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Using an Experimental Approach of Sustainable, Ecofriendly Natural Dyeing for The Creation of Sustainable Fashion Accessories

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Abstract

As the demand for sustainable, ecological and environmentally friendly textile products explodes, the fashion industry is following suit. The textile industry is showing particular interest in products based on natural dyes. In this context, this work carried out a literature review on the history of natural dyeing of textile articles and on the benefits and drawbacks of natural dyes for textiles. In addition, this research identified recent trends in the fashion industry and applied the results from the literature review to those trends. This study proposed textile models using the natural dyeing technique. These models were used for the manufacture of various textile products.

Keywords: Natural dyeing; environmentally friendly products; eco design

Introduction

Sustainability in clothing design is becoming an increasingly important issue. The clothing industry is at the root of many environmental problems. In order to implement an effective strategy to protect the environment and combat the causes of its degradation sustainability has become vital as both a concept and a process [1,2]. Eco-design throughout the creative process in the fashion industry has also proved fundamental to sustainability [3]. Numerous studies have shown that the techniques applied to dye a garment are of crucial importance in reducing the negative impacts of the textile industry, and this, by proceeding with an eco-design approach [4,5]. This is why waste reuse has become an urgent need for the fashion industry. The literature suggests that sustainable practices in the textile and clothing sector include the use of environmentally-friendly, renewable and ecological materials, as well as the reuse or recycling of waste. The use of natural dyes is considered an alternative for ecological fashion, as it does not contain synthetic and toxic dyes [6,7].

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Natural dyes, derived from plant sources, have been used by humans for thousands of years to colour fabrics and materials. These dyes offer several advantages over synthetic dyes, making them an attractive choice for communities concerned with environmental sustainability, health and overall beauty [8]. Natural dyes are considered sustainable as a dyeing process [9]. As they are derived from plant materials such as roots, leaves, flowers and bark, they are naturally green and environmentally friendly [10]. Their presence does not harm the water ecosystem, the fertility of the land or the beauty of the village. Being biodegradable, plant dyes do not release harmful toxins into the environment [11]. In contrast, synthetic dyes often contain non-biodegradable chemicals and can have adverse effects on ecosystems when released into water bodies [12]. Dye effects are being developed to offer unique designs with different visual effects. Scientific literature emphasizes the crucial role of designers in the textile and apparel sector and their capacity to minimize the use of chemicals and textile waste via responsible and ecological practices such as recycling, upcycling, and the extraction of natural dyes.

Dye effects using natural dyes are emerging. These dyes offer the advantage of unique colours and the potential to be non-toxic. Plants and minerals are a good source of natural colours. The application of plant-based colorants has been widely applied and has shown effective results. However, the application of natural colorants has always been associated with poor working properties. The challenge for designers is to develop visual effects using natural dyes on an industrial scale. The textile developed must respond to fashion trends, but it must also have good use properties such as washability, rub resistance and light fastness. The present work describes an experimental design approach combining theory and practice. It investigates the use of agricultural by-products as an important source of renewable natural dye for textile finishing. Numerous research studies have reported on the use of natural dyes to dye fabrics and garments. However, there has been relatively little work on the creation of textile collections using this material. Natural and synthetic textile materials are usually dyed or printed by screen or roller printing, with the aim of adding value according to the market segments and customers targeted.

In ancient times, textile dyeing was initiated using dyes extracted from natural sources of vegetable, animal or mineral origin, until pigments and synthetic dyes were invented and marketed in huge quantities. Most dyers and textile manufacturers have moved towards the use of synthetic dyes because of the advantages of availability, durability and cost effectiveness of synthetic dyes. On the other hand, synthetic dyes pose a great threat to the ecology as most synthetic dyes are synthesised from petrochemical sources through hazardous chemical processes. This has led to a growing awareness worldwide of the biological value of eco-friendly products and a renewed interest among consumers in using textiles (preferably made of natural fibres) dyed with natural eco-friendly dyes. Since prehistoric times, natural dyes have been widely known for their use in dyeing natural fibres such as wool, silk and cotton as well as leather. While the ancient art of dyeing textiles with natural dyes has withstood the ravages of time, the rapid decline of natural dyeing has continued due to the widespread availability of synthetic dyes at a very economical price.

