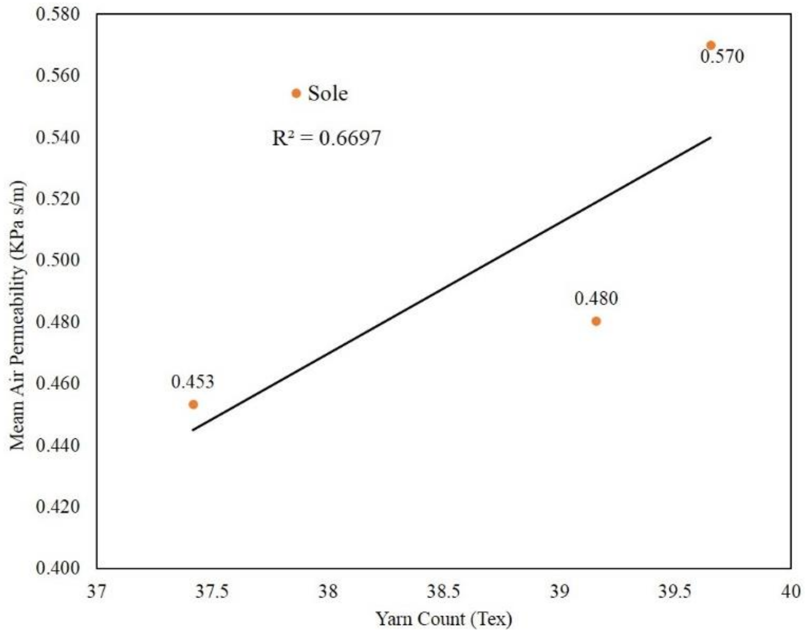

Figure 3. *Relationship between air permeability and yarn count in sole fabrics.*

The correlation analysis in Table 3 shows the relationship between the air permeability and yarn count. The *p*-value was 0.000 (p<0.05) and *r*-value was 0.814 (close to 1). This clearly shows the significant correlation between yarn count and air resistance. The finer the yarn of the fabric, the higher the air permeability.

Table 3. *Correlation between Yarn count and air permeability.*

		Yarn Count (Tex)
Air Permeability (KPa s/m)	Pearson Correlation	0.814**
	Sig. (2-tailed)	0.000

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

3.4 Effect of fabric thickness on the air permeability

Figure 4 shows the relationship between air permeability and thickness in sole fabrics. The R^2 value was 0.9558 (close to 1) and showed a strong positive linear relationship with almost perfectly well fit of data. This means that good air permeability property can be obtained by decreasing the fabric thickness and the air resistance.

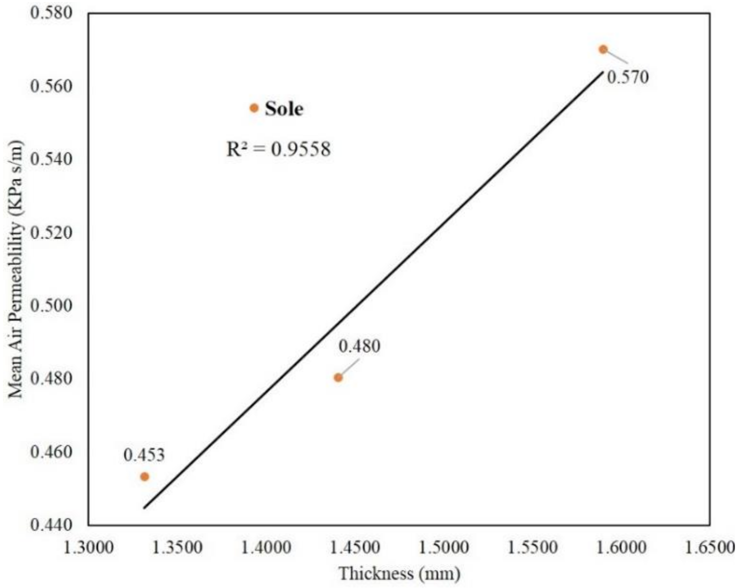

Figure 4. *Relationship between air permeability and thickness in sole fabrics.*

The correlation analysis in Table 4 shows the relationship between the air permeability and yarn count. The *p*-value is 0.000 ($p<0.05$) and *r*-value is 0.974 (close to 1). Therefore, a significantly positive correlation between fabric thickness and air permeability was evidently presented.

Table 4. *Correlation between Yarn count and air permeability.*

		Thickness (mm)
Air Permeability (KPa s/m)	Pearson Correlation	0.974**
	Sig. (2-tailed)	0.000

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

3. Conclusion

In this study, we investigated the relationship between the fabric parameters and physical properties of knitted socks fabric. It was found that the cotton proportion of fabric can greatly affect the air permeability of socks. High content of cotton of socks fabric tends to decrease the air permeability. The fabric thickness and yarn count were also found to be negatively related with the air permeability.

Acknowledgement

This work is part of final year project submitted by Kwok-tung Hui 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.

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AN ANALYSIS OF WATER VAPOUR TRANSMISSION ABILITY OF SOCKS

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Abstract: The present study investigated effects of fabric parameters on the water vapor transmission of socks fabric, which was measured by the cup method. It was found that the water vapor transmission of fabric was negatively proportional to the content of cotton and yarn count, before washing. Meanwhile, washing was found to increase the water vapour transmission.

1. Introduction

Wear comfort of textile products is an important factor determining consumer satisfaction for selecting clothing. The property of water vapor transmission (WVT) of fabrics is closely related with the wear comfort. The term WVT is defined as “the steady water vapor flow in unit time through unit area of a body, normal to specific parallel surfaces” in standard testing atmosphere [1]. The invisible moisture (water/perspiration) in the form of vapor passes through the air gap between yarns in a fabric from inner layer to outer layer. The permeability ability of moisture vapor is determined by grams of water per square meter in 24 hours. With high rate of moisture transmission of socks fabrics, the perspiration will not be accumulated on the skin surface [2]. And thus, the skin can be maintained dry when users are wearing the fabrics. Therefore, the water vapor transmission property is of high importance for textile products, especially for socks [3, 4]. The present study aims to investigate the relationship between the fabric parameters and water vapor transmission of knitted socks fabric, which was measured by the cup method.

2. Experimental

2.1 Fabric specimen

Men Supima socks were collected from an apparel company in this study and their specifications were shown in Table 1. Before testing, the socks were conditioned at 20±2°C and relative humidity of 65±2% for at least 24 hours.

Table 1. Details of the Supima cotton socks.

	Sample 1	Sample 2	Sample 3
Pictures			
Names	MEN SUPIMA COTTON WIDE RIB SOCKS	MEN SUPIMA COTTON CHECKED LINKS SOCKS	MEN SUPIMA COTTON PIQUE SOCKS
Types	Crew sock	Crew sock	Crew sock
Length (cm)	25 - 27	25 - 27	25 - 27
Color	Grey	Grey	Grey
Yarn count (Tex)	37.418	39.160	39.654
Thickness (mm)	1.33	1.44	1.59
Fiber Composition (%)	Supima cotton: 68 Nylon: 28 Polyester: 2 Spandex: 2	Supima cotton: 75 Nylon: 21 Polyester: 2 Spandex: 2	Supima cotton: 83 Nylon: 13 Polyester: 2 Spandex: 2
Fabric types in socks	Cuff: 1 x 1 Rib Instep & leg: 6 x 2 Wide Rib Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Checked patterns Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Moss stitch Sole, toe & heel: Single jersey

2.2 Water vapor transmission evaluation

The water vapor transmission property of fabrics can be measured by the cup method, as shown in Figure 1. The cup method is common and simple to evaluate the moisture transfer ability. The fabric is covered on the plastic cup containing distilled water. The water level is below the top of cup approx. 1 cm. This test should be in standard testing atmosphere (temperature in 21±1 ºC and the relative humidity in 65±2%).

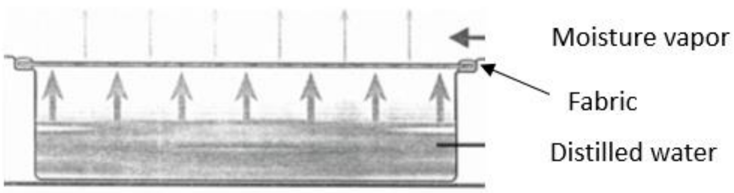

Figure 1. *Testing principle of WVT.*

The water vapor transmission can be evaluated by the weight difference of water in the cup. The weight loss can be considered as moisture vapor exposure in air. The performance of water vapor transmission of test specimen is calculated by Equation (1). The higher the value, the better the ability of WVT.

$$WVT = \frac{G}{A \times T} \ (g / m^2h) \qquad (1)$$

Where
WVT = Rate of water vapor transmission;
G = Weight change (g);
T = Time, 24 hours (h); and
A = Area of cup mouth (m^2).

3. Results and Discussion

3.1 Water vapor transmission analysis

The water vapor transmission properties of three samples is shown in Figure 2. Clearly, for the instep fabrics, sample 1 shows the highest water vapor transmission, whereas sample 3 with highest proportion of cotton shows the lowest ability of water transmission. In terms of instep fabric, the highest water transmission rate belonged to sample 2, and this ability of sample 3 is still the poorest. This could be explained by the different fabric materials.

