

Standardization and Quality Assurance of Herbal Pigments

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ABSTRACT

Herbal pigments, derived from various plant sources, are increasingly being recognized as safe and eco-friendly alternatives to synthetic colorants in food, cosmetics, pharmaceuticals, and textiles. These natural pigments, including anthocyanins, carotenoids, betalains, chlorophylls, and curcuminoids, not only impart vibrant colors but also offer therapeutic properties such as antioxidant, anti-inflammatory, and antimicrobial effects. However, the commercialization of herbal pigments faces significant challenges due to variability in raw material quality, extraction inefficiencies, pigment degradation, and a lack of uniform regulatory standards. Standardization of herbal pigments is essential to ensure consistency, stability, and efficacy across production batches. This involves comprehensive characterization of plant materials through botanical identification, physicochemical profiling, and phytochemical quantification using advanced analytical techniques like HPLC, HPTLC, UV-Vis spectrophotometry, and FTIR. Quality assurance further encompasses stringent adherence to Good Agricultural and Collection Practices (GACP), Good Manufacturing Practices (GMP), and robust quality control tests for contaminants, heavy metals, and microbial loads. The development of validated analytical methods, stability studies, and eco-friendly extraction technologies has advanced the reliability and scalability of herbal pigments. Additionally, regulatory frameworks provided by WHO, FSSAI, USFDA, and ISO are guiding the establishment of quality benchmarks, though global harmonization remains a challenge. This review emphasizes the need for integrated standardization protocols and quality assurance strategies to enhance the commercial viability and global acceptance of herbal pigments. Future research should focus on molecular-level authentication, sustainable production methods, and the application of AI-driven quality prediction models for industry-wide implementation.

Keywords: Herbal Pigment, Efficacy, Phytochemical, USFDA, Quality, Authority, Standardization, Regulatory, ETC

Introduction

Herbal pigments, naturally occurring colorants derived from plant sources, have garnered significant attention as safe and sustainable alternatives to synthetic dyes. These pigments, which include anthocyanins, carotenoids, betalains, chlorophylls, and curcuminoids, are widely used in industries such as food, cosmetics, pharmaceuticals, and textiles. Apart from their aesthetic appeal, many of these compounds exhibit potent bioactive properties, including antioxidant, anti-inflammatory, and antimicrobial effects, which enhance their functional value. The rising consumer preference for clean-label products, coupled with the environmental and health hazards associated with synthetic colorants, has accelerated the demand for natural pigments [1]. Despite their growing market potential, the commercialization and industrial application of herbal pigments face several challenges. Variations in plant species, geographical

origin, cultivation practices, and harvesting times contribute to inconsistencies in pigment quality and yield. Additionally, the lack of standardized extraction and processing methods often results in unstable products with limited shelf-life and reduced efficacy. Ensuring the reproducibility, purity, and safety of herbal pigments requires robust standardization protocols and comprehensive quality assurance strategies. The establishment of globally accepted quality standards is further complicated by the diverse regulatory guidelines across countries and regions. Regulatory bodies such as the World Health Organization (WHO), Food Safety and Standards Authority of India (FSSAI), and the United States Food and Drug Administration (USFDA) have set frameworks, yet harmonization remains a critical need. This review aims to explore the current methodologies for the standardization and quality assurance of herbal pigments, discuss emerging challenges, and highlight future directions for their sustainable industrial utilization.

Literature Of Paper

Reinhold Carle, Ralf Schweiggert: Natural Pigments in Food and Beverages: Industrial Applications for Improving Food Color (Woodhead Publishing, 2016) Detailed discussion on herbal pigments like betalains, carotenoids, chlorophylls, and anthocyanins.

Types of Herbal Pigments

Herbal pigments constitute a broad spectrum of naturally occurring compounds responsible for the vibrant coloration observed in plant structures such as flowers, fruits, leaves, and roots. These pigments not only contribute to aesthetic appeal but also exhibit significant pharmacological and industrial potential [2,3].

Anthocyanins

Anthocyanins are water-soluble flavonoid pigments that produce red, purple, and blue hues depending on the pH. Commonly found in berries, grapes, red cabbage, and hibiscus, these pigments are notable for their antioxidant activity and are extensively used in food and beverage industries as natural colorants.

