Reviving the use of plant dyes for sisal (*Agave sisalana*) fibres in a Brazilian artisan community

*Revitalizando o uso tradicional de plantas corantes de fibras de sisal (*Agave sisalana*) em uma comunidade artesã brasileira*

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ABSTRACT

Sisal fibre handicrafts, common in tropical regions, traditionally relied on plant-based dyes. However, these have largely been replaced by synthetic dyes, contributing to the loss of traditional knowledge. This study aimed to document plant species historically used to dye sisal and assess the potential for reintroducing natural dyes in a Brazilian artisan community. An ethnobotanical study was conducted through interviews and participatory dyeing workshops with 154 artisans selected via the snowball sampling method. Although artisans relied exclusively on synthetic dyes, they recalled 33 plant species that had formerly been used for dyeing. The trials expanded the range of natural dye options for sisal and renewed artisan interest in producing market-aligned colours. The adoption of eco-friendly, non-toxic, low-cost natural dyes that add value to their crafts also strengthened community engagement. Efforts like this, especially in regions rich in plant and cultural diversity, help preserve traditional practices and support more sustainable artisanal production.

Keywords: Traditional knowledge. Natural dyes. Ethnobotany. Dyeing plants. Eco-friendly products.

RESUMO

O artesanato com fibras de sisal, comum em regiões tropicais, tradicionalmente envolve o uso de plantas corantes. Porém, elas foram substituídas pelo uso de corantes sintéticos, levando ao declínio de conhecimentos tradicionais. Este estudo objetivou documentar plantas historicamente usadas para corar sisal e verificar o potencial de reintroduzir essa prática em uma comunidade artesã brasileira. Estudos etnobotânicos, utilizando entrevistas e oficinas participativas de tingimento, com 154 artesãos, por meio de seleção por bola de neve, foram conduzidos. Apesar de utilizarem somente *corantes sintéticos, foram mencionadas 33 espécies tintoriais. Os resultados das oficinas de tingimento expandiram o repertório de cores e criaram tonalidades alinhadas às demandas do mercado. A adoção de corantes naturais, por serem de baixo custo, livres de substâncias tóxicas e capazes de agregar valor aos produtos, também aumentou o interesse da comunidade. Estudos dessa natureza, especialmente em regiões com rica biodiversidade vegetal e cultural, ajudam na conservação de práticas tradicionais e promovem a produção artesanal sustentável.*

Palavras-chave: *Conhecimento tradicional. Corantes naturais. Etnobotânica. Plantas tintoriais. Produtos ecossustentáveis.*

1 INTRODUCTION

The textile industry is widespread worldwide, with cotton being the most widely used textile fibre (Kant, 2012). Other natural plant-based fibres used in clothing fabrics include linen and hemp, while sisal, pita, jute, and ramie are employed in the geotextile, rope, sack, and artefact industries (Nayak *et al.*, 2011; Simpson; Ogorzali, 2001).

The processing of these fibres, especially the chemical dyeing process, generates waste that can lead to environmental contamination and often contains heavy metals and other substances toxic to humans and the environment (Kant, 2012). In addition to dyes, mordants used in the dyeing process to fix colours can also be similarly toxic. Consequently, the synthetic chemicals used in fibre dyeing have caused significant environmental impacts (Kant, 2012). Thus, treating effluents from these industries in compliance with environmental regulations constitutes a significant challenge in the textile industry (Costa *et al.*, 2020; Kant, 2012).

Natural dyes can also ensure adequate colour fixation and may reduce production costs by using locally available plant resources (Costa *et al.*, 2020). In this context, natural dyes, such as those derived from plants, can constitute a sustainable alternative for this processing (Costa *et al.*, 2020). Alongside the use of natural dyes, the use of mordants, which are responsible for the quality and fixation of the colour, must also be managed with care to achieve the goal of eco-sustainable fibre production (Prabhu; Bhute, 2012).

Since ancient times, humans have used dyes extracted from plants, minerals, and some animals to colour fabrics (Kant, 2012; Simpson; Ogorzali, 2001). However, with the advent of chemical dyes, natural dyes were largely replaced in both industrial and artisanal dyeing processes (Kant, 2012; Ramadhanti *et al.*, 2019). This shift occurred mainly due to their lower cost, ease of use, and greater colour stability (Kant, 2012). Nevertheless, natural dyes can also provide effective colour fixation while offering environmental benefits and reducing production costs through the use of locally available dye plants (Che; Yang, 2022).

It is estimated that 100 million tons of dyes per year would be needed to meet the global demand for coloured fibres, making the use of plant-based dyes in large-scale industrial processes challenging (Ramadhanti *et al.*, 2019). However, in artisanal production processes, the use of natural dyes is viable, eco-sustainable and can add value to the final product. It provides originality and a distinctive design, meeting the growing demand for eco-friendly products (Che; Yang, 2022; Costa *et al.*, 2020). Growing consumer awareness of environmental issues has further increased the demand for such products (Costa *et al.*, 2020; Ramadhanti *et al.*, 2019).

Several kinds of natural dyes have been reported, whose specificity is related to the chemical composition of textile fibres (Che; Yang, 2022). Animal-derived fibres, such as wool and silk, are primarily protein-based and therefore require specific dyes. In contrast, plant-derived fibres are composed mainly of cellulose and lignin, with proportions varying by species (Simpson; Ogorzali, 2001). Thus, some dyes are more suitable for primarily cellulosic cotton fibres, while others perform better on more lignified fibres such as sisal (Chand; Rohatgi, 1994). Most studies on natural dyes have focused on cotton and wool fibres, widely used in clothing fabrics (Che; Yang, 2022). Few studies, however, have investigated natural dyes for sisal fibres.

