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Paint and Coloring Materials from the Brazilian Amazon Forest: Beyond Urucum and Jenipapo

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Abstract: The Brazilian Legal Amazon region is divided into at least 155 ethnic groups and has the largest concentration of Indigenous people globally. It represents one of the most extraordinary levels of human, cultural, and artistic diversity, but its material culture is one of the least well-studied. This is especially true in technical art history and conservation science, largely due to (1) the limited international awareness of the richness of materials and techniques used by these Indigenous people and (2) the limitations of knowledge access for many scientists to literature usually published in Portuguese within social sciences and humanities. One result is that these arts are marginalized within technical art history, conservation, and conservation science. To address this knowledge gap, the authors explore 70 materials—among them pigments, dyes, binding media, and varnishes—used for paint production and coloring processes, including syntheses. The authors facilitate research possibilities within technical art history, conservation, and conservation science by presenting data from historical texts from the 18th and 19th centuries and more recent scientific literature. The work aims to build a more global, inclusive, and decentralized vision of art history and to create a more pluralistic narrative of Indigenous art history from South America.

Keywords: indigenous art history; technical art history; heritage science; conservation science; art history; technical studies; natural dyes; plant-based dyes

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1. Introduction

The Brazilian Legal Amazon region has the largest concentration of Indigenous people globally, divided into at least 155 ethnic groups inhabiting 383 Indigenous lands [1]. It showcases an extraordinary level of human, cultural, and artistic diversity unparalleled elsewhere in the world, and the cultural items from these people are present in museums worldwide. Ticuna masks (Figure 1), for instance, are one of the greatest examples of the use of diverse paint and coloring materials by one of these Indigenous groups. These masks are used during female initiation rituals. Plant-based dyes and minerals have been used to produce paint colors including blues, greens, yellows, reds, oranges, pinks, whites, blacks, and browns, as shown in Figure 1. Although the Amazonian material culture is one of the least well-studied globally [2], recently these cultural items have been more consistently considered by Amazonian specialists [3]. The publication of the book "The occult life of things: Native Amazonian theories of materiality and personhood", edited by Santos-Granero (2009), is considered one of the pivotal works that catalyzed the resurgence of interest in Amazonian culture in the last two decades [3].

Figure 1. In the top left, a photograph (by Harald Schultz) shows a Ticuna artist decorating a bark cloth with several bowls containing paints with different colors. The other images (by Ader Gotardo) are examples of masks made with bark and used by Ticuna people in their female initiation rituals. The masks were collected by Harald Schultz, and both masks and photography belong to the Museum of Archaeology and Ethnology of the University of São Paulo, Brazil. From left to right and top to bottom, the reference numbers are IE 001,071 (by Harald Schultz) and RG 8649, RG 8682, RG 9960, RG 8686, RG 8717, RG 10,037, and RG 10,039 (by Ader Gotardo). Credits: *Museu de Arqueologia e Etnologia da Universidade de São Paulo*.

The low number of material culture investigations by Amazonian specialists can be partially explained by a reaction against past practices that focused on detailed descriptions of objects to determine cultural similarities and differences. Alternatively, it can be ascribed to the emphasis on people in recent theories concerning native Amazonian political economies, or the fascination among Amerindians with animals, resulting in a diminished focus on objects [3]. Furthermore, it can be related to the misleading understanding of the Amazon as "object-poor" and to the perception of a lack of "harbingers of classical civilizations", or to the fact that Amazonian cultures have only marginally influenced movements such as European modernism [2]. It can even be related to the international lack of awareness of the recent investigations about Indigenous art and aesthetics [4] worldwide. Particularly in technical art history and conservation science, the limited international awareness of the richness of materials and techniques used by Amazonian people throughout centuries could play a role, as well as limitations in knowledge access for many scientists to literature usually published in Portuguese within social sciences and humanities.

Physical and chemical analyses of Brazilian Indigenous cultural items (not exclusively from the Amazon Forest but including the Amazon Forest) have been carried out mostly on inorganic materials. Investigations of rupestrian paintings or painted rock art can be found [5,6], but the most common material studied is ceramic. Those studies focused on ceramics produced by people from the North and Northeast (States of Pará, Maranhão, Amazonas, and Rondônia) [7–15], South (States of Rio Grande do Sul, Santa Catarina, and Paraná) [16–22], Southeast (States of São Paulo and Minas Gerais) [23–26], and Midwest of Brazil (Pantanal region) [27]. Some studies on organic materials exist and focus on resins [28,29], feathers [30,31], and woods [32]. Although an exhaustive literature review has not been conducted about the scientific investigation of materials and techniques used by Brazilian Indigenous people, these works are a good representation of their cultural items that have been explored during the last twenty years.