Carotenoids

Carotenoids, a class of fat-soluble pigments, include compounds like beta-carotene, lutein, and lycopene. These impart yellow, orange, and red tones to plants such as carrots, marigold flowers, and tomatoes. Besides their coloring ability, carotenoids are valued for their provitamin A activity and antioxidant properties.

Betalains

Found predominantly in beetroot and amaranth, betalains are water-soluble pigments divided into betacyanins (red- violet) and betaxanthins (yellow-orange). These pigments exhibit high color stability under neutral to slightly acidic conditions and are also recognized for their antioxidant and anti-inflammatory potential.

Chlorophylls

Chlorophylls are green pigments essential for photosynthesis and are primarily obtained from green leafy vegetables, algae (like spirulina), and grasses. Chlorophyll a and b are the two main types, widely applied in natural food colorings, supplements, and detox formulations.

Curcuminoids

Curcuminoids, especially curcumin derived from *Curcuma longa* (turmeric), yield a distinctive bright yellow pigment. Beyond its colorant use, curcumin possesses a range of therapeutic effects, including anti-inflammatory, antimicrobial, and anticancer activities, making it a dual-purpose compound.

Flavonoids and Tannins

Though not always considered primary pigments, flavonoids and tannins influence plant coloration, particularly in combination with other pigments. Flavonoids contribute to pale yellow and cream shades, while tannins can lead to brown hues. Both classes offer notable antioxidant, antimicrobial, and astringent properties.

Table 1: Basic Pigment Ratio Evaluation

S.NO	Pigment type	Natural sources	Color range	Solubility	Ph Sensitivity	Typical use ratio (% w/w or Mg/g)	Notes/applications
1	Anthocyanins	Berries, grapes, hibiscus, red cabbage	Red to purple/blue	Water-soluble	High	0.1 – 1.0% w/w	Sensitive to pH; used in food and beverages
2	Carotenoids	Carrots, marigold, tomato, paprika	Yellow to red	Lipid- soluble	Low	10–50 mg/g	Stable in neutral pH; used in supplements, colors
3	Betalains	Beetroot, amaranth	Red- violet/ yellow	Water-soluble	Medium	0.5 – 1.5% w/w	Used in juices, natural food coloring
4	Chlorophylls	Spinach, spirulina, wheatgrass	Green	Lipid- soluble	Low	10–30 mg/g	Used in detox products, cosmetics
5	Curcuminoids	Turmeric	Bright yellow	Poor water solubility	Moderate	2–6% w/w	Antioxidant; used in food, pharma
6	Flavonoids	Citrus peels, tea, onions	Pale yellow to cream	Water-soluble	Moderate	0.5–2% w/w	Used for antioxidant benefits and color stability
7	Tannins	Tea, oak bark, pomegranate rind	Light to dark brown	Water-soluble	Low	1–3% w/w	Used in dyeing, pharmaceuticals

Challenges in Standardization

The standardization of herbal pigments poses several critical challenges due to the inherent variability and complexity of plant-derived materials. One of the primary issues is the inconsistency in raw materials, which can be attributed to differences in plant species,

genetic variations, geographical origin, seasonal fluctuations, and cultivation practices. These factors significantly influence the concentration and composition of pigments, leading to batch-to-batch variability in both quality and yield. Additionally, the lack of uniformity in harvesting, drying, and storage conditions further complicates the consistency of raw material quality [4]. Another major challenge lies in the extraction and processing techniques used to isolate pigments. The sensitivity of herbal pigments to factors such as pH, temperature, light, and oxygen often leads to pigment degradation during extraction, affecting both the color intensity and stability of the final product. Moreover, the absence of universally accepted standard operating procedures (SOPs) for extraction results in variable pigment profiles across manufacturers and research laboratories [5]. Stability issues also present significant hurdles, as many natural pigments are prone to oxidation and photodegradation, which limits their shelf-life and restricts their application in commercial formulations. The diversity of regulatory requirements across different countries, with varying standards set by agencies like USFDA, FSSAI, EU, and WHO, adds further complexity to achieving global acceptance and marketability of herbal pigments [6]. Ensuring consistent quality, safety, and efficacy of herbal pigments requires addressing these multifaceted challenges through comprehensive standardization protocols, advanced analytical techniques, and harmonized regulatory frameworks.

