Removal of Spa Oil Stains from Cotton and Lyocell Sheets as Assessed by Reflectance Analysis

Andrew Duckworth and Alexander Papiez

andrew@idealmanufacturing.com
Ideal Manufacturing Ltd., Atlas House, Burton Road, Finedon, Wellingborough, NN9 5HX, UK

Abstract

Bedsheet fabrics used in wellness and spa sector are often exposed to staining by spa oils, which could lead to early exclusion of the fabric in case of permanent staining, or due to damages by repeated bleaching. In this study, the removal of spa oil from lyocell and cotton bedsheets after an industry-typical washing process was investigated by the means of reflectance analysis of the stained surface, showing apparent better removal of spa oil from lyocell bedsheet than from regular cotton.

Introduction

Spa Oil Application

A representative component for a typical spa massage oil is grapeseed oil [1]. Being a non-volatile unsaturated triglyceride, if deposited on fabric and not removed or decomposed it will, in theory, most likely persist as a liquid. Over time, it may oxidise or polymerise to form stiff inclusions within the fabric.

On fabrics, liquids that wet the fibres can wick substantially by moving between and through the fibres until the interfacial and capillary forces that push the wicking process come to balance [2, 3]. All in all, for a finite volume deposited on a large area of fabric, wicking slows over time. By allowing a dose of oil to spread through a fabric until wicking has effectively ceased, the fibre and oil approach a state of interfacial and capillary equilibrium, essentially ensuring that, barring the effects of the wash on interfacial tension, the liquid oil remains relatively localised.

Equilibration is an essential process also because continued wicking therefore indicates an excess of oil. In some sense, during wicking the oil is not optimally supported by the fibre and it is oversaturated. The excess oil is the most trivial to remove because wicking is the process of seeking a more stable state, and the effective fraction of oil not seeking this is relatively stable. Ergo any oil load must be allowed to equilibrate.

Washing Process

As oils frequently spread to cover other materials, a typical wash process begins by stripping the bulk of oils and fats with an emulsifier to expose other soils. These are hydrated by the main detergent load, which continues to emulsify some residual fats to a certain degree while the mechanical action of the wash breaks apart the soils. The detergent, as well as any suspending agents and continued mechanical action, together help suspend the soils so they do not redeposit. Any remaining soil traces on the fibre are bleached to make them colourless to the naked eye before a softener is deposited on the fibre to restore the skin-feel or other mechanical properties of the fabric. Any residual chemicals are then rinsed away, and the process is complete.

Reflectance, Vision & Oil

While the term "reflection" usually invokes the idea of mirror-like objects, *diffuse* reflection is the matte-effect: the scattering of light [4]. Most simple everyday objects show some combination of both. Fabrics are good diffuse reflectors because they contain a high proportion of tiny surfaces to cause chaotic reflections that add up to diffuse reflection. When a colourless liquid such as water or oil wicks into a white fabric such as cotton, it appears darker or greyer (or brighter, if held up to a light) because it is more transparent: the air spaces in the fibre are filled with liquid, reducing the efficiency of those reflections so that light passes through instead of being reflected. Reflectance is a measurement of the relative intensity of light that is diffusely reflected from a surface. By measuring the reflectance at a set of wavelengths relative to some standard material, we obtain a reflectance spectrum.

The CIELAB unifying colour space breaks colours down into three component axes of human perception: L (lightness scale), a (green-red axis) and b (blue-yellow axis). The value of L, for colourless or near-colourless materials ($a \approx b \approx 0$), corresponds almost perfectly to its reflectance [5]. For white, grey and black materials, a reflectance spectrum will appear flat, measuring a constant (or near-constant) value of reflectance in the visible range of wavelengths. Therefore, when measuring the reflectance of white fabrics with and without oil, the reflectance directly quantifies the perceived lightness of the fabric and, consequently, the perception of cleanliness.

The means to convert between several colour measurement scales, including Lab and RGB, are well known and readily available in a variety of software packages, many of which are free. Therefore, in imaging, we can convert standard RGB images to Lab-approximation images and, extracting a monochrome image of L, begin to visualise impact.

Materials

Fabric bolts were provided by Lenzing. The fabrics are described in table 1.

Table 1: *Fabrics used for the study.*

Name	Description	/g m^{-2}
Cotton 100%	100% Cotton, bleached, mercerised, non-brightened fabric	130
Lyocell 100%	100% Lenzing Lyocell, non-brightened fabric	130

Experimental

Spa Oil Application

Grapeseed oil (0.5 ml) was applied along one short edge of a 5 cm by 20 cm swatch of each fabric and allowed to spread and equilibrate for 30 minutes. In this way, the oil was found to spread over no more than one half of the overall surface area of the fabric. The "oil-free" end of the fabric was a hemmed edge for reference.

Washing Process

All steps of the washing protocol maintained a constant dip level and mechanical action in a Girbau HS6013 industrial washing machine. Dummy load was 4.06 kg white PET, cottons and polycottons.