The low number of scientific investigations into organic materials from the Brazilian Amazon Forest lacks justification. In the current study the authors examine and explore dozens of paint or coloring materials sourced from historical texts, showcasing their abundance. The dearth of scientific inquiry carries profound implications for the understanding of art history, the conservation of existing collections, and the preservation of traditions that have not been documented or practiced over many years. It is important to highlight that the loss of cultural information is not only related to the degradation of those cultural items. The Indigenous cultures associated with those items are also at risk due to the decrease in tradition transmission and the disappearance of Indigenous people and raw materials due to violence and deforestation. For example, the Brazilian Amazon Forest deforestation rate was 14,542 km^2/year between 1988 and 2018 [33], increasing 34.1% between 2018 and 2019 and reaching protected lands [1,34]. In one area with isolated Indigenous people, the deforestation rate has dramatically risen to 654% between 2018 and 2019 [34].

Within the special issue "The stories that colours tell: Historical paintings, dyes and varnishes", this paper aims to raise international awareness about the materials and techniques employed by Indigenous people from the Brazilian Amazon Forest. It delves into the exploration of 70 materials used by these artists for paint production or coloring processes, emphasizing research possibilities in technical art history and conservation science. While primarily written for conservation scientists and technical art historians, the authors recognize the fundamental role of other professionals such as conservators, art historians, and anthropologists, given the interdisciplinary nature of this topic. The study highlights the abundance and variety of materials and techniques through investigations of historical texts written in Portuguese from the 18th and 19th centuries. Additionally, it examines the chemical knowledge, or the lack thereof, regarding some of these materials by referencing the recent scientific literature. The manuscript also explores potential research questions across various realms, including conservation, provenance, and art history. Throughout the text, the authors introduce research questions and then summarize and expand upon them in the conclusions section. Given the involvement of ethnographic items and Indigenous communities, ethical and legal considerations are also addressed in the conclusions section.

2. The Main Historical Texts

Five historical texts written by different authors in the 18th and 19th centuries were selected for their extensive and informative content regarding the materials of interest to the authors. These chosen works offer a broader overview of the materials used by various Indigenous people from the Brazilian Amazon region, rather than those used by specific groups. Despite being written during a time period characterized by religious dominance and extraction, these texts provide valuable insight. The authors of these works are João Daniel, Alexandre Rodrigues Ferreira, Johann Baptist von Spix, Carl Friedrich Philipp von Martius, and Antônio Ladislau Monteiro Baena. These texts have been widely referenced by scholars such as Martins [35], who conducted research on "*Tintas da terra, tintas do reino: Arquitetura e arte nas Missões Jesuíticas do* Grão-Pará (1653–1759)" (Earth paints, kingdom paints: Architecture and art in the Jesuit Missions of Grão-Pará (1653–1759)—authors' translation).

João Daniel, a Jesuit born in Portugal, arrived in Maranhão, Brazil, in 1741. In 1757 he was expelled from the country and subsequently imprisoned upon his return to Portugal. During his time in prison, he dedicated himself to writing about the Amazon River in his work titled "*Tesouro descoberto no máximo Rio Amazonas*" (Treasure discovered on the upper Amazon River—authors' translation), which was apparently produced during 1759 and 1762. The work adopts a model of a treatise, aiming to showcase the river's richness and potential for exploitation [36]. His work is divided into six parts, and the third part holds particular relevance to this study, as it explores "*das tintas mais especiais do Rio Amazonas*" (from the most special paints of the Amazon River—authors' translation), among other subjects. The two volumes from his work were republished in 2004 [37].

Alexandre Rodrigues Ferreira was born in Bahia in 1756. In 1779 he received his doctorate from the University of Coimbra, Portugal, and subsequently worked at the Royal Museum D'Ajuda from 1779 to 1783. Following that, in 1783 he embarked on a journey through the captaincies of Grão-Pará, Rio Negro, Mato Grosso, and Cuiabá, in Brazil, until 1792. The mission was to collect and prepare samples to be sent to the Royal Museum of Lisbon. His manuscript, "*Viagem filosófica pelas capitanias do* Grão-Pará, Rio Negro, Mato Grosso *e* Cuiabá" (Philosophical journey through the captaincies of Grão-Pará, Rio Negro, Mato Grosso and Cuiabá—authors' translation), was republished in 1974 [38].

