Part V

Novel technologies

TANDEM WET-ON-WET FOAM APPLICATION OF BOTH CREASE-RESIST AND ANTISTATIC FINISHES

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ABSTRACT

Wet-on-wet application of textile finishes is normally carried out using pad-mangles for application and stenters for drying and curing. The former method results in the release of significant quantities of effluent water, containing excess finish and auxiliaries. The latter method requires the consumption of large amounts of energy to remove the water. Overall, this results in a process which produces large amounts of waste and which uses large amounts of energy.

Foam application of finishes is known to minimise waste and to use much less thermal energy: the process is currently being used to apply crease-resist finishes. This paper describes a method for applying successive crease-resist and antistatic finishes using successive foam treatments without intermediate drying. The paper concentrates on the effects of using a range of dwell times of the foam on the fabric, which are critical to the success of the process.

Compared to the standard procedure, this technique would considerably reduce the amount of effluent produced and heat energy used. The usefulness of the process is also described in the paper in terms of the effectiveness of the finishes applied.

INTRODUCTION

Conventional pad-mangle processing

Addition of various finishes in one bath requires special chemicals and high skill and levels of expertise in recipe formulation and coupled with compatibility problems between the finishes, for instance when using an anti-static agent together with a crease-resist finish. The normal procedure is therefore to give an antistatic aftertreatment to the crease-resist finished fabric in a separate bath after the fabric has been cured. Traditionally, the pad-mangle technique has been used for each process, meaning that significant amounts of water are used as solvent and transporter of the finishes, and significant amounts of energy are used for subsequently removing that water. In addition, since not all of the solution of finish plus auxiliaries is fixed in the fabric, the pad-mangle process produces significant amounts of effluent, which has to be treated. The standard process, therefore, can be expensive and polluting.

Foam systems

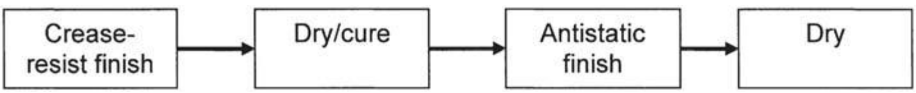
Foam is an agglomeration of gaseous bubbles, usually of air, dispersed in a liquid and separated from each other by thin films of liquid, known as lamellae. The use of air to extend the volume of a concentrated chemical solution in the form of bubbles is known as a **foam system**. Foaming a liquor to a larger volume (usually between 5 and 50 times the liquor volume) allows convenient volumetric control and hence ensures even distribution of the liquor in the fabric. Foam systems could be the most logical alternative to the conventional pad-mangle system for application of finishes in tandem, since the reagents are applied to the fabric in the form of a foam, in contrast to the conventional process of impregnating the fabric with a dilute solution of the reagent. Since air replaces water as the transport medium for the reagents, substantial energy savings in the drying of fabrics, less waste disposal and enhanced quality of the product can be realised.

EXPERIMENTAL

Experimental work involved the tandem foam application of a crease-resist and an antistatic finish at varying dwell times (dwell time is defined as the time to elapse between the application of the two finishes). Four dwell times were used (30, 35, 40 and 45 seconds respectively) as being those most likely to be used in practice.

The tandem wet-on-wet foam application method was that of Elbadawi and Pearson and was controlled to give a maximum wet pick-up up of 45% so that the potential advantages of foam add-on are not lost. This included crease-resist finish at 30% wet pick-up and antistatic finish at 15% wet pick-up. The crease-resist agent, which is an absorbed reactive finish, was applied before the antistatic agent, which is a topical finish.

For comparison purposes, fabric samples were also finished using the conventional pad-mangle system at the 60% wet pick-up level used commercially:



Tables 1a and 1b show the recipes for the crease-resist and antistatic finishes respectively; table 2 shows the fabric specification. Warcosoft NI 150 softener was included in the anti-static finish recipe only, since it was found logical to incorporate the softener (which aims to improve handle, in part a surface property) with the topical finish to operate at the fabric surface.

Table 1a Crease-resist finish recipe

reagent	Concentration (gl^{-1})	
	Pad-mangle	Foam
Permafresh[a]	55	110
Catalyst 8316	22	44
Laviron 118S[b]	-	15
Kelzan S[c]	-	2
Water	Adjust to 1 l	Adjust to 1 l

Table 1b Antistatic finish recipe

reagent	Concentration (gl^{-1})	
	Pad-mangle	Foam
Lurotex A25[d]	35	140
Warcosoft NI 150[e]	20	80
Laviron 118S[b]	-	15
Kelzan S[c]	-	2
Water	Adjust to 1 l	Adjust to 1 l

Notes to tables 1a and 1b:

a: Permafresh	DMDHEU-based crease-resist finish (Contract Chemicals)
b: Laviron 118S	amphoteric, fatty amine oxide surfactant (Henkel)
c: Kelzan S	xanthan gum thickener (Kelco International)
d: Lurotex A25	Non-ionic polyamide anti-static agent (BASF)
e: Warcosoft NI 150	fatty glyceride blend non-ionic softener (Contract Chemicals)

Table 2 Parameters of fabric used in this work

fabric composition	50% polyester/50% cotton
weave structure	satin
mass/unit area	189 gm^{-2}
thickness	0.45 mm

Foamed finishes were prepared using a Mondomix foam generator and were applied on the knife-over-roller using a Werner-Mathis coating device, set to give a coating gap of 0.3 mm. The coated fabrics were passed between a pair of rollers to collapse the foam. Fabric through speed was 4 m min^{-1}; the roller nip pressure was 1 kg cm^{-1}. Fabric samples were dried/fixed at 150°C for 3 min. Foam densities and coating gap were determined to give the correct wet pick-up and solid add-on values. Roller nip pressure and speed, and temperature and time were the standard values for the two finishes.

RESULTS

The economic and environmental advantages of foam processing are well established. However, these advantages would not count should the effectiveness of the finishes applied by using foam systems be significantly worse than by using conventional application methods. The finished fabrics were therefore tested for abrasion resistance, crease recovery angle, tear strength, tensile strength and fabric breaking extension, fabric shrinkage and de-cling time. The results are shown in table 4.

