



Baru Dye Applied to Fashion Accessories

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Abstract

The synthetic dyes used in the textile segment, besides causing a relevant negative impact on the environment, it may also cause problems to human health, such as contact dermatitis. Natural dyes may be an alternative to those, some even presenting properties as UPF protection. Considering Brazilian biodiversity and world interest, this article aims to contribute to the development of a dye from *Dipteryx alata* Vogel, which besides its various health benefits, it may also be used as a natural dye in fashion accessories and photoprotection agent. The results obtained from the development of the dyeing method of textile substrates present interesting information. However, continuity in studies is required for further improvement and to reach new markets.

Keywords: Natural dye; Photoprotection; Textile; Eco-friendly

Introduction

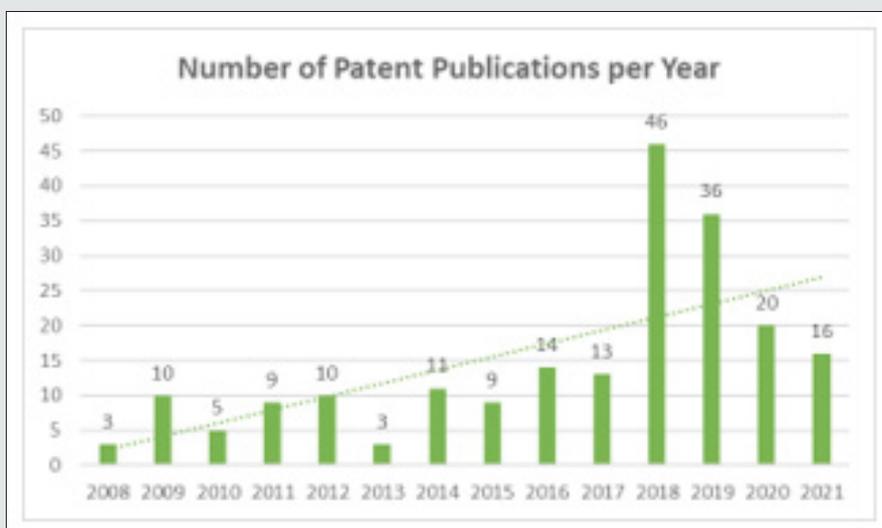
The clothing industry is one of the most important in the world, moving more than 1 trillion dollars annually, contributing to 7% of the world's exports, and employing approximately 25 million people. It is also one of the most unsustainable industries, according to the report "Fashioning Sustainability" released in 2007 by the British NGO Forum for the Future and one of the most polluting, according to a report by Deloitte, "Fashioning Sustainability 2013" [1]. According to the same Deloitte report, sustainability has become an imperative strategic business. Consumers want to relate to sustainable institutions and there is a high demand for sustainable products in the textile and cosmetics sector [2]. Brazil is located between the tropic of Capricorn and Ecuador, which is why it is a region that receives the greatest intensity of solar radiation, making it the country with the largest intertropical area. One of the ways in which sunlight can manifest its harmful effects is through the generation of reactive oxygen species by UV radiation, which has serious implications on human health, affecting cellular material directly or through photosensitization mechanisms [3]. Clothes that protect against solar radiation are increasingly popular, and they receive a titanium oxides bath to acquire this function, which is the same physical ingredient used in sunscreens. Simple actions such as avoiding sun exposure at times of greatest insolation and wearing sunscreen do not determine an absolute protection for people whose skin is more sensitive to the

sun exposure. Only opaque protection guarantees such complete skin protection [4]. This is possible with clothes treated for this purpose, which generally protect against ultraviolet A (UVA) and ultraviolet B (UVB) rays. The dyeing of plain or knitted textiles relies on chemical products and dyes, which may contain heavy metals (lead and mercury) and other carcinogens, which may represent a risk to final consumers. Furthermore, the cost to treat the effluent is something to be considered in terms of the final cost of the dyed textile.

