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# Diversity of natural food coloring plants in the city of Surakarta, Central Java, Indonesia

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**Abstract.** *Utami AS, Torimbanu AR, Saputra AF, Aulia AA, Utomo AN, Iskandar J, Naim DMd., Setyawan AD. 2025. Diversity of natural food coloring plants in the city of Surakarta, Central Java, Indonesia. Asian J Ethnobiol 8: 92-103.* The use of plant-derived food colorants is a longstanding culinary tradition in Indonesia, reflecting both ecological knowledge and cultural heritage. This study aimed to document and analyze the diversity of natural food coloring plants used in Surakarta City, Central Java, and to examine their cultural relevance, usage patterns, and conservation status. A total of 137 respondents across three urban villages—Mojosongo, Keprabon, and Baluwarti—were selected purposively and interviewed using ethnobotanical approaches including field visits and visual confirmation. Seventeen plant species from 13 families were identified as sources of eight major color types: yellow, green, red, purple, brown, white, orange, and blue. The most frequently used species included *Curcuma longa*, *Pandanus amaryllifolius*, and *Clitoria ternatea*, with coloring parts ranging from flowers and leaves to rhizomes and wood sap. While some plants were cultivated at home, others were purchased from traditional markets. The majority of species were classified as Least Concern, but one species (*Caesalpinia sappan*) was listed as Vulnerable, and several others remained unevaluated or Data Deficient. The results highlight how gender, age, and spatial context influence knowledge transmission, with older women, who play a central role, emerging as key custodians of biocultural knowledge. Although urbanization poses a threat to the sustainability of this knowledge, opportunities exist for revitalization through home gardening, school-based learning, and community-based conservation efforts. The study underscores the importance of safeguarding biocultural knowledge in rapidly modernizing urban environments as part of resilient food and cultural systems.

**Keywords:** Coloring, culinary, food, local community, natural dyes, plant

## INTRODUCTION

Food coloring is crucial in food production because it enhances the aesthetics and appeal of food. Food coloring can be obtained from plants, animals, insects, and minerals (Arshimny and Syamsu 2020). Some consumers are also aware that natural dyes obtained from fruits or vegetables can produce not only aesthetically pleasing food but also numerous health benefits (de Mejia et al. 2020). Several types of flowers can be used as food coloring, such as red hibiscus, red roses, red pineapple sage, red clover, and pink blossoms. Green vegetables that can be used as green coloring in foods such as spinach, fenugreek leaves, coriander leaves, bell peppers, broccoli, green cabbage, green beans, green radishes, and green chilies (Malabadi et al. 2022). There are plants native to Indonesia that are commonly used in food coloring, such as pandan and suji leaves (Suryani et al. 2020).

Natural plant pigments, such as anthocyanins, betalains, chlorophyll, and carotenoids, not only enhance the appearance of food but also provide antioxidant, anti-inflammatory, and protective health benefits (Amalraj et al. 2016; de Mejia et al. 2020). These pigments are environmentally friendly because they are obtained from renewable sources, involve minimal chemical processes, and are biodegradable. However, replacing synthetic dyes with natural alternatives still faces challenges, including variability in pigment stability, extraction methods, and market availability. Factors such as pH, light, temperature, and solvent type influence the efficacy of natural pigments (Jadhav and Bhujbal 2020).

Although synthetic dyes are still widely used due to their low cost and processing flexibility, concerns regarding their toxicity, especially in children, have prompted renewed interest in natural coloring agents (Suryani et al. 2020; Luong et al. 2023). Natural dyes are not only safer but also enrich the culinary identity and cultural continuity of local communities. This is particularly relevant in culturally diverse countries like Indonesia, where food traditions are strongly tied to identity, ritual, and place (Amrul et al. 2022).

Indonesia is a mega biodiversity country, not only in terms of natural resources but also in terms of cultural diversity. Each region has a unique culture, including knowledge, beliefs, arts, law, morals, customs, and community characteristics (Sutrisno et al. 2021). Natural dyes, such as those found in traditional foods, are closely tied to people's daily lives (Luong et al. 2023). Food plays a crucial role in the human body and is also closely tied to various aspects of human life, including sociocultural aspects. Food can be the identity of a region or ethnicity and adds value to cultural tourism (Annisa et al. 2023). Indonesia is a country rich in culture, one of which is its traditional food (Wijaya 2019); this is particularly important for ethnic communities because each food has a symbolic meaning; hence, coloring plants are important (Luu-dam et al. 2016). Surakarta is one of Indonesia's cities with numerous interesting tourist attractions and a cultural center that represents the wholeness of the Javanese people through their local wisdom. Surakarta has typical foods with historical and sociocultural symbols such as *nasi liwet*, *cabuk rambak*, *serabi*, *peek*, and *tengkleng* (Hermawan 2021).

Despite this rich tradition, little attention has been paid to systematically documenting the diversity and use of natural food-coloring plants in urban centers like Surakarta, which are undergoing rapid socio-ecological change. As modern food systems increasingly rely on industrial additives, the knowledge of naturally derived food dyes—especially those rooted in community practice—is at risk of being lost. Therefore, ethnobotanical documentation of these plants and their uses is urgently needed to support cultural preservation, public health, and sustainable food innovation.

Knowledge of natural food coloring is crucial, as it is linked to socioeconomics and traditional wisdom in local cuisine. It includes information about the types of plants used as natural dyes, the parts of the plants used, the resulting colors, and their purposes. This knowledge helps raise awareness about the maximum utilization of plants. Unfortunately, the use of natural dyes is declining due to the prevalence of artificial dyes, resulting in a decrease in the number of people experienced in processing natural dyes. Additionally, the younger generation is less interested in this area.

This study aims to document the diversity of natural food-coloring plants used by the community in three culturally significant villages of Surakarta City, Central Java, Indonesia. It also examines the parts used, color range, modes of acquisition, and conservation status of the species, providing a basis for safeguarding local culinary biocultural heritage in the face of modernization.

## MATERIALS AND METHODS

### Study site

This research was carried out in December 2023 in three villages of Surakarta City, Central Java, Indonesia: Mojosongo Village (Jebres Sub-district: 7°32'34"S, 110°51'7"E), Keprabon Village (Banjarsari Sub-district: 7°33'45.6"S, 110°49'12.6"E), and Baluwarti Village (Pasar Kliwon Sub-district: 7°33'41.4"S, 110°49'24.0" E) (Figure 1). Surakarta City is an urban area with a total area of 44.04 km² and a population of 528,044 (as of 2024), resulting in a density of 11,302.31 people per km² and a human development index of 83.54. Almost half of its economy is supported by the construction and trade services sector (BPS 2024). These villages were selected due to their rich cultural heritage and continuity of traditional culinary practices, making them ideal for studying community-based knowledge of natural food colorants.