Johann Baptist von Spix, a zoologist, and Carl Friedrich Philipp von Martius, a botanist, were both members of the Royal Academy of Sciences in Munich, Germany. In April 1817, they embarked on a journey to Brazil driven by their studies about nature. Throughout their time in the country, they traveled over 10,000 km, collecting zoological, botanical, ethnographic, and mineral items. Upon their return to Europe in 1820, they brought back their invaluable findings [39]. Their work, titled "*Viagem pelo Brasil*" (Journey through Brazil—authors' translation), was republished in 2017, with volumes 2 and 3 [40] being of particular interest for this manuscript.

Antônio Ladislau Monteiro Baena was a Portuguese who arrived in Pará, Brazil, in 1803. During his time in Brazil, he held both military and civilian assignments while also working as a mathematics teacher. What sets Baena apart from others is that he was not only a traveler in Grão-Pará. He moved to Pará in the early 19th century and completed his work "*Ensaio corográfico sobre a província do* Pará" (Chorographic essay on the province of Pará—authors' translation) in 1833; it was published in 1839. The purpose of his work was to "supply data for the complete registration of the Brazilian Empire" based on "nature and the best use that could be made of it"—authors' translation [41]. Baena's work was republished in 2004 [42].

3. Discussion: Paint and Coloring Materials from the Brazilian Amazon Forest

After reviewing the five historical sources described above, the current authors identified 70 materials used for paint production and coloring processes, including pigments, dyes, binding media, varnishes, and other materials, described in Table 1. This section is divided by colors (yellows, reds, purples, blacks, blues, greens, and white), and, due to limited space, the focus is on the pigments and dyes. Whenever possible, the contents for each pigment or dye were based on their historical descriptions, the taxonomy of the plants from which they were or have been extracted, and their chemical compositions. In addition, because in many cases it was not clear if the authors from the historical texts were referring to dyes or pigments, from now on the authors of this manuscript have only used the term colorant, which encompasses both dyes and pigments. In some cases, the terms ink and paint from the historical texts were also replaced by the general term colorant, since it was believed this is the most appropriate term.

Table 1. Summary of the findings for some materials used in paint production and coloring processes by some Indigenous people from the Brazilian Amazon Forest.

Color	Plant Name or Source Information	Other Names Found in the Literature	Possible Botanic Information	References
Yellow	Pacoã	Pacuã, pacuan, pacuán, papuan, pappuan, capim-papuã	*Panicum plantagineum* species	[37,42,43]
	Pau-amarelo			[37]
	Açafrão-da-terra		*Curcuma longa* L. species	[37,38,43]
	Tatajuba			[42]
	Mango-rataia			[42]
	Guariuba			[38,42]
	Leaves of several bromeliads			[40]
	Root of the tree urucum			[37]
	Yellow tauá clay [1]			[37]
Red	Heated tauá clay [1]	Curi		[37,38,42]
	Red clay [1]	Cori		[37]
	Pau-brasil		*Caesalpinia* trees	[37,40,44]
	Cochineal [2]			[37]
	Bicho Vermelho [2]			[37]
	Urucum	Annatto, urucu	*Bixa orellana* L. species	[37,38,40,45,46]
	Carajuru	Crajuru, caracuru	*Arrabidaea chica* species	[37,38,40,42,45,47]
	Pariri	Mato vermelho	*Arrabidaea chica* species	[37,47]
	Tajá vermelho		*Caladium bicolor* species	[37,48]
	Carrapicho			[37]
	Pacova-sororoca			[37]
	Mangue			[37,42]
	Muruxi ma-maurana			[42]
	Uruariua			[42]
	Caa piranga		*Picramnia guianensis* species	[42,49]
	Cumati	Cumatê	Myrtaceae family	[42,50,51]
Purple	Pau-brasil [3]		*Caesalpinia* trees	[37,44]
	Pacova-catinga			[42]
	Mucunan			[42]
	Cipreste			[42]
	Violet tree			[42]
	Caa piranga		*Picramnia guianensis* species	[37,42,49]
	Snail [2]			[37]
	Pariri	Mato vermelho	*Arrabidaea chica* species	[37,47]