Standardization Parameters for Herbal Pigments:

Botanical Identification

The first and most fundamental step in the standardization of herbal pigments is the accurate botanical identification of the source plant. This process ensures the correct selection of plant species and prevents adulteration or substitution, which can significantly affect pigment quality. Botanical identification involves a combination of macroscopic and microscopic examinations. Macroscopic evaluation includes observing key morphological features such as the color, size, shape, texture, and odor of the plant part used (e.g., flowers, leaves, roots). Microscopic analysis provides detailed insights into cellular structures, including epidermal cells, trichomes, stomata, and pigment-containing cells, which are unique to specific species. These diagnostic characteristics help differentiate genuine raw materials from adulterants or closely related species. Additionally, organoleptic evaluation, which assesses sensory attributes like taste, smell, and appearance, supports preliminary identification. For high accuracy, reference herbarium specimens or authenticated samples should be used as standards during identification. Correct botanical authentication not only ensures consistency in pigment yield and composition but also safeguards against the inclusion of toxic or ineffective plant materials. This step is crucial for maintaining the purity, efficacy, and reproducibility of herbal pigments across production batches, forming the foundation for further standardization and quality assurance procedures.

Physicochemical Parameters

Physicochemical analysis plays a pivotal role in the standardization of herbal pigments by assessing the fundamental chemical and physical properties of the raw materials and extracts. These parameters offer critical insights into the quality, purity, and stability of the pigments. Key physicochemical tests

include determining moisture content, which affects microbial growth and shelf-life, and ash values such as total ash, acid-insoluble ash, and water-soluble ash, which help evaluate the inorganic matter present, indicating contamination with soil, sand, or other extraneous materials. Extractive values, determined using solvents like alcohol and water, provide an estimate of the percentage of active phytoconstituents that can be extracted, reflecting the quality and potency of the raw material [7]. Additionally, pH determination and solubility studies are conducted to assess pigment behavior in various formulations. Swelling index and foaming index are also evaluated for certain pigment-containing herbs that exhibit mucilage or saponin content. Consistent results within specified limits for these parameters ensure batch-to-batch uniformity and establish quality benchmarks for raw materials. Physicochemical profiling is essential not only for initial quality assessment but also for maintaining pigment integrity during processing, storage, and application. Regulatory bodies mandate these evaluations as part of official monographs, forming a critical step in quality control protocols.

Phytochemical Profiling

Phytochemical profiling is a crucial step in the standardization of herbal pigments, as it involves the qualitative and quantitative analysis of bioactive constituents responsible for color and therapeutic properties. This process helps establish a comprehensive chemical fingerprint of the herbal material, ensuring its authenticity and potency. Preliminary phytochemical screening is conducted to detect the presence of various classes of compounds such as flavonoids, alkaloids, tannins, saponins, glycosides, and phenolic compounds, which may contribute to pigment formation. Advanced chromatographic techniques like High-Performance Thin Layer Chromatography (HPTLC), High-Performance Liquid Chromatography (HPLC), and Gas Chromatography-Mass Spectrometry (GC-MS) are employed to achieve detailed profiling. These methods provide specific retention factors (R_f values) and peak patterns that serve as distinctive chemical signatures for identification. Phytochemical profiling not only aids in confirming the presence of desired pigments but also helps detect adulteration, degradation, or presence of unwanted compounds. Establishing a phytochemical profile forms the basis for setting quality benchmarks and facilitates regulatory compliance. Furthermore, it enables correlation between pigment concentration and therapeutic efficacy, which is vital for product consistency in pharmaceutical and nutraceutical applications.