The washing and drying parameters are listed in table 2.

Table 2: *Parameters for drying and washing.*

Stage of Wash	T (°C)	T (s)	Chemicals	Notes
Emulsifier to Strip Oil	60	600	Premium Emulsifier, 15 ml/kg.	—
Main Detergent Wash	45	600	Atlas Pro, 15 ml/kg.	—
Peroxide Bleach	60	600	Hydrogen Peroxide, 10 ml/kg.	—
Softener	Ambient	300	Simply Soft, 10 ml/kg.	—
Rinse & Spin	Ambient	300	—	Spin cycle, max spin 60 s.
Rinse & Spin	Ambient	300	—	Spin cycle, max spin 300 s.

A Girbau ED340 industrial dryer ran for 30 minutes at an outlet temperature of 70 +/– 5 °C for 25 minutes to dry the load after each wash.

Reflectance Measurement & Analysis

An OceanOptics Maya2000Pro USB fibre-optic spectrometer was coupled to a HS2000 standard broadband white light source through a bespoke non-contact reflectance head. The spectrometer was controlled in MATLAB® with bespoke software. The reflectance standard was fused Teflon.

Reflectance spectra of fabrics were collected for pre- and post-wash samples. Relative reflectance is reported relative to a sample's oil-free region.

The mean reflectance value in the 750—795 nm region of the spectrum was chosen to represent the overall reflectance of a spectrum. The degree of recovery W = 1 – ((1-P)/(1-B)), where P is the post-wash relative reflectance of oily fabric and B is the baseline pre-wash relative reflectance of oily fabric. Thus, W takes values from 0—1 where 0 represents complete oil saturation and 1 represents levels of oil comparable to a blank.

The values of P and B directly convey the apparent brightness of an oily spot on fabric relative to its unstained surroundings.

Dye Contrast Photography

After washing treatments, fabric was dyed in a 1% aqueous solution of C.I. acid green 25, a water-soluble sulfonated anthraquinone dye, for 10 minutes before rinsing clear in deionised water and hanging up to dry. This dye has affinity for cellulose and is capable of dyeing fibre in spite of oil coverage, as demonstrated by the levelness of the dye after stripping the oil content with chloroform. It is insoluble in grapeseed oil, chloroform and mixtures of the two. The dye exacerbates the visual appearance of oil stains.

An oil-free section of the dry, dyed fabric was saturated with oil and the whole of each swatch was photographed under a halogen lamp shining through a white Teflon sheeting diffuser. The camera used a static white point and fixed ISO (automatic white correction disabled). The workup took place in GNU Image Manipulation Program 2.10.12. For the purposes of illustration, images were internally white-level-corrected using a mean value for the oil-free portion of fabric. Thus, any sample patches are made directly comparable. Sample patches were selected from the corrected images to represent the oil-free, washed oil and oil-saturated sections of fabric, converted to show the L-value of the CIELAB colour space.

Results and Discussion

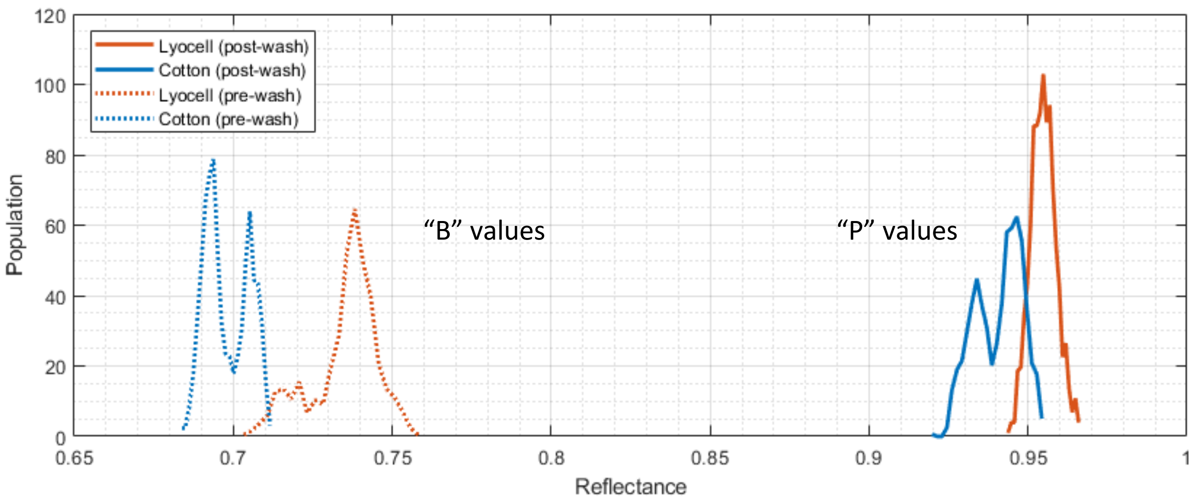

Figure 1: *Visualisation of the degree of recovery W, showing the lessened visibility of an oil stain on lyocell, relative to cotton.*