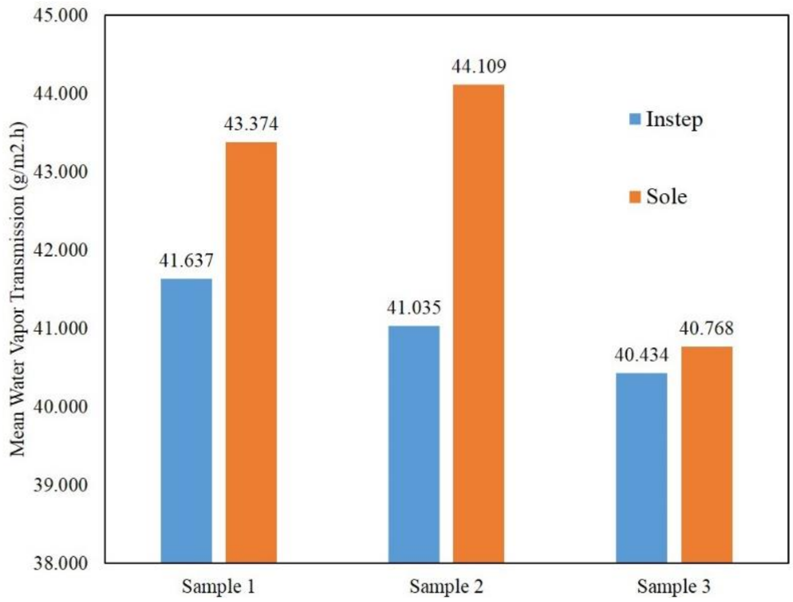

Figure 2. *Water vapor transmission of three sock samples.*

3.2 Effect of fiber composition on the water vapor transmission

Figure 3 shows the relationship between water vapor transmission and the Supima cotton percentage in sole fabrics. The R^2 value was 0.58891 (close to 0.5) and showed a strong negatively linear relationship (orange line) with moderate well fit of data. This means that the water vapor transmission can be decreased by increasing the Supima cotton proportion.

The correlation analysis in Table 2 shows the relationship between the water vapor transmission and Supima Cotton proportion. The *p*-value was 0.001 ($p<0.05$) and *r*-value was -0.767. This indicates the significantly negative relationship between Supima cotton content and water vapor transmission. Therefore, the higher the Supima cotton percentage, the lower the water vapor transmission is.

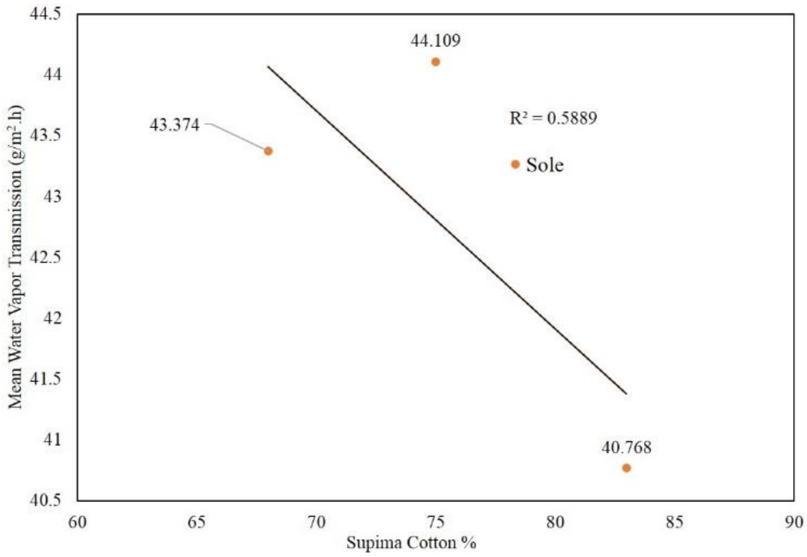

Figure 3. *Relationship between water vapor transmission and Supima cotton % in sole fabrics.*

Cotton has good moisture absorption ability due to its hydrophilicity, and the transmission of water vapor through cotton fabric are by means of diffusion and sorption-desorption [5]. Moisture transports through the technical back to the face of fabrics. If the water molecules absorbed by the fibers and attracted to the surface of yarn, moisture vapor is not easy to escape to outer environment and enclosed by the hygroscopic fabric.

Nylon is synthetic fiber with poor moisture absorption ability. Moisture in synthetic fiber is easy to transport and evaporate. Therefore, sample 1 has the highest ability of water vapor transmission both instep and sole fabric among three samples because it contained the highest proportion of nylon fiber.

Table 2. *Correlation between Supima Cotton % and water vapor transmission.*

		Supima cotton %
Water vapor transmission ($g/m^2.h$)	Pearson Correlation	-0.767**
	Sig. (2-tailed)	0.001

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

3.3 Effect of yarn count on the water vapor transmission

Figure 4 shows the relationship between water vapor transmission and the yarn count in sole fabrics. The R^2 value was 0.2508 (close to 0) and shows a negative linear relationship with weak well fit of data. This means that an increase in the yarn count may reduce the water vapor transmission ability.

The correlation analysis in Table 3 shows the relationship between the water vapor transmission and yarn count. The *p*-value is 0.057 (p>0.05) and *r*-value is -0.501. This indicates that there is no significant correlation between the yarn count and water vapor transmission.

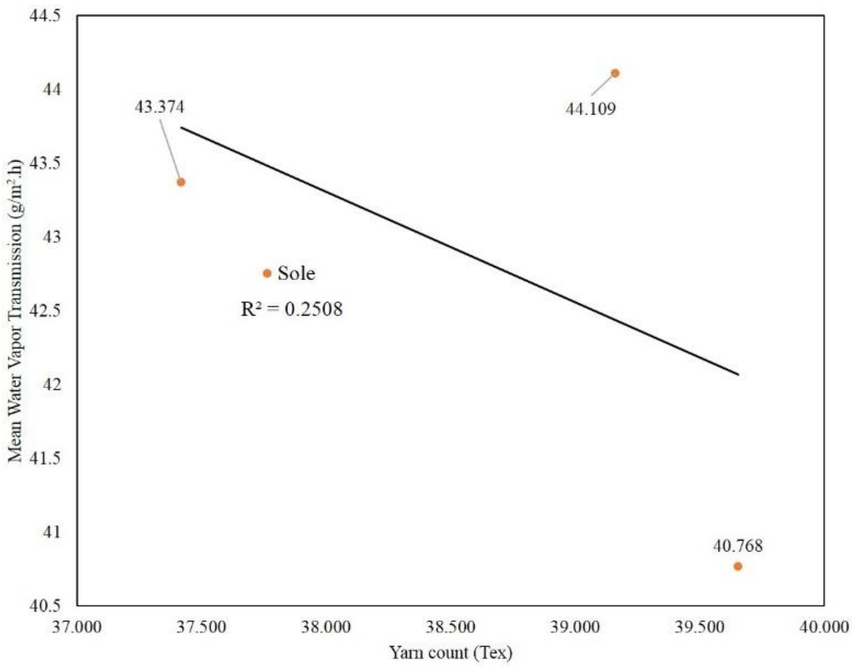

Figure 4. *Relationship between water vapor transmission and yarn count in sole fabrics.*

Table 3. *Correlation between yarn count and water vapor transmission.*

		Yarn Count (Tex)
Water Vapor Transmission (g/m2.h)	Pearson Correlation	-0.501
	Sig. (2-tailed)	0.057

Although previous work reported that the finer yarn count can cause better water vapor permeability [6, 7], which is not proven according to the experimental results in this study. A reasonable explanation may be that the hairiness of the staple spun yarn (Figure 5) affects the porosity of fabrics. An increase in the hairiness of yarn may decrease the space (porosity) between intra-yarns.

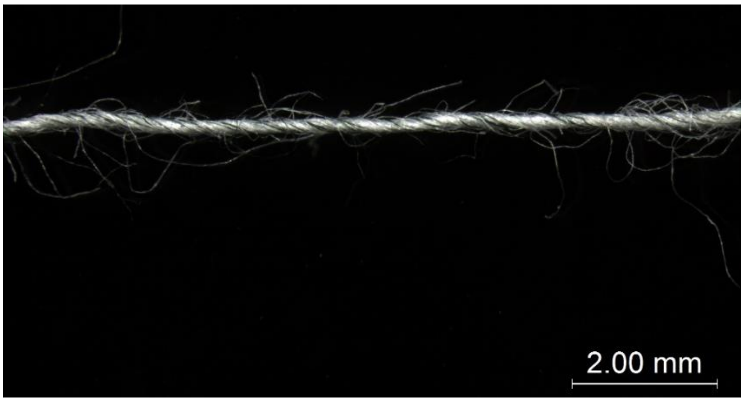

Figure 5. *The hairiness of cotton yarn.*

3.4 Effect of fabric thickness on the water vapor transmission

Figure 6 shows the relationship between water vapor transmission and the fabric thickness in sole fabrics. The R^2 value was 0.63787 and showed the moderate negative linear relationship with well fit of data. This means that an increase in the fabric thickness can decrease the water vapor transmission.

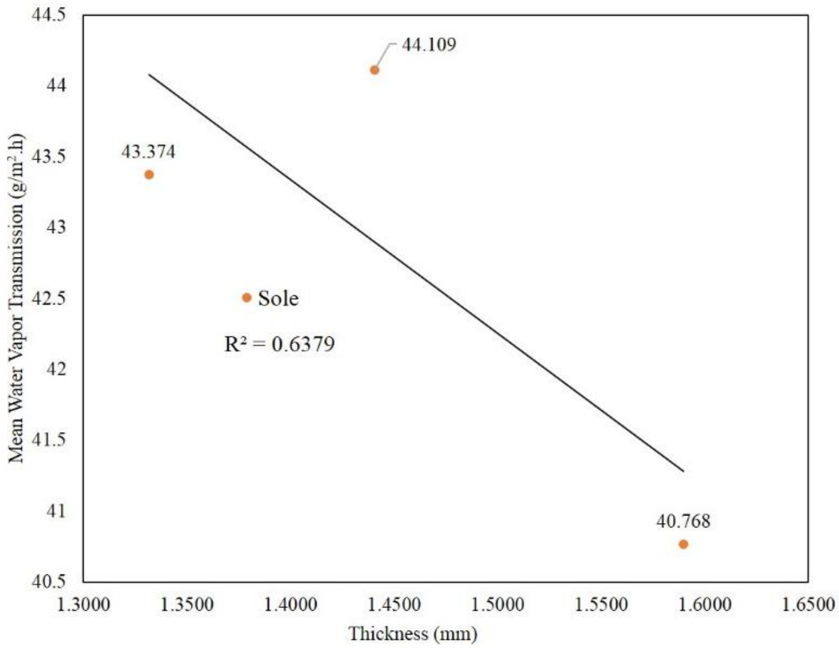

Figure 6. *Relationship between water vapor transmission and thickness in sole fabrics.*

The correlation analysis between water vapor transmission and the fabric thickness is shown in Table 4. The *p*-value is 0.000 ($p<0.05$) and *r*-value is –0.797. This demonstrates that a significantly negative correlation between water vapor transmission and the fabric thickness exists. The higher the water vapor transmission, the lower the fabric thickness. This finding was consistent with previous research [6].