Marker Compound Quantification

Quantification of marker compounds is a pivotal component of pigment standardization, as it ensures the consistency of active constituents across different batches. Marker compounds are specific phytochemicals that act as indicators of quality and efficacy for a particular herbal pigment. For example, curcumin is quantified as a marker for turmeric pigments, while betanin is measured in beetroot extracts. Quantitative analysis is typically performed using validated analytical techniques such as HPLC, HPTLC, and UV-Visible spectrophotometry, which provide precise and reproducible results. These methods are designed to measure the concentration of marker compounds with high sensitivity and specificity, adhering to parameters like accuracy,

linearity, precision, limit of detection (LOD), and limit of quantification (LOQ). Establishing marker-based specifications enables manufacturers to monitor and control variations arising from raw material quality, extraction efficiency, and processing methods. Regulatory authorities often require documented evidence of marker compound quantification as part of quality assurance protocols. This process not only supports product standardization but also assures consumers and regulatory bodies of the product's safety, efficacy, and therapeutic consistency.

Organoleptic Evaluation

Organoleptic evaluation involves the sensory examination of herbal pigments to assess characteristics such as color, odor, taste, and texture. Although considered a preliminary step, it plays an essential role in quality assessment by offering immediate, non-instrumental insights into the identity and acceptability of raw materials and finished products. Color intensity, hue, and brightness are visually inspected to ensure conformity with established standards, as visual consistency is critical for commercial applications in food and cosmetics. The natural aroma and taste are evaluated to detect any off-notes, which may indicate spoilage, adulteration, or contamination. Texture and feel provide clues about particle size uniformity and processing quality. Organoleptic parameters are often included in official monographs and pharmacopoeial standards as primary identification tests. While subjective, this evaluation is valuable when combined with analytical methods, serving as a quick screening tool during procurement, storage, and quality control checks. Furthermore, organoleptic consistency significantly influences consumer acceptance, making it a key parameter in the overall standardization of herbal pigments.

Quality Assurance Approaches

Quality assurance (QA) is a systematic process aimed at ensuring that herbal pigments consistently meet predefined standards of safety, efficacy, and purity. It encompasses a comprehensive set of guidelines, protocols, and analytical procedures that govern every stage of production, from raw material sourcing to the final product. The foundation of QA lies in adopting Good Agricultural and Collection Practices (GACP) to ensure that the plant materials are cultivated, harvested, and stored under controlled and hygienic conditions, minimizing contamination and preserving the integrity of the pigments [1]. Further, adherence to Good Manufacturing Practices (GMP) during processing is essential to maintain batch-to-batch consistency, prevent cross-contamination, and ensure compliance with regulatory standards. Quality control tests form an integral part of QA strategies. These include microbial limit tests to ensure the absence of harmful bacteria and fungi, heavy metal analysis for toxic elements such as lead, arsenic, mercury, and cadmium, and pesticide residue testing to ensure safe consumption. Mycotoxin screening is also performed, especially for pigments derived from roots and tubers, to prevent fungal contamination [8]. Analytical method validation is a key QA component, involving assessments of specificity, accuracy, precision, linearity, range, and sensitivity (LOD and LOQ) for each analytical technique employed. Stability studies under accelerated and real-time conditions are conducted to evaluate the shelf-life and storage requirements of the pigments, ensuring color retention and bioactivity over time [9]. Packaging also

plays a vital role in maintaining pigment quality by providing protection against light, moisture, and oxygen. Documentation, traceability, and batch records are maintained meticulously to ensure transparency and regulatory compliance. A robust QA system not only guarantees product safety and consistency but also builds consumer confidence and facilitates acceptance in global markets.