With all this, even after a century, the use of natural dyes has never completely eroded and is still used in different parts of the world. The market for natural dyes is growing. Although it is still a niche market, it is directly linked to the increased environmental awareness of the consumer. Market opportunities exist particularly in the green textile and eco-fashion industry. In recent times, many commercial dyers and export houses are reconsidering the possibilities of using natural dyes for dyeing and printings textiles for high-value global markets, as natural dyes, in addition to their ecological behaviour and social ethics, produce very rare, soothing and soft colours compared to synthetic dyes. On the other hand, although synthetic dyes are more economical and produce a wide variety of colours, they cause skin allergies and other damage to the human body, produce chemical toxicity/hazards during their synthesis, release unwanted toxic chemicals, effluents, etc. Thus, with an increasing number of companies being certified or exploring the commercial possibilities of green products, the demand for natural dyes is expected to increase to a great extent.

The new derivative of the luxury market today is the green fashion product which is supported by a social message where the customer intentionally pays a higher price knowing that it will one day save the earth where he/she lives. Thus, to achieve effective commercial use of natural dyes for any particular fibre and to achieve a proprietary natural colour palette with acceptable colour fastness and reproducible colour performance, appropriate and standardised scientific dyeing techniques and procedures need to be developed and adopted for the overall growth of the sector and society. This study investigates the implementation of an eco-friendly product line in which both the colours and materials are the direct outcome of a sustainable design process. The central aim is to provide viable alternatives to conventional textile practices by employing dyes sourced from renewable natural resources and non-toxic pigments obtained from plant-based waste. By integrating these environmentally conscious choices, the approach seeks to disrupt the fast fashion model-a major contributor to environmental degradation-by encouraging the adoption of nature-friendly dyeing methods that reduce chemical pollution and resource consumption.

In the subsequent section, the article presents a series of controlled experiments that form the practical foundation for designing sustainable fashion accessories through natural dyeing techniques. These experiments illustrate the feasibility and aesthetic potential of ecological methods, highlighting how responsible design principles can be effectively translated into tangible, market-ready products.

The Purpose of this Research is to

a) Making modern bags and accessories from dyeing textile fabrics (wool, cotton, linen) and leather according to the international fashion trends.

b) Applying dyeing methods and techniques using sustainable, ecofriendly naturals dyes for dyeing textile fabrics, which could be mixed with leather, for creating modern bags and accessories.

Materials and Methods

Dyes Source and Fabrics

The fabrics (cotton, wool, linen) used in this study were kindly supplied by CHIMITEX (Tunisia). Textile materials underwent a bleaching treatment prior to the dyeing stage. Various plant materials (dye plants and agricultural by-products), such as pomegranate bark and olive leaves, were used to extract dyestuffs. Impurities were removed by washing with water. After washing, all plant materials were dried in the shade. Samples were ground to powder using a laboratory grinder.

Description of the Dyeing Process

The dyeing technique used consists of impregnating the textile material (cotton, wool, linen) in the aqueous extract of the plant biomass in a pressurized Ahiba nuance autoclave (Data Colour International, USA) under agitation, following the process described in the figure below. Dyeing was carried out without mordanting or with a mordanting step. Three mordanting methods (pre-mordanting, simultaneous mordanting and post-mordanting) can be used. Two mordants, including hydrated aluminium sulphate (alum) and ferrous sulphate, were used at a concentration of 4%.

Tie and Dye: An Ancient Textile Art Form

Despite what many people think, tie-dye was not created in America in the 1960s. For centuries, the Incas, Japan, China, and India have all used variations of this technique. For instance, the centuries-old Japanese shibori technique and the roughly 5,000-year-old Indian bandhani technique are both used to create a variety of exquisite patterns on textiles meant for opulent kimonos. Furthermore, West Africa continues to produce colourful examples of tie-dye, demonstrating the practice's widespread presence outside of Asia. This ancient method selectively blocks areas from the dye's reach to produce beautiful patterns on textiles. The flow of dye to specific regions of the fabric is stopped by folding, stitching, crumpling, and other fabric preparation techniques. Usually, a damp cloth spread out flat on a table covered with plastic is used for the majority of the folding, crumpling, and twisting. The final design is determined by the fold pattern and dye placement. Depending on the type of knot, the outcome can be somewhat controlled and predicted with practice, but tie-dye is an intriguing and thrilling art form because of the element of surprise.