Table 4. *Correlation between thickness and water vapor transmission.*

		Thickness (mm)
Water Vapor Transmission ($g/m^2.h$)	Pearson Correlation	-0.797**
	Sig. (2-tailed)	0.000

4. Conclusion

In this study, we investigated the relationship between the fabric parameters and physical properties of knitted socks fabric. It was found that the cotton proportion of fabric can greatly affect the air permeability of socks. The water vapor transmission of fabric was negatively proportional to the content of cotton and the fabric thickness. The yarn count was found to not affect the ability of water vapor transmission.

Acknowledgement

This work is part of final year project submitted by Kwok-tung Hui 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.

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AN EXPERIMENTAL STUDY OF MOISTURE MANAGEMENT PROPERTY OF SOCKS

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Abstract: The wearing comfort of socks can be affected by the fabric properties of liquid moisture management. The present study aims to investigate the relationship between the fabric parameters and moisture management of sock fabrics. The moisture management of socks fabric was measured by the moisture management tester according to AATCC 195-2012. It was found that the cotton sock fabrics were waterproof before washing. This may be due to hydrophobic treatment. The cotton material seems not to be suitable for moisture transfer.

1. Introduction

Socks are daily used apparel products, its wear comfort is an important factor determining consumer satisfaction for selecting clothing [1]. However, the climate of some Asian countries is very humid and hot. The humid weather usually causes the fabric harder to dry. The wet fabric traps the moisture or sweat on the skin and affects the comfortability, especially for the non-breathable fabric, which may increase the risk of infection and hyperthermia [2]. Therefore, the liquid moisture management property is of high importance for textile products, especially for socks [3]. The wearing comfort of socks can be affected by the fabric properties of liquid moisture management [4]. The present study aims to investigate the relationship between the fabric parameters and moisture management of sock fabrics.

2. Experimental

2.1 Fabric specimen

Samples of Men Supima socks were obtained from an apparel company and their specifications were shown in Table 1. Before testing, the socks were conditioned at 20±2°C and relative humidity of 65±2% for at least 24 hours.

2.2 Liquid moisture management

The ability of moisture management of sock fabric can be measured by test method of AATCC 195-2012 by the moisture management tester (MMT). The mean average of liquid moisture transport result can be evaluated according to Table 2.

Table 1. Details of the Supima cotton socks.

	Sample 1	Sample 2	Sample 3
Pictures			
Names	MEN SUPIMA COTTON WIDE RIB SOCKS	MEN SUPIMA COTTON CHECKED LINKS SOCKS	MEN SUPIMA COTTON PIQUE SOCKS
Types	Crew sock	Crew sock	Crew sock
Yarn count (Tex)	37.418	39.160	39.654
Thickness (mm)	1.33	1.44	1.59
Length (cm)	25 - 27	25 - 27	25 - 27
Color	Grey	Grey	Grey
Fiber Composition (%)	Supima cotton: 68 Nylon: 28 Polyester: 2 Spandex: 2	Supima cotton: 75 Nylon: 21 Polyester: 2 Spandex: 2	Supima cotton: 83 Nylon: 13 Polyester: 2 Spandex: 2
Fabric types in socks	Cuff: 1 x 1 Rib Instep & leg: 6 x 2 Wide Rib Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Checked patterns Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Moss stitch Sole, toe & heel: Single jersey

Table 2. *Grading table of all indices.*

Index		*Grade				
		1	2	3	4	5
Wetting Time (sec)	Top	120	20 - 119	5 - 19	3 - 5	<3
	Bottom	120	20 - 119	5 - 19	3 - 5	<3
Absorption Rate (sec)	Top	0 - 9	10 - 29	30 -49	50 - 100	>100
	Bottom	0 - 9	10 -29	30 -49	50 - 100	>100
Max Wetted Radius (mm)	Top	0 - 7	8 - 12	13 - 17	18 - 22	>22
	Bottom	0 - 7	8 -12	13 - 17	18 - 22	>22
Spreading Speed (mm/sec)	Top	0.0 -0.9	1.0 - 1.9	2.0 - 2.9	3.0 - 4.0	>4.0
	Bottom	0.0 - 0.9	1.0 - 1.9	2.0 - 2.9	3.0 - 4.0	>4.0
One-way Transport Capability (R)		<-50	-50 - 99	100 - 199	200- 400	>400
Overall Moisture Management Capability (OMMC)		0.00 - 0.19	0.20- 0.39	0.40 - 0.59	0.60- 0.80	>0.80

*Grade 1 is the worst; Grade 5 is the best.

3. Results and Discussion

3.1 Liquid moisture management analysis

Table 3 shows the liquid moisture management of fabrics in sole part among three samples before and after washing. Before washing, the absorption rate, max wetted radius and spreading speed of the bottom fabric in three samples were 0. It is worth noting that R value (One-way transport capability) of three samples were smaller than -50 (-676.464, -668.767, -663.565). This means that the water cannot be absorbed by the fabric, the water droplet is in the form of spherical shape on the fabric surface as shown in Figure 1. The OMMC value of three samples are 0, in the range of Grade 1.

Table 3. *Liquid moisture management of three sole fabrics.*

		Sample 1		Sample 2		Sample 3	
Washing		before	after	before	after	before	after
Wetting time (sec)	top	13.71	12.92	12.84	8.21	9.31	10.35
	bottom	119.97	67.64	119.97	74.93	119.97	63.63
Absorption rate (%/sec)	top	223.50	107.93	83.94	54.86	52.62	359.3
	bottom	0	72.96	0	31.75	0	22.16
Max wetted radius (mm)	top	5	5	5	5	5	5
	bottom	0	5	0	5	0	5
Spreading speed (mm/sec)	top	0.36	0.38	0.38	0.60	0.53	0.47
	bottom	0	0.07	0	0.07	0	0.08
One-way transport capability (OWTC)		-676.46	-142.01	-668.77	-381.56	-663.57	-361.0
Overall moisture management capability (OMMC)		0	0.17	0	0.06	0	0.03

Figure 1. *The sphere shape of water droplet on the surface of sample 1, sample 2 and sample 3.*

After washing, the values of absorption rate, max wetted radius, spreading speed and one-way transport capability were shown in Table 3. Clearly, with regard to absorption rate, sample 1 has the highest value (72.96 %/sec), whereas the lowest value is seen in sample 3 (22.17 %/sec). The max wetted radius for all three samples are 5 mm. The rate of spreading for sample 3 is the highest, at 0.0784mm/sec, while sample 2 has the lowest spreading rate.

Although Supima cotton is the major fiber content of three samples (hydrophilic fiber), the results show the physical properties of three sample are hydrophobic. The possible reason may be due to the manufacturing process, which treats the cotton yarn with fluorochemcials for enhancing the properties of hydrophobicity and reducing absorbency to create "wicking window" (Textile Intelligence, 2007).

The mean OMMC of sample 1, sample 2 and sample 3 is 0.0338, 0.0604 and 0.1749, respectively, as shown in Figure 2. Therefore, the best OMMC among three samples is sample 3, with Grade 1. The properties of the fabrics are water repellent.

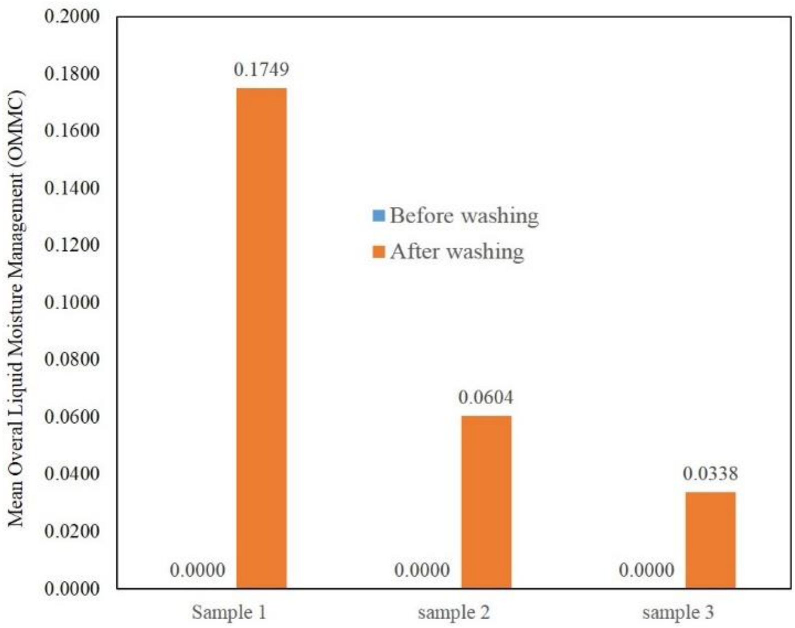

Figure 2. *Overall moisture management capability (OMMC) of three sole fabrics.*

3.2 Effect of fiber composition on the liquid moisture management

The relationship between OMMC and Supima cotton content in sole fabrics is shown in Figure 3. The R^2 value is 0.85984 (close to 1) and shows a strong negative linear relationship with almost well fit of data. This means that an increase in the proportion of Supima cotton may decrease the OMMC property.

The correlation analysis in Table 4 shows the relationship between Supima cotton % and the OMMC. The *p*-value is 0.000 ($p<0.05$) and *r*-value is -0.927 (close to -1). This indicates that a significant negative correlation exists between Supima cotton percentage and the OMMC. Therefore, the higher the proportion of Supima cotton, the more moisture trapped inside the fabric. Due to the good hydrophilcity of cotton fiber, the ability of transportation and release of moisture in the fabric is poor [5]. The previous research showed that the moisture transfer in cotton fabric is greatly influenced by capillary wicking [6]. This means that cotton fiber as hydrophilic fiber is not suitable for the transportation and removal of moisture.

