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Sustainability and Biotechnology – Natural or Bio Dyes Resources in Textiles

Carvalho C* and Santos G*

CIAUD, University of Lisbon, Portugal

Abstract

Local is global and global is local. Globalization changed the way we view society for the past decades and it presents advantages and disadvantages. Although to be global means an increased cultural intertwining or a higher flow of information and a social tolerance as well as the existence of a world market that enables productivity and accessibility they are also disadvantages related to the loss of cultural identity of certain cultures or sustainable issues that must be addressed.

On the other hand, this new century's challenges and issues are often strongly related to the usage of non-renewable resources and production procedures putting at risk the environment and people's health.

Regarding textiles, or its resources, the growing concern over environmental quality and users health has led to a gradual interest of the reintroduction of natural dyes (and preservation of biodiversity) into the fashion and textile design industries as opposed to the current production processes.

This study analyses the evolution of natural dyes and colour throughout the centuries focusing in the sustainability of textile industry and the conservation of biodiversity, local production and ancient knowledge on dyeing techniques. It also reveals that a revival of natural dyes (and ancient/local know how) in addiction to new cutting edge technologies (such as biotechnology) allows for an industrial feasibility. Results also indicate significant reduced environmental impact and new strategies for sustainable development regarding colours for textiles..

Keywords: Sustainability; Biotechnology; Textile dyeing processes; Natural dyes; Bio dyes

Introduction

Textiles and sustainability

Globalisation surely has many advantages - increased cultural intertwining (thus more acceptance and social tolerance), higher flow of information, vast market enabling production and so on. However, it has also created a set of challenges that must be addressed urgently [1].

People and lifestyle transform rapidly, and so their expectations. The past decades represent worried generations, increasingly aware of the significance of biodiversity's protection and the importance of ecological footprint's reduction [2].

The demand for natural products is highly observable in the market; there's an increase on organic goods' consumption, recycled and recyclable materials, non-animal tested products, etc. It is evident that the lifecycle of products, as well as their production processes, became a concern to exigent consumers, observant of sustainability issues that are presented to and from the industries [2,3].

Industries, in the other hand, are aware of the level of difficulty that represents attending to these necessary demands. Products integrating, simultaneously, culture, communities, environment, economy, green technologies and sustainable materials are a real challenge.

Textile industry is a vast world, with many materials and techniques employed. Involving one of the longest and most complex and difficult chains in manufacturing, it is one of the most pollutants sectors in the world. It contributes a great deal to poor labour conditions, non-renewable energy and water waste, contamination and environmental impact [1,4]. Some of its most problematic facets are the finishing processes such as dyeing [5]. Common dyeing processes involve the usage of fossil generated energy and heavy amounts of water. In addition, their effluents are a massive environmental concern when not conveniently treated before being released into natural waters [6].

Dyeing processes and challenges

Dyes represent a massive industry. Aware of the colour's influence over consumers, the textile and fashion industry explore this aspect in great detail, spending massive amounts of energy and money in the pursuit for the perfect colour. This is crucial so the product projects an intended message to increase sales [7,8]. Dyes' commercial availability is enormous and their process is one of the most fundamental aspects of textile industry commercial success; these must also be economical, available in high quantities and in diverse shades of colour. The higher demand for these compounds originated the synthesis of many millions of dyes in the past century [9].

Besides the pattern/printing, consumers demand for basic characteristics in textiles: high level of colourfastness regarding light, washings and perspiration. The colour must be uniform and of a solid shade throughout the substrate [9]. To guarantee these properties, the substances conferring colour to fibres must present high affinity with the substrates. These are factors depending on the substrate texture or composition as well as on treatments applied previously or after the dyeing process [6,9].

***Corresponding author:** Carvalho C, CIAUD, Faculty of Architecture, University of Lisbon, Portugal, Tel: +351 217 967 624; E-mail: cristina@fa.ulisboa.ptG. Santos, CIAUD, Faculty of Architecture, University of Lisbon, Portugal, Tel: +351 217 967 624; E-mail: reinodeprata@gmail.com

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Dyes do possess proprieties that render them susceptible to be manipulated or altered by an infinite number of chemical agents (mordants) Additionally, these properties are vital to help creating permanent bonding with fibres. These dyeing substances also differ from each other; they must be applied in different ways, through varied distinctive methods to produce colours in certain substrates [6,10]. Regarding dyeing application procedures, exhaust dyeing (batch), continuous (padding) and printing are amongst the most common used ones [9].