Results and Discussion

Colour Palettes of Dyed Textiles

The table below shows the colour palette obtained by dyeing various textile materials with natural dyes. Natural dyes extracted from dye plants and agricultural plants. The results of our eco-design process using vegetable dyeing have enabled us to obtain a variety of colours. By trying to apply the tie-and-dye technique to a few coloured fabrics, the result was subtly blended, shaded, juxtaposed.... but changing colours from one composition to the next. It has to be said, the more we play with effects and experimentation applied on textiles, the more we are faced with astonishing compositions. The tie-and-dye effect retracts and distorts space with a certain degree of unpredictability and spontaneity... generating very special visual effects. The results of our design process suggest that the application of a natural dye derived from agricultural waste can generate natural, non-chemical or toxic colours, enabling the design of unique, eco-friendly textile collections that can also be industrialized.

The reuse of agricultural waste creates natural colours, varied textures and a more striking resistance effect.

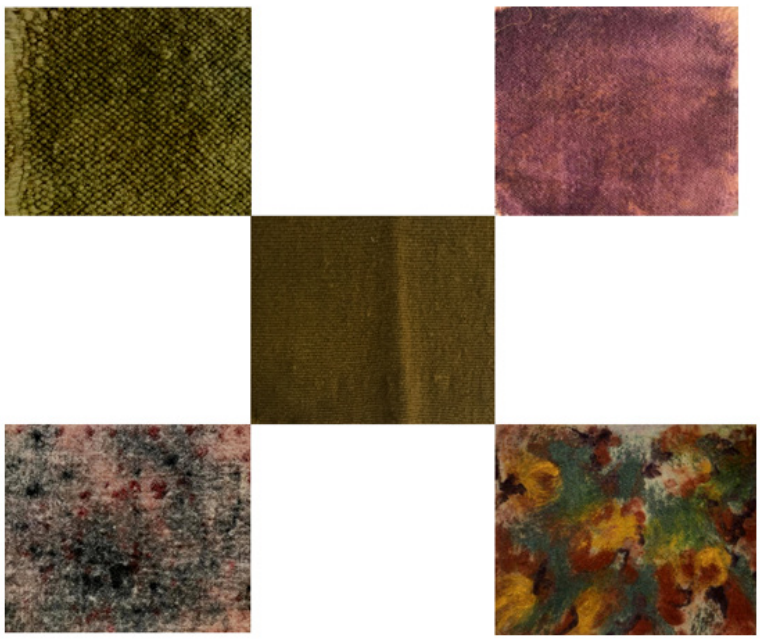

Figure 1: Wool fabrics dyed with natural dyes.

Figure 1 shows the wool samples developed in this study. This figure reveals several samples of wool fabrics dyed with natural dyes using a tie-and-dye design method, to show the wide range of tonal variations that can occur from this eco-friendly process. The sample in the centre demonstrates an even and uniform olive-brown tone indicating the solid and consistent tones that can be achieved. What is interesting about the surrounding samples is that they also exhibit the artistic and random results of tie-and-dye: the top-left sample has a surface texture with tonal variation of olive-green with subtle variation; the top-right sample has an infusion of deep purples and warm ochres, exhibiting a soft, cloudy essence; the bottom left sample has muted greys with red and black flecks in a random colour borrowing pattern, which is evident of organic textural results; while the bottom-right sample has a vibrant painterly effect of green, yellow, red, and purple layered on each other in unexpected ways.

As can be seen in these samples, natural dyes, when applied to fabrics and tie-and-dye methods, can produce consistent solid forms and complex multicolour projects, while honouring the aesthetics of handcrafted fabrics. Figure 2 illustrates the outcome of the same tie-and-dye process on cotton fabrics, using natural dyes, and highlights the different patterns and tonal depth possible on this substrate. The sample to the left shows a warm brown background with irregular dark and light areas that gives a subtle marbled impression that represents the organic flow of dye through the fabric and the natural pigment absorbance of the fibber. The sample to the right has a bright olive-green background with sharply delineated lighter motifs that leave a textured, almost topographical, look to the fabric. Both fabrics reveal how the resist effects of tie-and-dye, coupled with the interaction of the natural dye molecules with the cotton fibres, produced unique and non-reproducible designs that speak to the artisanal quality of each piece.