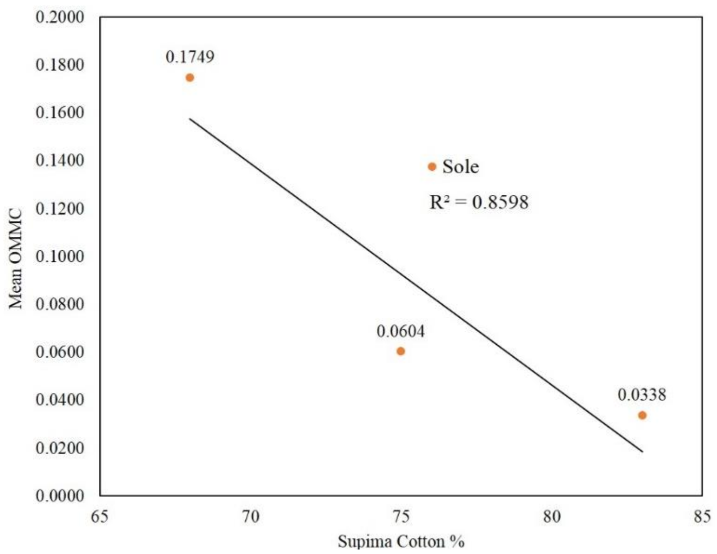

Figure 3. *Relationship between OMMC and Supima cotton % in sole fabrics.*

Table 4. *Correlation between Supima cotton % and OMMC.*

		Supima cotton %
Overall liquid moisture capability (OMMC)	Pearson Correlation	-0.927**
	Sig. (2-tailed)	0.000

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

4. Conclusion

In this study, we investigated the relationship between the fabric parameters and liquid moisture management ability of knitted socks fabric. It was found that the cotton proportion of fabric can greatly affect the liquid moisture management properties of socks. The liquid moisture management of fabric was negatively proportional to the content of cotton because of its hydrophilcity. Hydrophilic cotton fiber was found not to be suitable for the transportation of moisture.

Acknowledgement

This work is part of final year project submitted by Kwok-tung Hui 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.

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AN INVESTIGATION OF ABRASION RESISTANCE OF SOCKS

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Abstract: During wear, socks are subjected to different degree of abrasion which may shorten the life time of the products. This study is aimed to investigate the ability of sock fabrics to resist deterioration or wearing out in use. It was found that the increasing the cotton content of socks leads to an increase in the weight loss of socks, whereas nylon shows excellent performance in abrasion resistance. Washing seems no significant effect on the abrasion resistance.

1. Introduction

Socks are the clothing that could protect the foot in thermal neutrality and preventing foot from blister generating [1]. The development of socks has been diversified like the type, materials, and function, etc. Socks with good quality are conducive to prevent foot disease or smelly odor from foot. The wearing comfort of socks can be affected by a series of properties of the fabrics such as resistance to abrasion [2]. Resistance to abrasion is an important factor for socks in wear performance and durability [3]. The present study aims to investigate the ability of sock fabrics to resist deterioration or wearing out in use.

2. Experimental

2.1 Fabric specimen

Samples of Men Supima socks were supplied from an apparel company and their specifications were summarized in Table 1. In order to evaluate the washing effect on the socks, the socks were washed according to AATCC standard washing condition. Before testing, the socks were conditioned at 20±2°C and relative humidity of 65±2% for at least 24 hours.

2.2 Abrasion resistance

The abrasion resistance of socks fabrics can be tested by the method of ASTM D4966-12 (2016) via the Martindale Abrasion tester. The mass loss of fabric in percentage can be calculated by Equation (1).

$$Mass\ loss\ (\%) = \frac{A-B}{A} \times 100 \qquad (1)$$

Where

A = weight before abrasion (g); and
B = weight after abrasion (g)
The smaller the percentage, the better the durability of fabric specimen.

Table 1. *Details of the Supima cotton socks.*

	Sample 1	Sample 2	Sample 3
Pictures			
Names	MEN SUPIMA COTTON WIDE RIB SOCKS	MEN SUPIMA COTTON CHECKED LINKS SOCKS	MEN SUPIMA COTTON PIQUE SOCKS
Types	Crew sock	Crew sock	Crew sock
Length (cm)	25 - 27	25 - 27	25 - 27
Color	Grey	Grey	Grey
Fiber Composition (%)	Supima cotton: 68 Nylon: 28 Polyester: 2 Spandex: 2	Supima cotton: 75 Nylon: 21 Polyester: 2 Spandex: 2	Supima cotton: 83 Nylon: 13 Polyester: 2 Spandex: 2
Yarn count (Tex)	37.418	39.160	39.654
Thickness (mm)	1.33	1.44	1.59
Fabric types in socks	Cuff: 1 x 1 Rib Instep & leg: 6 x 2 Wide Rib Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Checked patterns Sole, toe & heel: Single jersey	Cuff: 1 x 1 Rib Instep & leg: Moss stitch Sole, toe & heel: Single jersey

3. Results and Discussion

3.1 Abrasion resistance analysis

The abrasion always occurs between the heel fabric of socks and shoes. In this study, the sole fabrics were used to carry out the abrasion resistance testing, and the results are shown in Table 2. It can be clearly seen that washing can significantly reduce the weight difference, for all the three samples. Also, the highest weight loss is seen in sample 3, whereas the weight loss of sample 1 is the lowest. This could be explained by the content of Supima cotton. High percentage of Supima cotton may lead to high loss of weight.

3.2 Effect of fiber composition on the abrasion resistance property

The relationship between the weight loss and Supima cotton proportion in sole fabrics was shown in Figure 1. The R^2 value of sole fabrics is 0.99731 (close to 1) and shows a strong positive linear relationship with perfectly well fit of data. This means that the high content of Supima cotton tends to increase the weight loss, and thus the property of abrasion resistance is poor.

Table 2. *Results of sole fabrics in abrasion resistance test.*

	Sample 1		Sample 2		Sample 3	
	before washing	after washing	before washing	after washing	before washing	after washing
original weight (g)	0.3935	0.4076	0.4106	0.4639	0.4453	0.5129
after weight (g)	0.2045	0.2274	0.1976	0.2316	0.1908	0.2308
weight loss (g)	0.1890	0.1802	0.2130	0.2323	0.2545	0.2821
weight difference (%)	48.030	44.210	51.875	50.075	57.152	55.001

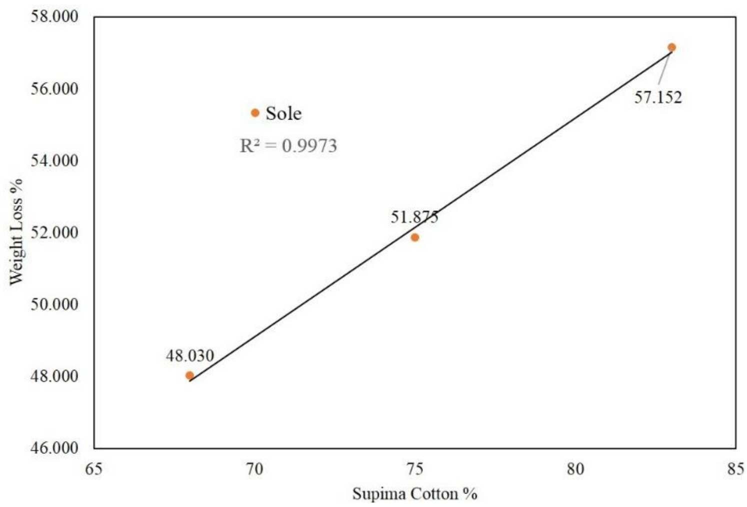

Figure 1. *Relationship between the weight loss % and Supima cotton % in sole fabrics.*

The correlation analysis between Supima cotton % and the abrasion resistance was shown in Table 3. The *p*-value is 0.000 ($p<0.05$) and *r*-value is 0.999 (close to 1). Therefore, there is sufficient evidence to indicate the strong and positive relationship between Supima cotton % and abrasion resistance. The fabric with higher proportion of nylon shows greater performance in terms of abrasion resistance. Therefore, sample 1 has the best ability of abrasion resistance because of its highest proportion of nylon fiber.

Table 3. *Correlation between Supima cotton % and abrasion resistance.*

		Supima cotton %
Abrasion resistance	Pearson correlation	0.999**
	Sig. (2-tailed)	0.000

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

3.3 Effect of washing on the abrasion resistance property

The property of abrasion resistance of fabric may be greatly affected by the washing. The significance is analyzed and is shown in Table 4. Clearly, the paired sample t-Test in Table 4 showed the difference in mean weight loss (%) of three samples before and after washing. The *p*-value is 0.273 ($p>0.05$) and *r*-value is 0.878. Therefore, there is no significant evidence to indicate the average difference and correlation between weight loss (%) of three samples before and after washing even though the weight loss % of after washing is less than that of before washing.

Table 4. *The difference in mean weight loss (%) of fabrics in sole part.*

t-Test: paired two sample for means	Fabrics in sole part	
	before washing	after washing
Mean	0.197	0.232
Variance	0.000184	0.00260
Pearson correlation	0.878	
P(T<=t) two-tail	0.273	

4. Conclusion

In this study, we investigated the relationship between the fabric parameters and liquid moisture management ability of knitted socks fabric. It was found that the increasing the cotton content of socks leads to an increase in the weight loss of socks, whereas nylon shows excellent performance in abrasion resistance. Washing seems no significant effect on the abrasion resistance.

Acknowledgement

This work is part of final year project submitted by Kwok-tung Hui 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.

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EFFECT OF PLASMA PRETREATMENT OF DYEABILITY OF SILK WITH ACID DYE

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Abstract: Plasma technology provides an effective way to modify the surface of polymeric materials and thus improve the physicochemical properties of this material. This study was a preliminary study in exploring the application of plasma technology in the surface modification of silk fiber. Experimental results revealed that the dyeability of silk fabric with acid dye was improved after plasma treatment.