Table 1. *Cont.*

Color	Plant Name or Source Information	Other Names Found in the Literature	Possible Botanic Information	References
Blue	Cartelhana			[42]
	Anil		*Indigofera tinctoria* species	[37,42,52]
Green	Acaricoára			[42]
	Mata-pasto			[37]
	Trifólio		Oxalidaceae family, *Oxalis* genus	[37,50]
Black	Jenipapo		*Genipa americana* L. species	[37,40,50]
	Smoke or soot from coconut fibers			[37]
	Vine			[37]
	Cotton flower			[37]
	Leaves of the paracauáxi tree			[42]
	Cauassu			[42]
	Mamaurana			[42]
	Uacapurana			[42]
	Piquiá			[42]
	Herb *Eclipta erecta* L.		*Eclipta prostrata* (L.) L. or *Eclipta erecta* L. species	[40]
	Macucu			[42]
	Murta			[42]
	Cumati	Cumatê	Myrtaceae family	[42,50,51]
White	Tabatinga [1]			[37,40,42]
Binding media, resins, and other materials [4]	Copaíba oil, andiroba oil, fat of jacaré-açu, fat of turtle, fat of peixe-boi, gum arabic, cashew gum (or resin), almécega, jutaísico, macacu, jotaí resin, copal powder (jitaicica), bark of the xixiiba tree, pedra-ume, cloves, urine, sour lemon juice or peel, peels of citrons, peels of oranges, peels of limes, jutahi resin (or gum), bark of the ingazeiro, sorveira gum (or resin)			[37,40,42]

[1] Inorganic material. [2] Animal source. [3] It results in the associated color when it is mixed with another material. [4] The terms gum and resin seem not to be differentiated in the mentioned historical texts, and this is why both are used here.

3.1. Yellows

Daniel describes yellow colorants as fine, vivid, and precious and writes that they alone would make the Amazon wealthy.

The pacoã herb, when boiled, produces a yellow colorant that Daniel compares to the preciousness of gold among metals, based on his perception of preciousness. He even mentions its use as a colorant for gilding. Pacoã seems to be *Panicum plantagineum* and is known by various names, including pacuã, pacuan, pacuán, papuan, pappuan, and capim-papuã [43]. Baena, also, refers to pacuan as a yellow colorant. Although no specific information about the chemical composition of the plant used by those Brazilian Indigenous people was found, to exemplify the importance of its investigation in the context of the cultural heritage field, it is possible to consider studies on other plants with likely related chemistry.

Identifying the yellow dyes' main components is an important aspect of material analysis. Different geographical regions might have distinct natural resources or traditional practices, leading to variations in dyes' chemical makeup. In such context, identifying minor components can also offer valuable insights, as they allow researchers to narrow down the geographical region from which those materials originated [53,54]. *Panicum melinis*, for instance, has yellow flavonoids [55]. Flavonoid yellows have been used since historical times for paint production and fiber dyeing [56]. The primary chromophores found in flavonoid natural yellow dyes are flavones and flavonols. Due to the widespread presence of flavonoids in numerous plants, their scientific analysis using techniques such as high-performance liquid chromatography with mass spectrometry proves to be a valuable tool for determining provenance information [57,58]. For instance, weld (*Reseda luteola* L.), which grows across most of Europe, primarily contains the flavones luteolin and apigenin. Dyer's greenweed (*Genista tinctoria* L.) is found throughout Central and Southern Europe, extending across Russian Asia and Sweden, and it contains the flavone luteolin and the isoflavone genistein. Young Fustic, originally found in Italy, the Near East, Eastern Europe, France, and Spain, is rich in the flavonols fisetin and myricetin, as well as the aurone sulfuretin. In contrast, Old Fustic, which is found in Cuba, Jamaica, Puerto Rico, and other West Islands, mainly consists of the flavonols morin, kaempferol, and benzophenone maclurin [59].

The identification of the different flavonoid components in these yellow dyes could help with establishing provenance for some of them as well as explain exchanges between Brazil and other countries. For instance, the pau-amarelo tree, the next yellow source material to be discussed, was not only used locally, but it was also exported from Pará to countries such as France, Holland, Portugal, and England [40]. Although the investigated reference does not provide specific details about the use of pau-amarelo, it certainly is a topic of interest for art history. In addition to material exportation, it is important to consider exchanges and adaptations of artistic practices between Europe and Brazil.

When mentioning the use of paus-amarelos, Daniel does not define the species of the trees. He describes how small pau-amarelo chips were boiled with cloth, producing a light-yellow color. Additionally, it is mentioned that a powder could be produced. Noteworthy is his report that other colors could be achieved through mixtures. This probably extends beyond mere physical combinations, as chemical reactions, such as changes in pH or the formation of chemical complexes, can also play a role. However, since Daniel does not detail the other colors or recipes, and considering the absence of scientific investigations, it cannot be stated whether the different colors are due to physical or chemical processes, or both. In Portuguese, pau-amarelo is related to the English term fustic, which covers woods of various origins, such as Young Fustic and Old Fustic mentioned before [52]. No scientific information was found about the coloring agents and biomarkers specifically from the trees used by the Indigenous people from the Brazilian Amazon Forest, but, for instance, pau-de-moura (*Chlorophora tinctoria*) is an example from South America and has morin, a flavonoid, as a coloring molecule [52]. For this colorant and others, specifically for the geographical region being discussed in this manuscript, research is needed to investigate both properties and connections to their cultural contexts. For example, if physical or chemical processes have been used to shift colors and transform colorants, what are the meanings of these new colors, materials, and processes for those people?