Dyeing matter possesses peculiar chemical properties that make it very distinct from other materials. This is the backbone of the dyeing process and the reason why colouring substrates is such a complex subject. There are, currently, thousands of different types of dyes, in the textile industry alone - a justified amount, as each fibre to be coloured requires dyes with specific features [11,12]. However, the extent usage of chemicals and water waste by the textile industry is an emergent ecological concern [6].

Regarding the usage of water, there are, normally, two types of wasted water during dyeing. One is the dye bath, which contains the remaining dye as well as other complex compounds that helped the bonding between colouring substance and fibre [9]. These residues and the amount of dye lost vary, depending on the type of dye used and variations of pattern and colour combinations. The other type is the wash/rinse water, a procedure to remove any excess dye present in the substrate. In addition to this, water is also needed to clean all the manufacturing components involved in the process [6].

These effluents are generally thrown into pure clean waters, representing one of the most critical environmental challenges. These contain hazardous substances that are easily able to reach reservoirs and water treatment stations. Some of the chemicals are harmful, toxic, carcinogenic, mutagenic, corrosive and irritant [6,13]. some are known hormone disruptors whilst others can affect the reproductive system [14]. Many of these do not break down in the environment, but instead build up in the body of animals and humans, creating mutations [6,13,15].

Sustainable Design

Bioresources – textile natural dyes

Designer and consumer's expectations towards sustainability in the textile field and their awareness of the issues surrounding current production processes triggered some consideration on matters such as climate, environment and health [3]. The preference for organic materials has, thus, increased. This has led to the reintroduction of ancient dyes in the market, natural dyeing colorants known for their biodegradable nature and less toxic features [16].

These ancient dyes are obtained through biological resources, usually plants or animals, and were used as far back as two thousand years ago. A dye is a coloured compound extracted only through physical-chemical (dissolution, precipitation, amongst others) or biochemical (fermentation) processes. This coloured substance must be soluble in an aqueous solution (dyebath) in which the material to be dyed is soaked in [9]. Natural dyes are perceived as safer due to their higher level of affinity with the environment, thus, causing less impact. Some can provide for high quality dyeing, great colourfastness properties and bright colour shades (applied with our without mordants).

Some of the known natural dyes also contain many properties appealing to the most of us, consumers. They are eco-friendly compounds, possessing medicinal advantages such as antimicrobial [17,18] and anti-inflammatory properties [19]. Besides, clothes dyed with natural dyes revealed a higher level of protection against UVR than the ones dyed with synthetic ones [20,21].

Natural colorants implementation

However, whilst nature is teeming with coloured compounds, not all that nature provides can be used in dyeing. Only a small percentage of these natural substances are applied to textiles - mostly deliver dull, uneven hues and poor fastness, when washed and exposed to light or perspiration. Most natural dyes still unspecified in terms of fastness properties and methods of extraction, production and application involved. As varied studies indicate, there's great need for research to overcome issues related to the implementation of natural dyes in modern dye houses, particularly regarding efficient dyeing recipes and their variations [22].

Additionally, the amount of dyestuff and colour shades provided is very limited. Dyeing with natural dyes is, consequently, highly costly. This class of colorants involve rather complex processes - long and difficult extraction methods and a high level of difficulty to produce and apply in order to obtain a quality dyeing. To better deal these aspects, varied studies suggest technologies such as ultrasound methods of extraction [23] and application [24], or less water usage procedures to reduce the ecological footprint of finishing processes [25].

Although all the natural dyeing substances' benefits and the significant interest of their re-introduction in the market, the challenges around scaling such compounds are complicated. Besides, transferring traditional natural dyeing methods to a modern dye houses require intricate experimentations or redesigning already implemented systems [26].

As mentioned, dyeing is a complex process involving chemical and physical occurrences. By the time of synthetics dyes' introduction to the market dyeing with natural dyes became an obsolete practise and most knowledge on techniques and procedures were lost. In addition, there is an extensive amount of data that has yet to be recorded; one still knows very little about what can biodiversity provide or which biological resources possess dyeing potential material. Recent studies prioritise the search for new biological resources, identifying new species of fauna and flora producing substances with dyeing potential [27]. The significance of such data lies on the hypothesis of certain isolated coloured compounds to be tested in textile fibres, to better evaluate their dyeing efficiency, hence applied to the industry. Again, further research on the subject is imperative and will be determinant to overcoming sustainability issues in the textiles sector.