1. Introduction

Silk is an important protein fiber because of its unique properties of wearing comfort, soft handle, good air permeability and elegant appearance [1]. Silk fiber is one of the strongest natural fibers with outstanding mechanical properties of high strength, stiffness, and toughness, under both tension and compression loading [2] and it is the only commercially available natural fiber in continuous filament form [3-6].

Plasma modification is an effective way for the surface treatment of polymers without affecting the original bulk characteristics of the polymers [7, 8]. Plasma treatment has been proved to improve the hydrophilicity of silk [9]. Thus, the present study aims to investigate the application of plasma treatment for the surface modification of silk fiber in order to achieve better coloration property. The untreated silk fabric will be dyed with acid dyes and compared with the plasma treated silk fabric.

2. Experimental

2.1 Fabric specimen pretreatment

100% silk fabric was used which was scoured with Diadavin EWN-T at liquor-to-goods ratio of 10:1 for 30 minutes before plasma treatment to remove the impurities. Next, the fabric was placed in the standard condition (temperature 21±1°C, relative humidity 65±2%) for 24 hours for drying.

2.2 Plasma treatment

The plasma generator Atomflo™ 400 series (Surfx Technology, US) was used for plasma treatment in this study. The gases used for plasma treatment were helium and oxygen, as shown in Table 1. The operation of plasma treatment was controlled by a controller. The flow rate of helium was 30 L/min, and the flow rates of oxygen were 0.1, 0.3, and 0.5 L/min. The discharge power was 150W. The jet-to-substrate distances were 3, 4, and 5mm and the plasma jet moving speed was fixed at 10 mm/s.

Table 1. *Purities of gases applied in the plasma treatment.*

Gas	Purity
Helium (Primary gas)	99.995%
Oxygen (Secondary gas)	99.7%

2.3 Dyeing experiment

Acid levelling dye was used in this experiment. The untreated and treated samples were cut into 5 x 5 cm for this dyeing test. Next, two dyebaths were prepared at 40°C. Then, two samples (treated and untreated) were put into the dyebaths and the temperature of the baths was risen to 100°C within 30 minutes. After that, the samples were boiled for 45 minutes and then were rinsed and dried. Finally, the surface morphology of the samples were observed and measured by spectrophotometer. The detail of stock solution and recipe were shown in Table 2.

Table 2. *Recipe of dyeing bath for silk fabric.*

Recipe	Concentration (w/w)
Dyestuff	2%
Sulfuric Acid	4%
Glauber's Salt	4 g/L

2.4 Evaluation of silk fabric treated with plasma

2.4.1 Wettability analysis

In this study, the wettability of silk fabric after plasma treatment was measured according to AATCC 79-2010, which is the standard determining the water absorbency of yarns, fabrics and garments. The untreated fabric was acted as the control sample. Methylene blue solution was used as an indicator.

2.4.2 Fourier transform infrared spectroscopy (FTIR) analysis

Fourier transform infrared spectroscopy (Spectrum 100 FTIR Spectrometer, Perkin-Elmer, USA) was used for determining the surface composition of silk fabric. The data were collected from 500 to 4000 cm^{-1} with the frequency of 1 cm^{-1}.

2.4.3 Dyeing evaluation

The dyeability of the treated and untreated silk fabrics were evaluated by a spectrophotometer (DataColour) by analyzing the CIE L*, a*, b* and ΔE values with illuminant D65 and standard observer of 10˚.

3. Results and Discussion

3.1 Wettability analysis

The hydrophilicity of silk fiber can be significantly improved via plasma treatment. The results of water absorbency of silk fabric after plasma treatment were shown in Figure 1. The untreated silk samples shows the poorest wettability with the formation of clear water droplet in fabric surface (Figure 1(A) and 1(B)), whereas after plasma treatment, the wettability of silk fabrics are significantly improved and shown in Figure 1(C) and Figure 1(D). This indicates that plasma treatment provides an effective way to improve the hydrophilicity of silk fabric.

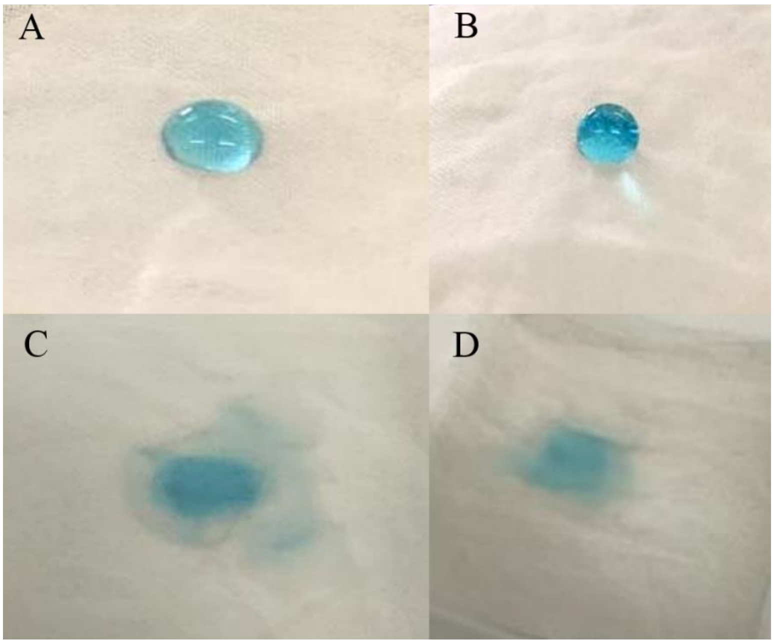

Figure 1. *Photographs of silk fabric, untreated samples (A) face; (B) back; and treated samples (C) face; (D) back.*

As shown in Figure 2, the distance of jet-to-substrate can greatly affect the effectiveness of plasma treatment. High distance introduces poor effectiveness of plasma treatment, which is same with the increase in the oxygen flow rate. Take the sample treated at 3 mm of jet-to-substrate distance as an example, clearly, oxygen flow rate 0.3 L/min shows the best treatment result, whereas the sample treated with flow rate 0.5 L/min has the optimal hydrophobicity. This could be related to the concentration of active species [8].

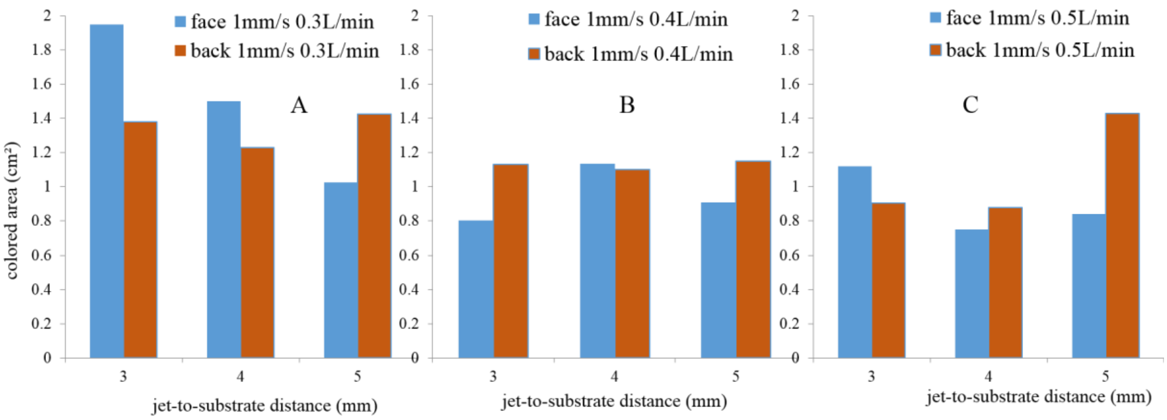

Figure 2. *Wettability of silk fabric treated with 1mm/s jet movement speed. The jet-to-substrate distances were 3, 4 and 5 mm, and the oxygen flow rates were 0.3 L/min (A), 0.4 L/min (B) and 0.5L/min (C).*

Effects of jet-to-substrate distance on the plasma treatment are further investigated, as shown in Figure 3. It can be clearly seen that the speed of jet movement is negatively related with the effectiveness of plasma treatment. This can be explained by the relationship between jet movement speed and plasma treatment duration. As the jet movement speed increases, the treatment duration is decreased. Although a long duration does not mean a better performance, a more significant modification of the fabric surface can occur. It provides enough time for the plasma species to penetrate into the fabric and cause a morphological change. Therefore, the treatment duration is required to be concerned and controlled carefully because it plays an important role in plasma treatment [10].

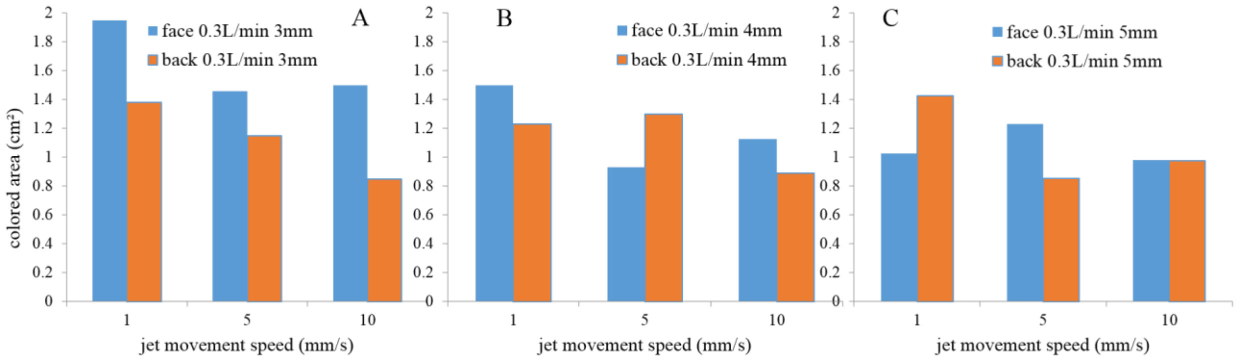

Figure 3. *Wettability of silk fabric treated with 0.3 L/min oxygen flow rate. The jet movement speeds were 1, 5 and 10 mm/s, and the jet-to-substrate distances were 3 mm (A), 4 mm (B) and 5 mm (C).*

As discussed above, the optimum plasma treatment condition is as follows: 3mm jet-to-substrate; 0.3 L/min oxygen flow rate; and 1 mm/s jet movement speed. The silk fabric for dyeing evaluation would be treated with plasma under this condition.