For non-flavonoid yellow colorants, Daniel and Ferreira mention ginger as a raw material for yellow paint or gilding. In the literature it is reported that, most likely, Daniel was referring to açafrão-da-terra [43], which is *Curcuma longa* L. (Zingiberaceae family), also known as turmeric. Turmeric is the colorant obtained from the roots of *Curcuma longa* L., and its chromophores are curcumin, dimethoxycurcumin, and bisdimethoxycurcumin [45]. Turmeric has been used as a colorant since ancient times in bark clothes, textiles, paintings, printings, and carpets [60], and this plant is native to India and southeast Asia, being exported to Europe in the 16th century [61].

In his manuscript, Baena mentions the use of tatajuba, mango-rataia, and guariuba (this one is also mentioned by Ferreira). Spix and Martius write about the use of leaves of several bromeliads, without providing additional specification. Daniel also mentions the roots of the urucum tree, highlighting the versatility of some plants in producing colorants. It is worth mentioning that the fruit of the urucum tree has been and continues to be used to obtain a red color.

Daniel also mentions inorganic materials, such as the yellow tauá clay. The clay is added to water, and the separation is made in a decantation process to obtain a cake that is dried for use as a colorant. No chemical investigation has been found in the literature on tauá yellow clay in the context of cultural heritage. However, as discussed in the next section, its coloration is expected to be due to the presence of goethite (α-FeOOH).

3.2. Reds

In Daniel's manuscript, he mentions the use of yellow tauá clay for the production of a red colorant. The process for creating the red colorant is described in several steps. Initially, yellow colorant is obtained from the clay, which then is placed in a vessel where it is heated over hot ember. The yellow material, after being heat treated, is transformed into a very bright red hue. The use of tauá and the heating process are also mentioned by Baena and Ferreira, the latter indicating that the red colorant obtained from tauá is referred to as curi. Daniel uses a similar name, cori, to describe a natural red clay employed in red paint production. In the literature, the use of similar terminologies is sometimes confusing. For example, the term tauá was also used to describe a red clay, whose coloration was attributed to the presence of Fe_2O_3 [62]. Although scientific analysis or technical studies of such yellow tauá clay were not found, it is reasonable to assume that it is an iron oxide-based colorant, specifically goethite, which is a yellow earth mineral primarily composed of iron hydroxide. Under heating, goethite dehydrates, forming hematite (α-Fe_2O_3). This process enables the production of various shades of yellows and reds, a practice that dates back to Roman times [63].

Among the organic materials discussed in the historical texts, one of the best known is pau-brasil (brazilwood), mentioned by both Daniel and Spix and Martius. The former author notes that the extraction and application of the colorant is similar to that described for pau-amarelo and reports that when mixed with other ingredients, it produces other colors, though these are not discussed by him. However, brazilwood, in contrast to the materials discussed so far, has been well-studied using several analytical techniques [64]. The main chromophore of brazilwood is brazilin, a tetracyclic homoisoflavonoid, which has poor coloring power but changes into brasilein upon oxidation, giving it a deep red to brownish color [44,61]. Other phenolic components isolated from brazilwood include xanthone, coumarin, and various chalcones, flavones, and other homoisoflavonoids. Brazilin is obtained from the heartwood of several species of *Caesalpinia* trees, such as *Caesalpinia brasiliensis* L. and *Paubrasilia echinata* (Lam.), also known as brazilwood and Pernambuco wood and *Caesalpinia echinata*. In different contexts, the use of brazilwood as a dyestuff and pigment has been regulated in part due to its fugitive nature and was commonly used in textiles and paintings due to its attractive color and lower cost compared to other natural red dyestuffs [44].

Another well-known raw material mentioned by Daniel is cochineal. Cochineal dye is a vivid red dye obtained from the female insect *Dactylopius coccus* Costa (formerly Coccus cacti [65]), which feeds on the nopal cactus (*Cactus opuntia* or *C. coccinilifera*). The use of cochineal dye dates back to pre-Columbian times in Mesoamerica, where it was highly valued for its intense color and durability [66,67]. To extract the dye in other contexts, cochineal insects are collected and killed with hot steam or vinegar and then dried in the sun. Once this step is completed, the dried cochineal is crushed to obtain a powder, which is easily soluble in water and alcohol. Depending on the type of mordant used and the pH of the dye-bath it is possible to obtain several shades from the cochineal dye, such as crimson, scarlet, and various shades of purples [44,68]. Cochineal contains a molecule called carminic acid, which is a red glucosidal hydroxyanthrapurin, and trace amounts of kermesic and flavokermesic acids [69]. In addition to the cochineal, Daniel cites the use of another animal, bicho vermelho, which releases a red colorant simply by running a damp finger over it. There is no other information about bicho vermelho, but it may be hypothesized that it is related to other species in the genus *Dactylopius*.