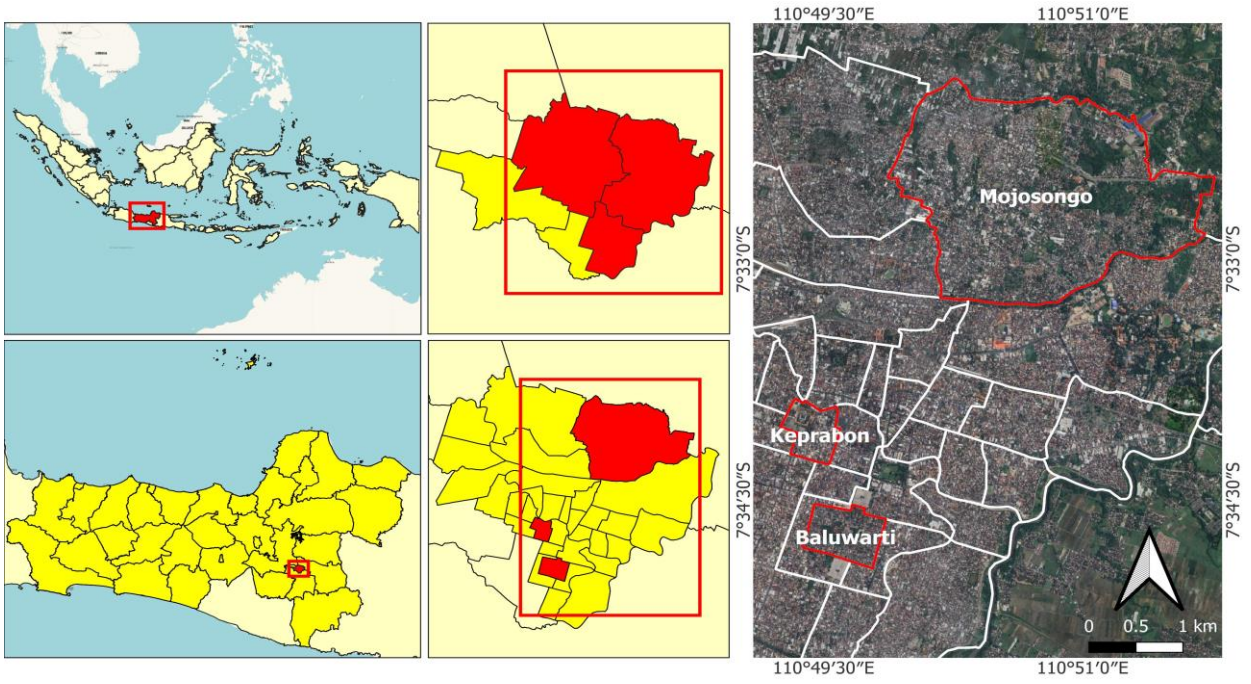



**Figure 1.** The location of Mojosongo, Keprabon, and Baluwarti Villages of Surakarta City, Central Java Province, Indonesia

**Data collection**

Data were collected using structured and semi-structured interviews with purposively selected respondents in the three target villages. Respondents were chosen based on their knowledge and use of natural food coloring plants. A total of 137 individuals participated, with an age range between 25-70 years and a gender distribution of 79% women and 21% men. The interview guide included questions on local plant names, parts used, colors produced, types of food colored, and the source (cultivated, purchased). Respondents were also asked to cite examples of local foods and drinks in which the plants were used. Interviews were conducted in Javanese and Indonesian, depending on the respondent's preference.

**Data verification and analysis**

The plant species mentioned by respondents were collected, photographed, and identified through field visits. Scientific names were confirmed using online databases, specifically Plants of the World Online (POWO, https://powo.science.kew.org/) and Global Biodiversity Information Facility (GBIF, https://www.gbif.org/). The conservation status of each species was validated using the IUCN Red List (https://www.iucnredlist.org/). Quantitative data, such as the frequency of citation, plant parts used, and origin (cultivated or purchased), were analyzed descriptively using percentage values. Visual summaries were presented in tables and figures.

## RESULTS AND DISCUSSION

**Socio-demographic profile of respondents**

This study involved 137 respondents from Mojosongo, Keprabon, and Baluwarti Villages in Surakarta City, Central Java. As shown in Table 1, the majority of respondents were women (79%), while men accounted for only 21%. This gender imbalance reflects the role of women as primary custodians of domestic food knowledge in Javanese households, especially in matters related to food preparation, traditional culinary practices, and the use of natural ingredients.

In terms of age distribution, respondents were mostly in the 46-55 year age group (31%), followed by those aged 25-35 years (24%), 36-45 years (19%), 56-65 years (16%), and over 65 years (10%). The predominance of middle-aged and older respondents suggests a generational gap in the transmission of knowledge regarding the use of natural food colorants. This pattern aligns with studies in other regions of Southeast Asia, where younger generations are increasingly disconnected from traditional food practices due to urbanization and modern lifestyles (Luong et al. 2023).

The socio-demographic structure of the respondents provides an important context for understanding the continuity and vulnerability of ethnobotanical knowledge. Older women, in particular, serve as cultural transmitters of plant-based culinary knowledge, often accumulated through lived experience rather than formal education. However, without deliberate intergenerational transfer, this knowledge may be lost over time.

These findings underscore the importance of targeting women—especially those in older age cohorts—in future education or conservation programs aimed at revitalizing natural food dye practices. Integrating such knowledge into school curricula, community workshops, or digital documentation platforms may help bridge this generational divide and ensure the sustainability of culinary biocultural heritage.

**Diversity of food coloring plant species**

A total of 17 plant species from 13 families were recorded as sources of natural food coloring in Surakarta, with detailed information provided in Table 2. These species include both widely cultivated and commonly purchased plants, reflecting a blend of home-based and market-based knowledge systems. The most frequently used species were *Curcuma longa* (turmeric), *Pandanus amaryllifolius* (pandan), *Clitoria ternatea* (butterfly pea), *Dracaena angustifolia* (suji), and *Cocos nucifera* (coconut), all of which are well-integrated into traditional Javanese food culture. These five species showed the highest citation frequencies among respondents and represent a core group of versatile and culturally significant food colorants.

Based on Table 3, the taxonomic distribution shows that the 17 species are evenly distributed between two major clades of angiosperms: eudicots (9 species, 53%) and monocots (8 species, 47%). At the family level, notable contributors include Zingiberaceae, Myrtaceae, and Fabaceae, with Zingiberaceae being the most frequently represented family, indicating its central role in Javanese culinary and medicinal traditions.

