

Ancestry and sustainability: industrializing tie-dye with natural dyes in the tunisian textile sector

Abstract

Natural dyeing is an ancestral craft that dates back to the earliest civilizations. This art perfectly aligns with the eco-design approach sought by many textile industries. Indeed, the fashion industry is rethinking its ways of manufacturing, consuming, and reducing the use of all substances that lead to water contamination and environmental pollution. The industrialization of ancestral dyeing is a process adopted by several Tunisian textile companies. However, this process is somewhat complex due to the sophisticated techniques involved, with Tie-dye being one of the prominent methods.

In this context, this article explores the fusion of this ancient technique with eco-design to reinvent modern textiles. By highlighting the Tie and Dye technique, the study examines how these methods can be integrated into sustainable design practices. The aim is to demonstrate that ancestral know-how can not only preserve cultural heritage but also offer innovative and ecological solutions to contemporary environmental challenges. This article discusses the results of our research on the industrialization of the traditional Tie and Dye effect and the exploration of new horizons in 'textile' eco-design within the Tunisian textile development laboratory, Chimitex, through the use of plant-based dyes.

Keywords: vegetable dyeing, Tie and Dye, leather effect, design, multidisciplinary

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Introduction

The various fields of design are characterized by their role as integrators of specific knowledge and practices. This makes them significant players in a world where knowledge has been fragmented throughout the development of sciences. The primary goal of modern designers is to increase production to meet the needs and desires of consumers.

Today, the concept of «eco-design» is present in all sectors of activity and is increasingly discussed due to the importance of eco-sustainability. Eco-design takes into account all factors that may impact the environment at any stage of a product's life cycle, aiming to reduce pollution. In recent years, companies have begun to pay more attention to ethical and environmental issues, leading to increased awareness among designers and promoters. Consumers are increasingly valuing products from brands that consider the sustainability of their products. Investing in sustainability allows companies to be more transparent and gain significant medium and long-term benefits.

The textile and clothing industry is of particular interest, as many companies have sought to introduce the concept of eco-design through the application of natural dyeing, which allows for unique colors while being environmentally friendly. This design approach uses natural dyes and reflects an eco-responsible approach on an environmental level.

Natural dyeing is an ancient eco-responsible activity. Our ancestors sought to distinguish themselves by coloring their clothes using various dyeing methods. Notable techniques include IKAT, KALAMKARI, and Tie and Dye. These coloring substances and methods have become a source of motivation for designers, encouraging them to develop their creativity in sustainable design. Textile designers have thus sought to revive these ancestral natural dyeing techniques, updating them and converting natural dyes into pigments to expand and/or open new perspectives in textile fabric design.

In this context, our article describes an experiment that goes beyond the traditional scope of natural dyes. Typically defined in most specifications as a soluble substance that colors a textile surface, natural dyes can be applied using specific techniques to convert them into pigments, thereby creating new ecological special effects. We begin by specifying that the use of natural dyes is an ancient art that employs the «Tie and Dye» technique, a particular form of this artisanal dyeing. We will examine the relevance and legitimacy of our pigment.

Starting from this premise, the first question to ask is undoubtedly how can we give an ancestral appearance to an industrially processed fabric? What materials and methods should be used to create new special effects with natural dyes ?

The multidisciplinary approach in the textile industry

The formation of a constructive mindset can only be achieved through a foundation of education and scientific culture. Science provides a critical analysis revealing the means and methods to develop human society. In other words, « *La science, d'abord comprise comme une connaissance vraie du monde (Aristote), ou comme une découverte des lois de la nature (Comte), a ensuite été comprise comme une représentation élaborée par la raison. L'expérience ne la précède pas nécessairement (Bachelard), elle est tirée par « l'effort mathématique qui forme l'axe de la découverte » (Bachelard, 1934, p. 58)*¹. Thus, science imparts skills and wisdom. Furthermore, the destiny of modern man is that of today's world, purely scientific and technological. Indeed, without science, countries cannot be involved in their development and the well-being of their communities.

Furthermore, the destiny of modern humanity is deeply intertwined with the scientific and technological advancements of today's world. Without science, countries cannot engage effectively

¹Science, first understood as true knowledge of the world (Aristotle), or as the discovery of the laws of nature (Comte), was later understood as a representation developed by reason. Experience does not necessarily precede it (Bachelard); it is driven by 'the mathematical effort that forms the axis of discovery' (Bachelard, 1934, p. 58).

in their development nor ensure the well-being of their communities.² Scientific research recognizes its fundamental social role: to transform mindsets, enhance quality of life, and prepare society for change.

