

# Research progress in the application of vegetable dyes

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**Abstract:** Vegetable dyes have been paid more and more attention because of their innocuity and good compatibility with the environment, but they can not completely replace chemical synthetic dyes. In this paper, the classification, identification method, application and existing problems of vegetable dyes are described, which can be used for reference in the further development of vegetable dyes.

## 1 Introduction

Vegetable dyes refer to pigments extracted from flowers, grass, leaves, seeds or fruits of nature as dyes. Because they are extracted from natural plants of nature, they have good compatibility and degradability with the environment. Compared with chemical synthetic dyes, plant dyes are non-toxic and harmless. Therefore, with

the improvement of people's awareness of social environmental protection, plant dyes have attracted more and more attention<sup>[1]</sup>. In addition, plant dyes have many functions, such as antibacterial<sup>[2]</sup>, in addition to dyeing properties. In this paper, the classification, identification, application and existing problems of vegetable dyes are reviewed.



Fig.1 Some vegetable dyes

The use of vegetable dyes can be traced back to thousands of years ago. Before the Qing Dynasty, it was always in the leading technical level in the world. Development history of vegetable dyes See Fig.2. However, it declined with the production of synthetic dyes. With the enhancement of environmental protection awareness, plant dyes have entered the public's vision

again. Moreover, the application of plant dyes is not limited to garment dyeing, but has broad prospects in home textile products, decorative products and other fields. In this paper, the classification, identification, application and existing problems of vegetable dyes are reviewed.

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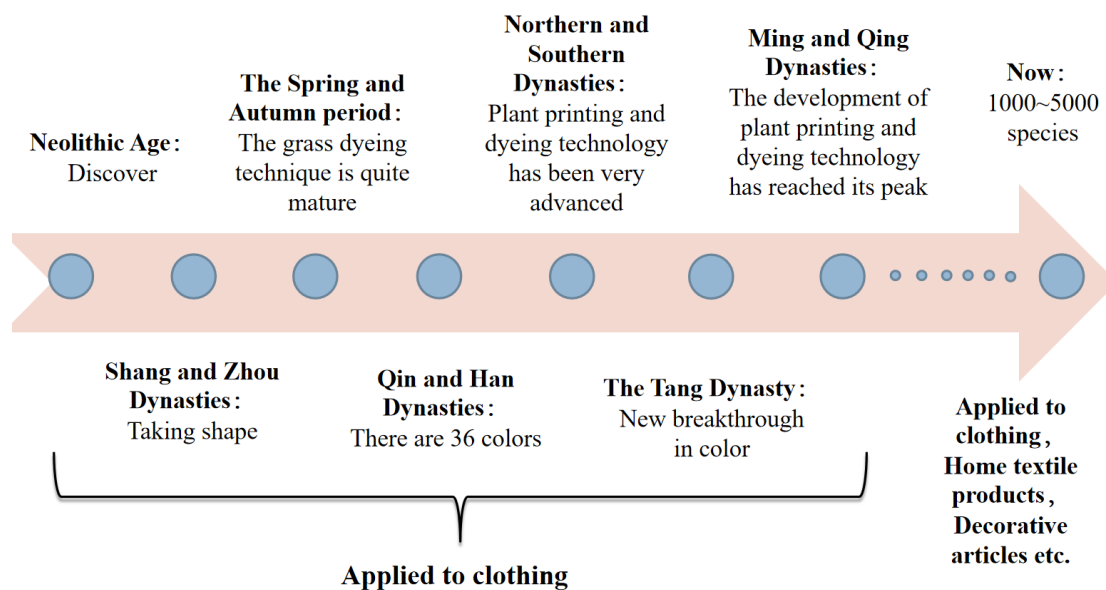


Fig.2 Development history of vegetable dyes

## 2 Classification of vegetable dyes

There are many kinds of vegetable dyes, which can be classified according to their chemical composition, apparent color, solubility and dyeing properties. According to chemical composition [3], it can be divided into carotenoids, naphthoquinones, anthraquinones, tannins, indigo, etc. According to the apparent color, it can be divided into [4] red (red), blue (cyan), yellow and black; Water soluble, oil soluble and alcohol soluble according to solubility [5]. According to dyeing properties [6], it can be divided into direct type, reduced type and mordant type.