**Table 1.** Socio-demographic profile of respondents in Baluwarti, Keprabon, and Mojosongo Villages, Surakarta City, Central Java, Indonesia

| Variable | Category | Total | Percentage |
|---|---|---|---|
| Gender | Male | 29 | 21.2% |
| | Female | 108 | 78.8% |
| Age group | 25-35 | 33 | 24.1% |
| | 36-45 | 26 | 19.0% |
| | 46-55 | 42 | 30.7% |
| | 56-65 | 22 | 16.1% |
| | >65 | 14 | 10.2% |
| Education | Elementary School | 35 | 25.5% |
| | Junior High School | 25 | 18.2% |
| | Senior High School | 52 | 38.0% |
| | Higher Education | 25 | 18.2% |
| Occupation | Housewife | 70 | 51.1% |
| | Traditional Food Vendor | 30 | 21.9% |
| | Civil Servant | 10 | 7.3% |
| | Other (retired, informal) | 27 | 19.7% |

**Table 2.** List of coloring plants in city of Surakarta, Central Java, Indonesia

| Family | Scientific name | Vernacular name | Local name | Part-use | Life-form | Color | Origin | Frequency | Food type | Local food/drinks |
|---|---|---|---|---|---|---|---|---|---|---|
| **Eudicots** | | | | | | | | | | |
| Apiaceae | *Apium graveolens* L. | Celery | *Seledri* | Leaves | Herbaceous | Green | 1 | 1 (*) | Drink | *Jus sledri, jus campur* |
| Arecaceae | *Cocos nucifera* L. | Palm sugar, Coconut cream | *Gula jawa*♣ *Santan* | Sap Fruit | Wood | Brown White | 1 | 22 (3*) | Drink Porridge | *Kolak, cendol/dawet, bandrek* *Agar-agar gula jawa Jenang, sumsum,grendul, bubur gaplek* |
| | | | | | | | | | Cake | *Dodol/jenang lot, klepon, kuwe cucur, wajik sokelat, nogosari* |
| | | | | | | | | | Soup | *Sayur lodeh* |
| Asparagaceae | *Dracaena angustifolia* (Medik.) Roxb. | Suji leaves | *Suji* | Leaves | Bush | Green | 1, 2 | 25 (3*) | Cake | *Klepon, wajik ijo, kue lapis, nogosari ijo* |
| Cactaceae | *Hylocereus polyrhizus* (F.A.C. Weber) Britton & Rose | Dragon fruit | *Buah naga* | Fruit | Creepers | Purple | 1, 2 | 15 (2*) | Drink Cake | *Jus buah naga, jus campur* *Kue bolu* |
| Convolvulaceae | *Ipomoea batatas* (L.) Lam. | Purple sweet potato | *Ubi ungu* | Tubers | Bush | Purple | 1 | 12 (2*) | Cake | *Kue bolu, kue talam, kue lapis* |
| Fabaceae | *Clitoria ternatea* L. | Telang flower | *Telang* | Flower | Creepers | Blue | 1, 2 | 31 (3*) | Drink | *Teh bunga telang* |
| | *Caesalpinia sappan* L. | Sappan plant | *Secang* | Wood | Wood | Orange | 1 | 1 (*) | Drink | *Wedang uwuh* |
| Malvaceae | *Hibiscus sabdariffa* L. | Rosella plant | *Rosella* | Flower | Wood | Red | 1 | 3 (*) | Drink | *Teh bunga rosela* |
| **Monocots** | | | | | | | | | | |
| Myrtaceae | *Syzygium polyanthum* (Wight) Walp. | Bay leaf | *Salam* | Leaves | Wood | White ♥ | 1, 2 | 7 (*) | Rice Soup | *Nasi liwet* *Sayur asem* |
| | *Syzygium aromaticum* (L.) Merr. & L.M. Perry | Clove | *Cengkeh* | Flower | Wood | Brown | 1 | 1 (*) | Drink | *Bandrek, wedang jahe* |
| Pandanaceae | *Pandanus amaryllifolius* Roxb. | Pandan plant | *Pandan* | Leaves | Bush | Green | 1, 2 | 62 (3*) | Cake Drink Porridge | *Kue bolu*, *kuwe cucur hijau* *Cendol/dawet* *Jenang/bubur* |
| Poaceae | *Cymbopogon citratus* (DC.) Stapf | Lemongrass | *Sereh* | Stem | Herbaceous | Brown | 1 | 3 (*) | Drink | *Bandrek, wedang jahe* |
| Rosaceae | *Rosa* sp. | Rose | *Mawar merah* | Flower | Wood | Red | 1 | 2 (*) | Drink Cake | *Sirup/teh bunga mawar* *bolu pelangi* |
| Solanaceae | *Capsicum frutescens* L. | Chili | *Cabe* | Fruit | Herbaceous | Red | 1 | 1 (*) | Soup | *Sambal goreng krecek,* |
| Zingiberaceae | *Curcuma longa* L. | Turmeric | *Kunyit* | Rhizome | Herbaceous | Yellow | 1, 2 | 77 (3*) | Rice Soup | *Nasi kuning, tumpeng tengkleng*, *gulai, opor, kare, soto* |
| | *Elettaria cardamomum* (L.) Maton | Cardamom | *Kapulaga* | Fruit | Herbaceous | Brown | 1 | 1 (*) | Drink | *Bandrek, wedang jahe* |
| | *Zingiber officinale* Roscoe | Ginger | *Jahe* | Rhizome | Herbaceous | Brown | 1 | 1 (*) | Drink Soups | *Bandrek, wedang jahe, ronde* *Tengkleng*, *gulai, opor, kare, soto* |

Note: (1): Buy; (2): Cultivated; 3*: Frequently used species; 2*: Occasionally used species; *: Rarely used. ♣ This could also be derived from *Arenga pinnata* (Wurmb.) Merr. ♥ This designation reflects community perception rather than direct pigment contribution; the actual color intensity is minimal

**Table 3.** Plant diversity and taxonomy

| Phylum | Family | Percentage | Genera | Percentage | Species | Percentage |
|---|---|---|---|---|---|---|
| Angiospermae | 13 | | 16 | | 17 | |
| Eudicots | 7 | 54% | 8 | 50% | 8 | 47% |
| Monocots | 6 | 46% | 8 | 50% | 9 | 53% |

These findings reflect the richness of angiosperm-derived pigments, as plants in this group produce a broad spectrum of natural compounds, including anthocyanins, chlorophylls, carotenoids, and betalains (Hop et al. 2022). The balance between monocots and eudicots also suggests that food-coloring knowledge is not biased toward any single morphological or ecological group, but rather reflects a practical selection based on availability, effectiveness, and cultural preference.