Table 4. Mean values of fabric parameters resulting from the use of foam and conventional systems for applying finishes in tandem

Mean values	Un-finished	Pad-mangle finish	Dwell time (sec) – foam finished			
			30	35	40	45
abrasion resistance (rubs x 1000)	29	16	25	21	16	19
warp crease recovery angle (°)	100	123	115	117	117	118
weft crease recovery angle (°)	96	131	125	122	123	121
warp tear strength (N)	14.2	11.6	10.7	10.2	10.6	10.4
weft tear strength (N)	12.3	10.8	9.7	9.6	9.4	9.4
warp tensile strength (N)	496	403	386	399	398	401
weft tensile strength (N)	470	382	374	377	367	361
fabric breaking extension (weft %)	14.2	11.6	11.5	11.5	11.4	11.4
fabric breaking extension (warp %)	21.7	17.7	17.4	17.4	17.0	17.2
warp fabric shrinkage (%)	1.7	0.2	1.1	0.7	0.0	0.0
weft fabric shrinkage (%)	0.0	0.0	0.0	0.0	0.0	0.0
decling time (sec)	19.7	17.5	14.5	13.7	12.5	11.7

DISCUSSION

Abrasion resistance

For foam-finished samples, abrasion resistance has a tendency to decrease with an increase in dwell time. This may be because the longer the dwell time, the greater the chance that the reactant will have to cross-link with the fibres before applying the anti-static finish, minimising any interaction between the two finishes. Excessive cross-linking may have occurred, leading to increased rigidity or decreased flexibility of the fabric, reducing the abrasion resistance. Dwell time had no significant effect on abrasion resistance.

Crease recovery angle

Both application methods are seen to increase the crease recovery angle, conventional finishing giving slightly better results. This could be because foam processing may lead to uneven distribution and effectiveness of cross-linking. Dwell time is seen to have no significant effect on crease recovery angle of the foam finished samples. Weft crease recovery is seen to be higher than that in the warp direction.

Tear strength

Both application methods reduce fabric tear strength, and foam processing was worse than conventional processing in this respect, probably due to uneven distribution of cross-linking weakening the fabric. Warp direction tear strength was higher than that in the weft direction for all finished fabrics, due to the normal higher strength of warp yarns in a fabric. Dwell time had no significant effect on tear resistance.

Tensile strength

Both application methods reduced the tear strength of the finished fabric to a similar degree. Dwell time had no significant effect on warp or weft tensile strength.

Fabric breaking extension

Both application methods reduced the breaking extension of the finished fabrics to a similar degree. Again, dwell time had no significant effect on this parameter. Breaking extension was slightly higher in the weft direction than in the warp direction, probably due to lower weaving tension and twist level in the weft.

Fabric shrinkage

Both finishing treatments decreased fabric shrinkage: there was no shrinkage in the weft direction in any of the treated fabrics, but there was a small amount of shrinkage in the warp direction. Higher dwell times appear to increase the extent of cross-linking, which could reduce subsequent fabric shrinkage.

Decling time

Both application methods improved the anti-static properties of the finished fabric, in this case to a greater extent when using the foam system. This is probably due to the fact that the foam system concentrates the finish to the fabric surface where it is most effective. The decling time decreased as the dwell time was increased, possibly due to there being a greater time available for surface application to dissipate in the case of a longer dwell time, increasing the concentration of the antistatic finish on the fabric surface.

CONCLUSION

The physical performance of the tandem wet-on-wet foam finished fabric was comparable to that of the conventionally finished fabric, although the former method gave a slightly decreased level of performance in some areas. This suggests that there is a future opportunities for improving the performance of the foam system *via* better control of foam properties and foam processing parameters.

More work needs to be done on the effect of dwell time on fabric performance. Shorter dwell times (below 30 s) will allow for rapid, commercially acceptable tandem wet-on-wet processing if successful in producing fabrics with acceptable levels of performance.

AN ALL NATURAL SLIP RESISTANT & ABSORBENT FIBROUS MATERIAL

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Keywords: coefficient of friction, moisture, absorbent, sweat loss, exercise, yoga

ABSTRACT

PVC-based exercise mats are the de facto standard practice surface for the millions of regular American *hatha* yoga practitioners. The 'sticky mat' provides a lightweight slip-resistant surface in dry conditions. However, this mat has inherent performance drawbacks and longstanding biocompatibility concerns.

'Postures' or *asana*-styles demand different properties from the standard exercise mat. The amount of perspiration generated by practitioners varies by style and athletic ability. In both cases the individual requires a slip-resistant practice surface. Standard foamed closed-cell PVC mats and cotton rugs provide insufficient properties in wet and dry conditions.

This study investigates changes in the ability of a mat to resist slippage upon absorption of water for the PVC mat, cotton rug and a novel slip-resistant and absorbent fibrous material. Dynamic coefficients of friction as a function of absorbed water are examined. The efficacy of each mat to resist slippage with absorbed water is correlated to expected sweat generation during practice. A prior predictive sweat loss response model to metabolic rate, environment and clothing is used.

INTRODUCTION

Polyvinyl chloride (PVC) is a soft material lauded for its inertness and subject to longstanding biocompatibility and environmental concerns. Various plasticizing agents used to modify the polymer behavior of the inexpensive material are also considered questionable. Yet today PVC petrochemicals are the second largest class of thermoplastics spanning the consumer marketplace from plumbing to children's toys.[1–4]

Hatha yoga

PVC found its way into the exercise and sporting goods industry as yoga mats in the 1970s. Hatha yoga 'postures', or *asanas,* comprise a subset of one of the six paths of Indian yoga ranging from devotion (*bhakti*) to knowledge (*jnana*). The word yoga itself translates loosely as 'yoke' or 'union,' describing ways to integrate the physical, mental and spiritual aspects of human existence. This system was most recently brought to the west in the 1950s and 1960s. Subsequently, *hatha* yoga has diverged into many styles catering to many types of practitioners. As of 2002, an estimated 18 million Americans practice some form of *asanas,* or the misnomer 'yoga'.[4]

In India, *asanas* are traditionally practiced on a thin cotton rug or a dirt floor. Yet in the west, practitioners found this material an insufficient means of providing traction that maximizes grip while preventing slippage.[5]

Styles & practice conditions

Numerous styles of *asanas* have emerged since the general yoga diaspora in the mid 20th century. Table 1 outlines popular types associated by physical difficulty. Students experience a range of practice conditions. More vigorous styles create substantial amounts of perspiration. Gentle to moderate difficulties tend to generate less. The amount and rate of perspiration varies by individual, instructor, and style. A typical session lasts for 30 minutes to 2.5 hours and can generate over 1 liter of perspiration.

For those who do not sweat, a synthetic sticky mat gives sufficient traction. For those who perspire even slightly, it offers little to no grip. For vigorous styles, perspiration can be moderate and this group uses cotton rugs. However, when wet the rug yields limited traction and does not resist slipping on smooth floor surfaces.