## 3 Identification methods of vegetable dyes

Plant dyed textiles are more and more popular in the market because they have the natural health care characteristics that chemical synthetic dyed textiles do not have. However, due to the influence of objective differences such as a wide range of sources and a large variety of plant dyes, there are many limitations in the identification of plant dyed textiles. At present, there are relevant researches and reports on the identification of textile dyed with vegetable dyes at home and abroad, mainly including physical property method, chemical method, spectral method, gas liquid phase mass spectrometry, etc. [7]

### 3.1 Physical property method [8]

The plant indigo dye and synthetic indigo dye can be identified according to the difference in physical properties. The synthetic indigo dye is the one with deep color, bright color and no special smell; The color of plant indigo dye is slightly dim, easy to clot, and the dye has a certain smell of grass. The identification of dyes by physical property method is simple and requires no

instruments and equipment, but requires identification personnel with certain experience. It is difficult for non professionals to identify plant dyes and chemical dyes by physical property method, and the universality is poor.

### 3.2 Chemical method

In order to effectively identify the textiles dyed with plant dyes, the decolorization method is used to identify the wool fabrics dyed with yellow plant dyes or the cotton fabrics dyed with gardenia plant dyes. Glacial acetic acid is selected as the identification reagent. Research shows that the glacial acetic acid solution can completely decolorize the yellow plant dyes on the wool fabrics or the gardenia plant dyes on the cotton fabrics, but it will not have obvious decolorization effect on the chemical dyes [9]. It is an effective method to identify wool fabrics dyed with yellow plant dyes or cotton fabrics dyed with gardenia plant dyes.

### 3.3 Spectral method

UV Vis spectroscopy can selectively absorb the wavelengths of various light of plant dye pigment molecules. Spectral methods are often used in the field of textile archaeology because of their advantages such as fast, non-destructive and in-situ testing. Some research results show that FT-IR and TOF-SIMS spectra can not only identify fibers in archaeological textiles, but also identify the types of natural dyes used. With the development of nondestructive testing technology, near-infrared diffuse reflectance spectroscopy, fluorescence spectroscopy, Raman spectroscopy and other spectral techniques have also been applied in the field of dye identification.

### 3.4 Gas liquid mass spectrometry

Gas liquid mass spectrometer is often used in combination with spectrum or mass spectrometry and

other technical means<sup>[10]</sup>. It is an effective means to analyze and identify complex samples, such as GC/HPLC-MS, HPLC-DAD, GC/HPLC-NMR, etc.<sup>[11-12]</sup> The mass spectrometry fingerprint analysis method was introduced into the identification of plant dyes on the silk fabrics unearthed from tombs, and the information of plant dyes (rubia cordifolia, sappan, turmeric, etc.) was successfully identified. The plant dyes on silk fabrics are extracted with hydrochloric acid, EDTA and formic acid, and the extracted plant dyes are analyzed by LC-DAD-MS method. The data results show that the types of plant dyes can be clearly distinguished with the dyes extracted with formic acid and EDTA, but they cannot be distinguished with hydrochloric acid.

With the development of science and technology, many technologies are used together to achieve fast, nondestructive, accurate dye identification and other purposes. In addition to the use of chemical reagents, it can be analyzed and confirmed by means of gas chromatography/mass spectrometry (GC-MS), liquid chromatography/mass spectrometry (LC-MS), Raman spectroscopy, near-infrared spectroscopy, ultraviolet spectroscopy and other spectral techniques, as well as the establishment of a plant dye structure feature resolution database.

## 4 Application of vegetable dyes

### 4.1 Application of vegetable dyes in textile printing and dyeing<sup>[13]</sup>

#### A. Natural fiber

Cotton fiber is comfortable and breathable. Dyeing this kind of fabric with vegetable dyes has attracted more and more attention. For example, Xu Jing et al.<sup>[14]</sup> extracted pigment from grape skin to study its dyeing of cotton fabrics; Wu Manlin et al.<sup>[15]</sup> extracted pigment from *Rubia cordifolia* to study its dyeing of cotton fabrics.