In the article "The use of wild plants in tropical South America" [46], urucum (*Bixa orellana* L.) is noted as being the most important colorant in tropical South America. Thus, it is not surprising that Daniel, Ferreira, and Spix and Martius all mention its use. The urucum colorant (also known as urucu) is extracted from the fruits of its tree, and Daniel points out the ease of obtaining a very thin powder, which can be removed from the fruit only by rubbing it with the fingers. This dyestuff is commonly known as annatto [45]. Its main coloring component is a red-colored carotenoid called bixin [70]. Annatto has been used in fabrics, manuscripts, cosmetics, lakes, and painting media [45]. In addition to red, annatto gives yellow hues [45,59], which is probably due to bixin isomers formed under heating [71–73].

Carajuru, also known as crajuru or caracuru, is a vine that results in a red colorant mentioned by Daniel as more esteemed than urucum. One can obtain the red colorant simply by rubbing its leaves and flowers. Once boiled, the leaves and flowers are removed from the mixture, and the settled colorant at the bottom is then collected. Carajuru is also mentioned by Baena, Ferreira, and Spix and Martius. In the literature, it is also mentioned that the extracted colorant is mixed with andiroba oil for application to the face and body [74]. Carajuru, crajuru, or caracuru seems to be a Brazilian (from the State of Pará) variety of a red colorant known as chica, the latter being a red colorant extracted from *Bignonia chica* [45]. Slater, in his book "The manual of colours and dye wares: their properties, applications, valuation, impurities and sophistications: for the use of dyers, printers, drysalters, brokers, etc.," from 1882 [75], distinguished between carajuru and chica. Chica is extracted from *Bignonia chica*, from Venezuela and Guayana, while carajuru is sourced from the species grown in Brazil, resulting in a redder and more brilliant color. *Bignonia chica* Humb. and Bonpl. (Bignoniaceae family) presents carajurin [45], but no studies regarding carajuru were found.

Pariri, or mato vermelho, is another plant mentioned by Daniel. He describes the plant as a shrub with small leaves similar to those from peach trees. Red can be obtained by crushing the leaves and infusing them with the fabric to be colored. In addition, the author also mentions that one can achieve the red color with a similar process as in the case of indigo (see the section on blues). Pariri can also result in purple coloring by passing the cloth (or colored piece) in mud and allowing it to dry. When mixed with other ingredients, pariri can yield various other colors. In the literature, the *Bignoniaceae Arrabidaea chica* is known as carajuru, puca panga, chica, or pariri [47]. Therefore, when Daniel mentioned pariri, he was most likely referring to a different plant from the one previously discussed (carajuru), but with similar structural features. This highlights the diversity of plants used by those Indigenous people but also misunderstandings and controversies that may be present in certain historical texts.

Tajá vermelho is another herb used for the production of reds. From this plant, a juice is obtained by heating the leaf over a fire and squeezing it to extract the colorant. As the tajá vermelho has large leaves, Daniel reports that the colorant is collected in large quantities. Its botanical name is *Caladium bicolor* [48], but no references about the coloring compounds present in the plant used by those people were found in the literature review, nor were references made to possible chemical reactions involved in the process of heating the plant to extract the colorant. Another herb mentioned that has no references about its coloring compounds is carrapicho. Despite this, Daniel reports that it is one of the most important red colorants.

The fruits of the pacova-sororoca were mentioned, but no details about its properties or colorant production were described. Moreover, there appears to be confusion with the name, as it is believed that Daniel was actually referring to pacova-catinga [43]. Baena cites pacova-catinga but does not mention the coloring property of pacova-sororoca. Instead, he states that pacova-catinga serves to produce purple, not red. It is important to consider that the use of these different names may be associated with distinct plants of the same family, not necessarily indicating confusion, and that chemical reactions could be involved in the color transformations of those plants' extracts.

Other raw materials mentioned in the texts include mangue, muruxi ma-maurana, uruariua, caa piranga, and cumati, by Baena. The latter author also mentions that when ropes made with curauá are treated with the muruxi colorant, they become more durable. Mangue is also mentioned by Daniel.