3.2 FTIR analysis

The FTIR spectrum of the silk fabric and control sample after plasma treatment were shown in Figure 4. For the untreated sample, the transmittance is stable in the range of 4000 to 2500 cm^{-1}. Until 2500 to 2300 cm^{-1}, there is a weak and small vibration due to the appearance of –C≡C– component on the surface structure. From 1800 to 1500 cm^{-1}, two peaks refer to the appearance of C–C bonds of a benzene ring. From 1300 to 1200 cm^{-1}, a peak appears as the –$C(CH_3)_3$ component. It is found that the untreated silk fabric contains the functional groups of alkanes. This can explain the weak wettability of untreated sample, because of lack of O–H and N–H groups which can form hydrogen bonds with water for wetting.

However, after treatment with plasma, some changes occurred in the chemical structure of silk fiber. Two small peaks from 3000 to 2800 cm^{-1} refer to R–C=O group. This helps to ensure that there was R–C=O group in the structure of treated silk fabrics. The function of this group is similar to O–H and N–H groups, which can form hydrogen bonds to improve the wettability of silk fabrics. This indicates that the wettability of silk fabric after plasma treatment is improved by the change of functional groups.

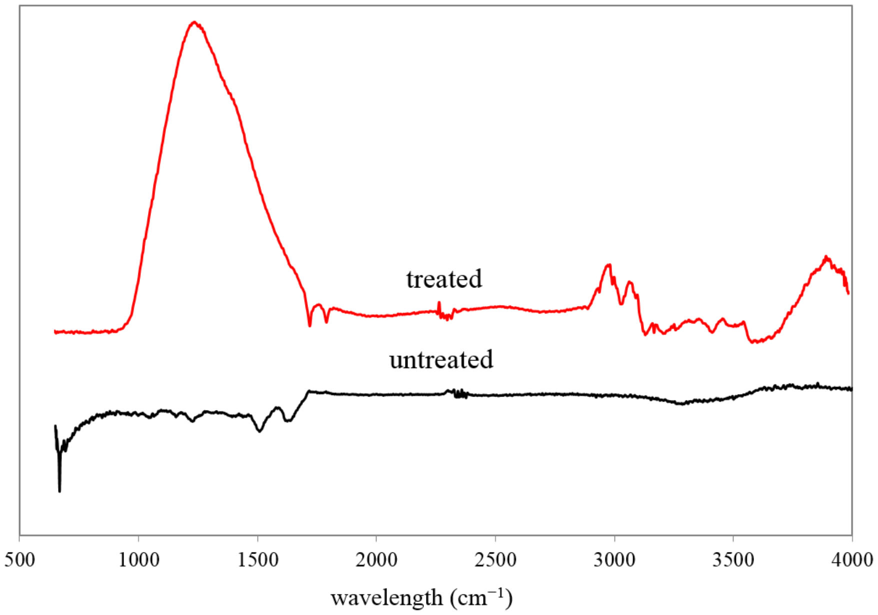

Figure 4. *FTIR spectrum of plasma treated silk fabric and control sample.*

3.3 Dyeability evaluation

Table 3. *CIE values of plasma treated silk sample and the control dyed with acid dyes.*

Samples	L*	a*	b*	ΔE
Untreated sample	31.257	43.071	13.782	3.01
Treated sample	29.056	41.271	14.773	
Difference (treated - untreated)	-2.20	-1.80	0.99	

From Table 3, it is noted that the CIE L*, a* and b* values of plasma treated silk fabric are changed after dyed with acid dye, and ΔE is 3.01. This ΔE values shows that the effect of plasma treatment is significant on the dyeability of silk fabric.

The L* value of untreated sample is larger than the treated sample which means the lightness of treated sample is lower. This is related to the color uptake of the fabric. As the surface modification of the treated fabric is finished, its color uptake should be better than the untreated fabric.

With regard to a* and b* values, they represent the difference on red/green axis and yellow/blue axis, respectively. The a* value of untreated fabric is larger than that of treated sample, while the b* value of treated fabric is larger than untreated sample. This shows that the redness of treated fabric is lower, whereas the yellowness is higher.

4. Conclusion

In this study, the effects of plasma treatment under different conditions on silk fabric were evaluated through the wettability, surface modification and dyeability. It was found that plasma treatment provides an effective way to enhance the wettability and dyeability of silk fabric via the formation of hydrophilic functional groups in the structure of silk fiber.

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This work is part of final year project submitted by Wing-chun Ma 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.

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WICKABILITY OF GAUZE PRODUCTS FOR INFANT

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Abstract: Gauze is an excellent material for infant apparel which can made in various forms and by a variety of methods, and thus have attracted great attention in baby care market. This study aims to identify the wicking property of the gauze fabric in baby care products, and to analyse the relationships between the wicking ability and fabric structure of baby soft gauze products. The experimental results revealed that a significant difference occurred for the gauze in the wicking ability. The cotton gauzes were found to show higher wicking rate than bamboo counterparts because of the higher hydrophilic property of cotton material. The fiber content and structure of fabric were the major parameters that affects the wicking ability.

1. Introduction

With the rapid development of baby apparel market, the demands for the standards of wear comfort and safety on infant apparel have been increased. The multi-functional gauze products become one of the main focuses in baby care market [1]. Gauze is an excellent material for infant apparel and has attracted great attention in baby care market [2]. The market share of gauze products for baby has been significantly increased due to its distinct advantages of gauze-structured fabrics. High quality and safety are the priorities of infant's apparel, and thus they must be subjected to serious evaluation and measurement before launched to market [3].

This study aims to identify the wicking property of the gauze fabrics in baby care products by comparing the current brands of infant gauze products in marketplace. A total of 9 gauze products, including cotton gauze and bamboo gauze from the famous infant supplies available in the market were investigated.

2. Experimental

2.1 Gauze samples

A total of 9 gauze products obtained from the market were used and their specifications were shown in Table 1. The products were conditioned at 20±2˚C and 65±5% for at least 24 hours before use.

2.2 Count measurement

The counts of fabric and yarn of gauze samples were calculated according to the standard test methods of ASTM D3887 and ASTM D4769. The unit of cotton gauze is picks and ends per inch; the unit of bamboo gauze is wales and courses per inch. The magnifying device was used for the fabric count, and the Tautex digital crimp tester was used for the yarn count testing.

Table 1. *Product specifications.*

No.:	Product name	Fiber content	Structure	Weight (g)	Size (cm)
1	Gauze Handkerchief	100% cotton	woven	10.44	30×32
2	Gauze Handkerchief	100% cotton	woven	9.61	32×32
3	Gauze Handkerchief For Baby	100% cotton	woven	9.57	30×30
4	Baby Gauze Handkerchief	100% cotton	woven	9.73	30×30
5	gauze handkerchief	100% cotton	woven	9.88	30×30
6	tail muslins	100% cotton	woven	2.63	12×12
7	Gauze Kerchief	100% cotton	woven	14.55	50×25
8	Mesh handkerchiefs	100% cotton	woven	12.25	30×30
9	Mesh handkerchiefs	100% bamboo	knit	20.61	30×30

2.3 Wicking properties evaluation

Wicking is one of the examples of the phenomena named capillarity, which means the encompassment of all dynamic and kinematic effects and the behaviour of phase interfaces. Wicking occurs when a fabric is completely or partially immersed in liquid or contact with a limited amount of liquid, such as a liquid drop on the fabric surface. Wicking experiment can be divided into horizontal wicking and vertical wicking. Wicking property of textiles is the movement of water or liquid through the fabrics. Two test methods were used in the measurement of wicking: (i) the Horizontal Wicking of Textiles (AATCC Test Method 198), used to evaluate the ability of horizontally aligned fabric specimens to transport liquid along or through them, and (ii) Vertical Wicking of Textiles (AATCC test Method 197), which is used to evaluate that of vertically aligned fabric.

2.3.1 Horizontal wicking test

The horizontal wicking test was to evaluate the ability of liquid transport along horizontal direction of fabric, and was investigated according to the AATCC Test Method 198. The wicking rate was calculated according to Equation 1:

$$W = \pi(1/4)(d1)(d2)/t \qquad (1)$$

Where
W = wicking time (mm^2/s);
d1 = wicking distance in length direction (mm);
d2 = wicking distance in width direction (mm); and
t = wicking time (s)

2.3.2 Vertical wicking test
The vertical wicking was investigated according to the AATCC Test Method 197. Equation (2) was used to calculate the vertical wicking rate.

$$W = d/t \quad (2)$$

Where
W = wicking rate (mm/s);
d = wicking distance (mm); and
t = wicking time (s)

3. Results and Discussion

3.1 Count analysis
The fabric count of the gauze samples was measured using magnifying device, and the yarn count was evaluated by the linear density using the Tautex digital crimp tester. The results are shown in Table 2. Clearly, the higher value of the fabric count means the finer fabric. The finer yarn tends to result in the lower linear density and the coarse yarn would present in the higher linear density. Different yarn parameters lead to different performances, such as wicking ability.

Table 2. *The counts of fabric and yarn of gauze samples.*

No.	Fabric count	Yarn count (Tex)
1	51x43	13.9
2	43x39	13.4
3	41x39	12.0
4	60x39	13.0
5	41x40	13.9
6	60x41	27.4
7	58x40	13.7
8	54x44	13.4
9	57x38	23.0

3.2 Horizontal wicking rate analysis
Table 3 showed the horizontal wicking rate of the gauze samples. High horizontal wicking rate means high spreading rate in horizontal direction. As can be seen, the sample 5 has the highest spread and absorption of water over 260 mm²/s. Samples 6 and 8 cotton gauze fail to be tested in terms of horizontal wicking because they do not absorb water.