Hemp fabrics have natural and soft luster, cool and breathable. They are often used to make summer clothes. The method of dyeing such fabrics with plant dyes has gradually come into people's sight. For example, Wang Xiaojuan<sup>[16]</sup> studied the extraction of pigment from *Rubia cordifolia* to dye linen fabrics, and the dyed fabrics have good fastness.

Silk is popular because of its soft handle, good moisture absorption and breathability, and comfortable wearing. Therefore, plant dyeing of silk fabrics has attracted more and more attention. For example, Yin Yunjie et al.<sup>[17]</sup> studied the dyeing of silk fabrics with purple sweet potato anthocyanins; Zhou Yuyang et al.<sup>[18]</sup> studied the dyeing of silk fabrics with curcumin.

Wool fabric has good heat preservation, resilience, air permeability and moisture permeability, so it is loved by people. Therefore, more and more people study dyeing wool fabric with vegetable dyes. For example, Shen Jiajia et al.<sup>[19]</sup> studied the extraction of pigment from oolong tea to dye wool fabrics; Ren Yanfei et al.<sup>[20]</sup> studied gardenia yellow dyed wool fabric.

#### B. Synthetic fibre

In addition to the above natural fibers, the dyeing application of plant dyes on synthetic fibers is also increasingly extensive, with acrylic fiber and nylon as the first. Acrylic fiber has poor dyeability due to its own characteristics, so modification treatment<sup>[21]</sup> is often used for acrylic fiber dyeing, such as Xu Fu et al.<sup>[22-23]</sup> through cationic modification of acrylic fiber, and the modified hematoxylin pigment has high dyeing fastness to acrylic fiber. The modified acrylic fiber was dyed by ferrous ion mordant dyeing method. By controlling the dyeing time, temperature and the amount of mordant, the acrylic fiber had better color fastness to washing and darker color. For nylon, mordant dyeing<sup>[24]</sup>, modification and ultrasonic assisted dyeing are often used to improve dye uptake and fixation.

### 4.2 Application of vegetable dyes in other aspects

In addition to textile applications, vegetable dyes have also been used in food, cosmetics, pharmaceuticals and other fields. For example, gardenia blue pigment can be used not only in textile printing and dyeing, but also in the food industry, such as the coloring of beverage products and other food additives, drugs and cosmetics; Mulberry is the fruit of mulberry, which is purple in appearance and can be directly eaten after washing. Mulberry pigment can be used as food and beverage additives. Mulberry also has the effects of nourishing yin and blood, clearing liver and improving eyesight, so it is used in the pharmaceutical industry; Capsicum red pigment, an effective dye in pepper, is used in cosmetics, medicine, food, feed and other fields. Turmeric can be used as antiseptic and colorant.

In addition, plant dyes can also be used as hair dyes. For example, Hu Yuli and other people studied the application of plant pigment dyes in hair dyes, summarized the types and principles of common hair dyes, summarized representative plant dyes, and expounded the value and market prospects of such hair dyes.

## 5 Conclusion

Vegetable dyes are green, environmentally friendly, non-toxic and harmless, but they are not widely used as chemical synthetic dyes. The main reason is that plant dyes have low color giving capacity and poor color fastness. An important reason for this problem is that the affinity between fabrics and plant dyes is poor, and the van der Waals force between fabrics is weak, leading to poor dye uptake and fastness. At present, the main methods to improve the color fastness of vegetable dyes are to modify the fabric fibers, improve the dyeing process and look for new mordants. In addition, microbial plant dyes can be developed or synthetic dyes with the same chemical structure as plant dyes can be synthesized.

Although vegetable dyes can not completely replace chemical synthetic dyes, they have a place in the market,

and they are particularly suitable for developing green products with high added value, such as health underwear products, infant clothing and supplies, and home textiles. Their development prospects are very good. Under the impact of the wave of green consumer products advocated by people today, natural dyes will have a broader development prospects.

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