3.3. Purples

According to Daniel, pau-brasil can also result in a purple hue when mixed with other materials, though he does not provide specific details. Baena, in addition to pacova-catinga, also mentions the use of mucunan, cipreste, and violet tree to obtain purples.

The caa piranga is a shrub whose purple colorant, according to Daniel, is one of the most frequently used by the Indigenous people. This plant is also mentioned by Baena. To obtain the color from caa piranga, the shrub (or its leaves) was boiled, and the material to be colored was infused. Daniel further notes that there are numerous other purple colorants, but due to the abundance and good properties of caa piranga, the Indigenous people pay little attention to the alternatives. Caa piranga is the local name given to *Picramnia guianensis* species [49].

Daniel also mentions a snail the size of a finger. In the snail, there is a substance that is green while in the animal, which turns purple when removed from it. This colorant, when applied to cloth, has an excellent colorfastness. Although the use of snails in the production of purple dyes and some of their chemical compositions are mentioned in the literature, nothing was found specifically about those used by native people from the Brazilian Amazon region. Still, the understanding of their chemical composition is important for, for instance, provenance determinations [76]. As a matter of comparison, purple snails *Plicopurpura pansa* have been historically used by Indigenous people from Mexico to dye clothing, and even today they continue to be used by groups such as the Chontales, Huaves, Nahuas, and Zapotecas [77]; these snails are distributed in the "Eastern Central Pacific from Baja California, Mexico, to Peru, and the Galapagos Islands".

3.4. Blues, Greens, Blacks, and White

Baena mentions cartelhana for the blues, but the most common raw material for this color seems to be anil, based on indigo. The blue colorant was obtained from both the shrub's leaves and its seed pods. Anil has been produced from several species of anileira (as it is called in Portuguese), the best known one being *Indigofera tinctoria*. Depending on the plant used to extract indigo, different qualities can be achieved for the final product [52]. From the 17th century onward, the term indigo became synonymous with anil in French and Portuguese. These species are native to India, South and Central America, Asia, etc. [45]. *Koanophyllon tinctorium* Arruda and *Cybistax antisyphilitica* (Martius) Martius species were mentioned to be found in Brazil [44]. According to Eastaugh and co-authors, for indigo production, steeping the leaves requires alkaline water to initiate fermentation, which can also be triggered by first composting the leaves beforehand [45]. However, neither of these two steps were described by Daniel. It raises the question of whether his account is incomplete or whether the Indigenous people used different species that allowed them to extract indigo without the fermentation step.

Regarding the greens, Baena mentions the acaricoára for dark green and Daniel the mata-pasto, emphasizing the green colorant from trifólio. Daniel also describes that there are many species of this plant but that just one produces a green juice perfect for coloring. Trifólio refers to several plants of the Oxalidaceae family, of the *Oxalis* genus [50], and there are over 250 species of *Oxalis* L. found in tropical and temperate regions [78]. Unfortunately, no information about the chemical compositions of the specific species used for coloring in

Brazil was found. However, in other contexts, there are reports indicating the presence and use of dyes from plants of the Oxalidaceae family. For example, *Averrhoa bilimbi* L. has been used to color foodstuff [79], and yellow, orange, and red to brown dyes are obtained from *Oxalis corniculata* L. [80].

About the blacks, Daniel points out their diversity, highlighting the use of the jenipapo fruit, which is also mentioned by Spix and Martius. It is undoubtedly one of Brazil's best-known materials when talking about Indigenous colorants, together with urucum. Jenipapo comes from a tree of the Rubiaceae family and the species *Genipa americana* L., *Gardenia genipa* Swartz, *Genipa excelsa* Krause., and *G. oblongifolia* Swartz. [50]. *Genipa americana* L. contains a colorless substance called genipin that produces a blue-violet color when in contact with the skin [81]. This molecule is an iridoid compound that forms blue colorants when reacting with amino acids and primary amines (including proteins) in the presence of oxygen [82]. However, not many scientific investigations in the cultural heritage context are available.

Daniel mentions that black could also be obtained through smoke or soot, prepared by burning coconut fibers, which had a high setting power. Additionally, a black colorant was derived from a vine, used for writing, painting, or coloring any material, as well as the bruised and trampled cotton flower. Although the author acknowledges the abundance of black colorants and the skill of the Indigenous people in coloring the cotton cloths, no specific details are provided. Baena also mentions burnt leaves, but from the paracauáxi tree, and briefly notes that cauassu, a palm tree, yields a dark colorant as well. Similarly, he mentions the mamaurana, uacapurana, and piquiá trees, where the latter's bark is used for obtaining a colorant used in writing. Spix and Martius also mention the use of the herb *Eclipta erecta* L.

