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Better than Beige: Sustainable colour for Lyocell

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Abstract

This paper introduces initial findings from a more extensive programme of research at the design/technology interface carried out in the School of Textile and Design, Heriot-Watt University, in collaboration with Lenzing, Austria. The PhD research is focused on the use of design methodology as a means to address the environmental impact of colour for fashion textiles, addressing the challenges and limitations in creating sustainable colour.

Recent literature commentary in the area of sustainable textile design reinforces our opinion that all forms of coloration, using either natural or synthetic colours, have some adverse environmental impact. On the basis of a previously-reported research project, it has been suggested that the most sustainable way to produce garments is to use unbleached, undyed organic fabrics. We are programmed to react to colour on a psychological and physiological level. Removing variety of colour on the grounds of sustainability is effectively suggesting that a world consisting only of light beige would be acceptable. However, from the perspective of both designer and consumer this conclusion, though environmentally-justifiable, sacrifices any textile design influence. Such textiles would not be enough to satisfy our human desire for colour. This paper raises the importance of exploring the environmental impact involved in creating colour for textiles through 'how we use and design with colour', an area which is rarely addressed within sustainable design.

This paper illustrates a textile designer's approach to these specific colour-associated issues, carried out in collaboration with Lenzing, global fibre manufacturers. The emphasis of the project was to explore innovative ways of colouring textiles through sustainable coloration methods. The research was underpinned by textile and coloration technology working in parallel with the design approach in establishing sustainable options for coloration.

The use of Lyocell fibres (Tencel) enabled exploitation of their strong environmental credentials and provided the basis of a cyclical model for sustainable colour involving life-cycle design thinking. The model is focused on the life-cycle of the Lyocell manufacturing process. Natural colour was extracted from the leaf and bark, which are by-products of the sustainably-forested eucalyptus from which the fibres are derived. No harmful chemicals were used at any stage and only water was used in the extraction process. Colour was applied to fabrics by screen-printing using gum tragacanth as a natural thickening agent for the print paste. The process was evaluated both with and without the use of mordants. Technical evaluation of the printed fabrics demonstrated a surprisingly good set of fastness properties, at a level comparable with those provided by many synthetic dye classes.

The research has highlighted that for sustainable design to be successful, it must incorporate and balance aesthetic value with environmental value, rather than sacrificing one for the other. The collection of textile design samples produced using a cyclical (life-cycle) method concludes that the natural eucalyptus-based dye may be suitable for commercial use. The process presents future potential for innovative design development and illustrates how the incorporation of traditional craft knowledge within current production processes can create solutions for sustainability. The paper concludes by suggesting future applications for this research.

Keywords

Sustainable, textiles, design, colour, Lyocell, life-cycle

Introduction

Textiles for fashion, at many stages of their life-cycle, contribute significantly towards environmental pollution, for example in terms of extensive consumption of chemicals, energy, water, and generation of waste. As an industry, fashion textile production is heavily reliant on diminishing, non-renewable natural resources. With increased awareness surrounding the use of these finite resources, there is ongoing debate, particularly in the scientific community, as to how much longer chemicals based on fossil fuels will continue to be available for use. While opinions range from 50 to 500 years, it is agreed that the reserves are limited and that research into new energy and material resources for textile production will be essential to satisfy future needs (Bechtold and Mussak 2009).

This growing awareness within the industry has led to a developing vocabulary for fashion and textile products that aim to be more environmentally responsible throughout the life cycles of clothing items. Terms such as bio, eco, natural, organic, slow, conscious and responsible are being used to categorize a variety of features of this type of 'green fashion'. Research in the area of sustainable design has gained momentum in recent years, aiming to provide innovative solutions for an industry that needs to evolve into more responsible and efficient systems of production. The focus of research and development has generally been to address fibre choice, garment design and production processes. In contrast, approaches to introducing colour have been largely overlooked. Developments in the area of textile coloration have been led by scientists and technologists with focus primarily on the chemistry involved, for example aiming to reduce the requirements for water, energy and raw materials used for dyeing and printing processes.