Regulatory Perspectives

The growing demand for natural colorants in food, cosmetics, pharmaceuticals, and textiles has prompted regulatory authorities worldwide to establish guidelines for ensuring the safety, quality, and efficacy of herbal pigments. However, the global regulatory landscape for herbal pigments remains fragmented, with diverse standards and varying degrees of regulatory oversight across different countries and regions. This disparity poses significant challenges for manufacturers aiming for global market penetration, as compliance with multiple regulatory frameworks becomes both complex and resource-intensive [10]. The World Health Organization (WHO) provides international guidelines for the quality control of herbal materials, which include general recommendations on Good Agricultural and Collection Practices (GACP), Good Manufacturing Practices (GMP), and analytical methodologies. Although WHO guidelines are advisory, they serve as a reference for national regulatory bodies in developing countries, aiding them in formulating their own standards for herbal products, including pigments.[11] In India, the Food Safety and Standards Authority of India (FSSAI) govern the use of natural colorants in food products. FSSAI has categorized permitted natural colors and established specific limits for their use in various food applications. It mandates stringent quality control measures, including tests for microbial contamination, heavy metal content, and solvent residues, ensuring consumer safety. The Bureau of Indian Standards (BIS) also provides specifications for natural dyes and pigments, primarily for their use in textiles and handicrafts [12]. The United States Food and Drug Administration (USFDA) classifies many herbal pigments under the Generally Recognized as Safe (GRAS) category, provided that they meet purity standards and are sourced from approved plant materials. However, USFDA enforces rigorous documentation requirements, including detailed safety assessments and evidence of historical use, to grant GRAS status. For dietary supplements and nutraceuticals, compliance with the Dietary Supplement Health and Education Act (DSHEA) is essential, which mandates quality control but does not require pre-market approval [13]. In the European Union (EU), the European Food Safety Authority (EFSA) regulates natural colorants under food additive regulations. The EU maintains an approved list of natural colors, each assigned an E-number (e.g., E100 for curcumin), specifying the permissible daily intake (ADI) levels. EFSA also requires comprehensive toxicological data, stability studies, and safety evaluations for new pigments seeking approval. In addition, the EU has strict regulations for cosmetic colorants, outlined in the Cosmetic Regulation (EC) No. 1223/2009, ensuring the safety of pigments used in personal care products [14]. The International Organization for Standardization (ISO) has developed standards focusing on natural colorants, particularly regarding sampling procedures, analytical techniques, and specifications for purity and performance. ISO standards are widely adopted in the textile industry for eco-

friendly dyeing practices and serve as a benchmark for quality assurance across international supply chains [15]. One of the primary regulatory challenges lies in the lack of harmonization between these diverse frameworks. Manufacturers often face difficulties in aligning their production processes with the distinct requirements of multiple regulatory agencies, leading to increased costs and delays in product approvals. Moreover, the absence of universally accepted monographs for many herbal pigments exacerbates these challenges, as companies are compelled to develop their own internal standards for quality control and documentation [16]. Collaborative efforts between international regulatory bodies, industry stakeholders, and research institutions are necessary to develop unified global standards for herbal pigments. Initiatives aimed at creating comprehensive monographs, validated analytical methods, and harmonized safety assessments can streamline regulatory compliance and foster greater acceptance of herbal pigments in global markets [15]. While significant progress has been made in establishing regulatory frameworks for herbal pigments, the industry still requires standardized global guidelines to ensure consistent quality, safety, and efficacy. Strengthening regulatory convergence will not only facilitate smoother international trade but also build consumer trust and encourage innovation in the development of new, sustainable, and safe herbal colorants.

Recent Advances in Standardization Techniques

In recent years, significant advancements have been made in the methodologies used for the standardization and quality assurance of herbal pigments. These innovations have enhanced the precision, efficiency, and reliability of pigment characterization, addressing many challenges related to variability, adulteration, and stability. One notable advancement is the integration of metabolomics and chemometric approaches in pigment analysis. Metabolomics involves comprehensive profiling of all metabolites present in a plant extract, providing a detailed chemical fingerprint. Coupled with chemometrics—statistical techniques that analyze complex data—this approach allows for the differentiation of authentic materials from adulterants and the assessment of batch-to-batch consistency. These methods have improved the capability to detect subtle variations caused by environmental or processing factors and facilitate the establishment of robust quality benchmarks [17]. Molecular marker-based authentication, such as DNA barcoding and genetic fingerprinting, has emerged as a powerful tool for confirming the botanical identity of pigment-producing plants. DNA barcoding uses short, standardized DNA sequences to accurately identify plant species, even in powdered or processed materials where traditional morphological methods fail. This molecular-level authentication enhances traceability, reduces the risk of substitution or contamination, and supports regulatory compliance [18]. Extraction techniques have also seen innovation, with a shift towards green extraction technologies that are environmentally friendly and efficient. Methods such as supercritical fluid extraction (SFE), ultrasonic-assisted extraction (UAE), and microwave-assisted extraction (MAE) offer improved yields, reduced solvent use, and shorter processing times. These techniques preserve pigment stability better than conventional methods by minimizing exposure to heat and oxygen, thereby enhancing the quality of the final product. Analytical instrumentation has advanced with the widespread