Table 1. Popular styles of western Hatha yoga[6]

Style	Description
Astanga	Vigorous
Bikram	Moderate, hot
Kundalini	Gentle
Iyengar	Moderate
Sivananda	Moderate
Viniyoga	Gentle
Vinyasa	Vigorous

PVC

Raw, PVC is a hard material that softens and shrinks at relatively low temperatures. A range of degradation mechanisms including thermal, chemical, photolysis, and irradiation yield a variety of often harmful byproducts.[7–12] Most notable are hydrogen chloride and chlorinated benzenes, notably dioxins.[3,13] To alter the behavior of the material, plasticizers such as di(2-ethylhexyl) phthalate (DEHP), diisononyl phthalate (DINP) and heavy metal compounds (lead, cadmium, mercury, zinc, tin & barium) have been used to stabilize and yield a variety of behaviors.[14] Plasticizing agents and products of degradation fuel the regulations for health and environmental concerns surrounding the manufacture, consumption and disposal of plasticized PVC.[15–17]

Regulations

The Delaney Clause of the U.S. Food, Drug and Cosmetic Act of 1958 states, “no additive shall be deemed to be safe if it is found…to induce cancer in man or animal…” Not until angiosarcoma (liver cancer) and what was later labeled the ‘PVC Disease’ were traced to autoclave vinyl chloride workers in the early 1970s did the U.S. Food and Drugs Administration regulate the amount of human contact.[12] A proposed regulation issued in September 1975 permitted continued use of PVC in contact with foodstuffs, “where the potential for migration of vinyl chloride is diminished to the extent that it may not reasonably be expected to become a component of food”.[18]

Table 2. Oekotex 100 Certified, chemical limits of sticky mats by Simply Yoga, London, UK[19]

Attribute	Value
pH	4.0-7.5
Formaldehyde	75ppm
Extractable heavy metals (arsenic, lead, cadmium, chromium, etc.)	92ppm
Mercury	0.02ppm
Pesticides (DDT, Lindane, Hexachlorobenzene)	1ppm
Phenols	2ppm
Organic tins	1ppm
Chlorobenzenes and chlorotoluenes	1ppm
Biocides	*None*
Forbidden flame retardants	*None*

Controversies

One of the more recent controversies surrounding the use of plasticized PVC in consumer products came with DINP in children’s toys. Of particular interest were teething rings imported from China, which contained 40–50% by weight. In early 1997, a Danish ban led to efforts from various EU countries to control or limit toys containing DINP. Greenpeace’s ‘Exeter Report’ of 1997 re-initiated worldwide controversy over the hazards of PVC and compositions plasticized with DINP. After a series of tests by Health Canada, Greenpeace and the National Environmental Trust petitioned the US Consumer Product Safety Commission (CPSC) to ban the material in related applications. Yet effects of low-level exposures for short durations may not induce acute symptoms.[14] As a result, rather than banning, the CPSC issued a request for manufacturers to discontinue production of consumer products containing DINP. In the EU, however, a recent directive phases out or controls the use of DINP in many plasticized PVC toys.

Worldwide production

Despite the controversies, PVC growth continues. The largest growth is shown in developing Asian countries where lack of social awareness and environmental regulations enable its unfettered expansion. In 2002, expected North American production of PVC was 9,350,000 metric tons with a slowing average annual growth rate of 4%. Compared with Asia, 12,920,000 metric tons with a 12% growth rate had doubled capacity in 5 years. In general, usage of PVC continues where lightweight, durable, and economic materials are needed.[2,20]

At single high-dose exposures, many PVC plasticizing and filler chemicals are known or suspected carcinogens. Reactions from chronic low-level exposures are not as well understood.[14] Before an assertion is made about the toxicity of PVC sticky mats, accurately identifying the contents is critical. Table 2 shows tested levels of toxic chemicals in an Oekotek 100-certified sticky mat by Simply Yoga, London, UK. Phthalate and other plasticizers are not included in this test. Toxic contents of other commercial sticky mats are not publicly available. In fact, Hugger Mugger (Salt Lake City, UT, USA), marketer of the most popular PVC 'sticky' mat the Tapas® Mat, makes no public disclosure about the contents, other than it is PVC-based.

Table 3. Absorptive capacity and tested amount of water by mat type

Mat	Mass Cotton (g)	Capacity (mL)	Tested (mL)
Tapas® mat	0	1	0 1
Yoke Mat™	30	100	0 6 12 25 50 100
Cotton rug	65	200	0 50 100 200

MATERIALS & METHODS

Three yoga and exercise mats were used in this experiment: a Tapas® Mat by Hugger Mugger, a Yoke Mat™ by Complete Circle (P.O. Box 1286, Fuquay-Varina, NC, 27526, USA), and a cotton rug by Prana (Vista, CA, USA). The Tapas® mat was composed of plasticized closed-cell foamed PVC. The cotton rug is a weft-faced plain weave cotton rug. The Yoke Mat™ is a proprietary all-natural fibrous material.

A 16.5 cm×61.0 cm piece of each mat was cut and soaked in tap water for 3 hours to establish the maximum absorptive capacity. Mats were tested for slip force at a range of absorbed water from 0 mL to maximum capacity. Table 3 summarizes the capacities and tested amounts.

After the capacity for each mat was established, the mats were allowed to dry for 2 days. The predetermined test water level was evenly applied and allowed to condition for 15 minutes. Once the water was absorbed, the mat was placed on a smooth enamel metallic surface. This simulates the typical wood, ceramic or linoleum floor surface. Concrete and clay bricks were used to apply a specific load over a given area, see Fig. 1. Weight applied varied from approximately 1.6 to 16.8kg. A calibrated spring balance by Chantillon's of New York, ca. 1892 was used to measure the amount of force required to induce mat slippage, or slip force *(FS)*, see Fig. 2. Once all measurable loads for the given absorbance were completed, water was again evenly added such that the total water added equaled the next test level. This iterative cycle was completed once the total capacity was reached.

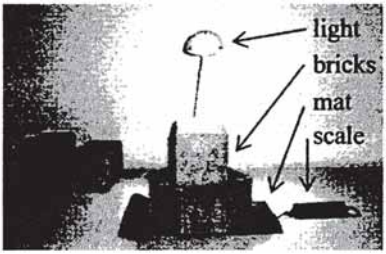


Figure 1. Slip force Measurement Setup

Figure 2. Scale

RESULTS

Linear models fit well for each slip force by load curve. The slope is effectively the dynamic coefficient of friction. Plots of F_S by load show different trends for each mat, Figs. 3–5. Table 3 shows slope coefficient, y-intercept and r-square coefficient of determination. Structural and surface changes with absorbed water as well as experimental variation account for the nonzero and negative intercepts. Analyses indicate strong correlations.

The slip force for the Tapas® Mat significantly decreased with small applications of water. The mat itself tears when pulling under high loads. Since the mat absorbs no surface water, a film is produced with application of 1mL of water. Additional water yielded no further reduction in slip resistance. The slip resistance of the cotton rug increased to an observed maximum at 100mL water. Both 50mL and 100mL showed similar curve trends. At the 200mL level, the slope decreased, albeit 70% higher than when dry.

The slip force for the Yoke Mat™ shows a wider range of response depending on the load and level of water. Up to 25mL, small levels of absorbed water show a higher resistance to slippage than wetted PVC. The slope decreases with larger amounts of water.

Each mat shows a similar threshold slip force of approximately 70 N at the maximum load of 770 kg.m^{-2}. Fig. 6 shows slip forces for all mats at and above 70 N. For the Tapas® Mat, the threshold force is a minimum. For the cotton rug, it is a maximum. The Yoke Mat™ shows an intermediate threshold at 70 N.