Baena mentions the use of macucu, murta, and cumati. The latter exhibits a natural purple color, which turns into a light black after treatment with urine, indicating a chemical reaction. Cumati is used for coloring gourds, and the production processes by the Indigenous people of Monte Alegre and Santarém are described by Ferreira. In Monte Alegre, the gourds were prepared and moistened, followed by spraying soot made from the wood of the uteira tree, resulting in a final black color. In Santarém, soot from breu was used, resulting in a reddish-black color. The gourds were then dried and soaked in cumati water before being placed on a mixture of sand and urine, which set the black background and polished the cumati's varnish. This process was repeated several times until the desired result was obtained. Then, they used colorants such as curi, tabatinga, tauá, anil, and urucum for decoration. Mixtures were made for the colorants' application, such as curi with the juice of the urucum seed, tabatinga with the juice of the cotton root, and anil with tabatinga.

In more recent contexts, the way of making Ribeirinhas gourds has been recognized as a Brazilian intangible cultural heritage [51], and IPHAN (National Institute of Historical and Artistic Heritage) mentions the use of cumatê instead of cumati. Cumati is a shrub of the Myrtaceae family, while cumatê is a term involving different families, including the Myrtaceae [50]. Although at least one of IPHAN's documents mentions the reaction of cumatê with ammonia from human urine (*Dossiê de registro do modo de fazer cuias no baixo amazonas* [51]), no technical studies were found about the chemical reactions involved on it or the final composition and properties of the formed black layer.

Daniel cites tabatinga as white, a thin clay that was used to whitewash houses. Baena mentions that tabatinga was mixed with gum (or resin) from the sorveira tree for greater resistance. The mixture of sorveira gum (or resin) with colorants is also mentioned by Spix and Martius, citing, for example, tabatinga and carajuru (red), when discussing painting earthenware. The terms gum and resin seem not to be differentiated in the mentioned historical texts, and this is why both are used here. The main chemical component found in a tabatinga sample was kaolinite [83].

4. Conclusions

This manuscript raises international awareness among scholars about the richness of materials and techniques used by Indigenous people from the Brazilian Amazon Forest in their paint and coloring practices. It is expected, as a consequence, to generate greater interest among conservation scientists, conservators, technical art historians, and other professionals in these cultural items, shifting these arts from the margins to the center of technical art history, conservation, and conservation science. The scientific investigation of these arts and cultures is crucial for fostering a more global, inclusive, and decentralized vision of art history, as well as creating a more pluralistic narrative of Indigenous art history from South America.

Clearly, the Indigenous people of the Brazilian Amazon Forest have not only extracted colorants from the forest but also engaged in processing them and creating new materials. The forest has become a space for Indigenous research, a laboratory where those people have been continuously investigating and experimenting with various materials and techniques. For example, the presence of acidic and basic materials in Table 1, such as citric peels and urine, suggests their engagement with pH changes in coloring systems.

The ongoing use and production of colorants by those people offer a unique opportunity to collaborate, work with, and learn from the Indigenous communities. Among other possibilities, their involvement can shed a light on the cultural significance of some colors, materials, and patterns, which can be challenging to discern without a deep understanding of the community's language, cultural context, mythology, and rituals. However, when collaborating with Indigenous communities, it is crucial to consider how such cooperation can genuinely benefit their existing cultures, traditions, and lives. Ensuring mutual respect and understanding is essential in fostering a meaningful partnership between scientists and Indigenous communities.

In this context, ethical and legal discussions in conservation science and technical art history are of utmost importance when collaborating with Indigenous communities or investigating ethnographic items. For example, who should scientists consult before investigating ethnographic items? How should scientists address different technical definitions and understandings when cooperating with Indigenous communities? What are the legal and ethical issues to be considered when scientists work with Indigenous communities to rescue and share their traditional knowledge? Conservation scientists and technical art historians should not forget that, in these cases, they are investigating "novelties" that were discovered by past Indigenous scientists represented by their current descendants. How are we to acknowledge and respect them? Many other ethical and legal discussions need to be considered, but this is outside the scope of this manuscript.

The discussions presented here also make clear the existence of misunderstandings in historical texts, usually associated with terminology. This underscores the importance of scientific research that combines the study of cultural heritage items, oral information from Indigenous communities, plants from the Amazon Forest, and the laboratory recreation of historic recipes to complement information from historical texts. The research possibilities for these arts are vast, including provenance studies, technical art history investigations, analysis of the mechanical, physical, and chemical properties of their materials, the development of analytical methods for material identification, and the evaluation of appropriate conservation methods and conditions. Such comprehensive research approaches will contribute to a deeper understanding and appreciation of these valuable cultural treasures.

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