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Article

The Study of Chinese Dyes Recipes on Silk from The Ming Dynasty to The Republican Period

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Abstract: The article presents a literature review of three Chinese manuscripts containing natural dyes recipes and three containing synthetic dyes from the Ming Dynasty to the Republican Period. The manuscripts mentioned were exclusively used as references and sources. Four databases were used to access the original documents, then, a translation from old mandarin to Spanish was made. For natural dyes, the results show four dyestuffs were commonly used to produce colors, sappanwood (*Caesalpinia sappan L.*), followed by safflower (*Carthamus tinctorius L.*), indigo (*Indigofera tinctoria L.*), and sophora (*S. japonicum L.*). While the synthetic dyes exported to or produced in China were mainly bluish, greenish, and violet probably because they were difficult to obtain from natural ones. The literature review of the dyes and their recipes can be a key factor in any art history or conservation study, improving the understanding of how the colors were achieved and as complementary information for analytical analyses. It provides useful details that contribute to the preservation of Chinese dye history on silk heritage.

Keywords: natural dyes; synthetic dyes; silk; recipes; Ming dynasty; Qing dynasty; Republic of China.

1. Introduction

There is no doubt of the importance of textiles and their colors for humanity. The knowledge to apply color on threads, yarns and fabrics can be traced back into the Neolithic Age, approximately, 10.000 BC and one of the earliest written documents referring to natural dyes were found in China 2.600 BC [1] (pp.1-9). This country is also place of the cultivated silk from the larvae *Bombix Mori*, considered the noblest textile. The silk played a major role for interconnecting society's economies and cultural exchanges between Asia, Europe, Africa, America, and Oceania for centuries [2]. In this sense, Chinese silk relics are spread around the globe on museums, cultural institutions, and private collections. Cultural heritage made from this material were broadly investigated in the sense of its history and symbolism, fiber degradation, and preservation strategies, nonetheless the same cannot be said for its dyes.

Traditional Chinese natural dyes on silk have been reported by some studies [3,4] (pp. 87-96), largely showcasing the analytical results of Tang and Song archeological findings from the Mogao Caves and late Qing noble clothing. Special attention is given to the identification and characterization of the main molecules of dyestuffs and mordents but not to the process of dyeing itself. There are few investigations about the introduction of synthetic dyes in China. The research of natural and synthetic colorant recipes is of great relevance as it studies which materials were used for the dye bath processes, how the colors were achieved, how the Chinese culture perceived color, and as complementary

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information for other areas such as art history, conservation, and analytical analyzes. The purpose of this study was to investigate the natural dyeing methods of silk in China by translating historical recipes. In fact, the study of the recipes is the main key to understand the dyeing silk of the Chinese people. Secondly, this work aimed to identify the early synthetic colorants used on silk, and how they classified and understood these colors. Hence, this article presents a literature review investigating a total of six documents. Three natural dye manuscripts from Ming and Qing dynasties, namely 多能鄙事 (Duoneng Bishi) from 1541, 天工開物 (Tiangong Kaiwu) from 1637, and 布經 (Bu Jing) from 1795 to 1850. As well as one custom document and two foreign catalogs of synthetic dyes, World Exhibition of the Austro-Hungarian Empire in Vienna of 1873, Dade Pigment Factory Direct Dye Samples, and Imperial Chemical Industries (China) Limited, aniline dyestuffs on silk (1948), respectively.

2. Materials and Methods

The method of this research was the descriptive investigation of documents and their comparison in between, organized into four steps. First, bibliography research was carried out from manuscripts available through university websites and libraries, as well as open access databases. Original documents and printed and online scientific articles were investigated exclusively as references and sources. Three online Asian and one open-source western database were selected as follows: 1. Classical Chinese books from the U-Parl Project (東京大学), 2. Ancient Chinese documents in Hong Kong (中國基本古籍庫), 3. Digital Archive of Toyo Bunko Rare Books, of National Institute of Informatics - Digital Silk Road Project, and 4. Internet Archive Public Domain.

In the next step, the originals were classified by the time of publication, technical precision, authorship, geographical region of production, and typology to determine their degree of reliability as historical sources.

Thirdly, a translation from traditional Chinese to modern Chinese and then to modern Spanish was carried out by the authors. For an accurate translation of art terms, the 視覺藝術科學與教常用英漢辭彙 (English-Chinese Glossary of Terms Commonly Used in the Learning and Teaching of Visual Arts) was used as a reference.

Lastly, the visual representation of each color pattern was extracted from the open-source project zhongguose.com.

3. Results and discussion

General descriptions of the manuscripts containing dye recipes were examined in terms of authorship, purpose, content, publication period, and intended audience. The natural dye documents can be categorized into four typologies: books associated with medicine and dietetics; silk painting manuals; almanacs of daily life, and specific dye recipe books. The first contributes to the knowledge of dyes with the description of herbs and plant parts used in the dyeing process, also used as oily essences, teas, and dyes in food, registered with botanical drawings. While those dedicated to the description of some colorants and organic materials used with pigments for painting help to complement the information. These two typologies emphasize agriculture and natural phenomena to produce textiles and their colors.

Almanacs of daily life or 日用類書 (ri yong lei shu) are a kind of books on daily activities arranged by categories and written by lower-ranking literati, presenting general content on silk and dyes. On the other hand, the specific recipe books were made by high-rank scholars and usually edited by the imperial house and of restricted circulation, offering detailed content. In total, ten documents were identified that relate to silk dyeing processes, of which eight are from the Ming Dynasty, and two from the Qing. The majority are classified as almanacs of daily life since they were published more frequently than other types of documents [5].

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Seven documents have been discarded, considering the scant information they offer in relation to silk dyes, and, in some cases, the restriction of coloring material only used in specific regions. The discarded papers were: 徽州府志 (Hui Zhou Fuzhi) - Huizhou Prefectural Chronicles; 大明會典 (Da Ming Huidian) - Collection of Laws and Systems of the Ming Dynasty; 古今醫統大全 (Gujin Yitong Daquan) - The Complete Works of Medicine; 物理小識 (Wuli Xiaoshi) - Little Knowledge of the Principle of Things; 芥子園畫傳 (Jiezi Yuan Huazhuan) - Manual of the Mustard Seed Garden; 內務府全宗檔案,織染局簿冊 (NeiWufu Quanzong Dang'an, Zhiranju Buce) - Dyeing and Weaving Archives Office and 本草綱目 (Ben Cao Gang Mu) - Compendium of material medica. On the other hand, for the analysis of the natural dyes used in silk, the 多能鄙事 (Duoneng Bishi) - Various Arts in Daily Life, 天工開物 (Tiangong Kaiwu) - Exploitation of Products of Nature and 布經 (Bu Jing) - The Book of the Cloth were chosen for the detailed offered, for having influenced their predecessors, and for being the most popular of their time.