Various scientific approaches can support the product design process in the textile field. The industrialization of creativity in this domain primarily revolves around the design of a new collection. The launch of a new collection is a complex process that involves the interaction of different skills, each representing a distinct function and carrying diverse, often conflicting interests. This process relies on continuous negotiation between these skills, highlighting the interaction between the creatives (usually the designer) and the experts in exact sciences (usually the engineer). "The interplay between designers and engineers is characterized by a mutual exchange of knowledge and constraints, where the designer's aesthetic and functional aspirations meet the engineer's technical feasibility assessments, resulting in a balanced and innovative product."³ It should be noted that the dialogue between these two main actors is based on the specifications imposed by the industry.

In addition to designers and engineers, other authority figures are integrated into the design process. These include production managers, such as the production director, product manager, commercial director, marketing director, and sales director. These individuals possess strategic knowledge and an understanding of the company's positioning and the role of the products they produce. Often, they play a decisive role in hierarchical decision-making. Through mutual exchanges within this structured environment, the creative idea is transformed into an innovative product.

However, the collective nature of creativity in the textile industry is not limited to what happens within a single company and the dialogue during the definition phase of a collection. The production process in the textile industry involves a long sequence of successive steps within an industrial chain.

To ensure the environmental sustainability of this creative and industrial process, the ISO 14006 quality standard provides a framework for integrating environmental management into the design and development of products. This standard defines product design and development as the set of processes that transform requirements into specified characteristics or specifications of a product, process, or system. Implementing ISO 14006 involves embedding environmental considerations at each stage of the design process, from material selection and resource efficiency to waste minimization and compliance with environmental regulations. Many textile companies adopt ISO 14006 to enhance their environmental performance and ensure sustainable practices throughout their production cycles. This holistic approach ensures that the entire production cycle, from initial concept to final product, adheres to environmentally responsible practices, ultimately enhancing both the sustainability and competitiveness of the products developed.⁴

In search of industrializable ancestral Tie-Dye

Today, being fashionable means being concerned with environmental issues. The promotion of ancestral tie-dye is a current topic, as it reveals ecological practices that adhere to the principle of sustainable development, such as natural dyeing using natural dyes. These dyes are not an innovation but a revival of a rich tradition. They cannot be compared to synthetic dyes in terms of efficiency for industrial applications. As Haddar⁵ notes, « *L'utilisation des matières colorantes d'origine naturelle remonte bien au-delà de l'apparition des premières traces d'écriture. En effet, l'homme s'est approprié très tôt les propriétés colorantes d'origine végétale, animale et minérale,*

employées pour la réalisation de peintures, laques et essentiellement teintures. Jusqu'à la fin du XIXème siècle, la teinture des tissus était réalisée à l'aide de colorants végétaux tels que le bleu indigo extrait du pastel, le rouge extrait des racines de la garance et le jaune provenant de la gaude » (p.05)².

Since prehistoric times, natural dyes have been used for coloring food, leather, and fibers such as wool, silk, and cotton. Indians have been considered the pioneers of the art of natural dyeing. Indeed, natural dyes are extracted from a variety of natural substances and objects, such as plants (e.g., indigo and saffron), insects (e.g., cochineal and lac bugs), animals (e.g., certain species of mollusks or crustaceans), and minerals (e.g., ferrous sulfate, ochre, and clay), without any chemical treatment.

Dyeing textiles with natural dyes involves several steps:

- a) **Mordanting:** Treating the fabric with a substance that allows the dye to bind to the fibers
- b) **Preparing the dye liquor:** Extracting or solubilizing the dye from the natural source.
- c) **Exhaustion:** Ensuring the dye fully permeates the fabric
- d) **Diffusion and migration:** Allowing the dye to spread evenly across the fabric
- e) **Fixation:** Setting the dye so it adheres permanently to the fabric.
- f) **Post-treatments (optional):** Improving fastness, enhancing color, or achieving tonal variations and final color matching.

Natural dyeing can be performed in various ways, including fiber dyeing, yarn dyeing, and fabric dyeing. Before dyeing with natural dyes, the fabric must be prepared by appropriate scouring, degreasing, bleaching, and pre-mordanting. Some traditional textile manufacturing processes require specific manipulations of the fabrics such as crimping, pleating, tying, and twisting. These processes develop the pattern designed after the coloring process. The fabrics thus treated are among many traditional textiles known in the Asian world, which are made using the tie-dye technique. This process involves using a binding technique that prevents the dye from penetrating the bound part. Moreover, «tie-dye» is an English term that means «tie and dye».

By exploring and industrializing these ancestral techniques, we can preserve traditional methods while promoting sustainable practices in the modern textile industry.