Aspects related to environmental, economic, and social sustainability are being increasingly appreciated by the growing number of concerned consumers. According to Araujo (2005), natural dyes are substances extracted only by physical-chemical processes (extraction, precipitation, etc.) or biochemical processes (fermentation) from an animal or plant raw material, in which those must be soluble in the liquid medium [5]. Although not all natural dyes have characteristics that provide a more vivid appearance of colors when compared to artificial ones, their use is greatly beneficial to the environment. In fact, the use of natural dyes is a major challenge for the fashion industry. Considering the demand for sustainable alternatives, a study of the current global scenario of natural dyes was carried out, through the analysis of the PATENTSCOPE database, in which the keywords used were: "natural dye" in the title and "textile" in the title or abstract. The

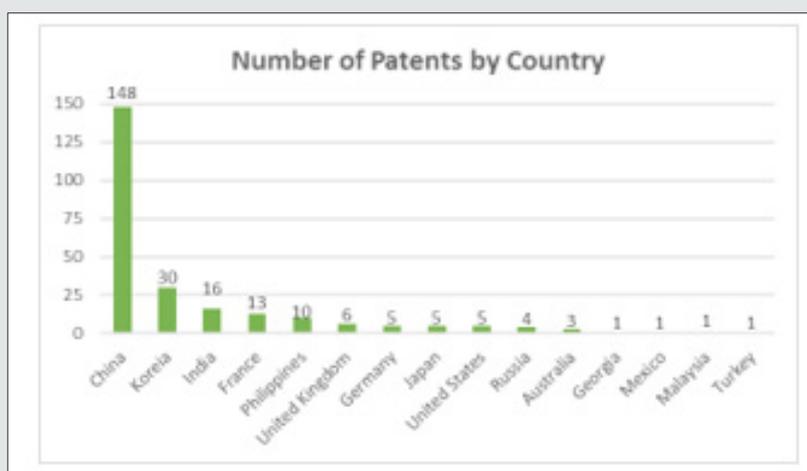
growth of patents related to natural dyes is remarkable, as shown in Graph 1. The years that show the highest number of filings are: 2018, in which there are forty-six patent filings, 2019 with thirty-six filings, and 2020 with 20 filings. The trend indicates an increase in the number of patents since the beginning of the last decade. From the publications cited in Graph 1, the countries which contribute the most are identified in Graph 2. Based on Graph 2, it is possible to conclude that China and Korea are, by far, more developed in their technological production on this topic than other countries, since their patent deposits represent 71.48% of the total deposits. To better exploit Brazilian biodiversity and to meet the world market trends, bark and endocarp of the species *Dipteryx alata* Vogel were used, promoting a true combination between the Amazon and

Cerrado biomes. The parts used were waste from the production of oils, meaning that, the pulp and nuts of the species are used, and the peel and endocarp are usually discarded. The textile dyeing sector has helped to promote a sustainable use of natural resources, especially in terms of circular economy. Packaging prototypes were obtained using the dyed material. Thus, the present investigation aimed to develop an ecological dye with photoprotective and modifying action, from species originated from Brazilian biodiversity. In addition, the international competitiveness of the Brazilian textile industry will be improved through the exportation of the sustainable photoprotective fabric. Additionally, this work reveals this new dyeing process prevents the fading of clothes and is non-allergenic [6].



Graph 1: Publications/Year.

Source: Elaborated by the authors.



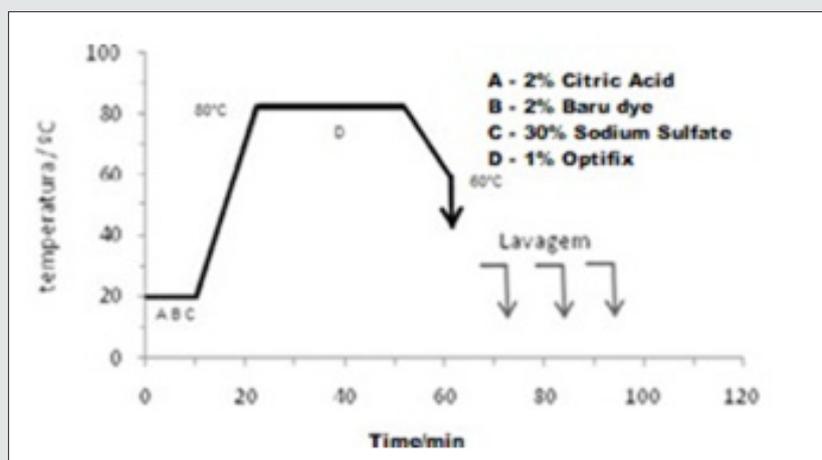
Graph 2: Patents/Country.

Source: Elaborated by the authors.