Table 3. *Horizontal wicking ability test result of gauze samples*

No.	Average wicking rate (mm^2/s)
1	203.8
2	162.5
3	219.0
4	196.5
5	276.6
6	N/A
7	126.9
8	N/A
9	144.9

3.3 Vertical wicking analysis

The vertical wicking rate of the gauze samples was shown in Table 4. High vertical wicking rate means high spreading rate in the vertical direction. As can be seen, the highest vertical wicking ability is seen in the sample 7, whereas sample 7 has the lowest vertical wicking rate. However, the vertical wicking rates of sample 6 and sample 8 cotton gauze failed to be tested because they do not absorb water.

Table 4. *Vertical wicking ability test result of gauze samples*

No.	Average wicking rate (mm^2/s)
1	0.76
2	0.79
3	0.74
4	0.65
5	1.77
6	N/A
7	0.44
8	N/A
9	1.12

Wicking ability determines the water absorbency property of a fabric. Wicking of material is a vital issue in a wide range of areas, which consists of the uptake in vertical direction and the spread in horizontal direction. Bamboo and cotton are the utmost importance for wetting, wicking and absorption. Water transport through the capillaries may be affected by the surface treatments such as finishing process, which may turn fabric surface into hydrophobic. This may explain why samples 8 and 6 fail to be tested in terms of wicking ability.

Since the knitted structure bamboo, the spaces between yarns is relative narrower than other cotton gauzes with open weave structure. Therefore, it is more ideal for bamboo to give excellent rate regarding wicking test.

4. Conclusion

In this study, the wicking properties of some famous brands of infant gauze products in market were fully investigated. It was found that a significant difference in the wicking ability occurred among the gauze samples with different materials. The cotton gauzes were found to show higher wicking rate than bamboo counterparts because of the higher hydrophilic property of cotton material. The fiber content and structure of fabric were the major parameters that affects the wicking ability.

Acknowledgement

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A STUDY OF AIR PERMEABILITY OF GAUZE PRODUCTS FOR INFANT

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Abstract: Air permeability is a significant factor for textile materials, which can be used to evaluate the breathability of fabrics, especially for the infant fabric products. This study aims to investigate the air permeability property of gauze products for infant. The experimental results revealed that a significant difference occurred for the gauze in the air permeability. The bamboo gauzes were found to show higher air permeability than cotton counterparts due to high interstice spaces.

1. Introduction

Gauze is an important material for infant apparel which can made in various forms and has drawn the attention in baby care market recently [1, 2]. Those products should have good properties such as non-toxic, good water absorption, soft handle and smooth surface are desirable [3]. Air permeability is a significant factor for textile materials, which can be used to evaluate the breathability of fabrics, especially for the infant fabric products [4]. This study aims to identify the air permeability property of the gauze fabrics in baby care products by comparing the current brands of infant gauze products in marketplace.

2. Experimental

2.1 Gauze samples

9 gauze products were collected from the market and their specifications were shown in Table 1. Before measuring the properties, the products were conditioned at 20±2˚C and 65±5% for at least 24 hours.

2.2 Surface analysis of gauze samples

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

2.3 Air permeability test

In this study, the air permeability tester, KES-F8, was used to test the air permeability of gauze samples. The KES-F8 was designed to measure the air permeability of a wide range of samples from high permeability to low permeability such as gauze fabric and waterproof fabric. The air permeability was determined by the rate of airflow, as stated in Equation (1).

$$R = \Delta P/V \quad (1)$$

Where
R = air resistance (kPa·s/m);
ΔP = pressure difference (kPa);
V = air velocity (m/s); and

Table 1. *Product specifications.*

No.:	Product name	Fiber content	Structure	Weight (g)	Size (cm)
1	Gauze Handkerchief	100% cotton	woven	10.44	30×32
2	Mesh handkerchiefs	100% cotton	woven	12.25	30×30
3	Gauze Kerchief	100% cotton	woven	14.55	50×25
4	tail muslins	100% cotton	woven	2.63	12×12
5	Baby Gauze Handkerchief	100% cotton	woven	9.73	30×30
6	Gauze Handkerchief	100% cotton	woven	9.61	32×32
7	gauze handkerchief	100% cotton	woven	9.88	30×30
8	Gauze Handkerchief For Baby	100% cotton	woven	9.57	30×30
9	Mesh handkerchiefs	100% bamboo	knit	20.61	30×30

3. Results and Discussion

3.1 Surface structure observation

In this study, eight fabric samples were made of 100% cotton with the same fabric structure, which are gauze fabric in plain weave with slightly different density. However, the yarn twist level, hairiness and layering of cotton gauze are different. Therefore, the surface morphologies of each samples are observed by microscope method and are shown in Figure 1.

As can be seen, the surface morphology of nine samples are not fully identical. Samples of 2, 3 and 5 have uniform and closely packed structure, which may cause better performance in wet processing. With regard to hairiness, samples 2, 6 and 9 presented lower hairiness, which could be explained by the different manufacturing processes.

3.2 Air permeability results analysis

Air permeability is an important factor in the performance of such textile materials as gas filters, fabrics for clothing and mosquito netting. Air permeability can be used to indicate the breathability of a fabric, such as a use in weather resistance clothing and able to detect changes during the manufacturing process. The filtration efficiency is also directly related to the level of air permeability.

The rate of airflow passing perpendicularly is adjusted to obtain a prescribed air pressure differential between the two fabric surfaces through a known area of fabric. From this rate of airflow, the air permeability of the fabric is determined. The air permeability results were showed in Table 2, including the average air permeability, standard deviation, and coefficient of variation for each sample. The higher value means the poorer performance of air permeability. It can be seen that the highest value is seen in the sample of 9, while the lowest value belongs to sample 7, indicating sample 7 has the best air permeability.

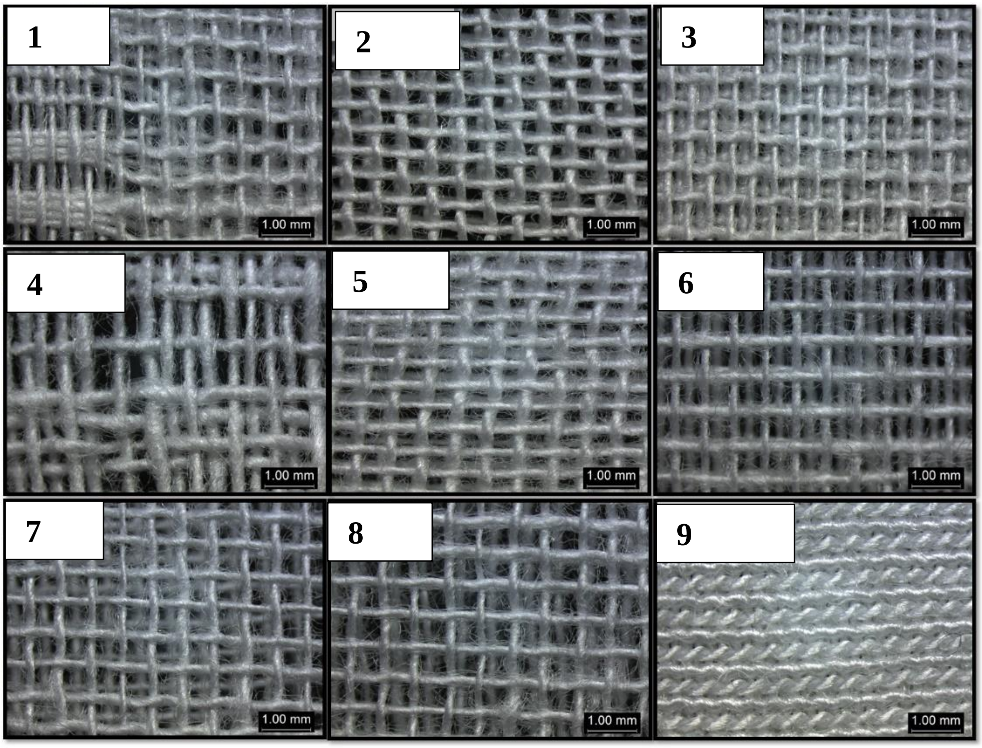

Figure 1. *Microscopy observation of gauze samples.*

Table 2. *The air permeability of samples.*

No.	R (kPa·s/m)
1	0.024
2	0.017
3	0.026
4	0.016
5	0.032
6	0.012
7	0.010
8	0.013
9	0.231

Fabric thickness and fabric density could be the answer to explain the different characteristics of air permeability. The importance of air permeability for the baby apparel is to avoid the risk of suffocation. The gauze goods suggest multiple usages with cover for breastfeeding, bedding, general cleaning fabric and the wrapping of infants. It is not acceptable if the product does not have a good air permeability.

4. Conclusion

In this study, the air permeability of some famous brands of infant gauze products were fully examined. It was found that a significant difference in the air permeability occurred among the gauze samples with different materials. The cotton gauzes were found to show higher air permeability than bamboo counterparts because of the higher hydrophilic property of cotton material. The bamboo gauzes were found to show higher air permeability than cotton counterparts due to high interstice spaces. The fiber content and structure of fabric were the major parameters that affects the air permeability.

Acknowledgement

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AN EVALUATION OF HAND FEEL OF GAUZE PRODUCTS FOR INFANT

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Abstract: Hand feel is an important properties of textile materials. The hand feel can be instrumentally measured as relative hand value which can describe the hand feel of a human touches a piece of fabric. This study aims to investigate the relative hand property of gauze products for infant. The experimental results revealed that a significant difference occurred for the gauze in the relative hand value. The cotton gauzes were found to show higher hand value than bamboo counterparts.