Sisal fibres (*Agave sisalana* Perrine ex Engelm., Asparagaceae) are classified as hard fibres, which limits their use to textiles not intended for clothing (Simpson; Ogorzali, 2001). However, the use of sisal fibres for crafting artisanal items has been reported in various parts of the world, especially in tropical regions (Gooroochurn; Socheta, 2016; Kumar; Allamraju, 2019). The production of these artefacts provides a source of employment and income, fostering women's empowerment and strengthening rural communities (Gooroochurn; Socheta, 2016). In Brazil, the crafting of rugs and other decorative artefacts from sisal is part of the cultural heritage of some communities. In the historic city of Mariana, in the state of Minas Gerais, the use of these fibres in artisanal work dates back over three centuries (Gonçalves, 2023). According to this author, traditional methods of fibre extraction and natural dyeing were originally used in the region but were gradually replaced over time. By the late 20th century, processed fibres began to be imported from the country´s northeastern region, and dyeing shifted to synthetic dyes, which can contaminate water resources with toxic effluents. The dyed fibres are used to create various artefacts, mainly rugs, as well as other artisanal items such as bags and wall hangings.

Sustainable practices must integrate environmental, economic, and social dimensions while prioritising social justice and the intrinsic value of ecosystems. Building a truly equitable green economy requires the sovereignty and active leadership of local communities who hold traditional ecological knowledge for biodiversity management and a holistic worldview that recognises the interdependence between humans and nature (Bina, 2013). Ethnobotanical studies play an important role in documenting and valuing traditional plant knowledge, including dye plants used in artisanal textile production. Artisan communities are key actors in socio-biodiversity value chains, as their activities rely on local biological resources and specialised knowledge related to the selection and processing of plant materials (Balik; Cox, 2020; Luczaj, 2023; Ramadhanti *et al.*, 2019). Crafts also embody community history, symbolism, and spirituality, reinforcing social ties through the intergenerational transmission of knowledge (Simpson; Ogorzali, 2001). However, traditional knowledge in artisan communities faces increasing pressures from modernisation, limited institutional support, and disruptions to knowledge transmission as younger generations adopt more globalised lifestyles (Ghose; Ali, 2023). Despite their cultural and economic importance, dye plants in artisanal production systems—particularly in fibre-based crafts and socio-biodiversity value chains—remain understudied. Research on dye plants and artisanal fibres, therefore, contributes to understanding how traditional knowledge sustains cultural identity, local economies, and more sustainable socio-biodiversity value chains (Ghose; Ali, 2023).

Brazil is the country with the greatest plant biodiversity in the world and also encompasses a rich traditional knowledge of plant use, including dye plants (Forzza *et al.*, 2012). Thus, to contribute to the sustainability of artisanal production and the biocultural conservation of a Brazilian artisan community, as well as to expand knowledge about natural dyes for dyeing sisal fibres, this study aimed to document plant species historically used as dye sources and to assess the potential for reintroducing natural dyeing practices within this community. We hypothesised that community members still possessed knowledge of using natural dyes to dye sisal fibres. Additionally, we assumed that plant species were available in the region for this purpose, thereby expanding the list of known dyeing taxa. Furthermore, we believed that conducting this action research in a participatory manner with the community would revitalise interest in using natural dyes for fibre dyeing, contributing to the sustainable development of the region.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The study was conducted in the district of Cachoeira do Brumado, municipality of Mariana, Minas Gerais, Brazil (Figure 1). Mariana is recognised as a national historical heritage site (Law No. 7,713 of July 6th, 1945) for its historical and cultural significance and its Baroque architectural style. The region's main economic activity is iron mining, followed by tourism (IBGE, 2010).

Mild temperatures, dry winters, and rainy summers characterise the region's climate. The relief is undulating, with altitudes ranging from 451 to 2,065 meters. The vegetation fits within the Atlantic Forest and *Cerrado* domains (IBGE, 2010). Cachoeira do Brumado is located at 21 Km from the municipal seat, with a population of 1,151 women and 1,110 men living in 824 households (IBGE, 2010). The population is multi-ethnic, resulting from the intermixing of indigenous peoples with African and European groups who settled in the region since the colonial period, in the early 17th century (Costa *et al.*, 2021).