Methodology

The plant species *Dipteryx alata* Vogel, known as baru, occurs in cerrado formations, mainly in Minas Gerais, Goiás, Distrito Federal, Mato Grosso and Mato Grosso do Sul, and is a soil nitrogen-fixing plant, occurring in more fertile soils [7]. It was processed in accordance with patent BR 10 2013 013080 0 A2, filed by Biodiversité company, obtaining the baru in powder form, marketed for the cosmetics area and used for the manufacture of specific products for make-up, masks, exfoliants and foods, specifically food supplements and nutricosmetics. Solubility and chemical compatibility tests as a function of temperature were carried out to determine a dyeing method for the textile substrates. Empirical

results allowed the determination of a dyeing method for the knitted cotton (CO) (after purge/bleached) substrates. The dyeing was carried out at different concentrations with recipes without the fixer and recipes with commercial Optifix CD (Clariant) fixer. Four dyeing procedures were carried out on textile substrates, as shown in Graph 3, with the following concentrations: 0.5%; 1.0%; 2.0% and 4.0% spm. The dyed substrates were analyzed by reflectance spectroscopy, using a Minolta model 2200d spectrophotometer in the visible region between 400 and 800 nm to determine the colorimetric coordinates in the CMC 2:1 system. The colorfastness to light, colorfastness to wash and the ultraviolet protection factor (UPF) were also quantitatively analyzed.



Graph 3: Baru dye application curve without fixer (ABC) and with fixer (D) process 'All In'.

Source: Elaborated by the authors.

The ultraviolet protection factor (UPF) indicates the ability of a textile to photoprotect the user's skin [8]. The UPF of the dyed fabric with the natural dyes were determined using a UV-VIS spectrophotometer (Lambda 800, Perkin Elmer), with a 150 mm integrating sphere from the Colorimetry Laboratory of SENAI CETIQT. All samples were analyzed dry and without tension, with the beam perpendicularly incident to the textile substrate. Eight measurements were performed for 4 specimens of each sample and the diffuse transmittance spectra were obtained with a step of 5nm in the spectrographic range from 400 to 290 cm^{-1} using the WinLab software, version 5.1.5. The temperature of $21.0 \text{ }^\circ\text{C} \pm 2.0 \text{ }^\circ\text{C}$ and the relative humidity of $65\% \pm 5\%$ of the measurements performed were controlled by a thermohygrometer, Hanna Instruments, model HI9564. The UPF values (average) were obtained statistically, according to AS/NZS Standard 4399:1996 [9], from the Equation 1 below, and then were normalized (Rated UPF) (Table 1).

$$UPF = \frac{\sum_{\lambda=280}^{400} E(\lambda) \cdot S(\lambda) \cdot \Delta\lambda}{\sum_{\lambda=280}^{400} E(\lambda) \cdot T(\lambda) \cdot S(\lambda) \cdot \Delta\lambda}$$

Where $S(\lambda)$ is the solar spectrum irradiance ($\text{W}\cdot\text{m}^{-2}\cdot\text{nm}^{-1}$) (tabled value), $E(\lambda)$ is the relative erythemal efficiency (tabled value), $T(\lambda)$ is the measured spectral transmittance, $\Delta\lambda$ is the range of measured wavelength (nm) and λ is the wavelength (nm). The solar spectrum used to calculate the protection factor was Melbourne, according to Table B2 of AS/NZS Standard 4399:1996 [9]. The UPF values determined for the functionalized textiles were classified according to the level of protection, according to Table 1. The colorfastness to wash tests were performed according to the ABNT NBR ISO 105-C06 standard in B1M condition, using a DW multifiber control fabric, steel balls, standard reference detergent WOB AATCC 1993 [10,11]. The colorfastness to light tests were carried out in accordance with the ABNT NBR ISO 105- B02 standard [12], in method 5 of the Weather Ometer equipment, with normal exposure, in a tempered zone, using a blue reference fabric, series 1-8, at the Black Panel temperature of $45 \text{ }^\circ\text{C}$, with approximately $6000 \text{ kJ}/\text{m}^2$ of radiant energy, $42 \text{ W}/\text{m}^2$ of irradiance. For packages confection, the machinery of the Prototyping Laboratory was used (1 needle/straight stitch machines and 3-wire overlock). For the applications of accessories, it was used an Ultimaker 3D printer and then gold jets were applied with varnish (Figure 1).