The introduction of non-natural dyes in silk approached the time from Qing Dynasty (1644-1912) until the end of the Republic of China on the mainland (1911-1949). Lesser documents were found compared to the natural dyes and two categories of documents can be traced, customs documentation and company catalogs.

3.1. Color classification

The idea of "color" denotes how a culture or individual perceives the world through visual aesthetics. In fact, the importance given to certain colors can largely explain why complex baths were carried out to achieve the desired shade. In China, they are extremely crucial due to the symbology attributed to them and, therefore, it is to be expected that this symbolic load is present not only in their silk artifacts but in the written sources as well. Briefly speaking, the five main colors used in China throughout its history originate from the ritualistic system 五行 - wuxing [6] and are called 五方色 (wu fang se): cyan 青 (qing); red 赤 (chi); yellow 黄 (huang); white 白 (bai) and black 黑 (hei). For this article, the three previously selected books were investigated in this sense, and two more documents were added for their richness in compiling and classifying colors:

- 齊民要術 (Qimin Yaoshu) – northern wei 北魏 386-535.
- 多能鄙事 (Duoneng Bishi) – 1320-1375 (1541 publication);
- 本草綱目 (Ben Cao Gang Mu) – 1578;
- 天工開物 (Tiangong Kaiwu) – 1637;
- 布經 (Bu Jing) – 1795-1850;

The documents of the last two dynasties strongly influenced the beginning of the republic era and are still used in the 21st century to a certain extent [7].

In order to understand the complex color name system of ancient Chinese, the written language can be divided into four categories: the modal terms adjectives or shades saturation, the basic colors or color family, textures associated with a color, and transitional color. All of them provide more than one synonym for each color. In Mandarin, some adjectives related to dark and light, when juxtaposed to an existing color name can change the shades of this original color. In other words, it can be classified as pale, saturated, dark, or even transparent when added to these specific adjectives. They are translated as "modal terms" [8] (pp. 193–208). A total of ten modal terms were found in the manuscripts, from which Ming and Dan are the most quoted ones. In Table 1, the modal terms are visually represented by the color blue and its shades:

Table 1. Modal terms and their visual representation from zhongguose.

Chinese name	Shade meaning	Visual representation
Zhan (湛)	deep and clear as crystal	
Qian (淺)	generic term for a light shade	
Cai se (彩色)	understood as a bright-bright color	

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Ming (明)	to refer to a bright color	
Dan (淡)	to characterize a pale color	
Fen (粉)	the unsaturated version of a color	
Za se (雜色)	a color with mottled dark undertones	
Mo (墨)	associated with a dark version of a color	
Shen (深)	it is the generic term for a dark tone	
Tie (鐵)	the darkest shade of a color	

This variety of terms makes it difficult to determine which shades or tints fall within the category of basic colors, such as red, yellow, blue, green, orange, purple, pink, gray, white, and black. For example, zong (棕) and zhe (褚) mean brown. The terms he, zong, and tu (褐, 棕 - pine bark, 土 - earth) are also used to designate brown, but rather linked to the idea of a sensation and texture. While zhe (赭 reddish brown) and cha (茶 tea, brownish-green) despite being included within the browns, rather fulfill the role of transitional colors between red and green, and in some cases may be considered to belong to other families of color [8,9] (pp. 36).

Cai, cui, lu, bi and qing (菜, 翠, 綠, 碧, 青) are under the green family umbrella, lu being the standard translation of "green". Qing is representative of the family of blues, suggesting bluish-green or cyan. Lan and Shui (藍, 水) are specifically blue, while Zi (紫) symbolizes purple. Ying and tao (櫻, 桃) are often mentioned for the idea of a rose color palette, and feng hong (粉紅) is preferred for the standard pink. The terms chi, hong, zhu, zhe, dan, and xie (赤, 紅, 朱, 赭, 丹, 血) are shades within the "red" family, with hong being a typical translation of red. Yin, tie, and hui (銀, 鐵, 灰) for grays, where yin is silver, a brighter gray. Tie (iron) for both dark greys and sometimes black. Huang and jin (黃, 金) for yellow and gold. Cheng and ju (橙, 菊) for orange and bai (白) for white. Hei, mo, and xuan (黑, 墨, 玄) are for black. After examining the texts, a color table containing the main colors was created and is depicted below (Table 2).

Table 2. Common traditional colors of the historical documents (zhongguose).

Chinese name	Visual representation	Chinese name	Visual representation
Black Family		*White Family*	
皂 (zao)		純白(chun bai)	
黑緇 (hei zi)		雪白 (xue bai)	
鉄 (zhi)		縞素 (gao su)	
玄 (xuan)		茶白 (cha bai)	
烏 (wu)		月白 (yue bai)	
Red Family		*Yellow Family*	
赤 (chi)		鬱金 (yu jin)	
大紅 (da hong)		槐花 (huai hua)	
葡萄青 (pu tao qing)		明黃 (ming huang)	
丹 (dan)		金黃 (jin huang)	
彤 (tong)		水黃 (shui huang)	
Blue Family		*Green Family*	
石青 (shi qing)		黑綠 (hei lu)	
玄青 (xuan qing)		豆綠 (dou lu)	

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靛 藍 (dian lan)		翠綠 (cui lu)	
毛青(mao qing)		油綠 (you lu)	
真青 (zhen qing)		中明 (zhong ming)	

3.2. Natural dyes recipes

The investigation of the natural dyes recipes on silk is divided from the oldest to the newest manuscript, followed by the document structure, the recipes, and then, a comparison between their contents. The recipe's metric units of mass, length, and time were calculated to the International System of Units. The translation of the recipes is given in the supplementary information section.