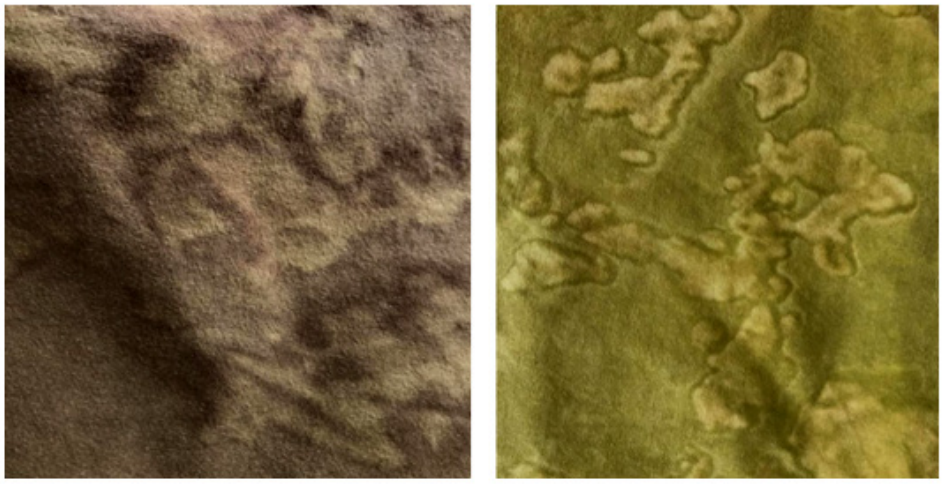

Figure 2: Cotton fabrics dyed with natural dyes.

Figure 3: Linen fabrics dyed with natural dyes.

(Figure 3) illustrates the outcomes of applying the same tie-and-dye technique to linen fabrics using natural dyes, demonstrating the material's capacity to capture warm, earthy tones with distinctive surface variations. The fabric on the left presents a predominantly uniform reddish-brown hue with soft, subtle shifts in shade, reflecting a gentle resist effect. In contrast, the sample on the right exhibits a more pronounced pattern, with lighter, irregular areas interwoven across the reddish-brown base, producing a dynamic and organic visual texture.

Chromatic and Textural Effects

The application of the tie-and-dye technique using mineral pigments in combination with plant-based dyes resulted in the emergence of distinctive and unpredictable patterns. Due to their insoluble nature, the mineral pigments did not merely alter the coloration of the fabric; instead, they formed an additional physical layer on its surface. This interaction produced unique textures and spontaneous visual effects, enhancing the tactile and aesthetic qualities of the textile far beyond simple chromatic variation. From a design perspective, the superimposition of colorants with different chemical and physical properties fostered a multi-dimensional surface treatment, where colour depth and texture coexisted to create visually rich compositions. This outcome underscores the potential of combining natural dyes with particulate pigments to expand the creative possibilities in sustainable textile design, while also contributing to the development of environmentally responsible decorative techniques.

Material Synergy

The alternation between the plant-based dye, which penetrates the fibbers, and the mineral pigments, which adhere to the fabric surface, generated a synergistic interplay of effects. This dual action not only enriched the chromatic depth but also introduced a tactile dimension, producing visual outcomes that could not be achieved by either medium alone. Such an approach demonstrates the potential of combining dyes and pigments with distinct physical and chemical properties to achieve complex and multi-layered results. Beyond its aesthetic value, this synergy offers new avenues for sustainable textile design, where natural, non-toxic colorants can be strategically integrated to enhance both visual richness and material performance.

Unpredictability and Innovation

The random and spontaneous nature of the effects obtained-particularly in terms of form and texture-proved to be a valuable source of innovation. Far from representing a limitation, this unpredictability revealed the capacity of these materials to produce unique results unattainable through standardized dyeing methods. The irregular distribution of pigments and the organic formation of patterns contributed to a visual richness that emerged from the interplay between controlled processes and accidental occurrences. These findings suggest that the deliberate embrace of spontaneity in textile manipulation can be a key parameter for generating rich, original visual effects. By integrating this element of unpredictability into the design process, practitioners can expand the creative boundaries of sustainable fashion, fostering products that are not only environmentally responsible but also aesthetically distinctive and artistically expressive.

Simulations and Finished Products

Building upon the fabrics developed during the experimental phase and informed by the outcomes of our chromatic trials, we proceeded to design and produce a curated collection of sustainable fashion accessories. This stage served as a practical extension of the research, enabling the transition from laboratory-scale experimentation to tangible product development. The process validated the technical feasibility and aesthetic potential of the proposed natural dyeing methodology, confirming its compatibility with design requirements in the fashion sector. Furthermore, the production of finished items provided an opportunity to assess the durability, colour fastness, and visual appeal of the dyed textiles under real-world conditions. The results demonstrated that the approach not only delivers environmentally responsible coloration but also meets the functional and aesthetic standards expected in contemporary fashion products. This direct application highlights the potential of natural dyeing techniques to be integrated into commercial design practices, offering a viable and scalable alternative to conventional synthetic dye processes.