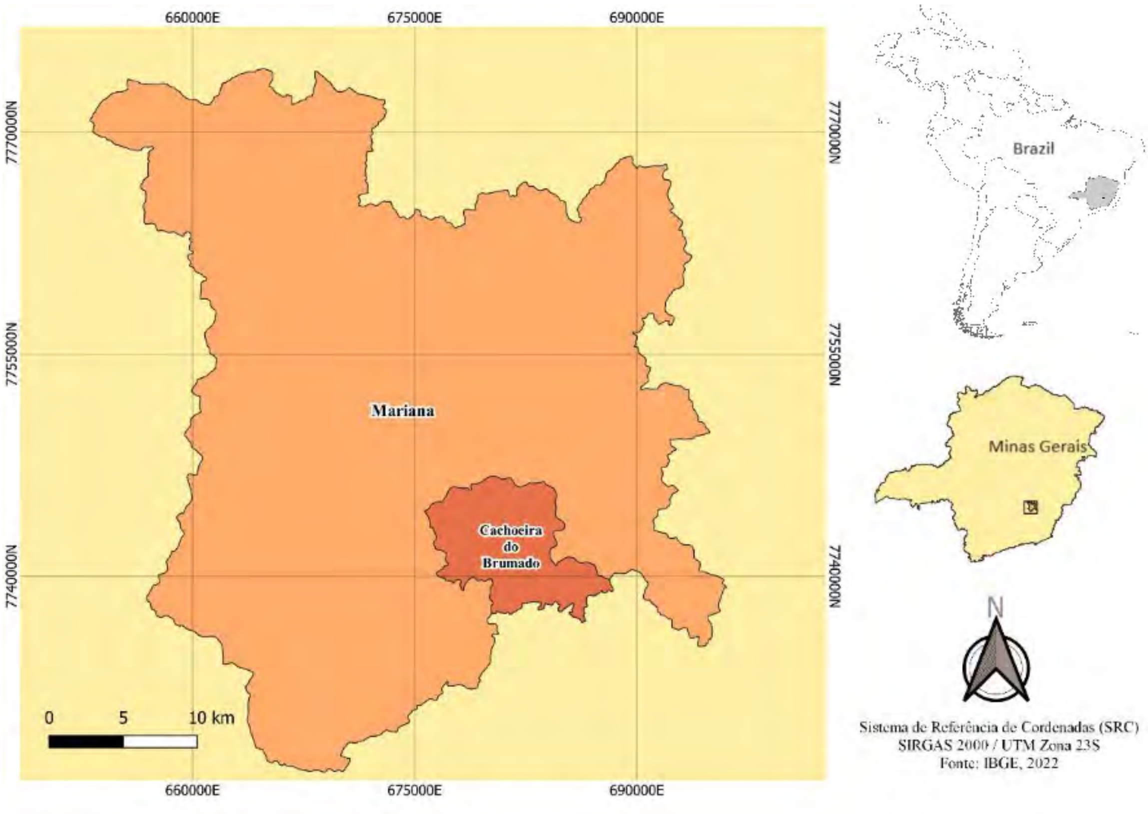

Figure 1 – Location of the district of Cachoeira do Brumado, Mariana, Minas Gerais, Brazil.

Source: Own elaboration.

The district of Cachoeira do Brumado is renowned for its craftsmanship, particularly sisal tapestry and soapstone cookware, which are important sources of local income (Gonçalves, 2023). It was estimated that there were around 260 sisal artisans in the district, with 60 of them organised since 1999 into an association, the AACB - Association of Artisans and Home Producers of Cachoeira do Brumado (IBGE, 2010). Most of the female population is involved in sisal tapestry. Although men also participate in this activity, they primarily work in the production of soapstone artefacts or in mining companies. The artisanal work relationships are familial, with artefact production taking place in artisans' own homes. In addition to rugs, other handcrafted products such as bags, curtains, and wall hangings are also produced on a smaller scale. The fibres used in the tapestry primarily come from sisal (*Agave sisalana*) leaves, obtained from plantations of Bahia, northeastern Brazil. To a lesser extent, pita fibre (*Furcraea foetida* (L.) Haw.), cultivated and processed within the district, is also used (Gonçalves, 2023).

2.2 ETHNOBOTANICAL STUDY

The ethical procedures for this ethnobotanical study adhered to internationally recognised principles of ethnobiological research. The study adhered to the guidelines of the International Society of Ethnobiology, particularly the International Society of Ethnobiology Code of Ethics, which emphasises prior explanation of research objectives, voluntary participation, respect for local knowledge, and informed consent (http://ethnobiology.net/code-of-ethics/). These procedures were also consistent with Brazilian legislation in force in 2002, when the data were collected.

The project was first presented to the community to explain its objectives and invite artisans to participate in the research. After obtaining participants' consent, all informants aged 18 or older who agreed to participate were interviewed. The interviews were carried out from June to September 2002. The participants were selected using the snowball sampling technique (Albuquerque *et al.*, 2014a), and the initial participants were identified at the meeting where the project was presented to the community. Semi-structured interviews were conducted (Albuquerque *et al.*, 2014b) to assess the traditional knowledge about the use of natural dyes and other aspects of fibre craftsmanship. Interviews were conducted using open-ended questions, allowing them to respond according to their own logic and concepts. A basic interview guide was used, including questions about the historical background of sisal tapestry craftsmanship in Cachoeira do Brumado, the sources and processing of raw materials, and aspects of dyeing and weaving. Regarding known plant species for dyeing sisal fibres, inquiries were made about the species used, the plant parts employed, methods of dye preparation, dyeing processes, and the colours achieved.

In addition to the interviews, guided tours were conducted (Albuquerque *et al.*, 2014b) to collect, herbarise, and taxonomically identify plant species mentioned for their dyeing properties. These tours also aimed to enrich the repertoire of recognised species with this potential.

The herbarium specimens were deposited at the Professor José Badini Herbarium (OUPR) at the Federal University of Ouro Preto. Commercial species and those lacking reproductive structures were not herborised. Species identification was conducted through morphological studies and by comparison with materials previously deposited in herbaria. Species nomenclature was verified using the Flora e Funga do Brazil (2026) and the World Flora Online (WFO, 2022) databases.

2.3 TRIALS WITH PLANT DYES

The trials were carried out in participatory workshops, together with community members. Trials were conducted to dye sisal fibres using 21 plant species cited in the ethnobotanical study, whose parts were available. These parts were collected and processed to extract pigments following local knowledge recorded in the survey. The dyeing procedures were based on community practices, with adaptations proposed by Ferreira (1998).