Several species, such as *C. ternatea*, *Hylocereus polyrhizus*, *Ipomoea batatas*, and *Hibiscus sabdariffa*, are known to produce vibrant purples and reds that align with global studies on anthocyanin-rich species (Luu-dam et al. 2016; Mahmud et al. 2023). Meanwhile, *C. longa* produces a strong yellow pigment due to its curcuminoid content (Amalraj et al. 2016), and *P. amaryllifolius* and *D. angustifolia* provide chlorophyll-based green coloring (Indrasti et al. 2018).

The widespread use of these 17 species across various food categories—ranging from drinks and cakes to rice and porridge—demonstrates the embeddedness of natural dyes in both daily and ceremonial cuisine. More than 40 local dishes were reported to rely on these species, many of which are associated with tradition and identity, such as *nasi kuning*, *tumpeng*, *dawet*, and *klepon* (Table 2; Figure 2).

The diversity of food-coloring species in Surakarta not only reflects botanical richness but also highlights the functional role of biodiversity in promoting cultural resilience and ensuring food security. Unlike synthetic dyes, these plant-based pigments carry layered meanings, including medicinal values, ritual significance, and aesthetic preferences. Therefore, their continued use is not only a matter of culinary tradition but also a matter of biocultural continuity.

**Plant parts used for coloring**

The food-coloring plants recorded in this study utilize a variety of plant parts to produce pigments, including flowers, leaves, fruits, rhizomes, tubers, stems, and wood (Figure 3). Among these, flowers were the most frequently used plant part, accounting for 29.4% of species. Plants such as *C. ternatea*, *Rosa* sp., *H. sabdariffa*, *Syzygium aromaticum*, and *Cocos nucifera* (sap for palm sugar) are commonly employed for their visually striking pigments.

Leaves represented the second most commonly used part (23.5%), with species such as *Dracaena angustifolia* (suji), *P. amaryllifolius* (pandan), *Apium graveolens* (celery), and *Syzygium polyanthum* (bay leaf). These plants typically contribute green hues due to their chlorophyll content, although, as discussed previously, the actual pigment contribution of bay leaves may be more perceived than visual.

Fruits comprised 17.6% of the colorant sources. *Hylocereus polyrhizus* (dragon fruit), *Capsicum frutescens* (chili), and *Elettaria cardamomum* (cardamom) were cited for their purple, red, and brown pigments, respectively. Dragon fruit, in particular, provides a vivid purple pigment due to its high betacyanin content, a finding supported by Mahmud et al. (2023). Rhizomes (11.8%), such as those of *Zingiber officinale* (ginger) and *C. longa* (turmeric), are valued not only for their strong pigments—yellow and brown—but also for their multifunctional use as spices and medicinal ingredients. The relative durability and storability of rhizomes may explain their widespread use (Maha et al. 2019; Nurshillah et al. 2022).

Less commonly used parts include wood (*Caesalpinia sappan*, 5.9%), tubers (*I. batatas*, 5.9%), and stems (*Cymbopogon citratus*, 5.9%). Although these parts are less prevalent, they offer unique pigments. Sappan wood provides an orange to red hue, depending on the pH (Luu-dam et al. 2016), while purple sweet potato and lemongrass lend their distinctive colors to cakes and drinks.

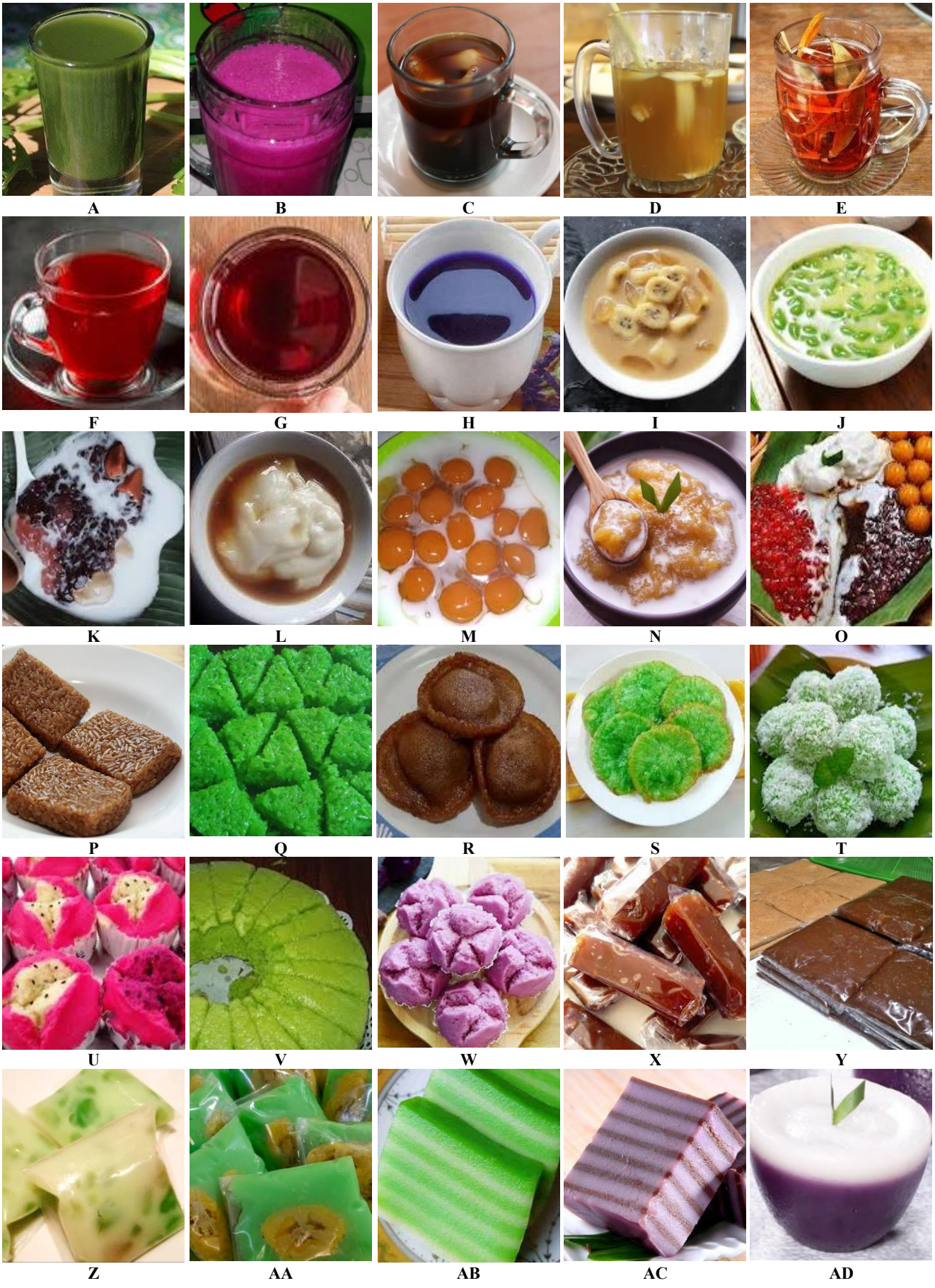
The selective use of certain plant parts reflects both practical and cultural considerations, such as pigment stability, ease of processing, culinary tradition, and symbolism. Flowers and rhizomes, for example, are often associated with festivities and rituals, whereas leaves and fruits are commonly used in everyday food preparation.