Colour is the most immediately visible feature in the design of textiles. It is often the main aesthetic concern for both the designer and consumer. It can also be the reason for financial success or failure of products within the marketplace. The main motivation for the use of colour within design is to create desirable aesthetics to ensure the commercial appeal and financial success of the product. Designers commonly demonstrate only a limited understanding of, or regard for, the environmental impact caused by the production of colour and its application to textiles. The global textile industry uses more than 700, 000 tonnes of dye each year. Depending on the particular dye class used, the percentage of dye that remains unfixed to the fibre during the dyeing process and finds its way into the effluent ranges from 5 to 50 per cent (Hardin 2007: 191).

There are two broad sources of chemicals which may be used to create colour: natural and synthetic. It is a common misconception to presume that natural inevitably means good and synthetic bad in terms of its effect on the environment. Until the mid-nineteenth century, when the development of synthetic dyes began, all textiles were coloured using dyes from natural sources (Cardon 2007: 20). The lower cost, better reliability, reproducibility, and larger scale of operation that was achievable with synthetic dyes, together with the development of new technologies that have taken place over the years, have meant that the traditional processes used for natural dyeing and knowledge and experience of the methods have been largely eliminated. Modern industrial processes use natural dyes only in specific niche markets. The dyes currently used for the industrial coloration of textiles are almost exclusively synthetic products of the chemical industry, manufactured from finite, non-renewable petrochemical sources (Christie 2001: 118). Application of these synthetic dyes to textiles generally involves intense use of chemicals, water and energy, with inevitable environmental consequences (Bide 2007: 74).

Current opinion within the research community is increasingly concluding that all methods of coloration of textiles have environmental consequences (Better Thinking 2006). The current systems for introducing colour must be considered as unsustainable over the longer term. This leads to the fundamental questions which have motivated the research programme reported in this paper: how would we produce colour without the use of chemicals derived from fossil fuels, and what happens when reserves run out?

While it may be argued that natural dyes offer some environmental benefit compared with synthetic dyes, for example in terms of cultivation from renewable natural sources, biodegradability and low toxicity, their use is not completely free of environmental impact (Glover 1998: 4). The cultivation of plants specifically for the production of natural dyes would require the use of a significant area of arable land, for which food production is a higher priority. In addition, natural dyeing of textiles commonly requires treatment with a mordanting agent, usually a metal salt, to fix the dye to fibres as many natural dyes have little direct affinity for fibres, and this mordanting process has inevitable environmental consequences (Bechtold and Mussak 2009: 319). Commonly, natural dyes also show inferior fastness properties, limiting their suitability for use on textiles, especially fashion. In aesthetic terms, the range of colour and depth of shades that are capable of being produced from natural dyes is limited, and in no way comparable with the rainbow of possibilities achievable from the use of the modern range of synthetic dyes.

There is, however, evidence of recent re-investigations of natural dyeing processes aiming to address some of these negative issues (Bechtold et al. 2003). It is proposed that, in striving to achieve sustainable colour, we must re-consider the use of renewable resources for textile coloration, and in doing so incorporate the aim towards a future zero waste, zero emissions society. The development of agricultural production of plants used purely as a source of colour, and the use of the currently established methods both for extraction of natural colour and its application to textiles, do not provide alternatives to dyeing with synthetic dyes that are necessarily sustainable or environmentally responsible. This paper provides an example of a new approach to sources of colour that incorporate the utilisation of waste and by-products. The broad aims of the research programme are essentially to design processes which link production with design so that they incorporate life-cycle thinking in order to produce sustainable colour, and to establish a model from which opportunities and limitations for creating colour within a product life-cycle may be evaluated.

Sustainable beige?