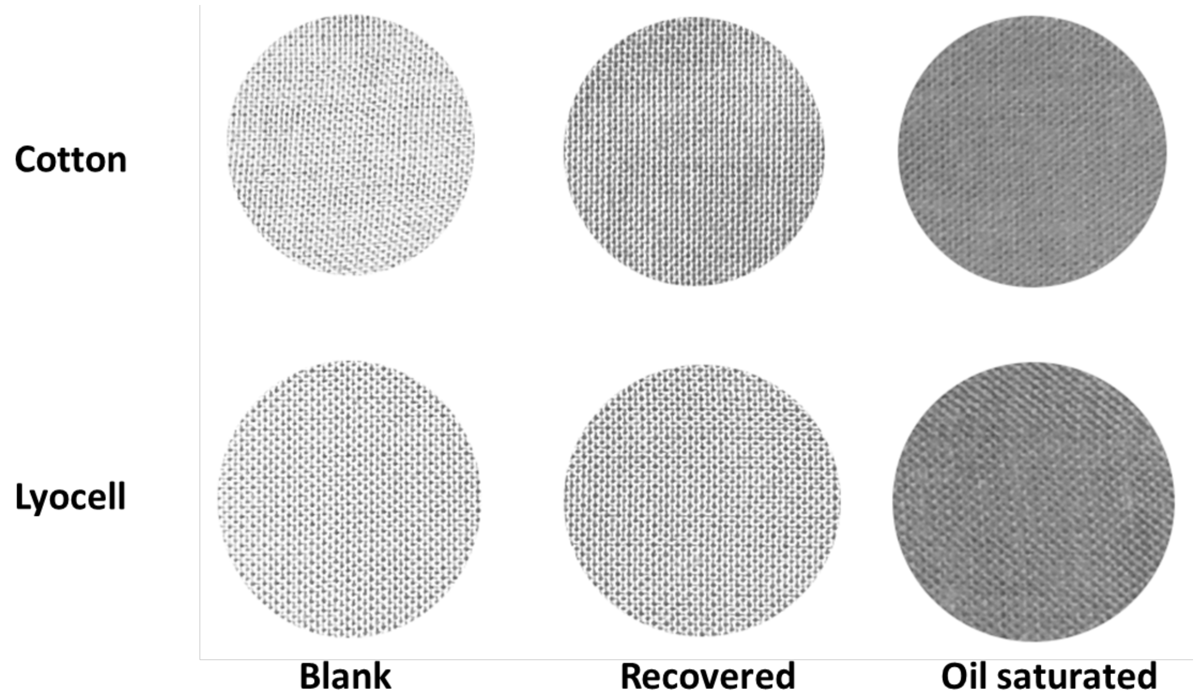

Figure 2: *L-values of cotton and lyocell fabrics. Compared to a fully saturated sample, a washed oil stain on cotton appears darker than an oil stain on lyocell washed under the same conditions.*

The degree of recovery W scales from 0 (no visible difference from oil saturation) to 1 (no visible difference from the blank). It averages 0.74 for cotton and 0.85 for lyocell. We can see in figure 1 that not only is W higher for lyocell than for cotton, lyocell both stains less visibly (higher "B" values, dotted traces on figure 1) and recovers better (higher "P" values, solid traces on figure 1).
The distributions of values in figure 1 are well-resolved, giving confidence that the values are distinct.

An imaging L-value is shown in figure 2. The L-imaging exacerbates the already-visible effect in a way that makes the presence of oil stains easy to capture and convey with a camera. After recovery, the Lyocell is consistently more similar visually and instrumentally to its blank than not, while the cotton standard is appreciably different. In reality, there is a visible "tide mark" of oil on both swatches.

The method provides an optical evaluation of the staining on the fabric surface, regardless of actual mass retention, i.e. the amount of oil still present in the fibre. It can be reasoned that pure lyocell could still give better consumer satisfaction in terms of "clean" perception than pure cotton in this application.

Acknowledgements

The authors are grateful to the UK Knowledge Transfer Network and Innovate UK for creating, supporting and funding the Knowledge Transfer Partnership (Partnership 11240) that made this work possible. We are thus also grateful to the partners Ideal Manufacturing Ltd. for the use of their wash testing facilities and Northumbria University for the loan of spectroscopic equipment.

References

[1] E. J. Craven, *Email exchange with The Grange Spa,* Private Communication, 2019.
[2] Y. S. Chi and S. K. Obendorf, "Aging of Oily Soils on Textile Materials: A Literature Review," *J. Surfact. Deterg.,* vol. 1, pp. 407-418, 1998.
[3] E. Kissa, "Wetting and Wicking," *Text. Res. J.,* vol. 66, pp. 660-668, 1996.
[4] B. Hapke, Theory of Reflectance and Emittance Spectroscopy, Cambridge University Press, 2005.
[5] M. R. Luo, "CIELAB," in *Encyclopedia of Color Science and Technology,* Berlin, Heidelberg, Springer, 2015.