These results demonstrate that local knowledge encompasses not only which species to use, but also which plant parts yield the desired aesthetic and functional outcomes in food. Such specificity underlines the sophistication of traditional culinary systems and the importance of preserving this knowledge amid changing dietary habits (Amrul et al. 2022).

**Plant life forms and their roles**

The 17 species used as food colorants in this study represent a range of plant life forms, including woody plants (35.3%), herbaceous plants (35.3%), bushes (17.7%), and creepers (11.8%) (Figure 4). Woody plants include *C. nucifera*, *H. sabdariffa*, *Rosa* sp., *Syzygium polyanthum*, *S. aromaticum*, and *C. sappan*. These species are often perennial and multifunctional, producing flowers, fruits, wood, or sap used in various food preparations. Their relatively large size and longevity make them suitable for home gardens, especially in the peri-urban and rural areas of Surakarta, where space still allows for the cultivation of trees.

Herbaceous species, such as *C. longa*, *Z. officinale*, *C. citratus*, *A. graveolens*, *C. frutescens*, and *E. cardamomum*, offer flexibility in planting and harvesting. Their short life cycles, adaptability to pots or narrow plots, and culinary relevance contribute to their continued use, even in constrained urban spaces.



A B C D E

F G H I J

K L M N O

P Q R S T

U V W X Y

Z AA AB AC AD


**Figure 2.** Several types of food and beverages with natural coloring plants from Surakarta City, Indonesia. Drinks (A-J): A. *Jus daun sledri*, B. *Jus buah naga*, C. *Wedang bandrek*, D. *Wedang jahe*, E. *Wedang uwuh*, F. *Teh bunga mawar merah*, G. *Teh bunga rosela*, H. *Teh bunga telang*, I. *Kolak*, J. *Dawet/cendol*. Porridges (K-O): K. *Jenang*, L. *Jenang sumsum*, M. *Jenang grendul*, N. *Bubur/jenang gaplek/singkong*, O. *Aneka jenang*. Cakes (P-T): P. *Wajik sokelat*, Q. *Wajik ijo*, R. *Kuwe cucur sokelat,* S. *Kuwe cucur ijo*, T. *Klepon*, U. *Bolu buah naga*, V. *Bolu ijo/pandan*, W. *Bolu ubi ungu*, X. *Dodol*, Y. *Jenang lot/alot*, Z. *Nogosari*, AA. *Nogosari ijo*, AB. *Kuwe lapis ijo*, AC. *Kuwe lapis ubi ungu*, AD. *Kuwe talam.* Rice (AE-AG): AE. *Nasi/sego liwet*, AF. *Nasi/sego kuning*, AG. *Tumpeng*. Soups (AH-A) AH. *Sayur asem*, AI. *Sayur lodeh*, AJ. *Soto*, AK. *Kari/kare*, AL. *Tengkleng*, AM. *Gulai*, AN. *Opor*. (photographs from many sources)

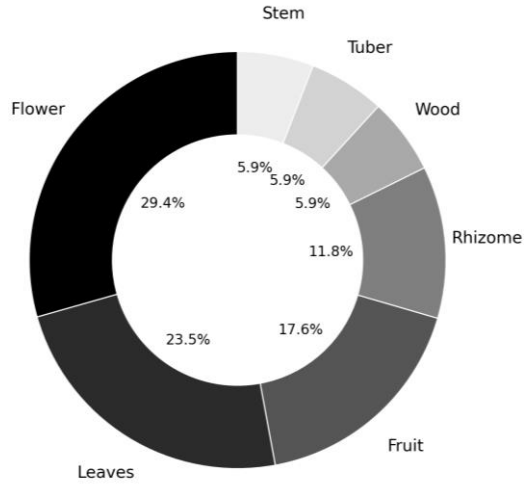



**Figure 3.** The part used by the food coloring plants in Surakarta City, Indonesia

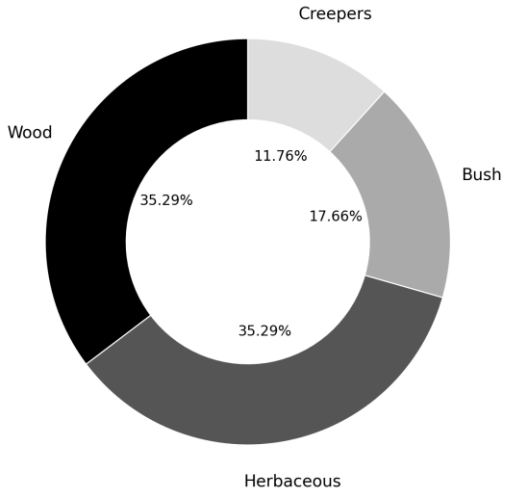



**Figure 4.** Diversity of life forms of food coloring plants in Surakarta City, Indonesia

Bushes—including *Dracaena angustifolia*, *P. amaryllifolius*, and *Ipomoea batatas*—are moderately sized and often grown for their leaves or tubers. Their compact form allows for integration into household agroecosystems, particularly in compounds with limited land availability. *D. angustifolia* and *P. amaryllifolius* are well known for their shade tolerance and utility in ornamental landscaping, making them dual-purpose plants.

Creepers, represented by *Clitoria ternatea* and *Hylocereus polyrhizus*, are commonly trained along fences or vertical supports. Their vertical growth habit makes them space-efficient and accessible to urban households. The popularity of butterfly pea flowers in tea and beverages has increased recently due to their antioxidant content and striking color properties, encouraging home cultivation even in small plots (Saati et al. 2018; Luong et al. 2023).

This distribution of plant life forms suggests a high degree of ecological and spatial adaptability among food-coloring plants, which enhances their relevance for both traditional and contemporary urban lifestyles. Households can select plant types based on available space, desired color output, and frequency of use. Additionally, the presence of woody and herbaceous plants in near-equal proportions reflects a well-balanced agroecological system.