The results of the linear fits for the slip force versus load curves were plotted against the water-to-cotton mass ratio. Figs. 7–9 show the plots of F_S-by-load linear-fit coefficient by mass ratio. For the Tapas® Mat and Yoke Mat™, the coefficient of friction decreased steadily with more absorbed water. The Yoke Mat™ showed a larger range of effective slip force resistance. The rug showed a peak force just under 2:1 mass ratio.

Figure 3. Slip Force by Load, Tapas® Mat

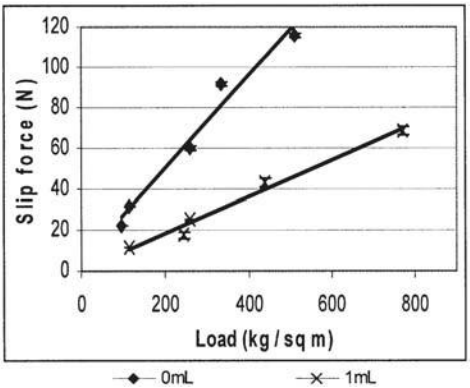


Figure 4. Slip Force by Load, cotton rug

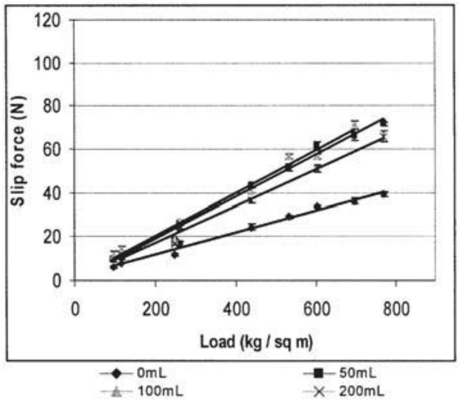


Figure 5. Slip Force by Load, Yoke Mat™

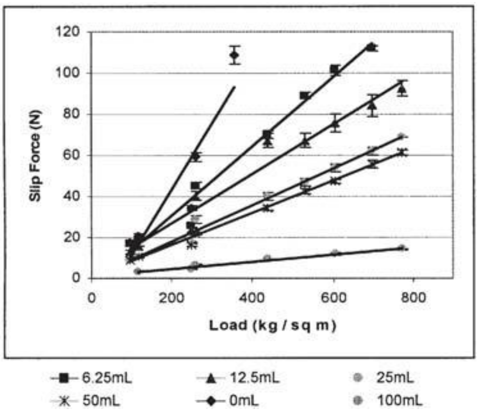


Figure 6. Threshold Slip Forces by Load

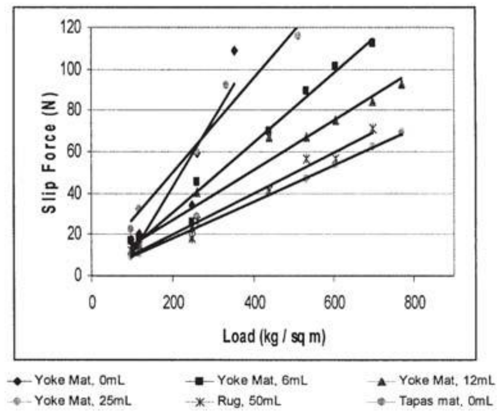


Figure 7. Tapas Coeff Fit

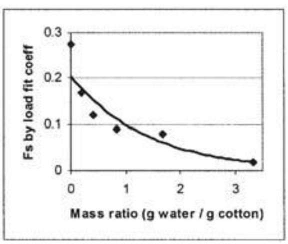


Figure 8. Yoke Coeff Fit

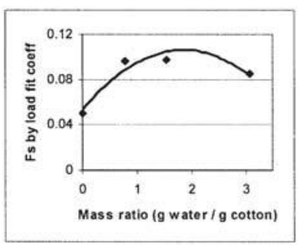
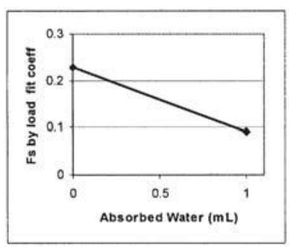


Figure 9. Rug Coeff Fit



DISCUSSION

The commercial success of the Tapas® Mat is due to its demonstrated ability to resist greater slip forces than a wetted cotton rug. This property is advantageous both as a secure foundation on smooth floor surfaces and by providing traction for the practitioner. In a comparison at absorbed water levels of 25% capacity, the basic Yoke Mat™ resists larger slip forces than a cotton rug and wetted Tapas® Mat. The Yoke Mat™ offers resistances to slippage above the threshold at water levels up to 12%.

Table 4. Linear correlations of slip force by load

Mat	Absorbed water (mL)	Coefficient	Y-intercept	R-square
Tapas® Mat	0	0.2293	3.8840	0.9692
	1	0.0899	0.3196	0.9867
Cotton rug	0	0.0499	1.8380	0.9870
	50	0.0971	-0.7411	0.9897
	100	0.0982	0.3191	0.9753
	200	0.0845	0.1391	0.9885
Yoke Mat™	0	0.2745	-8.8784	0.8465
	6	0.1680	-3.0191	0.9788
	12	0.1204	2.8027	0.9625
	25	0.0886	0.4124	0.9877
	50	0.0787	0.2672	0.9948
	100	0.0174	1.1475	0.9789

In order to evaluate the viability of the slip-resistant and absorptive fibrous material in practice, an assessment of conditions and expected sweat rate is necessary. The experiments of Shapiro, et al[21,22] show actual and predicted sweat loss rates for various exercises, environments and clothing for 34 heat-acclimated males. The model adjusts previous models for additional interactions and more accurately predicts sweat loss.

While a majority of yoga practitioners are female, this model provides a framework to extrapolate sweat loss. The study correlates such human parameters as age, weight, height, body surface and body fat with environment conditions of temperature, relative humidity and convection with thermal insulative values of clothing ensembles. Exercise conditions consisted of walking at a speed of 1.34 $m\text{-}s^{-1}$. For the purpose of yoga, the clothing value for shorts is applicable.

The environmental and exercise conditions closely representing the styles of yoga is shown in Table 5. Sweat loss is approximate and adjusted as amounts depend on the individual's athletic ability. The amount of sweat reaching the mat is further dependent on the evaporation rate. In order to compare the actual values for the absorbed water levels in a mat, the sweat loss must be taken in proportion of the body surface area in contact with the mat. This does not apply for heavy perspiration rates where drips are formed. At these levels, rate of transfer of moisture to the mat increases, as does the amount absorbed by clothing. For vigorous conditions, the sweat loss is decreased by the surface area covered by shorts, which compensates for body area whose sweat is absorbed by the shorts. The surface area of mid-thigh-length shorts is 12.01%.