3.2.1. Manuscript 1 多能鄙事

In 多能鄙事 there are twelve volumes, and the fourth introduces textile processing and finishing. It is divided then into two categories: the washing method and the dyeing method 染色法 (ranse fa). Washing methods include wool, bamboo cloth, kudzu, silk, linen, ramie, soap washing, and so on. The dyeing method is classified by colors: red, brown, green, black, cyan, orange, yellow, etc., with a total of fourteen. The author also differentiates between processes of direct silk dyeing (直接染色), mordant dyeing (媒染), and over-dyeing (套染的). It is explained the multicolor dyeing system aims to obtain a wider range of colors by combining or adding different dye baths to the silk. In the over-dye method, there are two to three baths. The most representative is the method with 小紅, or light red, which is the more detailed process recorded. In it, a first bath with sappanwood (蘇木 sumu) is carried out, followed by alum, a second bath with sophora and yellow lead oxide powder, and a third bath with sappanwood again (recipe 1).

There are records of auxiliary dyes, mainly mordants. It is known that the same natural colorant will show different colors due to the different mordants used. 多能鄙事 pays special attention to this process, establishing three methods to create effects on dyed silk: pre-mordanting, dye mordanting, and post-mordanting. The author states under normal circumstances, aluminum mordent 鋁媒染 (lu meiran) produces bright and vivid colors, copper mordant 銅媒染 (tong meiran) exhibits a reddish hue, and iron mordant 鐵媒染 (tie meiran) develops smoky gray tinges. It is described how alum dissolves in water until it boils, and degummed silk is immersed for about an hour. The method of using aluminum mordant as a pre-mordant is one of the oldest and simplest, historically developed in different geographical areas, as is the case of Egypt with the Stockholm Papyri document in 4 AD [10] and also mentioned by the Roman Pliny the Elder in his book Natural History in 77 AD and 79 AD [11]. One of the simplest alum mordanting recipes is for the dye sappanwood (recipe 2). In this recipe, we can see the pre-mordanting with alum, a common system in European silk dye recipes.

There are also other simple recipes for direct dyes or with a mordant. There are four processes for red, resulting in the colors 暗茶褐 (an cha he), 棗褐 (zao he), 明茶褐 (ming cha he). The sappanwood can be used with 褐色 (he se) - *Calligonum colubrinum*, adding two mordants, called double mordanting 雙重媒染. First, alum mordant is used and at the end of the process, green alum mordant is used, to give depth to the color. In this regard, it should be noted that depth, gloss, and other color properties are not only related to the mordant, but also to the characteristics of the fabric or yarn used. The following recipe uses acacia from Japan or 槐花 huihua with sappanwood, it specifies the making of a mordent to avoid the change of yellow color during the process, according to Liu Ji's note. On the other hand, in the Compendium of Materia Medica, of a later date, it is specified that mordanting is not necessary, but that it can be dyed directly, obtaining various colors such as yellow, red, and green. The acacia recipe records the use of its leaves, a soap, and alum, but further details are omitted.

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3.2.2. Manuscript 2 天工開物

天工開物 is arranged in three chapters called upper, middle, and lower, with a total of 18 subchapters and 123 illustrations. In the first chapter, there are six subchapters, where the second and third, 乃服 (nai fu): sources and processing methods of raw materials for clothing and 彰施 (zhang shi): dyeing method of vegetable dyes, delves into precisely describing the dyeing of silk and fabrics made with other types of fibers.

In 乃粒, in the first section called clothing (衣料 yi liao), the author classifies the types of materials with which garments can be made, with a basic division between vegetable origin: cotton (棉 mian), hemp (大麻 da ma), abutilon (黀麻 qing ma) and kudzu (葛 ge). And those of animal origin: leather (皮 pi), wool or animal hair (毛 mao), and silk (絲 si). Next, he describes the method of raising silkworms, and then the weaving technology, that is, how the cloth is woven. Four main fabrics are mentioned related to silk, brocade, satin, twill, and taffeta. The third chapter is subdivided into five sections, in which the first 諸色質料 (zhuce ziliao): colored materials distinguish 19 reddish colors, of which the first is 大紅色 (da hong se) made with safflower 紅花 (hong hua) – recipe 3. He mentions four colors that also use safflower as a coloring raw material: 蓮紅 (lian hong or lotus red), 桃紅 (tiao hong or peach pink), 銀紅 (yin hong or silver red) and 水紅 (shui hong or water red) – recipes 4-7.

The second section talks about the blues 藍澱 (landian). The author specifies five types of vegetal blues, and they all bear the generic name of indigo, and the same dyeing process is carried out. Detailing their names, 茶藍 chalan is *Isatis indica* (*Cruciferae*) – recipe 8, 蓼藍 liaolan is *Polygonum tinctorium* (Chinese indigo), 馬藍 malan is a *Acanthaceae*, 吳藍 wulan is a *Leguminosae*, and 莧藍 xianlan an *Amaranthus*. These natural indigos were not only used in China, but also exported to Europe until the chemical synthesis of this color in 1880 [12].

The third section details the use of the root, stems, and leaves. The fourth section talks about the safflower again and the last one is dedicated exclusively to the *Sophora japonica* or 槐花 (huai hua) – recipe 9, mainly denoting yellows and greenish yellows. Particularly this section emphasizes the use of everyday agricultural and cattle raising tools, and also indicates the ease of preparing the recipes.

Very little information about the other colors is provided, making it inconsistent for translation at the moment. The other recipes are 赭黃色 ocher yellow, 鵝黃色 goose yellow, 金黃色 golden yellow, 茶褐色 dark brown (from tea) 大紅官綠色 scarlet-green, 豆綠色 green bean, 油綠色 oil green, 天青色 sky blue, 葡萄青色 grape blue, 蛋青色 cyan egg, 翠藍色 turquoise blue, 天藍色 emerald-blue, 玄色 reddish black (ant), 耦製褐貲, lunar white and grass white 草白色 and ivory 象牙色.

3.2.3. Manuscript 3 布經

The last recipe book examined, 布經, is the one that offers a greater depth in terms of techniques and processes to produce cotton fabric and its dyeing. The book also denotes the recipes can be replicated on silk. It contains detailed information on vegetable dyes, color combinations, their prices, thread spinning, and dyeing processes divided into 28 subtitles. Unlike the other two analyzed manuscripts, this one studies the textile technology in the Shanghai area, specifically in Songjiang, where the cotton textile industry developed rapidly in the Qing Dynasty [13] (pp. 468–499).