In ethnobotanical terms, the diversity of growth forms also reflects how communities engage with plants not only as functional materials but as elements of the cultural landscape. Trees provide permanence and symbolism, while herbs and vines allow for dynamic, seasonal interaction with food traditions.

**Color types and cultural use patterns**

The 17 species documented in this study were used to produce eight major color groups in local foods and beverages: yellow, green, red, brown, purple, white, orange, and blue (Figure 5). Among these, brown was the most frequently represented color, derived from species such as *C. nucifera* (palm sugar), *Z. officinale* (ginger), *C. citratus* (lemongrass), *E. cardamomum* (cardamom), and *S. aromaticum* (clove). Brown pigments are commonly associated with traditional drinks and desserts, offering both color and a distinctive aromatic profile.

Yellow was the second most dominant color, primarily produced by *C. longa* (turmeric), which contains curcuminoids with strong pigment and medicinal value. In Javanese culinary culture, yellow symbolizes festivity, sanctity, and prosperity, and is prominently featured in celebratory dishes such as *nasi kuning* and *tumpeng*.

Green hues were obtained from chlorophyll-rich leaves of *P. amaryllifolius* (pandan) and *D. angustifolia* (suji). These plants are widely used in both sweet and savory preparations, particularly in traditional cakes like *klepon*, *putu ayu*, and *nagasari*, which are popular in markets and ceremonial settings (Murtini et al. 2020).

Red tones were contributed by *C. frutescens* (chili) and *Rosa* sp. (rose), with occasional references to *S. aromaticum* (clove), although its pigment is more accurately classified as brown. While these species are not primarily cultivated for coloring, they impart reddish or warm hues when used in sambals, herbal infusions, or decoctions.

Purple tones were extracted from *Ipomoea batatas* and *Hylocereus polyrhizus*, both of which are gaining popularity in urban food innovation due to their vibrant pigments and nutritional value. These plants are commonly used in pudding, steamed cakes, and cold beverages.

White, although not traditionally considered a color in dye taxonomy, was identified as a perception-based category. As previously noted, some respondents included *Syzygium polyanthum* (bay leaf) and *Apium graveolens* (celery) under this group, believing they contributed to a clearer or whiter appearance in dishes such as *sayur asem* and *nasi liwet*. Although the pigment contribution is minimal, this perception-based categorization highlights the emic perspective on culinary aesthetics.

Blue coloration was solely attributed to *Clitoria ternatea*, whose anthocyanin-rich petals are used in herbal drinks (*wedang telang*), rice (*nasi biru*), and desserts. Orange hues were derived from *Caesalpinia sappan*, used in health drinks and syrups, especially during festive occasions.

These findings underscore the profound connection between color choices in traditional cuisine and the interplay of symbolic, aesthetic, and functional considerations. Bright and bold colors are often associated with festivity, while subtle colors such as white or green imply purity and freshness. The cultural embeddedness of these hues makes natural dyes not only functional additives but also carriers of meaning and memory.

**Acquisition mode: Purchased vs. Cultivated**

The coloring plants identified in this study were accessed through two primary modes: cultivated in home gardens or urban spaces, and purchased from traditional markets or street vendors. According to Figure 6, nine species (52.9%) were purchased, while eight species (47.1%) were grown at home or cultivated locally.

Cultivated species include *C. longa*, *D. angustifolia*, *P. amaryllifolius*, and *C. ternatea*, which were reported by respondents as commonly grown in home gardens. These plants are typically easy to grow, tolerant of various microclimates, and require low maintenance. Their cultivation reflects local ecological knowledge and the use of micro-agroecosystems to sustain daily food needs, especially among older women who manage home gardens. Other species, such as *C. citratus*, *C. frutescens*, *S. polyanthum*, and *A. graveolens*, were more often purchased from traditional markets, although they may occasionally be cultivated.

In contrast, species such as *Z. officinale*, *H. sabdariffa*, *C. nucifera*, *Rosa* sp., *I. batatas*, *E. cardamomum*, *C. sappan*, and *H. polyrhizus* were purchased more frequently. These species are either not commonly grown in constrained urban spaces, not available year-round, or are perceived as higher quality when obtained from specialized sellers.

The dominance of purchased colorants suggests an increasing reliance on market-based access, possibly linked to changes in land use, housing density, and urban livelihood patterns. In highly urbanized areas such as Keprabon and Baluwarti, limited space and shifts toward wage labor have contributed to a decline in the capacity for plant cultivation. However, the fact that nearly half of the species are still cultivated reflects the persistence of traditional agroecological practices, especially in peripheral areas like Mojosongo. These practices support not only self-sufficiency but also the in situ conservation of plant genetic resources.

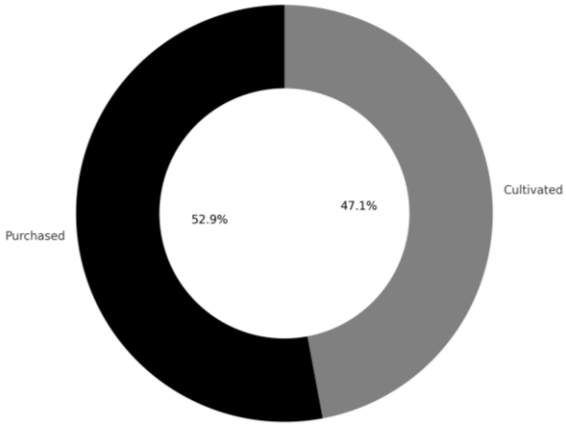



**Figure 5.** Mode of acquisition of food coloring plants in Surakarta City, Indonesia

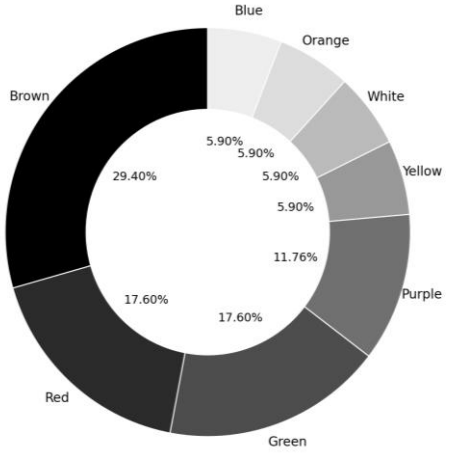



**Figure 6.** Diversity of food coloring plants in Surakarta City, Indonesia

From an ethnobotanical perspective, acquisition mode is not only a matter of access but also reflects social values, economic constraints, and shifts in cultural foodways. Plants cultivated in households tend to be embedded in household routines and intergenerational knowledge, while market-purchased species may indicate the commodification of traditional practices. Understanding how communities acquire these plants offers insights into the dynamics of food system resilience, dietary change, and the sustainability of biocultural heritage in urban settings.