adoption of high-resolution chromatographic and spectroscopic methods. Ultra-Performance Liquid Chromatography (UPLC) and tandem mass spectrometry (MS/MS) provide high sensitivity and specificity for pigment compound detection and quantification, even at trace levels. These technologies facilitate precise marker compound quantification, impurity profiling, and degradation product identification, contributing to comprehensive quality control [19]. The application of nanoformulation technologies is gaining traction in improving the stability and bioavailability of herbal pigments. Encapsulating pigments in nanoparticles or liposomes protects them from environmental degradation, enhances solubility, and allows controlled release in pharmaceutical or cosmetic formulations. This not only extends shelf life but also enhances therapeutic and functional efficacy [20]. Data management and quality prediction have been revolutionized by the integration of artificial intelligence (AI) and machine learning (ML) tools. These technologies analyze large datasets from various quality control tests to predict pigment stability, optimize extraction parameters, and detect anomalies in production batches. AI-driven models enable real-time monitoring and decision-making, reducing errors and improving overall product consistency [21]. Technological advances have significantly improved the accuracy and robustness of herbal pigment standardization. Combining molecular authentication, green extraction methods, advanced analytics, and AI-based data analysis paves the way for more sustainable, reproducible, and high-quality natural colorant production. Continued research and adoption of these innovations will be critical to overcoming existing challenges and meeting increasing global demand for safe and standardized herbal pigments.

Applications of Standardized Herbal Pigments

Herbal pigments, derived from a variety of plant sources, have found increasing applications across multiple industries due to their natural origin, safety profile, and multifunctional properties. Their integration into pharmaceuticals, food, cosmetics, and textile industries reflects a global shift towards sustainable, health-conscious, and environmentally friendly products. Standardization of these pigments ensures consistency, safety, and efficacy, which is critical for their successful application and consumer acceptance.

Pharmaceutical Industry

In pharmaceuticals, standardized herbal pigments serve multiple roles beyond mere coloration. Traditionally, plant-derived pigments like curcumin (from turmeric), anthocyanins (from berries), and betalains (from beetroot) have been valued for their therapeutic properties, including antioxidant, anti-inflammatory, antimicrobial, and anticancer activities. Standardization ensures that these pigments retain their bioactive constituents in precise quantities, providing consistent pharmacological effects [14]. Herbal pigments are often used as natural coating agents in tablet formulations. The color imparted by these pigments aids in product identification, improves patient compliance, and enhances the aesthetic appeal of medicines without introducing harmful synthetic dyes. Moreover, because of their bioactive nature, some pigments contribute to the therapeutic effect, turning colorants into functional excipients [22]. The use of herbal pigments in topical formulations such as ointments, creams, and

gels is gaining traction as well. These pigments often possess skin-beneficial properties, including photoprotection and anti-aging effects. For instance, carotenoids are known to protect skin cells from UV-induced damage, while flavonoid-based pigments may reduce inflammation and oxidative stress. Standardized pigments ensure reproducibility of these benefits and maintain stability in complex pharmaceutical matrices.