More than 60 types of reds, blues, greens, yellows, oranges, purples, blacks, grays, whites, and browns are registered and subcategorized by shades within their color families, of which 44 of them have specific formulas. The main shades of blue include 蒲藍 Grape Blue, 天藍 Sky Blue, 翠藍 Turquoise Blue, 赤藍 Red Blue, 京藍 Beijing Blue, 海藍 Sea Blue 寶藍 Royal Blue, 湖藍 Lake Blue, 月藍 Moon Blue, 軟藍 Blue smooth and double blue 雙藍. The main shades of green include 水綠 aqua green, 柳綠 willow

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green, 淺翠 light green, 中明 medium gloss, 圓眼 round eyes, 鴨綠 duck green, 竹綠 bamboo green, and 油綠 oil green. The main white shades include Moon White 月白, Moon White Dark 暗月白, Moon White 淺月白 Light, and Moon White Green 綠月白.

The majority process is done through mordant dyeing, a combination of colors in the same bath, and overdyeing to obtain a wide variety of shades, largely of vegetable origin. The main dyes used are: 五倍子 *Galla chinensis*, 紅花 safflower, 蘇木 sappanwood, 槐米 *Sophora japonicus*, 象鬥 acorn (quercus), 橡椀子 acorn (walnut), 黃柏 cork, 斛皮 *Dendrobium orchid* petals, 靛青 indigo, 大黃 rhubarb, 黃栌木 *Cotinus coggygria* (sumac - wood), 梔子 gardenia, and 黃柏木 *Phellodendron chinense* (yellow cypress). The additives used are green alum/vitriol (ferrous sulfate), alum (aluminum salt), 礜 phosphate, 鹼 alkali, 烏梅 smoked plum, and 杏仁油 almond oil.

The main recipes for dyeing yellow are complex as they require several baths with different dyes and additives, these are *Cotinus coggygria*, yellow cypress, gardenia, *Sophora japonicu*s, and acorn (walnut and quercus). For some darker colors sappanwood is also used, while for red the author mainly uses safflower and, although rhubarb has a yellow coloring principle, it is not used alone. Indigo is applied to achieve bluish tones and can be combined with other plants such as rhubarb, safflower, *Cotinus coggygria*, Chinese galla, and acorn (walnut). These last two also generate black. To achieve the purple color, safflower is used with indigo, and for greens indigo, rhubarb, and sophora or yellow cypress.

In this book, there are three recipes to draw attention to. The first is another recipe for great/scarlet red, using different materials such as one extra dye (turmeric) and two additives which the plum juice is repeated compared to 天工開物. The second is the bleaching process while the third is the dye color only found in this book called 油綠 oily green (recipes 10-12). It is the only document that clearly states the use of threads and not only fabrics.

3.2.4. Comparison of the natural dye's documents

In manuscript 1, brown tones predominate due to the combinations of black, red, and yellow, with a limited color range. The emphasis on earthy and no vibrant tones indicates a document intended for the common population since the dark color concealed dirt [14] (pp. 33-48). It can also indicate the foreign influence of the Yuan dynasty when brownish tones were preferred to dye clothes. The dyes used are made up of easily accessible materials such as teas, black beans, lotus leaves, etc. They not only give brown and grey colors but are considered of low quality, unlike those obtained by conventional dyeing materials such as safflower and indigo. The tools used are simple everyday bowls and pots. This book is a summary report of experiments based on a wide range of popular dyeing processes.

In manuscript 2, the volume dedicated to dyeing silk is the one with the fewest number of characters in the book and the least informative, although a greater richness of colors is appreciated than his predecessor Duoneng Bishi. It does not include pigments or colorants of animal origin as dyestuff.

Differently, from the last two documents, manuscript 3 mentions a bleaching process for cotton and silk, made by the ashes of some plants and called "bright alkali". The plant's names are not specified, and a deeper investigation is necessary. On the other hand, several materials are necessary to reach the desired colors in this manuscript, and they are more expensive overall.

Among the comparisons between the three main documents of natural dyes on silk, it has been possible to correlate the number of color names with the materials that generate such color. For a better timeline contrast, the manuscript about the written language structure of the Han Dynasty, 說文解字 Shuowen Jiezi, was also analyzed. As would be expected, the older the document, the lesser sources for color materials, and consequently for color names.

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- Nine coloring materials have been correlated for a total of 39 color names in "Shuowen Jiezi";
- In “Duoneng Bishi” there are 12 dyestuffs from which a total of 42 names are obtained;
- In "Tiangong Kaiwu" for 16 raw materials there are 57 names;
- In "Bu Jing" there are 66 names for 18 kinds of coloring materials.

In relation to silk degumming, it is a pre-treatment considered essential in all three documents. It consists of carrying out the degumming for several days to extract impurities and fats, generally with water and calcareous substances such as mollusk shell ashes, followed by exposure to the sun and, finally, soaking to clean the silk with an aqueous solution of plant ashes such as huang lian (黃連 *Coptis chinensis*), different from the bright alkali mentioned before, so that the fibers can fully absorb the desired color and shine. Other practices that could be added were the beating of the silk before the first degumming to obtain greater whiteness and softness.

The number of times a dye and its additives are mentioned denotes the abundant use due to the ease of acquisition or the value given to the raw material. The most used additives in the analyzed documents are potassium alum, potassium sulfate dodecahydrate or alum hydrate ($KAl(SO_4)_2{\cdot}12H_2O$) and green vitriol, ferrous sulfate or Iron (II) sulphate ($FeSO_4{\cdot}xH_2O$), both found in China (Figure 1). The most common dyes are sappanwood, followed by safflower, indigo, and sophora (Figure 2). The botanical origin of these plants is respectively *Caesalpinia sappan L.*, imported in the Six Dynasties (220-589 AD) to Guangzhou, *Carthamus tinctorius L.*, also introduced to China along the Silk Road in III AD [15] (pp. 230-239), followed by the two natives' plants *Indigofera tinctoria L.* and *S. japonicum L.*. Sappanwood is also known as 蘇木 (su mu), 蘇 方 / 枋 (su fang) or 蘇 方 / 枋 木 (su fang mu). Safflower can be identified as 紅花 (hong hua), 川紅花 (chuan hong hua) or 紅藍 花 (hong lan hua). While indigo as 靛 (dian), 靛青 (dian qing), 大青葉 (da qing ye) and 板藍根 (ban lan gen). Sophora has also four synonymous 槐米 (huai mi) sprout, 槐花 (huai hua) flower, 槐子 (huai zi) fruit and 槐樹 (huai shu) tree. Both alum and green vitriol have two names 明矾 ming fan or 鋁媒染 lu meiran, and 鐵媒染 tie meiran or 硫酸亞鐵 liu suan ya tie.