Figure 4: Development of tote bag Prototype Products.

Figure 5: Development of bag Prototype Products.

Following the series of dyeing experiments carried out on wool, cotton, and linen fabrics, the research advances to its central objective: exploring the application of these naturally coloured textiles in the creation of contemporary fashion accessories aligned with international trends. In this context, two tote bag prototypes and three additional bag prototypes were designed and produced, showcasing the practical and aesthetic potential of the developed materials. The outcomes of this experimentation are illustrated in (Figures 4&5).

Conclusion

The experiments conducted served as the foundation for a responsible design approach, culminating in the creation of durable fashion accessories. The use of natural dyes and eco-friendly fabrics validated an environmentally respectful production method, offering a tangible alternative to conventional industrial practices The application of an eco-responsible design methodology emerges as a relevant lever to address current environmental challenges and mitigate the negative impacts of the textile industry. This approach-grounded in the use of renewable resources and non-polluting processes-contributes to the search for sustainable solutions, demonstrating that innovation in design can be achieved in harmony with environmental preservation. Future research should explore additional eco-responsible alternatives in fashion design, with the aim of refining production processes, enhancing scalability, and expanding the creative possibilities of sustainable fashion. By combining various perspectives and areas of expertise, this new design methodology promotes a multidisciplinary approach and helps engineers and designers work together throughout the product development process. Such collaboration fosters creativity and problem-solving skills and is consistent with the standard procedures seen in many textile companies, where cross-functional teams collaborate to develop and improve products that satisfy both technical specifications and aesthetic standards.

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Conflicts of Interest

The author declares that there is no conflict of interest.

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References

1. Daukantienė V (2023) Analysis of the sustainability aspects of fashion: A literature review. Textile Research Journal 93(3-4): 991-1002.
2. Su Y, Fan Y, Liu G, Tian M, Li J (2023) A Review on Sustainable Method to Evaluate Heat and Moisture Transfer in Clothing Material. Sustainability 15(3): 2747.
3. De Ponte C, Liscio MC, Sospiro P (2023) State of the art on the Nexus between sustainability, fashion industry and sustainable business model. Sustainable Chemistry and Pharmacy 32 :100968.
4. Fonseca A, Ramalho E, Gouveia A, Henriques R, Figueiredo F, et al. (2023) Systematic Insights into a Textile Industry: Reviewing Life Cycle Assessment and Eco-Design. Sustainability 15(21): 15267.
5. Sagnak M, Berberoglu Y, Kazancoglu Y (2024) Sustainable Performance Assessment of Textile and Apparel Industry in a Circular Context. In Sustainable Manufacturing Practices in the Textiles and Fashion Sector PP. 199-228.
6. Wang Y, Liu C, Zhang X, Zeng S (2023) Research on Sustainable Furniture Design Based on Waste Textiles Recycling. Sustainability, 15(4): 3601.
7. Mabuza L, Sonnenberg N, Marx-Pienaar N (2023) Natural versus synthetic dyes: Consumers' understanding of apparel coloration and their willingness to adopt sustainable alternatives. Resources, Conservation & Recycling Advances 18: 200146.
8. Baaka N, Ben Ticha M, Mabrouk S, Dhaouadi H (2023) Environmentally friendly dyeing of wool and silk fabrics with natural colorant of turnsole (Chrozophora tinctoria L.). Environmental Science and Pollution Research 30(27): 1-13.

9. Abdelileh M, Ben Ticha M, Kordoghli B, Khiari R, Meksi N (2023) Dyeing of Modified Acrylic Fibers with Indigo Carmine: Modeling and Optimization of the Dyeing Process Using a Combination of RSM and ANN Methodologies. Fibers and Polymers 24(7).

10. Habib N, Ali A, Adeel S, Aftab M, Inayat A (2023) Assessment of wild Turmeric–based eco-friendly yellow natural bio-colorant for dyeing of wool fabric. Environmental Science and Pollution Research 30 (2): 4570-4581.

11. Kailash BR, Charles B, Ravikanth G, Setty S, Kadirvelu K (2022) Identifying the potential global distribution and conservation areas for Terminalia chebula, an important medicinal tree species under changing climate scenario. Tropical Ecology 63 (4): 584-595.

12. Islam MT, Jahan R, Jahan M, Howlader MS, Islam R (2022) Sustainable textile industry: An overview. Non-Metallic Material Science 4(2): 15-32.