1. Introduction

In the baby apparel market, gauze is an excellent material for infant apparel [1-3]. Relative hand value is a significant factor for textile materials, which describes the hand feel of a human touching a piece of fabric according to AATCC Test Method 202. The primary purpose of the calculation of fabric hand value is to determine the quality of fabric by evaluating the characteristics such as softness, smoothness and stiffness. The fabric hand depends on one's judgment, which is closely related to time, season, trend and region together with individual preferences [4]. According to the previous work [5], fabric hand can be stimulated by the physical tactile sensation to the mechanical properties of a fabric. Several studies reviewed that the fabric hand could be expressed in sensory feeling of physical properties of a fabric and analyzed through measurement parameters, for examples, the stiffness, softness and roughness [6, 7]. The present study aims to investigate the relative hand property of gauze products for infant.

2. Experimental

2.1 Gauze samples

Nine gauze products were collected from market and their specifications were shown in Table 1. Before the hand feel measurement, the products were conditioned at 20±2˚C and 65±5% for at least 24 hours.

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2.2 Relative hand value measurement

In this study, the fabric hand value was evaluated by the PhabrOmeter system according to AATCC Test Method 202 which can measure fabric characteristics such as relative hand value, drape index, softness, smoothness and stiffness.

Table 1. *Product specifications.*

No.:	Brand name	Product name	Fiber content	Structure	Weight /g	Size /cm
1	AMOR (A)	Gauze Handkerchief	100% cotton	woven	10.44	30×32
2	ST	Gauze Handkerchief	100% cotton	woven	9.61	32×32
3	PIP	Gauze Handkerchief For Baby	100% cotton	woven	9.57	30×30
4	NUK (N)	Baby Gauze Handkerchief	100% cotton	woven	9.73	30×30
5	CC (C)	gauze handkerchief	100% cotton	woven	9.88	30×30
6	MC	tail muslins	100% cotton	woven	2.63	12×12
7	MO	Gauze Kerchief	100% cotton	woven	14.55	50×25
8	MIC	Mesh handkerchiefs	100% cotton	woven	12.25	30×30
9	MB	Mesh handkerchiefs	100% bamboo	knit	20.61	30×30

3. Results and Discussion

3.1 Fabric value analysis

Relative hand value is an index of hand value data relative to a reference fabric, to predict the tactile sensory when a human handing a fabric, and shows the overall hand value performance of a fabric. The hand values of gauze samples are shown in Figure 1.

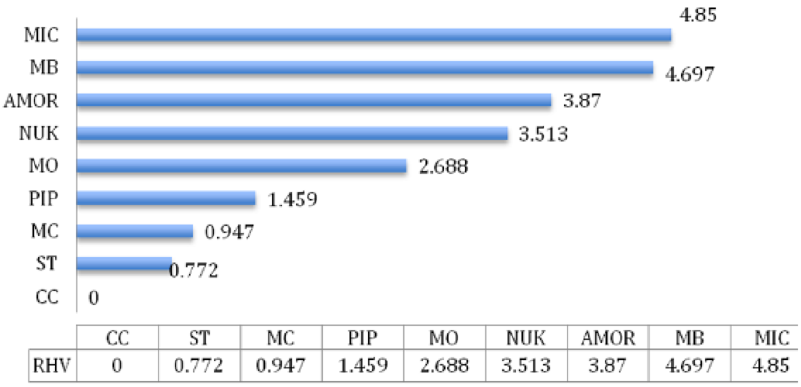

Figure 1. *Relative hand value of different brands of gauze fabric with different materials.*

CC was used as the control fabric. As shown in Figure 1, the sample MIC has the highest hand value, while ST is the lowest in hand value. MC and PIP are slightly higher than the CC gauze sample.

3.2 Fabric attributes analysis

Figure 2 shows the fabric scores of all gauze samples in resilience, softness and smoothness. The higher resilience score and softness score, the better the performance. It can be clearly seen that the scores of softness and smoothness are close to 90, while the resilience score ranged from 46 to 56.

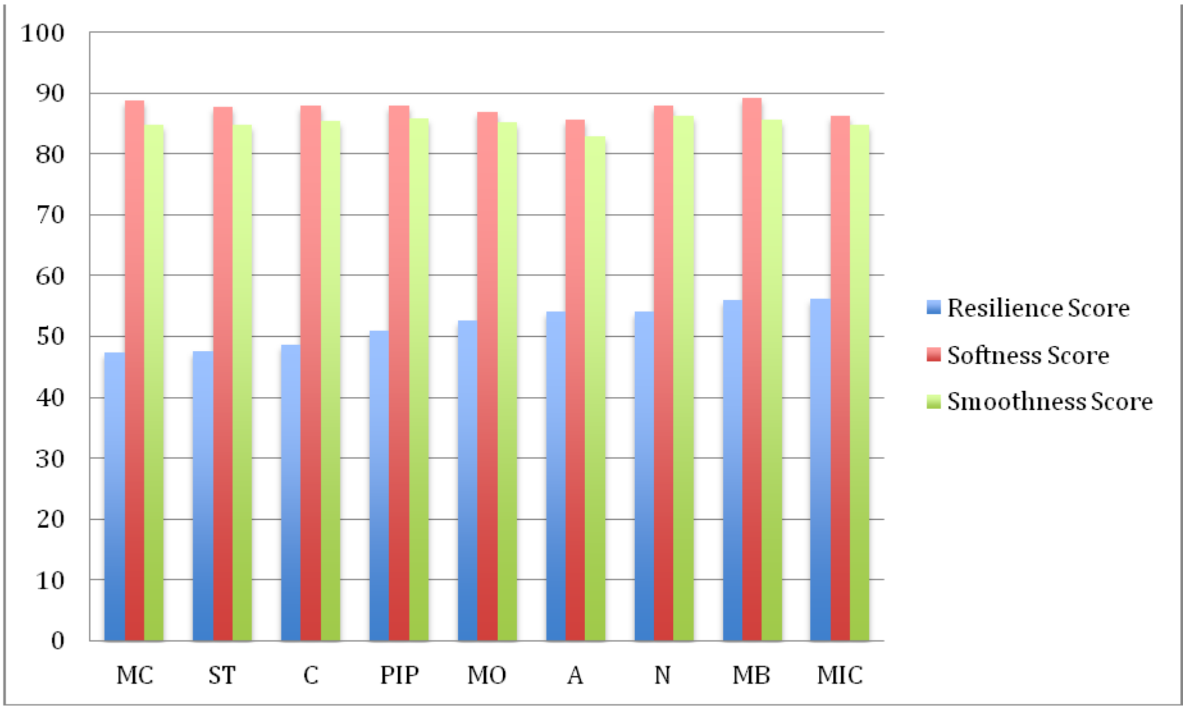

Figure 2. *Comparison of resilience, softness and smoothness of gauze samples.*

Resilience can be explained as stiffness, flexibility and the ease of bending. It is a crucial factor of maintaining the geometrical shape. According to the PhabrOmeter, the higher score represents the better resilience. In general, the resilience of all cotton samples is at a similar level whilst the bamboo sample shows the highest score in resilience.

Softness is the utmost importance for baby products, for the use on sensitive skin. It can be described as compressibility. The higher score represents the better softness. Since 100 is full mark, all the brands is already above the average, as shown in Figure 2. MB has the highest score close to 90, which is the highest among 9 samples. The softness among samples are ranged from around 85 to below 90.

Smoothness is related to the surface friction and appearance. The surface friction can be explained as a resistance from slippage. The scores of smoothness of 9 samples are in the range from around 82 to 85, among which the lowest score was AMOR (A) with approximately 83 marks. The higher smoothness (higher score) would give a flatter surface and neat image.

Drape index is a parameter representing the drape behaviour of a fabric. The drape ability increases when the index decreases, as shown in Figure 3.

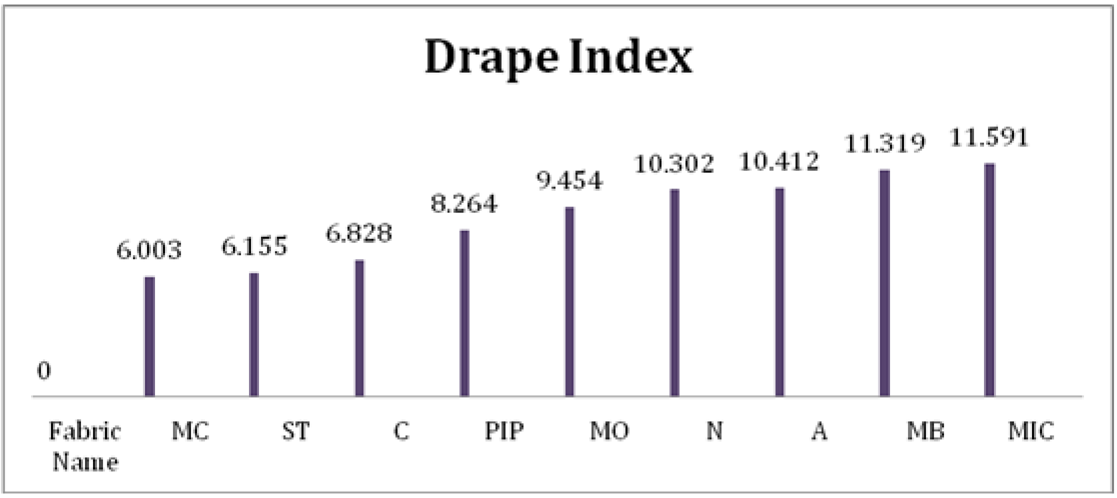

Figure 3. *Comparison of drape index of gauze specimens.*

4. Conclusion

In this study, the hand feel of some brands of infant gauze products in market were fully evaluated. It was found that a significant difference in the hand feel occurred among the gauze samples with different materials. The cotton gauzes were found to show higher hand feel values than bamboo counterparts.

Acknowledgement

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DEMAND FACTORS OF NATURAL DYES OF SMEs/ OTOP AND START-UP ENTREPRENEURS FOR TEXTILE PRODUCT DEVELOPMENT

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

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.

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.

Methodology

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.

1. 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.

Results 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.

Conclusion

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.

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