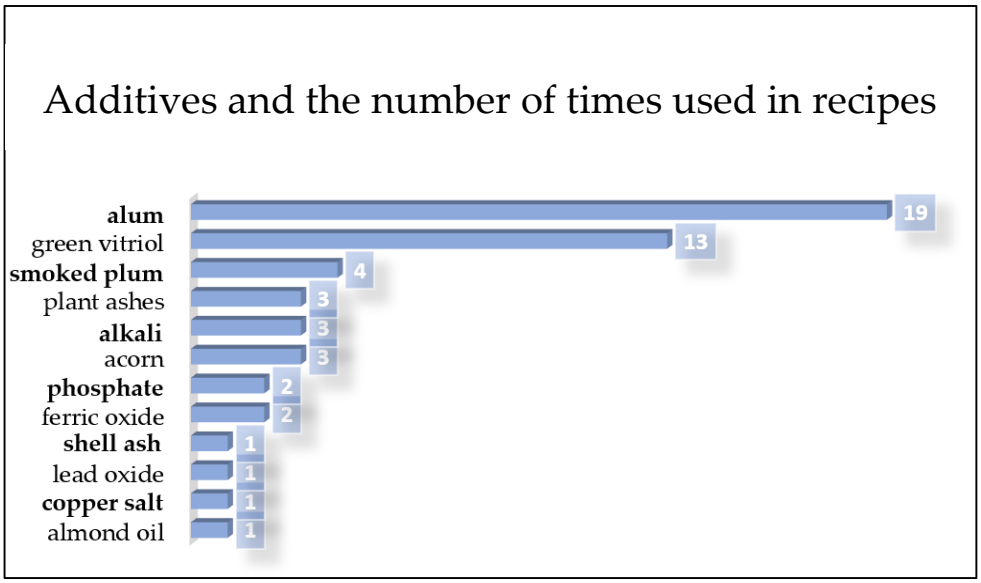

Figure 1. The number of times one additive is mentioned in the three books analyzed.

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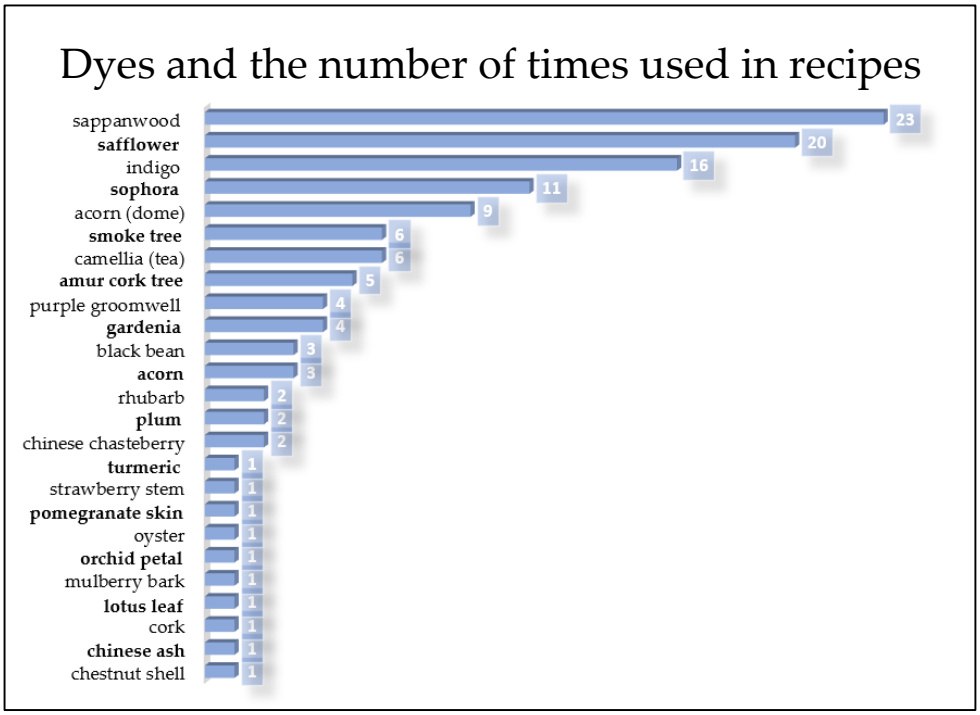

Figure 2. The number of times one dye is mentioned in the three books analyzed.

According to research on traditional dyes and colors on silk from archaeological findings [16-21], there are other five materials usually employed as relevant silk dyestuffs. They are mandarin peel (橘皮 ju pi – *Citrus tangerina*), violet (紫丁草 zi ding cao – *Viola philippica*), Indian rosewood (黃檀 huang tan – *Dalbergia*), Indian madder (茜草 qian cao – *Rubia cordifolia L.*) and the bark of the Chinese hazelnut (華榛 hua zhen – *Corylus chinensis*).

If we compare the evolution of the silk dyeing baths in Europe, there are specific periods in which the trend for colors and the palette range evolves. In this sense, the first relevant publication appears in the Middle Ages. It states that higher tint colorants cannot be mixed with lower tint colorants, that is, stable colorants such as indigo, with unreliable colorants such as weld (*Reseda luteola*). In this period the predominant color in recipes is red [22]. With the introduction of dyes from the East, the range increases and moves towards the blue color, mainly the Indian indigo genera. After the colonization of America, the possibilities of colors undergo another exponential increase. In the 18th century, there is already a great interest in leaving well-described recipes in which more than 200 tones appear and in which concepts such as spectrum color, tones, nuances, and reduced ranges are introduced [23].