Based on the size of an average western female body, the surface area of hand and foot is 0.009677m^2 and 0.01742m^2. The total surface area is 0.05419 or approximately 5.42% of total body surface area. Using this ratio, the amount of expected moisture directly transferred to the practice surface is calculated as a fraction of the non-evaporated sweat loss. In the studied form, the Yoke Mat™ more effectively resists slipping than the PCV mat and cotton rug at water levels above 12.5mL. This corresponds to an absorption rate of 125 mL.m-^{2}, which is range a large portion of practice styles and athletic abilities.

Table 5. Sweat rate† by style and moisture absorption

Asana Style	Description	Non-evaporated Sweat loss ($g \cdot m^{-2} \cdot h^{-1}$)	Moisture Absorption for Practice Surface ($mL \cdot m^2$)
Astanga	Vigorous	25 – 560	6.0 – 151.8
Bikram	Moderate, hot	580 – 932	157.2 – 252.6
Kundalini	Gentle	0 – 50	0 – 13.5
Iyengar	Moderate	0 – 126	0 – 34.1
Sivananda	Moderate	0 – 126	0 – 34.1
Viniyoga	Gentle	0 – 50	0 – 13.5
Vinyasa	Vigorous	25 – 560	6.0 – 151.8

† modified from *Shapiro, et al*[21,22]

CONCLUSIONS

The technical applicability of the Tapas® Mat is demonstrated in Fig. 6 for the adjusted sweat loss rates during a one hour course. The slightly-moist conditions of many practitioners require a slip force above the threshold. Yet, both the PVC mat and cotton rug fail to provide adequate slip resistance. Most practice in slight to moderate levels of absorbed perspiration, and the Yoke Mat™ provides an effective and all natural solution. Vigorous routines of seasoned practitioners may also fall into an effective range. Material selection and fabrication specifications will address this deficiency and may significantly improve the slip force at lower loads and higher water levels.

In general, the health and performance motivations for a machine-washable and dryable all-natural slip-resistant and absorbent fibrous material are shown. Effective coefficients of friction for three mats at different levels of absorbed water define the performance areas. The Yoke Mat™ offers resistance to slippage for most *asana* styles.

FUTURE WORK

The design of the Yoke Mat™ was not optimized for structural and surface changes due to swelling. High performance materials may also be chosen to enhance the overall properties of the material. The fibrous material may find other consumer and industrial applications where slip resistance and water absorption are desired.

ACKNOWLEDGEMENTS

The author extends his gratitude to Chris Moses of the Institute of Textile Technology for editing this manuscript, Beryl Bender Birch and Stan Woodman of The Hard & The Soft Astanga Yoga Institute for their *asana* styles discussions, Prana and Forrest Yoga Circle for support, and the International Sivananda Yoga Vedanta Centres of Woodbourne and NYC, NY for their superb intensive 6-month training in *asanas, karma* yoga and Vedanta.

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LASER AND DEVORE

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ABSTRACT

This paper will discuss the printing process popularly known as devore and will highlight the problems associated with the disposal of residual dyes, chemicals and waste products, generated as possible pollutants to the water course, by this process. A comparison of conventional printed devore will be made with an environmentally responsible futuristic devore effect achieved through laser technology.

Keywords: Laser, Devore, environmental, substrates.

THE IMPETUS

Environmental legislation and the attendant regulatory pressures pertaining to waste management are felt throughout the world of textile production.

It is a recognisable fact that the world of fashion is not a knowledge-based industry, and, in general the contemporary fashion designer is less concerned, often unaware, of the negative effects to the environment created by their design decisions, the problems associated with textile production are largely ignored the philosophy being: 'after all it is someone else's problem'.

This attitude begins, and is often fostered, through the print and design training that U.K. students receive at college and university. Within the majority of these courses there is no attention given to the disposal of residual dyes or chemicals that remain after a printing process. It is to be noted that in general, interdisciplinary textile cross-fertilisation within the textile disciplines at university level, although much desired, is more often than not impossible to achieve. It is not surprising therefore that graduating fashion designers have no concept of textile production or how the subsequent realisation of the desirable fabrics they order for garment collections happens.

DEVORE

There is a saying prevalent within print education: 'if you cannot do it… devore it'. Good print is difficult to master and achieve, the suggestion being: devore always looks goods, even as a simple stripe and spectacular effects are possible when combining multiple design solutions. But, the print process commonly known as "Devore" or "Burn-Out" is a particularly renowned pollutant, not only does the process generate chemical and colour waste it also generate large quantities of fibrous sludge.

The devore process works by chemically destroying one fibre or more in a bi-component or multi-component substrate, generating effects that resemble lace and creating textiles with different degrees of translucency, transparency and opacity. It is a misnomer to think this process is a 'cheap and cheerful' alternative to conventional print, it is not, the chemicals and dyes employed for manufacture combined with the energy hungry processes reliant upon steam, dry, bake and repeated wash-off combined with the labour intensive printing action ensures a high price end product.

All print departments within educational establishments have their own set of recipes for student application. The following two recipes for devore are typical of such print related handouts.

DEVORE PRINTING RECIPES.

RECIPE 1: DEVORE OR BURN-OUT PRINTING

Fabrics: Silk/viscose; polyester/cotton; nylon/viscose.

Devore or burn-out printing produces a 'Lace' effect of transparent/translucent areas and opaque areas. It relies upon one of the fibres being degraded by components in the print paste leaving the other fibre as an open network. Experimentation is needed to achieve good results.

Recipe:

500	grams	Thickening 301
20	grams	Glycerine
150	grams	Aluminium sulphate
40	grams	Tartaric acid
290	grams	Water
1000	grams	Litre of print paste.

Method:

1. Weigh out thickening 301, water and glycerine into a plastic pot.
2. Weigh out the aluminium sulphate and tartaric acid. Add to the plastic pot and mix well on a high-speed mixer.

PRINT ..... DRY..... BAKE..... RUB-OUT ..... WASH ..... DRY

Printing:

Make sure that the print paste penetrates the fabric well.
For velvet fabrics print on the back of the cloth not on the pile. This needs to be taken into consideration when making screens, as any design will come out back to front. The number of pulls you will require will vary depending upon your strength, and the type of screen used, but you will need at least six pulls.

Baking:

Bake at 170 °C for 5 minutes until the cellulose turns brown/black in colour.

Rub-out:

Rub-out as much of the burnt-out cellulose as possible before washing the fabric.

It is important that the a vacuum cleaner is used to suck up the loose fibres and a face mask and gloves are worn for protection.

Washing off:

1. Wash in warm water with detergent until clear of all burnt areas.
2. Rinse well in warm water.

RECIPE 2: DEVORE OR BURN-OUT PRINTING

Fabrics: Wool blends; wool/polyester; wool/cotton.

Devore or burn-out printing produces a 'Lace' effect of transparent/translucent areas and opaque areas.

It relies upon the wool fibres being degraded by the sodium hydroxide in the print paste leaving the other fibre as an open network. Experimentation is needed to achieve good results.