**Conservation status of dye plants**

To assess the sustainability of food coloring plant use in Surakarta, we examined the conservation status of the 17 recorded species based on the IUCN Red List. As shown in Table 4, 5 species (29.4%) are categorized as Least Concern (LC), 1 species (5.9%) as Vulnerable (VU), 4 species (23.5%) as Data Deficient (DD), and 7 species (41.2%) have Not Yet Been Evaluated (NE).

The relatively low proportion of LC species, including *C. longa*, *C. citratus*, *S. polyanthum*, *C. frutescens*, and *C. nucifera*, suggests that only a fraction of the commonly used colorant plants have been formally assessed and are considered not at risk under current usage patterns. These species are generally widespread, adaptable, and often cultivated, indicating a relatively low ecological threat level.

However, *C. sappan*, the only species listed as Vulnerable (VU), raises concern. Its hardwood is valued for producing red dye and is widely used in herbal remedies and traditional beverages. Due to increasing market demand and overharvesting, this species faces significant pressure in the wild. Sustainable harvesting protocols and cultivation-based conservation efforts are urgently needed to ensure its continued availability.

Four species—*D. angustifolia*, *Z. officinale*, *C. longa*, and *I. batatas*—are classified as Data Deficient (DD), indicating a lack of adequate population and distribution data despite their frequent local use. This emphasizes the need for targeted conservation research that incorporates ethnobotanical significance and regional usage patterns.

In addition, seven species—*A. graveolens*, *P. amaryllifolius*, *H. polyrhizus*, *E. cardamomum*, *C. ternatea*, *H. sabdariffa*, and *Rosa* sp.—have Not Yet Been Evaluated (NE) on the IUCN Red List. This large proportion underscores the gap between global conservation assessments and culturally important plant taxa used in traditional food systems.

Bridging this gap is essential to support inclusive and locally relevant biodiversity conservation, especially in urbanizing regions where traditional ecological knowledge can inform both scientific priorities and sustainable resource use.

While the overall conservation status may not raise immediate alarm, ongoing use of wild-sourced or under-documented species necessitates vigilance, particularly in the face of habitat loss, urbanization, and changing agricultural practices. Promoting in situ and ex situ conservation, as well as encouraging the cultivation of culturally significant dye plants at home, can support both biodiversity and food heritage preservation.

Furthermore, community-based monitoring and participatory conservation strategies—especially involving women and elders who are key holders of culinary knowledge—can enhance plant protection efforts while maintaining cultural continuity.

**Ethnobotanical reflections and urban challenges**

The use of natural food coloring plants in Surakarta reflects more than culinary preferences—it embodies a dynamic ethnobotanical tradition rooted in ecological adaptation, symbolic meaning, and intergenerational knowledge. As demonstrated in previous sections, coloring plants are selected not only for their visual effects but also for their roles in ritual, identity, and sensory experience, forming an inseparable part of Javanese foodways.

However, urbanization introduces significant challenges to the continuity of this knowledge. In the more densely populated areas of Keprabon and Baluwarti, traditional food plants are being increasingly replaced by store-bought products, and the practice of cultivating dye plants is in decline. Younger generations show reduced familiarity with food-coloring species, relying more on synthetic food

dyes or pre-packaged ingredients that offer convenience but little cultural meaning.

This erosion of practical knowledge is compounded by shrinking green spaces, time constraints, and dietary modernization, all of which limit opportunities for experiential learning. Many respondents noted that plant-based dyes are now used mainly during religious holidays or special occasions, and are no longer an integral part of everyday cooking routines. The cultural knowledge, once ubiquitous, now risks becoming a specialized, nostalgic domain.

At the same time, a growing interest in organic food, heritage cuisine, and natural ingredients presents opportunities for revival. Urban agriculture movements, herbal drink entrepreneurship, and culinary tourism may offer new platforms for revaluing traditional food dyes. Schools, markets, and family spaces can serve as loci of knowledge transmission, especially if younger people are engaged through creative and participatory methods.

Preserving the use of natural coloring plants thus requires both cultural and ecological strategies. On the one hand, documentation and education efforts must center on elders—especially women—as key knowledge holders; on the other hand, policy and infrastructure should support home gardening, plant exchanges, and biodiversity-based livelihoods. This dual approach can help embed ethnobotanical traditions into the future fabric of urban life.

Ultimately, the study of coloring plants in Surakarta reveals how biocultural knowledge is constantly negotiated within changing landscapes. Recognizing and supporting this knowledge not only honors local identity but also contributes to broader goals of food sovereignty, sustainability, and cultural resilience.

This study documented the ethnobotanical knowledge of 17 food-coloring plant species used by communities in Mojosongo, Keprabon, and Baluwarti Villages in Surakarta, Indonesia. These species represent diverse plant families, parts used, life forms, and acquisition modes, producing a spectrum of eight color categories in traditional foods and beverages. Although only a minority of these species are currently listed as Least Concern by the IUCN, many remain unevaluated or classified as Data Deficient or Vulnerable, highlighting the urgency of targeted conservation efforts (Cazalis et al. 2023).

The study reveals that food coloring practices are embedded in cultural values, gendered knowledge systems, and spatial dynamics, with older women serving as key knowledge holders. Yet, urbanization, market dependency, and lifestyle changes pose significant threats to the continuity of this tradition. Sustaining the use of natural dyes requires an integrated approach that combines household-based cultivation, formal and informal knowledge transmission, and community-based conservation strategies. Recognizing the cultural and ecological significance of these plants is critical not only for preserving food heritage but also for promoting urban biodiversity and resilient local food systems in a rapidly modernizing landscape.

**The diversity of parts used**

Figure 3 shows that the diversity of plant parts used as food coloring consists of seven parts: leaves, flowers, fruit, tubers, rhizomes, wood, and stems; the most widely used plant parts are the flowers of five plant species, accounting for 29.40%. These plants include butterfly flowers (*C. ternatea*), coconut flowers (*C. nucifera*), rose flowers (*Rosa* sp.), cloves (*S. aromaticum* (L.) Merr. & L.M.Perry), and rosella flowers (*H. sabdariffa* L.). Furthermore, plants that utilize the leaves are four species or 23.50%, including *suji* leaves (*D. angustifolia*), *pandan* leaves (*P. amaryllifolius*), bay/*salam* leaves (*S. polyanthum* (Wight) Walp.), and celery leaves (*A. graveolens* L.). The next part of the plant is fruit, which has three or 17.60%, i.e., dragon fruit (*Hylocereus polyrhizus* (F.A.C.Weber) Britton & Rose), chilies (*C. frutescens* L.), and cardamom (*E. cardamomum* (L.) Maton). The dragon fruit's inside parts are also used in food coloring, and the flowers, fruit skin, and leaves are also used as herbal medicine (Luu et al. 2021).