It has been suggested that 'the perfect t-shirt', in terms of sustainability, would be constructed from unbleached, undyed organic cotton (Black 2011: 82). While there is technical and social justification for the conclusion from this study (Gwilt and Rissanen 2011: 79), the removal of colour from the process of design for textiles is arguably unsustainable from a design perspective, based on the very nature of design. After all, how desirable can beige be? It is questionable as to whether the plain light beige 'eco-fashion' look would appeal widely to both designers and consumers who have higher expectations in terms of colour. This approach to colour prioritises environmental concerns over aesthetic value.

In striving for a solution beyond beige and also questioning whether sustainable colour can be created, the research described in this paper has explored definitions for the meaning of sustainable. It is suggested that the term has more than seventy definitions (Holmberg and Sandbrook 1992: 20). The use of 'sustainable' in the context of design, fashion and textiles has been steadily increasing, and this has resulted in frequent confusion and misinterpretation in terms of its meaning (Galvic and Lukman 2007). The *Oxford English Dictionary* cites the meaning of the word sustainable as 'able to be maintained at a certain rate or level' and, in an environmental sense, as 'conserving an ecological balance by avoiding depletion of natural resources'. There have been a number of specific initiatives to address the issues in the context of textile products, for example that they may be labelled as 'sustainable' if the raw materials originate from organic farming and if the manufacturing processes comply with ecologically and socially acceptable production methods (Ganglberger 2009: 353). This statement is rather specific in that it may exclude other valid alternatives, including the approach described in this paper.

In questioning whether sustainable colour can be created we have adopted the concept that the essence of sustainability concerns 'learning to live in harmony with our planet and to take from it only what we are able to give back to it', which is our modification of an original suggestion in a Design Council paper (Thompson 2011: 2). On the basis of this principle, the textile designer is encouraged to balance aesthetic and environmental value of products.

A cyclical approach towards sustainable colour

To establish a method for sustainable coloration an experiential methodological approach was used in which life-cycle design thinking was incorporated into the creative practice of the printed textile designer. In engaging with product design from concept to end of life, the designer gains experience and understanding of environmental implications of design decisions, incorporating this new knowledge into the future design process.

In aiming to unite aesthetic value with environmental value within the design process, design decisions are made not only on the basis of aesthetic, tactile and technical qualities of materials, but also on the environmental credentials of raw materials used to produce sustainable products (Hallet and Johnston 2010: 167). Fibre selection is the first decision that impacts on both aesthetic and environmental performance of textile products. An important approach to sustainability within the fibre industry involves mimicking the natural regenerative cycle of nature by production methods in closed loop systems. Closed loop fibre production has provided the initial foundation for the cyclical process that is required within the research described in this paper from which to achieve sustainable colour.

Lyocell, marketed as Tencel by the manufacturers, Lenzing AG (Austria), is a regenerated cellulosic fibre which has strong environmental credentials (Taylor 1998: 191; Mather and Wardman 2011: 115). The manufacturing process uses as its raw material wood pulp derived from eucalyptus species, particularly *Eucalyptus Grandis*, *Urophylla*, *Nitens* and *Dunnii*, all of which are hybrids. These species are farmed on land described as 'marginal', i.e. unable to sustain agricultural crops. They are fast growing and have low requirements for water and pesticides. The manufacture of Lyocell involves dissolving the pulp in N-methylmorpholine-N-oxide (NMMO) containing a small amount of water. The fibres are formed by a dry-jet wet spinning process in which the viscous, concentrated solution of cellulose is extruded through a spinneret into a water bath. The organic solvent, which is claimed to be essentially non-toxic and biodegradable, is recovered at a rate of 99.5 per cent (Mather and Wardman 2011: 115). Unlike other regenerated cellulosic fibres, such as viscose, there is no chemical conversion involved and the cellulose content of the pulp used to feed the Lyocell process remains chemically unchanged in the final product.