3.3. Introduction of synthetic dyes in China

In relation to industrial dyes, three very different stages can be appreciated: the first of them is the exclusive use of natural dyes, followed by a transition or adaptation phase in which natural and synthetic colors were mixed in the same bath or textile, followed by a third stage in which the use of synthetic dyes predominated. This transition period began with the first synthetic dye with William Henry Perkin's mauveine in 1856, an aniline derived from coal tar [24]. Followed by fuchsin in 1858-1859 and alizarin in 1869. With the development of aniline dyes, an unprecedented range of intense colors became available, characterized by their high affinity to animal fibers and low cost, but poor lightfastness. The acid dyes for animal fibers were synthesized in 1875, with the synthesis of indigo in 1880 and Victoria Blue B in 1883 [25]. As a result, by the 1870s in Europe, commercial natural dyes were disappearing, while in China their replacement was just beginning. At the same time, the development of new textile fibers was carried out. In 1890 there were

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effective results in imitating the appearance of silk, based on cellulose fiber, called rayon, and finally in 1930 nylon (polyamide compound polymer), the first synthetic fiber.

In China, the history of synthetic dyes begins strongly after the defeat in the Second Opium War (1856-1860), where the ports, more precisely those of Guangzhou and Shanghai, were forced to open to foreign trade, with the massive influx of European goods and with them industrial dyes, called western dyes (洋色 yan se). Hence, natural dyes were gradually replaced in the late Qing dynasty and the early Republic of China [26] (pp. 119-123). In fact, the use of synthetic in this country is a still-growing field given the little research carried out in this regard, possibly derived from the expulsion of foreign companies and their documents during the Republic of China in the mainland (1912-1949) and the founding of the People's Republic of China. Another factor was the randomness with which the colors that arrived were named. Some authors point out that the dyes entered before 1870, while others defend the possibility of having been introduced in China in 1887, specifically synthetic indigo, which was sold by foreign companies in Shanghai.

Based on the contributions of a few works published and foreign trade documents, such as the "World Exhibition of the Austro-Hungarian Empire in Vienna of 1873", we can have a glimpse of the most widespread dyes and pigments at the beginning of the formation of modern China. According to some papers [27], not only chemical dyes were imported, but also a few natural plants, animals, and organic pigments such as European varieties of indigo, cochineal (胭脂蟲 yan zhi chong) introduced in 1582, shellac (紫膠 zi jiao) and Prussian blue. Besides the list of materials and objects in customs documents and international fairs, information can be obtained from the catalogs of international companies. There were two prominent companies of synthetic dyes in the XIX century in this country, the British Pigment Company installed from 1860 to 1919, and the German Illy Tintes de Chemische Fabric Greisheim-Elektro, which began selling its products through the Shanghai Foreign Company Lihe 上海禮和洋行 [28].

The main dyes identified from the documents in the 19th century were Prussian blue, Saxon blue, Victoria blue, aniline blue, mauve, fuchsia, crystal violet, aniline violet II, aniline yellow, alizarin, rouge d'Andrinople, aniline red, rhodamine B, aniline gray, aniline black, emerald-green, and aniline green (Table 3). Among these 18 colors, five of them are blue, four are in the purple spectrum, and three are green, while the least imported dyes are yellow, pink, black, and gray, containing only one mention of each. No brown or orange materials were identified. The preference for blue, violet, and green, is probably because they are difficult to obtain in natural dyes recipes, on the other hand, yellows, reds, and blacks take longer to undergo alterations. It can be seen the basic dyes, anilines, were preferred due to the low price, the ease of acquisition, or an economical polity. The possible entry date of these dyes varies from 1840 (Prussian blue) to the Republic Period (rhodamine B, aniline black, and aniline violet II). The time of arrival of some colors remains unknown such as emerald-green. The gap of at least ten years from the commercialization of the synthetic dye in Europe to the importation of such colors could indicate a resistance against foreign products in the Chinese market and the use of non-natural dyes as unnecessary.

Table 3. Main identified dyes in China in 19th -20th centuries documents.

Coloring material	Creation/commercialization date	Reference	Possible entry date in China	Reference
Prussian blue 普藍/普魯士藍/洋藍	1724-1725	Cameo materials database	1844-1850	List of materials from World Exhibition of the Austro-Hungarian Empire 1873

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Saxon blue 靛藍胭脂紅	1743	Cameo materials database	?	-
Indigo 靛青	1880	Cameo materials database	1887-1890	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Victoria blue 維多利亞藍	1883	Cameo materials database	?	-
Aniline blue 品藍/品月/苯胺藍	1860	Cameo materials database	1873	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Mauve 玫瑰/淡紫色/紫瑰/茄色/苯胺紫	1856	Cameo materials database	1873	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Fuchsia 紫紅色	1858-1859	Cameo materials database	1870	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Crystal violet 結晶紫	1883	Cameo materials database	?	-
Aniline violet II 苯胺紫 II	1866	Cameo materials database	Republic of China	Dade Pigment Factory Direct Dye Samples
Aniline yellow 苯胺黃	1861- 1864	Cameo materials database	1880	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Alizarin 茜素	1869	Cameo materials database	1873	List of materials from World

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Rouge d'Andrino-ple 洋紅	1740	Cameo materials database	1873	Exhibition of the Austro-Hungarian Empire 1873 List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Aniline red 品紅/苯胺紅	1859	Cameo materials database	1873	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Rhodamine B 玫紅/羅丹明	1887	Cameo materials database	Republic of China	Dade Pigment Factory Direct Dye Samples
Aniline grey 苯胺灰	1863	Cameo materials database	1880	List of materials from World Exhibition of the Austro-Hungarian Empire 1873
Aniline black 苯胺黑	1863	Cameo materials database	Republic of China	Imperial Chemical Industries (China) Limited
Emerald-green 巴黎綠	1814	Cameo materials database	?	-
Aniline green 苯胺綠	1877	Cameo materials database	1880	List of materials from World Exhibition of the Austro-Hungarian Empire 1873

By about the 1940s, the publications and catalogs on synthetic dyes increased, both made by the Chinese, European, and North American companies in this country. At this time, special editions were being made for the Chinese market, where one can find the same dyes as in Europe, but with different preferences. In 1940, "Dade Pigment Factory Direct Dye Samples" 德國大德顏料廠直接性染料樣本 [29], a German company for silk, wool, and cotton, were published in the United States and China, where 120 colors can be counted. Some of them are Brilliant Congo Violet R, Erika B, Brilliant Benzo Violet B, Chicago Blue 3BL, Dianil Blue G, Fast Indigo Blue 200 new, Pluto Brown GG 907, Oxamine

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Claret B, and Direct Deep Black E883. The book was edited for nine regions of China, reaching a fair distribution: Hongkong, Canton, Hankow, Changsha, Chungking, Tsinanfu, Tientsin, New Chawng, and Harbin. Albeit there is a great variety of colors, more pages are dedicated to pinkish, bluish, and violet shades. In 1948, at the very end of the republican period, the Imperial Chemical Industries (ICI) 大英颜料公司- 中國英商卜内门洋碱有限公司 an important distributor of Great Britain Pigment Company products from 1926 to 2008, and the British trader Bunei menyang Co., Ltd. issued a book in English and Mandarin containing samples, dye formulas, name, color number, the color family, and the price of aniline dyes specifically for silk [30]. More than 125 colors can be counted. Among some of its colors are Jade Green CN, Lissamine Green VS, Methyl Violet 2B Lumps 125 (B), Clorazol Violet RS, Auramine 026 (B), and Lissamine Fast Yellow 2GS (A). At the end of the book, some stamps can be seen, and the dyes are not the same as in the first catalog.