**Table 4.** Species with conservation status

| Family | Scientific name | Local name | IUCN Conserv. Status (2022) |
|---|---|---|---|
| Arecaceae | *Cocos nucifera* L. | *Gula Jawa* | Least Concern (LC) |
| Apiaceae | *Apium graveolens* L. | *Seledri* | Least Concern (LC) |
| Asparagaceae | *Dracaena angustifolia* (Medik.) Roxb. | *Suji* | Vulnerable (VU) |
| Cactaceae | *Hylocereus polyrhizus* (F.A.C.Weber) Britton & Rose | *Buah naga* | Data Deficient (DD) |
| Convolvulaceae | *Ipomoea batatas* (L.) Lam. | *Ubi ungu* | Data Deficient (DD) |
| Fabaceae | *Caesalpinia sappan* L. | *Secang* | Least Concern (LC) |
| Fabaceae | *Clitoria ternatea* L. | *Telang* | Not evaluated (NE) |
| Malvaceae | *Hibiscus sabdariffa* L. | *Rosela* | Not evaluated (NE) |
| Myrtaceae | *Syzygium polyanthum* (Wight) Walp. | *Salam* | Least Concern (LC) |
| Myrtaceae | *Syzygium aromaticum* (L.) Merr. & L.M.Perry | *Cengkeh* | Not evaluated (NE) |
| Pandanaceae | *Pandanus amaryllifolius* Roxb. | *Pandan* | Data Deficient (DD) |
| Poaceae | *Cymbopogon citratus* (DC.) Stapf | *Serai* | Not evaluated (NE) |
| Rosaceae | *Rosa* sp. | *Mawar* | Not evaluated (NE) |
| Solanaceae | *Capsicum frutescens* L. | *Cabe* | Least Concern (LC) |
| Zingiberaceae | *Zingiber officinale* Roscoe | *Jahe* | Data Deficient (DD) |
| Zingiberaceae | *Curcuma longa* L. | *Kunyit* | Data Deficient (DD) |
| Zingiberaceae | *Elettaria cardamomum* (L.) Maton | *Kapulaga* | Not evaluated (NE) |

The next part of the plant is the rhizome, which has two (or 11.80%), more specific: ginger (*Z. officinale*) and turmeric (*C. longa*). The least used plant parts are stems, tubers, and wood, each of which is used in only one (or 5.90%) case, such as sappan wood (*C. sappan*), purple sweet potato tuber (*I. batatas*), and lemongrass (*C. citratus*). People only use certain parts of plants (such as flowers, rhizomes, and fruits) because they have limited knowledge regarding the natural coloring of plants. Rhizomes are widely used because there are many types, and in addition, they tend not to be easily damaged and can be used either fresh or dry (Nurshillah et al. 2022). Additionally, wood is rarely used because it is difficult to process into a food coloring. According to Bayram et al. (2015), certain flowering plants, such as saffron (*Crocus sativus* L.), roselle (*H. sabdariffa*), and marigold (*Calendula officinalis* L.), are edible and can also serve as natural food coloring agents.

**Diversity of life forms**

Figure 4 revealed that herbaceous plants accounted for 35.29% of the total, bushes for 17.66%, wood for 35.29%, and creepers for 11.76%, which aligns with the life form plant diversity of the people in Mojosongo, Keprabon, and Baluwarti villages, as shown in Table 2. In those three villages, six species were at tree categories growth form (*C. nucifera, H. sabdariffa, S. aromaticum, Rosa* sp., *S. polyanthum,* and *C. sappan*), then herbaceous with six species (*C. frutescens, C. citratus, E. cardamomum, A. graveolens, C. longa,* and *Z. officinale*), bush with three species (*D. angustifolia, P. amaryllifolius,* and *I. batatas)*, and creepers with two species (*H. polyrhizus* and *C. ternatea*). These results showed that people used palm sugar, rosella, cloves, roses, *salam*, and *secang* more often as food coloring in the habitus wood category. Then, the people on sites still use chilies (*C. frutescens*), cardamom (*E. cardamomum*), celery (*A. graveolens*), turmeric (*C. longa*), and ginger (*Z. officinale*) as food coloring in the herbaceous category.

**Plant origin**

People are drawn to a diverse range of natural ingredients for food coloring, including dragon fruit, chili, cardamom, palm sugar, *telang* flower, rosella, cloves, roses, celery, *suji* leaves, bay leaf, *pandan* leaves, lemongrass, *secang*, turmeric, ginger, and purple sweet potatoes. Although most plants were obtained through purchase (71%) or home cultivation (29%), none of the respondents mentioned obtaining plants through social sharing or neighbor donations. This may reflect the urban character of Surakarta, where limited yard space and reduced social-agrarian ties have led to a decline in such practices. Furthermore, five species of plants, including turmeric, roses, pandan, suji, and *telang*, make up the remaining 29.4% of the cultivated species (Table 2; Figure 5). Providing plant dyes by purchasing them is preferable to growing them yourself or asking your neighbors, because many people do not have yards or gardens for cultivation, and some people prefer to grow ornamental plants rather than food plants.

People living in urban or rural areas often have dye plants planted in their yards or gardens, and they can also purchase them at local markets or supermarkets. Research conducted in Vietnam indicates that individuals residing in cities or urban areas tend to use dye plants more frequently than those living near forests. Ethnic communities only use dye plants in a few ceremonies (Luong et al. 2023).

In conclusion, this study documented the diversity and ethnobotanical relevance of 17 plant species used as natural food colorants by communities in Mojosongo, Keprabon, and Baluwarti Villages of Surakarta, Central Java. These species vary in taxonomy, plant parts utilized, life forms, and modes of acquisition, and are employed to produce a wide range of color categories in traditional foods and beverages. The findings highlight that natural food coloring practices are deeply embedded in cultural identity, ritual expression, and gendered knowledge systems, particularly among older women. However, only a small proportion of the species are classified as Least Concern by the IUCN, while others remain Data Deficient, Vulnerable, or have not yet been evaluated, indicating an urgent need for ethnobotany-informed conservation strategies. In the face of urbanization and declining intergenerational knowledge transmission, sustaining the use of natural food dyes requires a combination of home-based cultivation, community awareness, and integration into food heritage education. Protecting and revitalizing this biocultural knowledge not only contributes to culinary diversity and public health but also supports urban ecological resilience and plant conservation efforts.

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