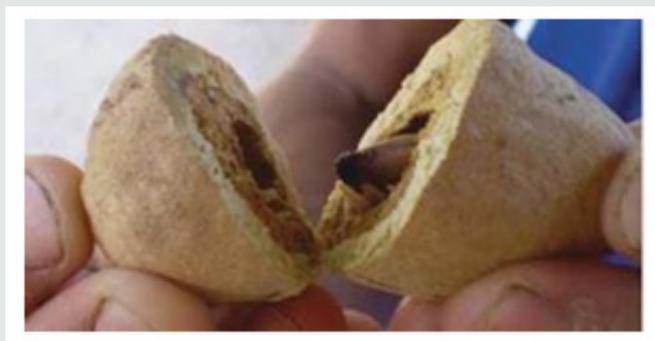


Figure 1: Baru basic structure [6].

Table 1: UPF Classification System according to AS/NZS Standard 4399:1996.

UPF Range	UV Protection Category	Effective UV Transmission (%)
15 - 24	Good Protection	6.7 – 4.2
25 - 39	Very good Protection	4.1 – 2.6
40 - 50, 50+	Excellent Protection	0 – 2.5

Results and Discussion

The development of the dyeing method for the baru dye was satisfactory due to the fixation and development of the color on cotton, reducing the dyeing time and temperature, as shown in Figure 2. It was possible to verify an increase in the wash fastness on cotton substrate, as shown in Table 2. This indicates that it is possible to work with other commercial and natural fixatives to improve the product, changing the quantities of fixatives and their chemicals characteristics. The assessment of UPF was carried out on substrates without application of baru dye and with application of 2% Baru, and the results are shown in Table 3. The dyeing with the plant species dyes, in addition to color, conferred UV protection

to the treated fabric, compared to the untreated fabric, with 30 FPS. The results of blocking solar radiation in the UVA-UVB region of the photoprotective fabric are significant and reveal the potential for applicability in the weaving and manufacturing sector. Regarding the dyeing process, it is possible to compare the textile substrate before and after dyeing. Thus, heavy metals are evaluated using the NM-300-3 standard, as shown in Table 4, where it is possible to observe that the dyed textile substrates values were below those allowed [13]. These results corroborate the low toxicity claimed for such dyes. Figure 3 illustrates the prototypes made with the photoprotective fabric in different designs in order to assess its applicability for makeup packaging based on Baru's pigment.



Figure 2: Baru dyeing in cotton.



Figure 3: Bags made from fabric dyed with Baru

Table 2: Transfer System and Change of Color Fastness to Washing – NBR ISO 105 C06 B1M:2010 and Color Fastness to Light - ISO 105 B02:1994.

Samples	Color Fastness to Wash – NBR ISO 105 C06 B1M:2010		Color Fastness to Light - ISO 105 B02:1994
	Transfer	Alteration	Alteration
2% Dipteryx (Baru) dye: Cotton substrate without fixative	Wool=5 Acrylic=5 Polyester=5	1	2
2% Dipteryx (Baru) dye: Cotton substrate with fixative	Polyamide=5 Cotton=5 Acetate=5	2	2

Table 3: Transmittance values (%) for the range of UVA (400 to 315nm) and UVB (315 to 290nm) of the analyzed sample. Calculations based on the formulas of Norm AS/NZS 4399:1996.

Textile Substrate	T% (UVA)	T% (UVB)	Normalized	Classification
CO PT control	33.1817	24.9296	0	0
CO 2% Baru	2.9247	2.6634	30	30

Table 4: Quantification of Metals by Atomic Absorption with Graphite Furnace and Hydride Generator, Digestion method. Heavy metal soluble in textile extraction standard NM-300-3.

Textile Substrate	Elements	Concentration (mg Kg ⁻¹)	Limit of quantification (mg Kg ⁻¹)
CO PT Control, CO 2% Baru	Mercury	<0.25	0.25
	Chrome	<5.0	5
	Cadmium	<2.5	2.5
	Lead	<5.0	5
	Barium	<50.0	50

Conclusions

It was presented a sustainable baru dye, used in a dyeing method at low temperature. The dye has a difference in its hue that differs from pastel tones (earth colors) presented by most natural dyes. The application of natural baru dye on cotton significantly increased the ultraviolet protection factor (UPF), from 0 to 30.

Regarding color fastness to washing and light, depending on the market to which the textile is destined, studies with natural fixatives and metrological tests are recommended to better inform the final consumer. Besides all the benefits provided by the natural dye, such as ultraviolet protection and good colorfastness to wash, it was also possible to use the dyed textiles with baru dye in fashion accessories.

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Declaration of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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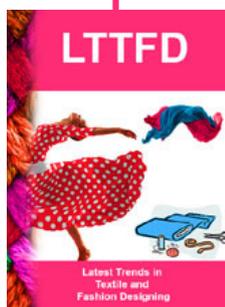


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