The synthetic dyes on silk in China from the beginning of the 20th century present broader options of colors in new catalogs and books. The country itself started producing syntherized dyes and the consumption of natural ones was decreasing. This scenario could be explained by changes in politics and the welcoming of modernized thoughts as the end of the imperial power in 1911 and the Republican Era. Still, a preference for bluish and purplish colors remains.

4. Conclusions

In this work, the dyes and their additives recipes in silk and the Chinese traditional color classification system were examined. The information generated provides clear evidence of the opulence of materials and colors available. For that reason, complex manuals and recipe books were created to document all the processes involved, from the crop to textile finishes.

In Chinese culture, the natural dyes of animal origin were rarely used, and the vegetable color sources are primarily endemic, in contrast with the European tradition. There are colorings and mordants repeated in all the three main documents inspected; however, they do not have the same recipe. There are few mentions of threads, prioritizing the dyeing of silk fabrics. The most used additives in the historical records are potassium alum and green vitriol, while the most common dyes are sappanwood, followed by safflower, indigo, and sophora.

The first synthetic dye detected in China on silk was from England back in 1870, although the possible entry date is still open to debate. The results show mainly blue (specifically synthetic indigo), green and violet colors were imported. This is probably because they are difficult to obtain in natural dyes. In the 20th century, in the Republican time, an increase in synthetic dye varieties and consumption can be observed. International publications and catalogs with silk samples were sold in the Chinese market, where, again, one can notice the preference for bluish and purplish tones.

The research provides details that contribute to the understanding and preservation of Chinese dye history on silk heritage. The literature review of the dyes and their recipes can be useful in any art history or conservation study. In fact, the reading and translating of the recipes is the main novelty of the article. They are the key to understand the dyeing methods of the Chinese people.

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Data Availability Statement: The databases used during the current study, by previous inscription, are available on:

1. http://u-parl.lib.u-tokyo.ac.jp/archives/english/the-zhongguo-jiben-guji-ku
2. https://lib.hku.hk/database/accd/index.html
3. http://dsr.nii.ac.jp/toyobunko/index.html.en
4. https://archive.org/
5. https://www.edb.gov.hk/attachment/tc/curriculum-development/kla/arts-edu/resources/va-curri/visual_arts_glossary20171206.pdf
6. http://zhongguose.com/
7. https://cameo.mfa.org/wiki/Category:Dye_Analysis

Conflicts of Interest: The authors declare no conflict of interest. We confirm that neither the manuscript nor any parts of its content are currently under consideration or published in another journal.

Supplementary Information

Botanical names and origin attribution to the sappanwood dye

It was imported to China in the Six Dynasties to Guangzhou, the country's foreign trade center, and during the Tang and Song dynasties, as a medicinal material and dye to Japan. In the Yuan and Ming dynasties, it became the main source of red dyes in textiles. The earliest record is credited as being written in Nan Fang Cao Mu Zhuang (南方草木狀 or Description of Vegetation in South China) in the Jin dynasty. Apart from *Caesalpinia sappan L.*, it is likely that after the Tang dynasty, as the encounters between Europe and China were more recurrent, the names of sappanwood also refer to foreign sequoias of other types, as seen in "A map of the myriad of countries of the world" of the Ming (坤 輿 萬 國 全 圖 – kun yu wan guo quan tu) of the missionary Matteo Ricci, who points out the origin of this dye in Brazil, but in reality, it is another plant of the same family *Caesalpinia echinata* 巴西 蘇木 or true Brazilwood, which was also often confused with its cousins *Adenanthera pavonina*, *Caesalpinia leiostachya*, *Caesalpinia pluviosa* and *Cenostigma pyramidale*.

Translation of the natural dye recipes

Table 4. Recipes translations from manuscript 1.

Recipe 1:	**小紅套染的 (over-dyed light red)**
Original text	"以練兩十兩為率用蘇木四兩黃丹一兩槐花二兩明職員一兩先將槐花炒令香碾碎以淨水二升煎一升之上濾去下白職員末了些少攪勻下入絹絹 卻以沸湯一碗化開解餘職員入黃絹浸半時許 將 蘇木以水二碗煎一碗之上，煎至一半仍為濾渣器浸片時扭起 將頭汁溫熱下染出絹帛急手提轉浸半時許可提轉六扭起吹於風頭令幹勿令日其色鮮明什妙初讀上文" [SIC]
Translated text	"Take the twelve liang[1] silk, use sappanwood (four liang), one or two huang dan (*Plumbum rubrum*), two liang from *Sophora japonica*, and one or two alums. Add some alum powder, stir well, and add silk. Boil a bowl of soup to dissolve the remaining alum, and soak in the yellow silk for a while. Fry a bowl of hematoxylin in two bowls of water[2], filtering the residue to make the first juice, then put the residue in a bowl and fill it half full of water. Fry until half is still stored in the colander. Fry the residue in two bowls with water and fry again, mix with the second juice, add the yellow pill, stir very evenly, add the yellow silk to the alum, transfer it so that it is uniform, soak, twist, and heat. Dye the silk, spin it quickly, dip it half a time, and spin it six or seven times. Blow it dry. Do not leave under the sun."
[1] 1 兩 (liang) = 40g. [2]A bowl of water (一碗水) = 500ml.	
Recipe 2:	**蘇木鋁媒染 (sappanwood alum mordanting)**
Original text	"以練帛十兩為率，用蘇木四兩，黃丹一兩，槐花二兩，明礬一兩，先將槐花妙令香，碾碎，以淨水二升煎一升上下入絹帛。卻以沸湯一碗化開解餘職員，入黃絹浸半時許。將蘇木以水二碗煎一碗之上，濾去渣為頭汁頓起再將渣水一碗半煎至一半仍濾別器貯將渣又水二碗煎一碗又去渣與第二汁和黃頭在內部旋轉成極勻。下入職員了黃絹，提轉令勻，浸片扭起。將頭汁溫熱，下染出絹帛，