Recipe:

750	grams Solvitose thickener
50	grams Sodium hydroxide Pellets
200	grams Cold water
1000	grams Litre of print paste

Method:

It is necessary to wear full protective clothing when preparing, printing and washing off: goggles, rubber gloves, long sleeved overall.

1. Very carefully weigh out the sodium hydroxide pellets and add them very slowly to the cold water in the plastic pot. This process produces a large amount of heat so allow too cool in a safe place. Label the container clearly to avoid any accidents.

2. Weigh out Solvitose thickening into plastic pot.

3. Very carefully and slowly add the cold Sodium Hydroxide to the Solvitose, mixing well.

4. Label the container with the correct hazard warning label and put in a safe place until it is used for printing.

PRINT ..... DRY ..... STEAM ..... WASH-OFF ..... DRY

Printing:

Wear goggles, gloves and a long sleeved overall. Make sure that the print paste penetrates the fabric well. The number of pulls you will require will vary depending upon your strength and the type of screen used: but you will need at least six pulls. Wash screen.

Very carefully label areas of printing to warn others of the dangers of caustic burns while the print dries.

No mention is made of eventual waste disposal and experience proves that the number of print students who adhere to such health and safety guidelines suggested within these hand-outs is negligible.

The textile practitioner

Janet Stoyel is a practicing artist and practitioner in the applied arts, she owns and operates a small, successful decorative textile business, established in 1994, The Cloth Clinic, and has a fractional post as a Senior Research Fellow at the University of West of England, Bristol.

Personal ethics

As a research practitioner investigating: Fabric Finishes and Treatments for Apparel and Interior Applications, whilst studying for a Master of Philosophy degree, at the Royal College of Art, London, in 1992–94, environmental concerns arose, regarding the safe disposal of textile generated waste in the form of chemicals and dye effluent. Subsequent research showed it is practically impossible to remove **ALL** such potentially polluting substances from the water chain. This fact prompted in depth research and the hunt for a technology that would preclude the use of dyes, chemicals or wet processes for the creation of permanent patterning and decorative effects, and, which would perform in what was deemed to be an environmentally responsible manner. A search for a technology which would be ecologically sound and energy efficient, which would be capable of creating fully-recyclable textiles without and extraneous fibre, yarns, threads, equipment and tools to eventually become recognised pieces of acceptable textile machinery.

It became a matter of personal concern, whilst researching textile finishing, printing in particular, the sheer quantities and volumes of textile waste and effluent generated by student activity. Research has shown that government legislation is firmly in place for the disposal of industrial textile wastes and effluents, but, small non-commercial establishments with lower quantities of such matter are not regulated and as such almost all effluent and waste is released directly into the drains, sewage system and water courses.

If a university has a three-year course with twenty print students per year printing, a considerable amount of waste is released slowly into the waterways system and so manages to avoid legislation and controls for waste. Magnify this number of students in an area such as Greater London with its plethora of colleges and universities offering print courses, include the graduate textile printers who establish workshops in the surrounding area and the levels of textile effluents rises considerably, and, as such may even rival industrial output and be worthy of legislatory action.

The fact that the devore print process produces so much damaging effluent and yet is considered to be so very beautiful, desirable and costly when applied to fashion items is a complete paradox and was the final deciding factor in the search for a new clean and economical technology.

Lasers

Laser is acronym for: Light Amplification by Simulated Emission of Radiation.

Lasers are not new and have been used in many applications, including the Ministry of Defence for many years. In this instance what is new is the application to which they are being directed. Working in close collaboration with a UK-based company who manufacture laser optics for a missile firing system on the Challenger tank, and after intense sampling of numerous base substrates over a two year period, a personally designed and commissioned laser system was subsequently developed and installed in the workshop premises, of The Cloth Clinic, in the Blackdown Hills of East Devonshire.

Substrates

Exhaustive sampling to determine the perfect mix of synthetic components with which to create the ultimate effects required for commercial viable, comfortable, wash-and-wear product, resulted in engineered-base substrates combining intimate blends of polyester and polyamide being manufactured by a collaborating French weave concern. To dispel myths and misconceptions pertaining to polymeric exclusivity for laser processing, it must be noted that base substrates other than thermoplastic **are** suitable for laser processing, the final decision regarding the type of base substrate, its fibre composition and integral structure are reliant upon end use application.

The laser is capable of producing an effect very similar to devore effects whereby part of the surface of a substrate is abraded by a single or multiple high-speed laser heads, leaving a transparency and translucency similar to the print effects of chemical degradation by devore. The laser 'burn-away' effect is practically instantaneous, different levels and depths of erosion are feasible and detailed three-dimensional effects may be easily achieved. Designs are generated via digital camera, subsequently grey-scale techniques are readily achievable. The laser process generates minimal dust; this dust is extracted through a fume extraction system complete with air filter guards. The equipment is computer controlled and includes a comprehensive self-registration system to ensure perfect accuracy. The laser is a low energy, 10 watt, sealed unit and works from a single-phase electricity supply. Running cost is minimal balancing, out the expensive initial outlay for capital equipment acquisition. Many different types of substrate may be processed, substrates as sheer as polyester chiffon and as coarse as corduroy have processed successfully.

Product

The textile product from conventional devore, created by the print-based process, is soft and fluid and it often incorporates dyed and printed pattern. A silk and viscose velvet substrate is the most popular base material for luxurious fashion garments and scarf accessories. The finished articles require careful handling and need dry-cleaning. The print process is also popular for furnishing fabrics on cotton or linen mixed fibre substrates when the finished article is used to create room dividers, curtain and window treatments, and such end uses maximise the transparency/opacity characteristics of the process.

Laser devore on the other hand may consist of any type of substrate base. It is not necessary to create mixed fibre blends to 'burn-away' one or more of the fibre components, since the sensitivity of the technology allows partial degradation of the textile surface to be achieved. Handle and drape characteristics are generally reliant upon the base substrate selected. It is also possible to intensively process a stiff-coated base substrate in an all-over format thereby removing most of the surface dimension to produce a completely different material from the original. The laser devore effects are particularly striking on leather and suede-base substrates. Dependent upon textile properties, these laser devore materials may be easily labelled, wash and wear.

CONCLUSION

It is an irrefutable fact that devore is popular with fashion designers, it is also popular with the textile buying public. Devore, as a fashion fad, resurfaces approximately every ten to fifteen years; would it prove so popular next time it is reinvented if more information pertaining to the potentially hazardous environmental consequences of its manufacture were public knowledge?

Will this cyclical time span be sufficient to realise the creation of base substrates and dyes completely compatible with digital printing technology

The particular laser system currently used for processing is not capable of printing colour, but, with the advent and subsequent fast development of digital printing systems, it is only a matter of time before some enterprising agency combines the two technologies and a cleaner more efficient method of producing a full devore competitive product is realised, making it feasible to print without pre-coating base substrates and abandon the process of steam fixing inks.