Tie-dye: An ancestral textile art form

Contrary to popular belief, tie-dye was not invented in America in the 1960s. Various forms of this technique have been practiced in India, Japan, China, and among the Incas for centuries. For example, the Indian bandhani technique, which dates back approximately 5,000 years, and Japanese shibori, used for centuries to create various refined patterns on fabrics intended for luxury kimonos.⁶ Moreover, The practice of tie-dye extends far beyond Asia, with vibrant examples still produced in West Africa. This age-old technique uses dyes to create stunning patterns on fabrics by selectively blocking areas from the dye's reach. Folding, stitching, crumpling, or other fabric preparations prevent the flow of dye to certain areas. Generally,

²The use of natural dyes dates back well before the appearance of the first traces of writing. Indeed, humans very early on appropriated the coloring properties of plant, animal, and mineral origins, used for making paints, lacquers, and primarily dyes. Until the end of the 19th century, fabric dyeing was done using plant dyes such as indigo blue extracted from woad, red from the roots of madder, and yellow from weld.

most of the folding, crumpling, and twisting is done on a wet fabric laid flat on a plastic-covered table. The pattern of the folds and the placement of the dyes determine the final design. With experience, the final result can be predicted and controlled to some extent (depending on the nature of the knot), but the element of surprise makes tie-dye an exciting and interesting art.

This Figure 1 shows fabrics dyed using the tie-dye method. We notice the use of two tying techniques: circles, also known as the «sunburst effect,» and the «pleat effect».



Figure 1 African fabrics in Tie and Dye made by Togolese dyers.³

Sunburst effect: The circle design is relatively simple to create, yet one of the most spectacular. Simply grasp the fabric with your thumb and index finger at the chosen point for the center of the circle. With the other hand, make sharp and evenly spaced folds around the central axis (like a closed umbrella). Securely anchor knots with string or elastic bands around the base up to the tip.

Pleat effect: After laying the fabric on a flat surface, place the thumbs of both hands firmly together on the fabric. Position the fingers one or two centimeters in front of the thumbs and pinch the fabric to lift a pleat. Continue pinching additional pleats until you reach the end of the fabric.

Over the past two years, there has been a strong resurgence of tie-dye patterns on fashion runways. Thanks to an industrialization process, textile designers have used synthetic dyes in the creation of this art. The fabric manipulation procedures now employ industrial tools.

As a researcher in the field of textile design, working with the ChimiTex Plus group as part of a research agreement, we have sought to industrially design tie-dye patterns using plant-based dyes with an ancestral identity.

Industrialization of Tie and Dye

The process of industrializing the ancient technique of tie-dye involves modern tools and materials, allowing for consistent and scalable production while preserving traditional methods. At ChimiTex, we initiated this project by carefully selecting dyes rooted in Berber heritage, specifically turmeric and pomegranate, known for their historical use and vibrant hues. To seamlessly integrate these traditional dyeing methods into modern industrial processes, we followed a meticulous approach.

Dye selection and fabric preparation

To ensure optimal dye absorption and colorfastness on cotton fabric, we employed several preparatory steps. We began with

desizing, removing any sizing agents that could interfere with dye uptake, and cationization, which enhances the fiber's affinity for dye extracts. These preparatory processes are crucial for achieving even and lasting coloration.

For the desizing process, we used the following materials and chemicals:

Enzymes: Amylase enzymes to break down starch-based sizes.

Sodium Hydroxide (NaOH): To create an alkaline environment that aids in the removal of synthetic sizes.

Detergents: To assist in the emulsification and removal of size residues.

Water: As the medium for soaking and rinsing the fabric.

For the cationization process, we used:

Quaternary Ammonium Compounds: Cetyltrimethylammonium bromide (CTAB) to impart a positive charge to the cotton fibers.

Sodium Hydroxide (NaOH): To maintain the necessary alkaline pH during the cationization process.

Water: To prepare the solution for applying the cationic agent.

By carefully executing these steps, we ensured that the cotton fabric was adequately prepared for the dyeing process with turmeric and pomegranate extracts, thus enhancing dye uptake and ensuring vibrant, long-lasting colors.

Dyeing procedure

After preparing the fabric, we implemented a precise technique involving the local application of caustic soda using a wash bottle. This critical step involves carefully applying the caustic soda solution to specific areas of the fabric to create distinct patterns. The caustic soda reacts with the fabric, altering its chemical composition in these targeted spots, which in turn changes how the fabric absorbs the dye. Once the caustic soda is applied, the treated fabric is dried in an oven to set the caustic soda effect and then neutralized with acetic acid to balance the pH levels, ensuring the fabric's integrity.