Thus, sustainability may be claimed for Tencel as a fibre, until coloration and finishing stages. However, there is inevitable environmental impact occurring at the stage in the life-cycle when colour is applied to the fabric, with a consequent effect on sustainability. In the approach to sustainable coloration of Tencel adopted in this research, it was considered a requirement that no exterior materials should be brought into the production process, and that the colour should ideally be derived from materials already existing within the closed loop production process.

Analysis of the Lyocell process for Tencel identified a potentially sustainable source of natural colour as the leaves and bark of the particular species of eucalyptus used for its production. Currently, the trees are debarked in the field and the leaves and bark are left there as natural compost. Precedent for the use of eucalyptus as a source of colour for textile dyeing was evident from publications in the colour technology area (Ali et al. 2007: 559; Mongkholrattanasit et al. 2009: 319; 2010: 272), as well as its use in craft-based natural dyeing processes (Flint 2008).

As these by-products are being utilised as natural fertiliser within the production process, the aim was to optimise the resource by extracting colour from them before they are returned to the ground as fertiliser. Working in collaboration with the Tencel fibre manufacturer Lenzing, quantities of fresh bark and leaves of the species of eucalyptus that are used in Tencel manufacture were obtained from the farms in South Africa where they are grown.

For a successful method leading to sustainable coloration, it is important that the colour available within the closed loop is able to be extracted and stored for later application on to fabric when desired. A simple extraction of the dried leaves and bark using boiling water, with no additives in both cases, provided a reasonable quantity of an orange-brown crystalline material after evaporation, a process adapted from a previous report (Ali et al. 2007: 560). The process is illustrated in Figure 1. In principle, the solid residue from the leaves and bark after the extraction process could be returned into the life-cycle to fulfil their purpose as a composting material.

Figure 1. Images of the extraction process

A popular method for producing naturally dyed textiles is to combine the plant source with boiling water in a large vessel to create a dye bath. The dyeing process as a method of coloration, using either natural or synthetic dyes, is water and energy intensive and in terms of natural dyeing it is more suited to small-scale production. As an alternative method for colour application, screen printing was used in this research. Using this method, localised coloration and creative pattern formation may be achieved to create attractive colour effects while minimising the use of dye. The print paste was prepared simply using gum tragacanth as a natural thickening agent. This material selected as a natural gum is obtained from the dried sap of the plant species *Astragalus Tragacanthus*. It is biodegradable and readily available at low cost and it was found that the dye extract dissolved readily in an aqueous solution of the gum to provide a paste suitable for screen printing.

The grade of fibre known as Tencel A100 was selected because it is known to be highly receptive to coloration. Initial print trials using this print paste on untreated Tencel gave prints that exhibited a degree of non-uniformity, creating a blotchy appearance across the fabric surface. Consequently, a light scouring of the fabric at 40°C was carried out using a dilute aqueous solution of an environmentally-responsible surfactant. This process contrasts with the rather vigorous scouring procedure, often supplemented by bleaching, that is commonly employed as a print pre-treatment for other natural cellulosic fabrics, such as cotton.

Screen prints of the scoured Tencel A100 with the pastes derived from the eucalyptus extracts were finished by a traditional steaming process to promote fixation. Attractive golden-yellow prints on a clean white fabric background were produced, as shown in Figure 2. The colours of the initial prints derived from extracts of the eucalyptus leaves and bark were virtually identical, as shown in Figure 3, presumably because the compositions of the coloured materials from the two sources are similar. Previous studies of eucalyptus extracts have identified the principal coloured components as flavonoid species, found in association with tannins and polyphenols (Monkholrattanasit et al. 2010: 346).

Figure 2. Images of print samples
1 x pull of print paste across fabric 2 x pulls of print paste across fabric

Figure 3. Images of printed colour samples

Leaf Bark

In view of the fact that natural dyes commonly require a mordant treatment for adequate fixation on textiles so that they are resistant to washing, rub-off or fading with exposure to light, printing was also carried out on a range of fabric samples pre-treated with a selected group of mordants. The mordants selected included alum, which is traditionally the most commonly-used and most effective mordant, although its use introduces some environmental consequences as a metal-containing agent (Cardon 2007: 20). The other mordants used were tannic acid, proposed recently as a natural botanical alternative to metal-containing mordants (Burkinshaw and Kumar 2009: 53), calcium carbonate and soya milk, which are commonly used in natural craft dyeing, in particular for eucalyptus (Flint 2008: 87).