Digital print technology and textile laser technology are still in their infancy, but the future looks promising for collaborative digital technology ventures, these in turn should revolutionise textile education, blurring the boundaries between textiles disciplines and producing multi-skilled practitioners. And, perhaps a new genre of devore.

CELLULOSE—PROTEIN TEXTILES: UTILISATION OF SERICIN IN TEXTILE FINISHING

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ABSTRACT

Sericin was used for cotton textile finishing in pad-dry-cure process. By means of Fourier Transform Infrared spectroscopy-Attenuated Total Reflectance (FTIR-ATR), fixation reactions of sericin on fabric surface were investigated. Estimation of sericin extent on fabric surface was performed using Supranolechtbordeaux B acid dye. The greater K/S values were observed for the samples treated with greater concentrations of sericin in finishing solutions. Variations in amount of sericin on fabric surface affected free formaldehyde content, crease recovery angle and water retention properties. With increase in concentration of sericin, free formaldehyde content and electrical resistivity of the samples decreased while crease recovery angle insignificantly increased with certain amount of sericin. The textile treated with sericin shows good wear properties and the finishing process is considered as a technique for protein fixation on the surface of cellulose textiles.

INTRODUCTION

Sericin has been currently exploited in many applications such as cosmetics, separation membrane, supplementary food and medical materials.[1] Modified fibres with sericin have been invented.[2–4] Its prevention in abrasive skin injuries and rashness has also been investigated.[3–4] N,N'-dimethylol-4,5-dihydroxyethylene-urea has been used as crosslinking agent for cotton fabrics in pad-dry-cure process[5–6], and the correlations between physical properties and dye ability of treated fabrics, and sericin content in finishing solution have been reported. However, permanent fixation of sericin on fibre surface has not been yet mentioned.

In this investigation, sericin was used to modify cotton fabric surface. The existence of sericin on fabric surface was analysed using FTIR-ATR. The treated fabrics were dyed with Supranolechtbordeaux B acid dye, amount of sericin on fabric surface were evaluated using the K/S function. Changes in free formaldehyde, crease recovery angle and electrical resistivity of the samples treated with various amount of sericin were evaluated.

EXPERIMENTAL

Preparation of treated fabrics

Finishing solutions containing chemicals as shown in Table 1 were prepared. 140×30 cm of woven twill, mercerised, and bleached cotton fabric was padded on a laboratory padder containing finishing solution, and then dried in laboratory dryer regarding to manufacturer recommendation. Each treated fabric was cut into two halves. One was retained without further treatment while another was washed with distilled water at 70°C for 30 min (liquor ratio of 1:50).

Table 1. Finishing solution recipes

Sample code	Component			
	Sericin (g/l)	DMDHEU-based reagent (ml/l)	Magnesium chloride (g/l)	60% Acetic acid (ml/l)
UT	-	-	-	-
0 (blank)	-	40.0	10.0	1.0
2.5	2.5	40.0	10.0	1.0
5	5.0	40.0	10.0	1.0
10	10.0	40.0	10.0	1.0
25	25.0	40.0	10.0	1.0
50	50.0	40.0	10.0	1.0

Characterisation of fabric surface

FTIR-ATR was used to characterise surface of washed-treated fabrics and sericin powder. DMDHEU-based reagent was padded on KBr disc and characterised using FTIR.

Estimation of sericin content on fabric surface

Treated fabrics were dyed with a 2.5% (owf) solution of Supranolechtbordeaux B acid dye at a liquor ratio of 1:50, at pH 3.1, for 30 min at 60°C. After drying at room temperature, reflectance of dyed fabrics was measured at 541 nm on a Pye Unicam SP 8–100 double beam spectrophotometer with diffuse reflectance sphere 0°/d. Changes in sericin content on fabric surface were evaluated using K/S_{corr} values as calculated from equation 1.

$$\left(\frac{K}{S}\right)_{corr} = \left(\frac{K}{S}\right)_{sample} - \left(\frac{K}{S}\right)_{blank} \qquad (1)$$

Determination of free formaldehyde content

Content of free formaldehyde from freshly treated samples was determined according to LAW112.[12] 1 g sample was extracted with 100 ml of distilled water in closed bottle at 40°C for 1 hr. The extract was then filtered. 5 ml of aliquot was added to 5 ml of reagent prepared from 15% (W/V) ammonium acetate, 0.2% (V/V) acetylacetone and 0.3% (V/V) glacial acetic acid, and the mixed solution was kept at 40°C for 30 min. Absorbances of solutions were then spectrometrically measured at 412 nm. Formaldehyde content was obtained using a calibration curve constructed with defined amounts of formaldehyde.

Determination of crease recovery angle

Crease recovery angle (CRA) of the samples were performed according to DIN 53890 at 5 and 30 min. CRA of specimens in warp and fill directions was measured separately, CRA° (W+F) of specimens was reported.

Determination of electrical resistivity

Electrical resistivity of treated fabrics was measured using a Teraohmmeter (Siemens, 7 KA 1100). The samples were placed between two plate electrodes of 11 cm diameter, electrical resistivities of the samples were measured at a constant voltage of 100 Volt.

A set of identical determinations was conducted on untreated sample, which was treated as control. All samples were conditioned in a standard atmosphere of 65% RH at 20°C for a minimum of 48 hr prior to determination.

RESULTS AND DISCUSSION

Fixation of sericin on fabric surface

Figures 1 and 2 show FTIR-ATR absorbance spectra of treated cotton fabrics and finishing agents (DMDHEU-based reagent and sericin) respectively. When cotton fabric was treated with DMDHEU-based reagent alone, a peak appears at 1706 cm^{-1} as seen in Figure 1 (a). This peak corresponds to ν(C=O) in DMDHEU-based reagent as compared with FTIR spectrum of DMDHEU-based reagent in Fig. 2. These peaks show stable intensity shifts to 1695 cm^{-1} in spectra of cotton fabric treated with DMDHEU-based reagent and various amount of sericin because of reactions between DMDHEU-based reagent and sericin. In Figures 1 (c), (d) and (e), additional absorption bands appear at 1745, 1652, 1540–1520, 1457 cm^{-1}. These bands correspond to ν(C=O) of generated ester group from crosslinked reaction, and ν(C=O), δ(N-H) and ν(C-N) in sericin, respectively. From FTIR results, it was proved that DMDHEU crosslinked cellulose and sericin chains in the pad-dry-cure process. Besides the cellulose crosslinking operation, fixation of sericin occurred by chemical bonding to cellulose.