Following traditional dyeing procedures, the dyes were extracted by maceration for 72 hours, using a ratio of 100g of dyeing plant parts to 800mL of water and 2mL of 25% ammonium hydroxide (commercial ammonia). Ammonia replaced the previously used cattle urine in the processes (Ferreira, 1998). After maceration, the mixture was decocted for 1 hour. Subsequently, once it reached room temperature, the liquid was filtered to remove the dyeing plant parts. For dyeing the fibres, they were added to the obtained liquid (in an approximate 1:4 (v/v) ratio) and decocted again for 1 hour. After this process, a mordant was applied to stabilise and enhance the effectiveness of the dyeing, and the mixture was decocted once more for 1 hour. The mordants evaluated were: 1) Iron acetate, obtained by macerating and manually stirring daily for three days 20g of steel wool in a solution containing 200mL of water, 30g of wheat flour, and 20mL of vinegar, which was then filtered as suggested by Ferreira (1998). The ratio used was 20mL of mordant per litre of dye. 2) Salt (sodium chloride), in the proportion of 20g per 10L of dye solution. After the solution reached room temperature, the fibres were removed and placed to dry on clotheslines under the sun. The results of these trials were presented and discussed in a subsequent workshop.

3 RESULTS

A total of 154 artisans were interviewed (127 women and 27 men). At the time of the study, their ages ranged from 18 to 72 years; most were younger than 20. This ethnobotanical study allowed us to document aspects of the craftsmanship involving sisal and pita fibres, identify available dye plant species, and describe traditional dyeing processes with natural dyes, as detailed below.

3.1 ASPECTS OF CRAFTSMANSHIP USING FIBRES IN THE CACHOEIRA DO BRUMADO DISTRICT

According to the interviewees, plant-fibre weaving in the region began in the 18th century, with fibres extracted from *Furcraea foetida*, locally known as pita. The earliest artefacts were tools used for gold panning in watercourses. Later, artisans began weaving saddle pads, placed between the backs of pack animals and the saddles of muleteers who connected regional economic centres. The art of weaving diversified over generations, including new products such as rugs, curtains, bags, and decorative objects. These artefacts are crafted at home, employing family labour.

Although the first rugs were adorned with hues from plant-based dyes, by the end of the 20th century, all artisans had adopted industrial chemical dyes. The residues from this process were discarded into the soil or watercourses. To dye the rugs, the artisans dissolved 30g of synthetic aniline in 1 litre of boiling water. This solution was then diluted in a container with water, in a proportion that varied according to the intended shade. The fibres were submerged in the liquid, left to soak for about 3 hours, rinsed and hung to dry in the sun. A 30g bottle of synthetic aniline was priced at approximately R$10.00 (~US$ 2.00) and was sufficient to dye about 3 kg of sisal fibres. The fibres used for dyeing were usually the darker parts of the lot acquired. The dyed fibres were used to create geometric patterns that decorate the artefacts, with the base weave made of undyed sisal fibre (Figure 2). The colours obtained with synthetic aniline result in vivid and striking hues.

Most artisans reported that the use of natural dyes was in decline due to the ease of processing and acquiring synthetic dyes, as well as a lack of knowledge and familiarity with the process of dyeing with plant-based dyes. Approximately 40% of the interviewees reported some knowledge about natural dyes, mainly acquired through parental transmission. According to their accounts, this knowledge still existed, especially among the older residents of the district. Despite their then-current reliance on synthetic dyes, artisans emphasised that the cost of these materials strained their production budgets. Additionally, they had been unaware of the toxicity of chemical dyes to both humans and the environment, which raised their concern when these risks were presented in this study. As a result, they expressed interest in reviving the knowledge of plant-based dyes and dyeing techniques previously used in the region.

Figure 2 – Aspects of sisal craftsmanship in the district of Cachoeira do Brumado, Mariana.

Source: The authors

To extract dyes from plants, it was reported that the dyeing parts were macerated in water with an ammoniacal compound. Traditionally, this compound came from animal urine (mainly cattle), but it was later replaced by commercial ammonium hydroxide solution. After at least 12 hours of maceration, which varies depending on the species used, the material was boiled for 1 hour and then strained. The fibres were then immersed in the dye solution, ensuring complete coverage. To stabilise the colours, salt (sodium chloride) and iron acetate were used as mordants. The iron acetate was obtained by macerating rusty nails (approximately 20g) for at least three days in a solution of water (500mL), vinegar (15mL, 1 tablespoon), and wheat or cassava flour (30g or 2 tablespoons). This solution was strained and added after the fibres were boiled with the dye material, at an approximate ratio of 1:50 (v/v), followed by another hour of boiling. The mordant solution could be refreshed by adding more water, vinegar, and flour to the container with the rusted nails, using the same proportions. Other iron sources, such as steel wool or metal fragments, could replace nails. Salt, as a mordant, was also added to the boiling fibres at a ratio of 20g (1 tablespoon) per 10 litres of the dye solution.

3.2 THE DYEING SPECIES

A total of 33 species with dyeing properties were reported, belonging to 24 families. The Fabaceae family had the highest number of dyeing species (Table 1).

Table 1 – Plant species and respective families, local (Portuguese) and English common names, and parts used in the dyeing of sisal fibres reported by artisans from Cachoeira do Brumado, Mariana, MG, Brazil. Voucher=Herbarium OUPR registration number.