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Translated text	急手提轉，浸半時許。可提轉六，七次，扭起，吹於風頭令幹，勿令日曬，其色鮮明什妙” [SIC] “Weigh 100g of sumu, soak it in 2 L of water for 2 hours, weigh 50 g of alum and dissolve it with 1L of warm water as a mordant. Fry the soaked dye material for 20 minutes and filter it while hot to get the best. Put the cloth in the filter and soak the dye solution for 20 minutes. Take out the dyed fabric and soak in the mordant for 20 minutes. Take out the dyed cloth and soak it in the overdyeing solution for 20 minutes, then take out the dyed cloth, rinse it and dry it in the shade, and cut out a sample of 20 cm in length and width. Repeat overdyeing of remaining fabric as needed.”

Table 5. Recipes translations from manuscript 2.

Recipe 3:	**大紅 (great/scarlet red safflower)**
Original text	“大紅色其質紅花餅一味用烏梅水煎出又用堿水澄數次或稻稿灰代堿功用亦同澄得多次色則鮮甚 染房計便宜者先染蘆木打腳 凡紅花最忌沉 麝袍服與衣 香共收旬月之間其色即毀凡紅花染帛之後若欲退轉但浸濕所染帛以堿水,稻灰水滴上數十點其紅一毫收傳仍還原質所收之水藏於綠豆粉內放出染紅半滴不耗 染家以為秘訣不以告人” [SIC].
Translated text	“To dye with safflower, it is boiled with ebony water (plum juice and rose petals) and rinsed with alkaline water several times. You can also use rice straw ash to replace water, it will have the same effect. The color is particularly bright. Before applying it to the fabric, the fabric uses lacquer water to make the background color and then safflower water to dye. Avoid being mixed with agar and musk. Clothes cannot be placed next to incense or lavender, as the color will fade in a month. After dyeing the silk fabric with safflower, if you want to return the original color, you only need to soak the dyed silk fabric and drip tens of drops of alkaline water or rice ash water. The red color is gone, and the original plain color is restored. The remaining red water is stored in the mung bean flour. It is removed by adding an acid solution such as ebony water and is stained red without any loss. The dyer thinks the secret is not to tell the others."
Recipes 4-7:	**蓮紅 丨 桃紅 丨 銀紅 丨 水紅 (red safflower)**
Original text	“染蓮紅桃紅銀紅水紅這四種顏色的原料也是紅花餅色的深淺視染料用量多寡而定 這四種顏色都不能用黃繭絲來染必須用白絲才能呈色” [SIC].
Translated text	“The raw materials for dyeing lotus red, peach red, silver red, and water red are also those of safflower, the depth of which depends on the amount of dye. These four colors cannot be dyed with yellow cocoon silk, only white silk can be used for color.”
Recipe 8:	**茶藍 (indigo)**
Original text	“凡種茶藍法冬月割獲將葉片片削下入窖造澱其身斬去上下近根留數寸薰幹埋藏土內春月燒淨山土使極肥松然後用錐鋤刺土打斜眼插入於內自然活根生葉其餘藍皆收子撒種畦圃中暮春生苗六月採實七月刈身造澱凡造澱葉與莖多者入窖少者入桶與缸水浸七日其汁自來每水漿一石下石灰五升攪沖數十下澱信即結 水性定時沉澱於底” [SIC]
Translated text	“The method of planting indigo is to harvest in the month of Lidong (October of the imperial calendar), pluck the leaves one by one, and put them in the cellar. Cut off the tops and bottoms of the remaining indigo stems, leaving just a few inches near the roots, and bury them in the ground after drying. In the spring of the following year, burn the mountain weeds to make the land fertile and loose, and then use a conical hoe (the hook of the hoe is bent inward, the hoe is eight inches long) to Dig the ground, make an oblique hole, and insert the indigo tea stem into it. The roots will naturally survive and give birth to leaves. The rest of the blue is harvested from seed and planted in the border

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	garden. Seedlings emerge in late spring, seeds are collected in June and cut blue to form indigo in July. When doing indigo, if there are a lot of leaves and stems, put them in the basement and put some in the bucket or tank. After soaking in water for seven days, the blue liquid will leach out naturally. Put five liters of lime into each stone-blue liquid, stir it dozens of times, and soon the blue color will form. After resting, the indigo sank to the bottom."
Recipe 9:	**槐花 (sophora)**
Original text	"凡槐樹十餘年後方生花實 花初試未開者曰槐蕊綠衣所需猶紅花之成紅也 取者張度與簄稠其下而承之 以水煮一沸漉乾捏成餅入染家用 既放之 花色漸入黃收用者以石灰少許曬拌而藏之" [SIC]
Translated text	"After more than ten years, the tree has flowers and fruits. Those who have not flowered in the first test are called huairui, which is needed to make green clothes. Take zhang du and yu (bovine feeding tool) thick and inherit it. Boil the water, dry it and knead it (the flower) into a cake, which is then dyed for home use. The color of the flower gradually turns yellow, and the user mixes it with a little lime in the sun and then takes it out."

Table 6. Recipes translations from manuscript 3.

Recipe 10:	**大紅 (great/scarlet red safflower and saffron)**
Original text	"大紅川紅花二百斤薑黃十兩烏梅十五斤生碳灰七鬥" [SIC]
Translated text	"Put 100kg of Sichuan saffron, twelve of turmeric, 7.5kg of smoked plum, and seven buckets of raw coal ash."
Recipe 11:	**明鹼 (bleaching)**
Original text	"廣灰六至七斤明鹼六至八斤" [SIC]
Translated text	"Use 3 to 3.5 kg of gray and 3 to 4 kg of bright alkali."
Recipe 12:	**油綠 (oily green)**
Original text	"翠藍腳地槐米三十斤白礬八斤青礬五斤廣灰" [SIC]
Translated text	"Use turquoise blue, 15kg Sophora japonica, 4kg alum, 2.5kg green and grey alum."

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