These are a few reasons why natural dyes' usage is such a challenging subject for the industry. Although presenting many beneficial properties, its viability at a massive industrial scale is, so far, not easily attained. These demands call for finding alternatives in sustainable dyeing and radically new ways of creating and manufacturing materials as well as deeper scientific research.

Biotechnology Textile – Sustainable Materials

Alternatives in product design and manufacturing

Textiles' sustainability issues are gradually being exposed and debated. Legislation is emerging as more demanding and pollution control boards are progressively restricting guidelines for the textile industry. General targets are synthetic dyes'production, application and related effluents; their usage represents serious toxicological issues and

a threat to the ecosystems and human health [28,29].

Until fairly recently, manufacturers focused attention on industry elements that would enable quick profit (maintaining final product's cost low or efficiency in production). Emerging design strategies in sustainable and responsible design question the current systems of manufacturing considering aspects like environment, consumers and technologies.

Some fashion designers and brands have adopted a conscious, attentive and critical position towards sustainable issues, integrating human well-being and green philosophies at the core of their corporate identity [15]. These companies, generally part of the slow fashion movement, provide design prepared to sustain communities, encourage and support local employment while, simultaneously, aiming towards environmental protection. They represent local production, raw materials such as natural dyes or fibres and traditional know how by producing and resourcing locally [2].

Environmentally, is of great significance that designers and manufacturers understand, in greater depth, the lifecycle and real capital of products being created. It is mandatory that designers/brands generate strategic and tactical approaches to design process and question how can goods be projected and manufactured to better serve and suit consumers, and the planet. Aspects such sustainable improvement, environment, consumer's values, wishes and needs must be taken into account as well as the search for radical new production alternatives, to efficiently meet the requirements of this new century [30].

It is crucial to examine the possibilities of new substance or materials emerging as well as new manufacturing methods and potential impact on the world. It is no longer only about resources exploitation but also about providing, through products, wellbeing and social improvement. Furthermore, is about providing consumers with highly smart and eco-friendly products and materials; creating goods or textiles which lifecycle enables to adapt accordingly to the consumer's characteristics and inevitable changes - age, shape, taste, needs, etc. [31].

The scope of science currently allows for a completely new radical way of rethink materials or for innovative methods of producing. With increasingly more technological innovation and breakthroughs as well as collaborations between scientists and designers the world has been noticing the intensification of biotechnologies as the foundation (green strategies) of many sustainable design projects [32].

Bio-cooperation - biotechnology impact on the world

Biotechnology application in textiles dates back over two thousand years - from fibres to natural dyes [33]. Kandra et al. [34] more recently, the management of residual waste, by microbes Novotny et al. [35]. The leap from classic to modern biotechnology involved only the ideal innovative tools to discover different uses and functions of bio resources, thus allowing for the improvement of this new field [36]. These sophisticated technologies' evolution is accentuated through significant advances in genetic engineering and synthetic biology, where the use of living organisms are seen as a biological process that may replace industrial or mechanical systems [37].

Synthetic Biology is, in broader terms, the engineering of biology. Its purpose is to make biology available to the requirements of everyday life, considered as highly effective to overcome environmental issues and tackle pollution [38].

Bio resourced technologies' increase is rapidly transforming the world with its infinite number of applications and possibilities; biotechnological processes play a key role in increasing and promoting sustainable production. In the Design or Textiles fields, biotechnologies' practices are normally associated with sustainable development and green manufacturing processes - pollution control and prevention, resources conservation, cost reduction. This approach enables for a new radical way of rethinking materials [38] as it consists in building new biological functions or systems or re-designing existing natural ones (Synthetic biology org). The production of biomaterials is a significant impact of this technology [38].

Textile and fashion designers are looking to science as part of the creative process, producing unique and often surprising results [31]. Cut edge and complex technologies serve better apparel industry in terms of quality innovative garments. Although most technology is considered underexplored, the recent trend of extensive use of biomaterials in product and fashion garments is growing exponentially, given their possibilities.

Bioresourced colorants – natural and bio dyes

As mentioned, natural dyes possess many benefits, particularly for consumer's health and the planet. However, their extraction, production, application and implementation are rather complex, not to mention the lack of knowledge surrounding techniques and bioresources. Nevertheless, some issues regarding their usage might be attenuated through cut edge, sophisticated, technologies such as modern biotechnology. Additional sustainable alternatives to toxic synthetic dyes consist in the use of fibres possessing natural colour (classic biotechnology) or modified to do so (modern biotechnology).