Family / Species	Local common names	English common names	Used parts	Voucher
Adoxaceae *Sambucus australis* Cham. & Schltdl.	Sabugueiro	Elder	Aerial parts	23244
Amaranthaceae *Beta vulgaris L.* *	Beterraba	Sugar beet	Roots	
Amaryllidaceae *Allium cepa* L.	Cebola	Onion	Bulb cataphylls	
Anacardiaceae *Schinus terebinthifolia* Raddi	Aroeira	Brazilian peppertree	Aerial parts	15590
Arthoniaceae *Herpothallon rubrocinctum* (Ehrenb.) Aptroot & Lücking	Mancha-vermelha		Whole plant	
Asteraceae *Baccharis crispa* Spreng.	Carqueja		Whole plant	22410
Bidens pilosa L.	Picão		Whole plant	22356
Bignoniaceae *Handroanthus albus* (Cham.) Mattos. *	Ipê-amarelo		Stem bark	
Pyrostegia venusta (Ker Gawl.) Miers	Cipó-de-são-joão		Flowers	22113
Bixaceae *Bixa orellana* L.	Urucum	Annatto	Seeds	22408
Commelinaceae *Tradescantia pallida* (Rose) D.R.Hunt	Trapoeraba-roxa	Purple heart	Aerial parts	22116
Convolvulaceae *Ipomoea batatas* (L.) Lam. *	Batata-doce	Sweet potato	Leaves	
Fabaceae *Andira anthelmia* (Vell.) Benth. *	Angelim		Stem bark	
Indigofera suffruticosa Mill.	Anileira	Indigo	Aerial parts	15189
Paubrasilia echinata (Lam.) Gagnon, H.C.Lima & G.P.Lewis	Pau-brasil		Stem sawdust	
Piptadenia gonoacantha (Mart.) J.F.Macbr. *	Angico		Stem bark	16326
Senna occidentalis (L.) Link. *	Fedegoso	Coffee senna	Aerial parts	
Lauraceae *Persea americana* Mill.	Abacate	Avocado	Seeds	
Loranthaceae *Struthanthus podopterus* (Cham. & Schltdl.) G.Don	Erva-de-passarinho	Mistletoe	Whole plant	29913
Marantaceae *Maranta arundinacea* L. *	Araruta	Arrowroot	Rhizomes	
Melastomataceae *Clidemia urceolata* DC.*	Olho-de-pombo		Leaves	22408
Pleroma estrellense (Raddi) P.J.F.Guim. & Michelang.	Quaresmeira		Leaves	22409
Meliaceae *Cedrela fissilis* Vell.	Cedro	Acajou wood	Stem sawdust	
Moraceae *Ficus carica* L.	Figo	Fig	Leaves	

Family / Species	Local common names	English common names	Used parts	Voucher
Musaceae *Musa paradisiaca* L.	Banana	Banana	Pseudo stem sap	
Myrtaceae *Myrcia guianensis* (Aubl.) DC.*	Caá		Stem bark	15591
Plinia peruviana (Poir.) Govaerts	Jabuticaba		Pericarp	
Psidium guajava L. *	Goiaba	Guava	Leaves	
Onagraceae *Fuchsia regia* (Vell.) Munz	Brinco-de-princesa	Fuchsia	Flowers	15195
Pinaceae *Pinus* sp.*	Pinus	Pine	Stem sawdust	
Poaceae *Andropogon bicornis* L.	Capim-rabo-de-burro		Aerial parts	16214
Rubiaceae *Coffea arabica* L. *	Café	Coffee	Seeds	
Zingiberaceae *Curcuma longa* L.	Açafrão	Turmeric	Rhizomes	

** Species not tested in the dyeing trial*

Source: Organized by the authors

Some dyeing materials came from inedible parts of cultivated fruit species, such as avocado (seeds), fig (leaves), jabuticaba (fruit pericarp), and banana (pseudo stems), or from the outer cataphylls of onion bulbs. Others were derived from species often cultivated for different purposes, such as turmeric (*Curcuma longa*) and annatto (*Bixa orellana*), whose rhizomes and seeds, respectively, were also used as food colourants. Other sources included elder (*Sambucus australis*), used for medicinal purposes, and ornamental species such as fuchsia (*Fuchsia regia*) and purple heart (*Tradescantia pallida*).

The species picão (*Bidens pilosa*), anileira (*Indigofera suffruticosa*), erva-de-passarinho (*Struthanthus podopterus*), and carqueja (*Baccharis crispa*) were spontaneous plants occurring abundantly in anthropogenic landscapes. Some native forest species were also reported in this survey, such as angelim (*Andira anthelmia*), angico (*Piptadenia gonoacantha*), cedro (*Cedrela fissilis*), caá (*Myrcia guianensis*), olho-de-pombo (*Clidemia urceolata*), and quaresmeira (*Pleroma estrellense*). The vine cipó-de-são-joão (*Pyrostegia venusta*) and aroeira (*Schinus terebinthifolia*) were abundant in open areas, forest edges, and anthropised zones. Pulverised sawmill residues (sawdust) from various species were also mentioned as dyeing materials, such as pau-brasil (*Paubrasilia echinata*), angelim (*Andira anthelmia*), cedro (*Cedrela fissilis*), and *Pinus* sp. (Table 1).

About 40% of the interviewees reported knowing about natural dyes, but most of them mentioned only one species. The average number of dye species known per artisan was 1.6, and none of them cited more than four dyeing species. The most cited species was Curcuma longa, followed by Bixa orellana.