The actual dyeing process involves several key steps. First, a dye bath is prepared using natural dye extracts from pomegranate and turmeric, renowned for their rich, vibrant hues. The dye bath is maintained at 60°C to create an optimal environment for dye absorption. The neutralized fabric is then immersed in this dye bath for 15-20 minutes, with constant stirring to ensure uniform exposure to the dye. This controlled process allows the fabric to absorb the dye evenly, resulting in consistent and vibrant coloration. After dyeing, the fabric is thoroughly rinsed with cold water to remove any excess dye and then dried in a low-temperature oven, to set the colors firmly.

The Figure 2 below illustrate the striking results achieved through this method.

We notice that the patterns differ from one fabric to another. This is due to the texture of the fabric (denim, velvet, etc.).

By using other methods, such as the application of fixing agents with varying concentrations, we achieved different effects. Unlike dyeing, where the extracts are water-soluble natural dyes, in this second experiment, they are used as pigments. Indeed, these pigments are well known in the field of pigment printing.

³<https://www.africocouleur.com/teinture-artisanale-des-tissus-africains/>



Figure 2 Tie and Dye effect dyeing.⁴

Towards the design of new ecological special effects

The development of new ecological special effects in textile dyeing has led to innovative techniques and results. The dye used in this process is a viscous paste similar to that used in printing. To create these special effects on textiles, we followed a series of precise steps. First, we prepared the dye by heating it to 100°C for 60 minutes, mixing 150 ml of water with 50 grams of coffee or 10 grams of turmeric and an appropriate amount of QG Biotex SE. Next, we combined 10 grams of this prepared dye with 60 grams of raw Erotex and 30 grams of Lac 72. This mixture was subjected to polymerization for 30 minutes to set the colors and effects on the fabric. After polymerization, the fabric was brushed to enhance the special effects and provide a unique texture. Finally, the drying process was carried out in an oven at 120°C for 15 minutes, which permanently fixed the effects and stabilized the fabric.

Unlike the typical outcome of fixing a pigment on a textile substrate, this method produces a shine with a durability and texture reminiscent of leather. This significant departure from traditional methods underscores the innovation possible in textile dyeing when combining both technical and creative expertise.

Technical and creative contributions

Initially, these guidelines emerged from purely technical experiments conducted by textile engineers. However, the role of designers in developing research on special effects is increasingly recognized. Designers contribute significantly by establishing guidelines and utilizing various tools at each stage to achieve the desired effects. This interdisciplinary approach combines theoretical frameworks, state-of-the-art techniques, and detailed observations, leading to new models for integrating vegetable dyes as pigmentary dyes. This fusion of engineering precision and design creativity is essential for advancing textile innovation.

Qualitative research and creative techniques

The research underpinning these developments is qualitative, focusing on creative processes and experimental operations. One such operation is the «dripping» technique, which results in a printed substrate with intricate, intertwined patterns. This technique exemplifies how creative methods can yield unique and sustainable textile effects (Figure 3).

Such qualitative exploration highlights the synergy between traditional craftsmanship and modern methodologies in achieving novel textile aesthetics.

To give our fabrics an ancestral appearance, we integrated other techniques, mainly the manual wrinkling technique. After fixing this wrinkling effect with the press, we spread the solution on the fabric

⁴Photos taken by us.

using a spray gun. The folds prevented the paste from penetrating the entire fabric, resulting in an effect similar to that of Tie and Dye (Figure 4).

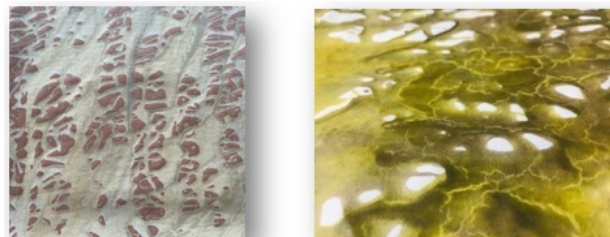


Figure 3 Collection of fabrics with ecological leather effect.⁵

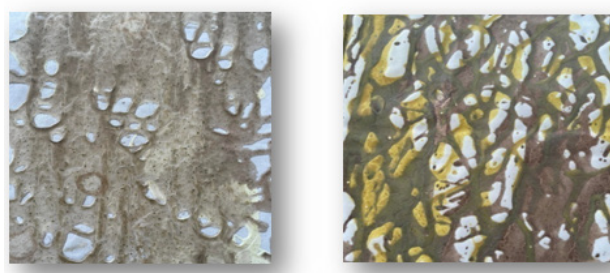


Figure 4 Tie and Dye leather effect.⁶

This new design approach can foster a multidisciplinary perspective and promote collaboration between engineers and designers. This approach is common in textile companies for the development of their products.