We are already familiarised with natural colorants to dye (from fauna and flora) or naturally dyed cotton fibres (pale shades of brown, beige, green, red), both used since ancient times [39]. There's also reference in the literature to silkworms producing naturally wide-ranging coloured silk fibres, when manipulating their diet or environment [40]. Another example can be analysed in the Madagascar's origin Orb Weaver Spider producing silk fibres that are naturally golden dyed [41].

Such choices are effective to decrease energy and water waste, saving fibres from most of textile finishing procedures. Other naturally dyed fibres consist in genetic engineered experiments [33], with varied coloured silk fibres being produced.

Following the biological technologies approach, there's also the production of coloured compounds through a rather unusual mediums – microorganisms or microalgae [42]. This is a phenomenon that occurs naturally in nature, often found in different plants' microsystems (rhizosphere) or glaciers [43] Manipulating at times their environment, different colour shades can be produced [31,44].

This mechanism, using living bacteria to produce substances, might be considered as a sustainable strategy for dyes' mass manufacture, creating less-environmentally damaging materials [45].

Its effectiveness finds in Synthetic biology a way to enable the production of specific dyes designed to meet the industry's demands and consumer's expectations. Microorganisms can, not only grow rapidly but also, be programmed to provide varied dyes with different properties and different colours, being simultaneously cost effective.

Some pigments created through bio machines were already isolated in lab. *"E-chromi"* is one of such projects, born from the collaboration of scientists and designers who genetically engineered bacteria to secrete

a variety of coloured pigments, visible to the naked eye. Standardised sequences of DNA (biobricks) were designed and inserted *into E.coli* bacteria enabling for the production of colours such as red, yellow, green, blue or violet, possibly allowing for its application on textiles [45].

The usage of sophisticated technologies, such as Synthetic Biology, contributes to profound transformations in the sector and to the concept of Design itself. Its impact will, surely, invite new scenarios and generate vital debating [32]. As we are slowly capable of manipulating nature and build things with biology, we are increasingly witnessing a new era in Design, manufacturing products and producing materials that empowers for a more sustainable future [45].

Conclusion

It is a challenging period for the textile industry, with the economic downturn threatening sales and a growing awareness of real social and environmental challenges, such as climate change, wars over resources and increasing consumer's expectations of brands.

One of the most complex aspects of the industry is the dyeing process. It is one of the most pollutant components of textiles with a heavy ecological footprint. Toxicity, water waste and contamination, non-renewable generated energy consumption, health hazards for humans and ecosystem in general, etc.

Awareness on environmental issues has led to the interest of natural dyes reintroduction in the market. Although having many benefits, the reality is that their implementation on a massive industrial scale is rather incompatible to the needs of manufacturing. Industry demands for a great variety of colour shades as well as high quality colourfastness as well as economical dyes - vital requirements for commercial success. Additionally, natural colorant dyeing techniques, and bio-resources involved, lack deeper research. Nevertheless, with the significant improvements on biotechnologies witnessed during the last decade, some fundamental alternatives might be considered.

The appropriation of biotechnologies exerts increasing influence in our daily lives. Technological innovation and breakthroughs in textiles are establish to meet a variety of objectives such as improvement of varied species of plants used in the manufacture of fibres or their properties, production of new types of fibres, different types of dyes, effluents' management, amongst others. Environmental biotechnology (white and brown biotechnology) and specially Synthetic Biology, plays a key role in increasing and promoting sustainable production.

Textile and fashion designers are looking to science as part of the creative process, producing unique and often surprising results [31] (En Vie, 2013; Grow your own, 2013). Cut edge and complex technologies serve better apparel industry in terms of quality innovative garments; the recent trend of extensive use of biomaterials in product and fashion garments is growing exponentially, given their possibilities. Their contribution is vital to sustainable development or green manufacturing processes – prevent pollution, reduce costs and resource's conservation.

Sometimes introducing visionary and radical strategies for improving the performance of objects around, biotechnology multiple applications are focused and designed to deal with sustainable development and core industrial issues. The possibilities of such technologies suggest different approaches on responsive design assimilating science and technology, the environment, sustainable strategy, wellbeing and social innovation.

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