3.3 DYEING TRIALS

Extraction and dyeing tests of sisal fibres were carried out with 21 species out of the 33 species mentioned in the ethnobotanical survey (Table 1). The species that were not tested either did not have sufficient material available for testing, or their extraction would impact their populations. The parts of the species used, as well as the pigment extraction and dyeing procedures for sisal fibres described in the ethnobotanical survey (Table 1), were utilised.

A wide variety of colours and shades was obtained from the tested dye plants in the local flora (Figure 3).

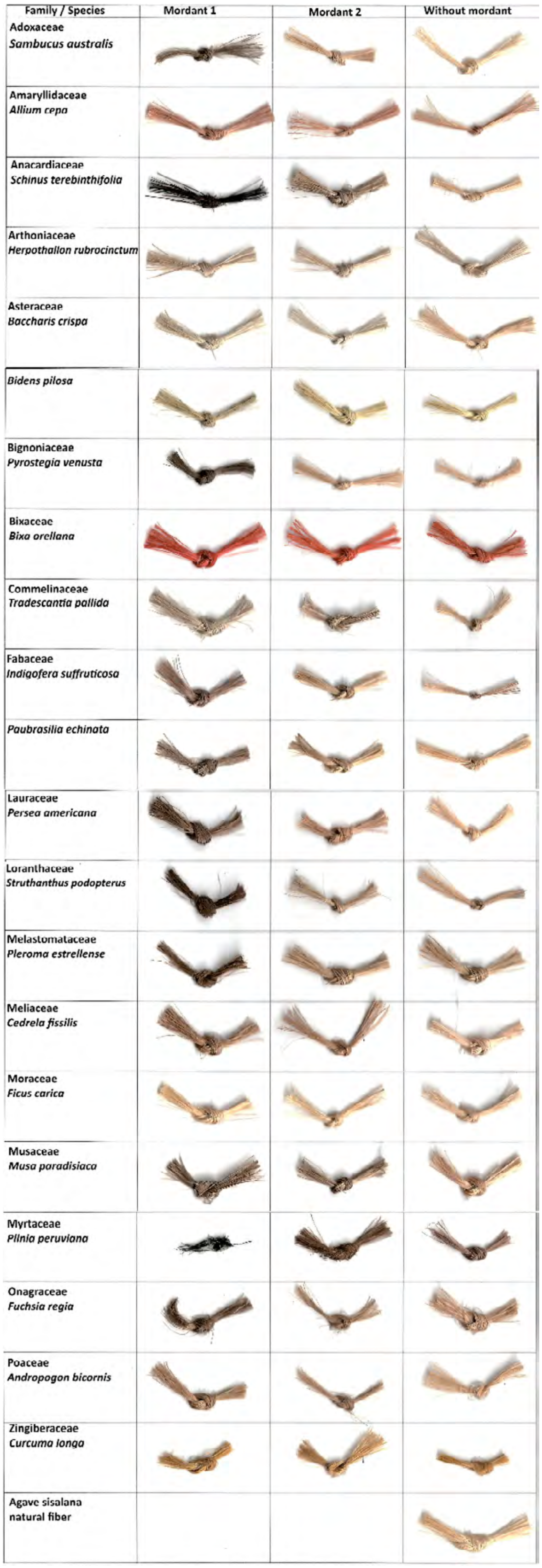

Figure 3 – Original and dyed sisal (*Agave sisalana*) fibres using plant-based dyes and different mordants in the artisan community of Cachoeira do Brumado, Mariana, Minas Gerais, Brazil. (Mordant 1: salt, Mordant 2: Iron acetate).

Source: The authors

4 DISCUSSION

Although artisans in Cachoeira do Brumado no longer used natural dyes to dye sisal fibres at the time, the community still held traditional knowledge of this practice. About 40% of the interviewees reported some knowledge of natural dyes; however, the richness of recognised dyeing species was low, with most artisans citing only one species (average=1.6 species/artisan) and no more than four. Similar values for known dyeing species richness have been reported in Sierra Leone (MacFoy, 2004), Zimbabwe (Ganduri *et al.*, 2011), and India (Mahanta; Tiwari, 2005), with even lower values found in traditional communities in regions such as China (Liu *et al.*, 2014), India (Kala, 2009), Timor (Sabuna; Nomleni, 2020), Indonesia (Sabuna *et al.*, 2018; Seran *et al.*, 2022), as well as in other Brazilian regions (Sá *et al.*, 2007).

Although the art of fibre dyeing with natural dyes is an ancestral practice in the region, it declined with the introduction of synthetic dyes in the mid-19th century, as occurred in many parts of the world (Bechtold *et al.*, 2003; Kant, 2012; Liu *et al.*, 2014). The shift was mainly attributed to the ease of using synthetic dyes and the subsequent loss of practical knowledge required for natural dyeing. At the time of the survey, most sisal artisans were younger than 20 years old, and their knowledge was often limited to the names of a few species transmitted by older relatives, signalling an ongoing process of cultural erosion. Given that traditional knowledge is typically transmitted orally, it is highly vulnerable to disappearance (Toledo; Barrera-Bassols, 2015). Ethnobotanical studies, therefore, play an important role in documenting and reviving this knowledge, particularly in traditional communities that are its main custodians (Hart; Cox, 2000; Liu *et al.*, 2014). However, the revival of this practice also depends on the community's recognition of its value. In this action-research, artisans acknowledged the cultural, environmental, and economic benefits of dye plants, as discussed below.