Science, creativity, and collaboration: pillars of textile designers' methodology

The acquisition of a constructive mindset relies on solid education and scientific culture. Science provides us with a critical analysis of the world, allowing us to understand its workings and identify the levers of societal progress. As highlighted by Gaston Bachelard, a French philosopher of science, «science is not necessarily preceded by experience; it is driven by the mathematical effort that forms the axis of discovery» (Bachelard, 1934, 58).¹ By equipping us with skills and wisdom, science illuminates our destiny and enables us to tackle the challenges humanity faces. Without it, the involvement of countries in the development and well-being of their communities becomes illusory.

Scientific research, aware of its fundamental social role, is committed to transforming mindsets, improving quality of life, and preparing society to adapt to change. This transfer of knowledge and education constitutes one of the pillars of its action. The process of

⁵Ibid.

⁶Ibid.

designing textile products is enriched by various scientific approaches. The industrialization of creativity in this field primarily focuses on designing new collections, a complex task that requires the interaction of multiple and sometimes conflicting skills.

This process relies on continuous negotiation between these skills, notably between the creatives, usually the designers, and the experts in exact sciences, usually the engineers. The dialogue between these two pivotal actors revolves around the specifications imposed by the industry.⁷ This interdisciplinary communication ensures that the final product meets both creative and technical standards, fostering innovative outcomes.

Other authoritative figures, such as production managers (production director, product manager, sales director, marketing director, and sales manager), also integrate into the design process. Their skills in terms of strategic knowledge, positioning, and understanding of the company's role and its products are essential. Often, these figures play a decisive role in terms of hierarchical responsibility. It is through exchanges within a framework defined by mutual links that the creative idea materializes into an innovative product.

The collective nature of creativity in the textile industry extends far beyond interactions within a single company and dialogue during the collection definition phase. The textile production process involves a long sequence of successive steps within an industrial chain. The ISO 14006 standard for environmental management systems defines product design and development as the set of processes that transform requirements into specified characteristics or specifications of a product, process, or system.⁴ This definition highlights the comprehensive nature of design, which encompasses not only the conceptualization phase but also the entire production cycle.

In our experience, the terms «design» and «development» are used interchangeably, sometimes to define the different stages of the entire process of transforming an idea into a product. They extend to products, processes, and services offered by the laboratory or company. Design must therefore be in constant contact with the market, both to meet demands and to propose innovative offers. We note that it is a structured concept. Furthermore, Louis Toupin describes design as a «activité relativement structurée»^{7,8}

Design and development in the textile field are among the resources currently available to companies to improve their position in the market, thus achieving increased competitiveness, with innovation being the most interesting driver for this task.⁹ Product development is the process of taking a product idea from planning to market launch and product review, in which business strategies, marketing considerations, research methods, and design aspects are used to bring the product to practical use.

The textile industry thrives through the synergy of science, creativity, and collaboration. By leveraging scientific knowledge, fostering interdisciplinary communication, and embracing the collective nature of design, the industry can continuously innovate and offer products that meet the evolving needs of consumers and society at large.¹⁰⁻¹⁶

Conclusion

Based on our extensive exploration and experimentation, the design and development of new special effects not only enhance product innovation but also foster a positive interaction with customers. This strategic approach not only improves the company's

⁷«relativement structurée activité»

image and perception but also effectively meets evolving customer needs. By introducing novel products to the market, driven by both existing and new customer demands, companies can significantly increase their market share and competitiveness.

In today's highly competitive and global market, characterized by increasing consumer demand for differentiated and environmentally conscious products, effective product design is crucial. Companies must strategically approach the design and development of new products and services, considering environmental factors alongside quality and safety standards. This strategic vision ensures that projects are systematically executed through a structured design process, encompassing phases from problem identification and research formulation to prototype design, testing, and final evaluation.

Our experiment with natural dyes such as turmeric and madder, incorporating ancestral techniques like Tie and Dye, has yielded innovative results. These efforts have not only advanced the integration of plant-based dyes in traditional textile dyeing but have also introduced new aesthetic and functional dimensions to cotton fabrics, reminiscent of leather and imbued with a rich ancestral heritage. This aligns with findings that heritage-inspired designs can create unique product identities that resonate with contemporary consumer preferences, highlighting the significance of cultural and historical influences in modern product design.

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Conflicts of interest

The author declares that there is no conflict of interest.

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