Technical evaluation of the printed fabrics found that there was essentially no difference between the performance of fabrics treated with the range of mordants and the unmordanted fabric. This is an extremely important result in the context of sustainability as the need for mordanting is one of the main negative environmental consequences of natural dyeing. An explanation for this observation is provided by reports that eucalyptus contains natural tannins, which are capable of acting as fixing agents for the dyes (Mongkholrattanasit et al. 2010: 346).

A visual evaluation of the effect of dye concentration in the print paste on developed colour showed that the optimum level for dye strength was 4 per cent. Higher concentrations (8 per cent and 16 percent) did not produce an increased colour depth and there was evident undesirable colour loss into the effluent during wash-off. Optimised samples for technical testing were printed using unmordanted fabric with print pastes at a concentration of 4 per cent of the dye obtained from both leaves and bark. Results of a technical investigation into the dye performance demonstrated that the printed fabrics showed excellent fastness to washing and rubbing with very good light-fastness, remarkable results for unmordanted natural dyeing, and comparable with the level given by many traditional synthetic dyes (Ellams et al. 2013: 5). Figure 4 illustrates an example from the final prints produced.

Figure 4. Image of print sample – striped vest

Cyclical coloration: Designing beyond beige

A method which incorporated life-cycle design thinking into the creative process has been developed as an approach to creating sustainable coloured fabric on an industrial scale. This design process was integrated into the closed loop production process which ensures that the coloration was sustainable. A transferable model which may be referred to as 'cyclical coloration' was developed. Natural colour is produced within the sustainable product life-cycle by extraction of natural dyes from the leaves and bark of the eucalyptus from which the fibre is derived, and screen prints produced from these dyes show remarkably good technical performance. The research provides an example of the potential to utilise by-products or waste from industrial scale manufacturing in an existing system for textile production to produce sources of colour.

The process presents potential for future innovative design development and illustrates how the embedding of traditional craft knowledge within current production processes can create adaptive processes and solutions for sustainability. It has subsequently been demonstrated successfully that the technology is transferable to modal, another regenerated cellulosic fibre produced by Lenzing from beech; screen printing of modal using the natural colour extracted from the beech leaves and bark in this case provided an interesting nude pink colour.

In our opinion, and that of Lenzing, this research could be feasibly introduced into commercial industrial practice. The simple extraction process to produce the dye would be easily achievable on an industrial scale. Lenzing are manufacturers of the fibres, not fabrics, and so are not in a position to utilise the possibilities directly, but they would be supportive of proposed developments in the fabric production industry to commercialise the concept (Taylor 2013).

Better than beige, but no rainbow?

A significant limitation of the system developed is that it is capable of providing only one colour, although the attractive colour and the level of performance offer exciting design possibilities leading towards fashion fabrics, and a process which offers significant advantages in terms of sustainability. Currently, in terms of colour variation it is possible only to vary shade depth through altering the number of passes across the fabric during screen printing, illustrated in Figure 2. Research is ongoing into extending the range of colours available, while taking due consideration of sustainability.

The research presented in this paper provides a foundation model that has been used to inform subsequent stages of ongoing research with the focus progressing on to the relationships between fibre, structure, colour and their use in the garment life-cycle. It explores the role that design can play in limiting environmental impact through life-cycle extension utilising a range of design practice concepts to address the environmental issues and evolving the design process in order to incorporate responsible, informed design decisions with production processes at the outset of a life-cycle.

It is envisaged that this focus on incorporating colour into life-cycle considerations and encouragement of designers to make informed, responsible design choices at the initial stages of development will impact positively on the environmental credentials of a textile products.

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