Indeed, synthetic dyes provide a wide range of stable and vibrant colours, along with reproducibility and ease of processing. However, their toxic nature has become a critical concern due to the harmful effects on several life forms, including humans. The presence of toxic substances such as sulphur, naphthol, nitrates, formaldehyde, and heavy metals like chromium, copper, arsenic, lead, cadmium, mercury, nickel, and cobalt can affect artisans' health during handling. Additionally, these dyes produce highly toxic effluents that could contaminate soil and water (Bechtold *et al.*, 2003; Che; Yang, 2022; Kant, 2012). This information, shared during the discussions throughout the development of this work, was previously unknown to the artisans and helped increase their interest in using natural dyes. Thus, the fact that natural dyes are biodegradable and therefore more environmentally sustainable has further attracted the community's attention. Additionally, the economic benefits generated by using natural dyes also contributed to the renewed interest in this technique. Firstly, the process required a few inputs to obtain a wide variety of dyeing materials, which were available locally. These materials included by-products from plants used for other purposes, as well as species that were abundant in the local flora. In addition, the potential for natural dyes to add value to local craftsmanship and open new market opportunities for eco-friendly products (Che; Yang, 2022) also attracted the artisans' attention.

An important aspect observed, as noted by the artisans themselves, was that unlike the vivid colours produced by synthetic dyes, natural dyes produced pastel tones. This characteristic provides a better design aligned with contemporary market trends (Becker, 2016), adding value to the products. For example, plant-based dyes from erva-de-passarinho, carqueja, picão, capim-rabo-de-burro, fig, avocado, and onion produced softer shades, which match prevailing design preferences in the sisal craft market. The adoption of synthetic dyes in Andean communities in Peru (Mayolo, 1989) also caused profound changes in the original designs of artefacts, with recent designs prioritising vivid colours. This phenomenon has been observed globally in various other textile products (Che; Yang, 2022; Mayolo, 1989). In addition to pastel shades, the use of plant-based dyes enabled the production of black dye, which was in demand in the market and had not yet been achieved with synthetic anilines on sisal fibres. This colouration was obtained from the use of aroeira leaves (*Schinus terebinthifolia*), a native and abundant species in the region, as well as from the pericarp of jabuticaba (*Plinia peruviana*), a native species widely cultivated in home gardens. Another interesting observation by the artisans was that fibres processed with natural dyes became softer, making weaving easier, and were pleasantly scented with plant extracts. These extracts, in addition to imparting fragrance to the fibres, are also recognised as antimicrobial agents, providing greater durability to fabrics (Che; Yang, 2022).

Despite the growing interest in natural dyes and sustainable materials (Che; Yang, 2022), studies addressing plant-based dyes for sisal fibres remain scarce in the scientific literature. Most available research has focused on textile fibres such as cotton, wool, and silk, which are primarily used in the clothing industry. In contrast, investigations into hard fibres used in artisanal production remain limited (Che; Yang, 2022). This highlights an important gap in both ethnobotanical research and studies related to socio-biodiversity value chains. In this context, documenting traditional knowledge and evaluating the potential of locally available dye plants for use with sisal fibres contribute to expanding the academic discussion on sustainable artisanal production and the valorisation of biocultural resources.

Sisal craftsmanship is more prevalent in tropical regions of the world, which have higher plant biodiversity, and consequently, a greater number of potentially dyeing species (Das; Kalita, 2016). Moreover, megadiverse countries often have a rich traditional ecological knowledge associated with the use of natural resources (Toledo; Barrera-Bassols, 2015). The richness of traditional ecological knowledge in the studied region is supported by various ethnobotanical studies (Costa *et al.*, 2021; Messias *et al.*, 2015; Prado *et al.*, 2021; Urriago-Ospina *et al.*, 2020). However, none of these studies addressed dye plants. Dye plants have an ancestral use in the region, where indigenous peoples originally used pigments for body painting and artefact dyeing (Sá *et al.*, 2007). Additionally, various dye pigments were used over three centuries ago in the painting of numerous Baroque sacred artworks (Parma *et al.*, 2023) found in the municipality of Mariana and the nearby city of Ouro Preto, both recognised as national and world heritage sites, respectively.

In a study conducted in Mauritius (Gooroochurn; Socheta, 2016), around 12 dye plant species for sisal fibres were identified, including turmeric, coffee, and onion skins, which were also mentioned in the present study. Studies in Brazil (Ferreira, 1998; Sá *et al.*, 2007) and across Latin America (Caparrós, 1995; Mayolo, 1989) report a vast diversity of dye plants for cotton and wool fibres. Some of the cited species overlap with those identified in the present work. Among these common species is turmeric (*Curcuma longa*), an Asian plant cultivated worldwide and introduced to Brazil during the colonial period. Another species common across various dye plant surveys is annatto (*Bixa orellana*), known locally as urucum, a native of South and Central America (Flora e Funga do Brazil, 2026), which was one of the plants taken to the old continent at the beginning of the colonisation of the Americas (Donkin, 1974). Several species of *Indigofera* are also reported as dyes for various fibres, especially cotton, including *I. suffruticosa*, mentioned in this survey (Das; Kalita, 2016; MacFoy, 2004; Mahanta; Tiwari, 2005). In sisal fibres, the usual blue colour produced in cotton fabrics by this species was not obtained (Ferreira, 1998; Simpson; Ogorzali, 2001). However, the pigment extraction and dyeing process used, following locally employed methods, differs from those reported for obtaining blue colouration in cotton and wool fibres, which involve fermentation processes (Simpson; Ogorzali, 2001).