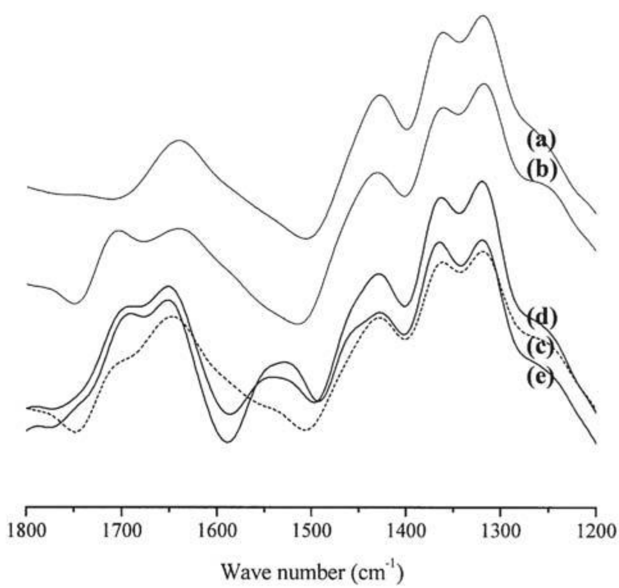

Figure 1. FTIR-ATR absorbance spectra of untreated fabric (a), fabrics treated with DMDHEU-based reagent alone (b) and with combination of DMDHEU-based reagent and sericin 10.0 (c), 25.0 (d), 50.0 g/1 (e).

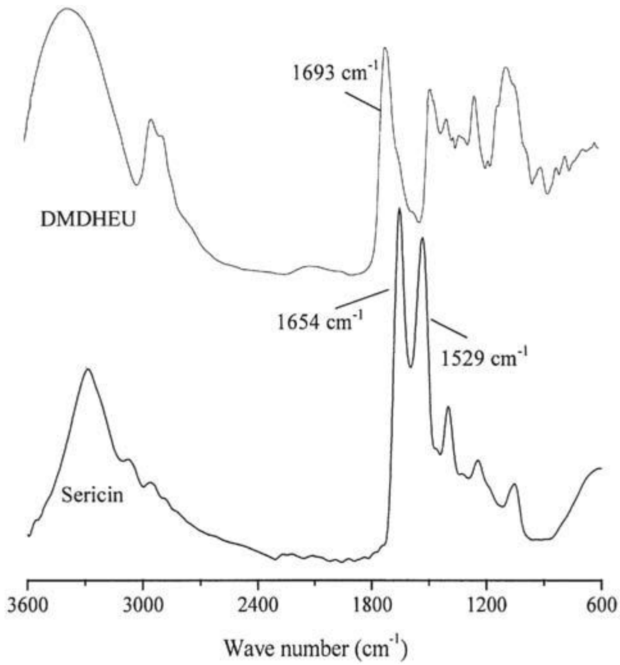

Figure 2. FTIR absorbance spectra of DMDHEU-based reagent (on KBr pellet) and sericin powder (FTIR-ATR).

Content of sericin on fabric surface

Table 2 shows K/S values of dyed samples. Samples treated with the DMDHEU-based reagent alone lowered K/S from the value of untreated cotton. Increase in concentration of sericin in finishing solution is assumed to relate to greater sericin content on fabric surface. Therefore, increase in K/S_{corr} with sericin content was observed as shown in Figure 3. K/S_{corr} values of unwashed samples were comparatively less than those of washed due to hydrolysis of sericin during dyeing.

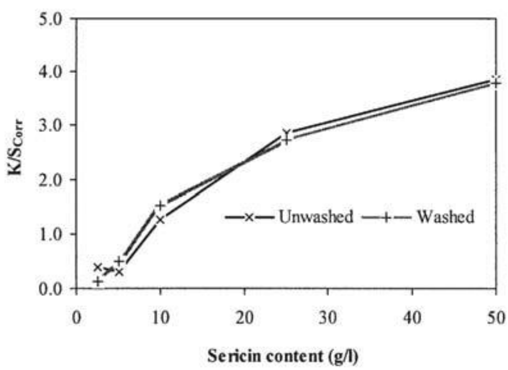

Figure 3. Relationship between K/S_{corr} of dyed samples and concentration of sericin in finishing solution.

Formaldehyde content

Table 2 shows formaldehyde content in freshly treated samples. Dramatic lowering in formaldehyde content was observed for the samples treated with greater concentrations of sericin. Very low amounts of formaldehyde at 40 and 50 ppm are found for the samples treated with 25 and 50 g/l of sericin, respectively.

Crease recovery properties

CRA (Warp+Fill) of unwashed and washed samples were comparable as seen in Figure 4. The values of the samples treated with DMDHEU-based reagent dramatically increased compared to untreated control. Increase in sericin concentration on the sample surface affected CRA insignificantly. Although a slight decrease was observed when sericin >25 g/l was used.

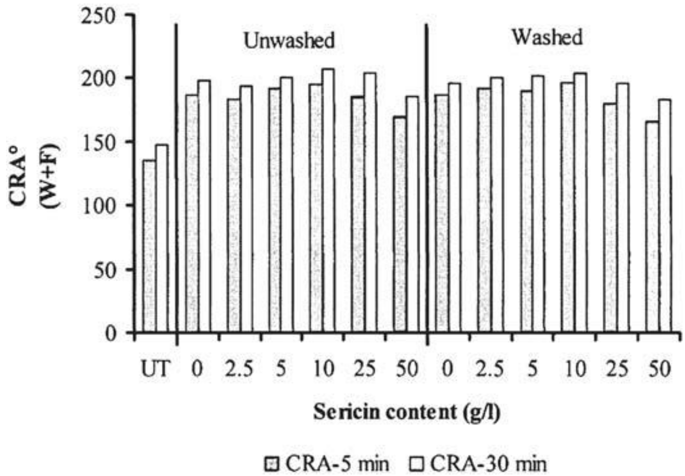

Figure 4. Crease recovery angle (Warp+Fill) against sericin content in finishing solution.

Table 2. Properties of unwashed (UW) and washed (W) samples

Sample code	K/S		Free formaldehyde (ppm)	Electrical resistivity ($\times 10^7$ Ohm)	
	UW	W		UW	W
UT	1.26	-	-	123.3	-
0	1.08	0.75	161	20.8	1112.3
2.5	1.47	0.89	123	14.0	1300.0
5	1.38	1.25	95	15.0	1166.7
10	2.33	2.27	82	17.2	1296.7
25	3.81	3.60	40	6.03	95.3
50	4.86	4.60	50	7.7	80.0

Electrical resistivity

Electrical resistivity of untreated sample was intermediate between unwashed and washed samples. The values of unwashed samples were much less than those of washed samples as the presence of conductive hydroscopic substance; magnesium chloride. In comparison with washed samples, electrical resistivities remarkedly decrease with greater amounts of sericin present on fabric surface.

CONCLUSION

Sericin was successfully crosslinked on fabric surface using a common finishing agent; a DMDHEU-based agent. Sericin was present on fabric surfaces as there were crosslinking reactions between DMDHEU, sericin and cellulose occurring during paddry-cure process, which was analysed using FTIR-ATR. Elevation in amounts of sericin on fabric surface lowered formaldehyde content and changed fabric properties. Electrical resistivity of treated samples decreased with increasing sericin content while crease recovery angle only slightly changed with certain amounts of sericin.

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