Even though some chemical inputs, such as ammonia used in the extraction processes of natural dyes, need to be purchased by the artisans, adopting the use of natural dyes would significantly reduce processing costs. The expense for dyeing 1 kg of fibre was estimated at approximately R$ 0.35 (~ US$ 0.05), over 60 times lower than the cost of synthetic aniline. Ammonium hydroxide is known to enhance pigment extraction from plants (Dan *et al.*, 2024), as many pigments are not water-soluble. However, careful handling is required to avoid health risks, particularly from toxic gas inhalation. Training workshops are therefore essential to ensure safe practices, including proper handling of substances, the use of protective equipment, and adequate working conditions.

Mastering natural dyeing techniques is a process that requires practice and precision to achieve the desired colour fixation and tone. Colour shades vary according to the adopted procedures and the products used for pigment extraction and fixation (Ferreira, 1998). Mordants play an important role in this process by promoting the bonding of pigments to cellulosic fibres, which generally have low affinity for natural dyes. However, mordants can alter the pH of the dye solution, often changing the resulting shade (Ferreira, 1998; Prabhu; Buthe, 2012). Thus, different mordants may produce different colours; for example, sisal fibres dyed with Calendula officinalis flowers using different mordants yielded colours ranging from yellow to brown, depending on the mordant used (Mariselvam *et al.*, 2023). The use of mordants is also part of traditional knowledge in natural dyeing across many communities (MacFoy, 2004; Mariselvam *et al.*, 2023), including those in the region under study. The effectiveness of the mordants used by the studied community was demonstrated through the dyeing trials and is also corroborated by Ferreira (1998). The use of similar mordants was also documented among traditional communities in Sierra Leone (MacFoy, 2004).

Many mordants used in the textile industry are toxic and pose environmental risks. In contrast, the mordants employed in artisanal processes are both effective and environmentally advantageous (Bechtold *et al.*, 2003). Metal salts, such as iron acetate, have proven efficacy in darkening tones and enhancing colour stability (Simpson; Ogorzali, 2001). Meta-mordanting, as described by the studied community, proved highly effective. Adding the mordant at the final stage of the dye bath simplified the operation, reduced water consumption, and allowed artisans to adjust the desired final shade, as noted by Bechtold *et al.* (2003). Mordants were particularly effective in producing brown and black hues, as observed in other fibres (Bechtold *et al.*, 2003). In contrast, the yellow shade obtained from turmeric and the red shade from annatto seeds showed little change with mordant addition, indicating a strong affinity of these pigments with sisal fibres. Probably, these pigments are less affected by pH variation or because these plants naturally contain substances that act as mordants (Simpson; Ogorzali, 2001).

In line with other developing regions rich in plant and cultural biodiversity (Mahanta; Tiwari, 2005; Mayolo, 1989; Nayak *et al.*, 2011), the adoption of natural dyeing for fibres by artisans can improve the socioeconomic and environmental conditions of communities and reduce the significant environmental damage caused by chemical dyes, which impact soil, air, water, and human health.

Several locally available species proved effective for dyeing sisal fibres, expanding the repertoire of plants known for this use. The results also stimulated artisans' interest, who highlighted the diversity and quality of the colours, as well as the economic, health, and environmental benefits. Consequently, they expressed interest in reviving the use of plant dyes and eco-friendly dyeing techniques. The promising outcomes of this study, together with evidence of ongoing loss of traditional knowledge about dyeing plants, suggest that ethnobotanical studies of this nature should be developed in regions that traditionally use these resources to ensure the preservation of this knowledge.

Ecological responsibility involves not only environmental awareness but also economic and social benefits. The use of natural dyes is economically viable, relies on locally accessible resources, and can add social, cultural, and environmental value to regional crafts. Artisans and vendors should encourage consumers to make responsible purchases by promoting the concept of sustainable products. Adopting eco-friendly practices in artefact production can enhance product value while supporting environmental conservation, ensuring sustainability. This approach could be applied to other regions engaged in sisal crafts, taking into account their cultural and environmental particularities.

5 CONCLUSIONS

The dyeing experiments demonstrated that several plant species cited by artisans can produce a diverse range of colours and shades on sisal fibres, thereby expanding the set of taxa recognised as suitable for dyeing this material, which remains relatively understudied in natural dye research. Beyond colour diversity, artisans emphasised the practical advantages of plant-based dyes, including the use of locally available resources, reduced production costs, softer fibres, and aesthetic qualities aligned with contemporary artisanal design.

The results support the study's hypotheses that knowledge of dye plants had persisted within the community and that locally available species could be effectively used to dye sisal fibres, highlighting the potential for revitalising these practices. The research process also contributed to raising awareness among artisans about the environmental and health impacts associated with synthetic dyes, while reinforcing the cultural, ecological, and economic value of traditional dyeing knowledge.

Reintroducing plant-based dyes in sisal handicrafts is a promising strategy to strengthen the sustainability of artisanal production by integrating environmental, cultural, and socioeconomic dimensions. Future efforts should focus on strengthening knowledge transmission through training activities and continued experimentation with dyeing techniques. Further research evaluating colour fastness, durability, and production scalability will be essential to support broader adoption of natural dyes and to promote sustainable socio-biodiversity value chains.

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STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

The authors declare that no generative AI or AI-assisted technologies were used inthe creation, writing, or editing of this manuscript.

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