Food industry

The food industry is one of the largest consumers of herbal pigments, motivated by consumer demand for clean-label products and increasing health awareness. Natural pigments such as annatto (bixin), paprika (capsanthin), turmeric (curcumin), and beetroot (betalains) are widely used to enhance the visual appeal of processed foods, beverages, confectioneries, and dairy products [23]. Standardization of food-grade herbal pigments is critical to ensure safety and maintain color consistency, as variations can impact consumer perception and product quality. Strict quality assurance protocols are necessary to control parameters such as pigment concentration, microbial contamination, heavy metals, and residual solvents. This not only ensures compliance with regulatory limits but also preserves the organoleptic and nutritional qualities of food products.[16] In addition to coloring, many herbal pigments exhibit functional benefits, such as antioxidant activity that can extend shelf life by preventing lipid oxidation and spoilage. For example, anthocyanin-rich extracts from berries can serve as natural preservatives, reducing reliance on synthetic additives. Some pigments also provide nutritional benefits by contributing vitamins and polyphenols, making the products nutritionally enhanced. The beverage industry utilizes herbal pigments extensively in fruit juices, soft drinks, and teas. Pigments impart vibrant colors that appeal to consumers and signal natural origins. Moreover, due to their water solubility, pigments like anthocyanins and betalains are particularly suitable for beverages. Standardization guarantees that the final products maintain uniform color and meet food safety standards.

Cosmetic Industry

Cosmetics are another major sector where standardized herbal pigments have made significant inroads. The global preference for natural and organic beauty products has spurred demand for pigments free from synthetic dyes, heavy metals, and other toxic substances. Herbal pigments such as carotenoids, flavonoids, and curcuminoids are incorporated into foundations, lipsticks, eye shadows, and skincare products to impart natural, attractive hues. Beyond coloration, these pigments contribute bioactive properties that enhance skin health. Antioxidant pigments help neutralize free radicals generated by environmental stressors like UV radiation and pollution, thereby reducing premature aging and skin damage. Some pigments also exhibit anti-inflammatory and antimicrobial activities, which can soothe sensitive skin and help manage conditions like acne. Standardization in cosmetics is crucial for ensuring product safety, efficacy, and consumer satisfaction. Consistent pigment concentration and purity prevent adverse

reactions and maintain visual appeal. Furthermore, standardized herbal pigments support claims related to natural origin and therapeutic benefits, which are increasingly important in marketing and regulatory approval.[3] The cosmetic industry

also benefits from advances in pigment formulation, such as microencapsulation and nanoemulsion technologies, which improve pigment stability, skin penetration, and controlled release. These innovative delivery systems allow for longer-lasting color and enhanced bioavailability of beneficial compounds.

Textile Industry

The textile industry has a longstanding history of using natural dyes and pigments derived from plants. In recent decades, environmental concerns and regulatory restrictions on synthetic dyes have renewed interest in herbal pigments as sustainable alternatives. Natural pigments offer biodegradability, low toxicity, and reduced ecological impact compared to synthetic dyes that often contain harmful heavy metals and carcinogens [6]. Standardized herbal pigments are essential in textile applications to ensure reproducible color intensity, fastness, and durability. Traditional dyeing methods using natural pigments suffered from poor reproducibility and low fastness properties; however, advancements in extraction, purification, and mordanting techniques have improved performance. Standardization of pigment source, concentration, and application protocols leads to consistent coloration outcomes suitable for commercial production [11]. Natural pigments such as indigo, madder (alizarin), turmeric, and henna are widely used in dyeing cotton, silk, wool, and other natural fibers. These pigments provide a broad palette of colors, ranging from yellows and reds to blues and greens. Eco-friendly mordants derived from plant or mineral sources replace toxic metallic salts, making the dyeing process safer and environmentally benign [4]. The use of standardized herbal pigments in textiles aligns with consumer trends favoring sustainable fashion and ethically produced garments. Certifications related to organic and natural textiles often require compliance with strict quality standards for natural dyes. Thus, standardization supports transparency and traceability in the supply chain.

Other Emerging Applications

Beyond traditional sectors, herbal pigments are gaining interest in emerging fields such as food packaging, pharmaceuticals as diagnostic agents, and biomedical imaging due to their biocompatibility and functional properties. For instance, natural pigments with antioxidant and antimicrobial activities are being explored for active packaging materials to extend food shelf life [22]. Agriculture, some herbal pigments are studied for use as eco-friendly insect repellents and growth enhancers. Their non-toxic nature makes them suitable for integrated pest management strategies that reduce reliance on chemical pesticides [23]. Standardization in these novel applications is vital to ensure reproducibility, safety, and regulatory compliance. As research expands the utility of herbal pigments, quality assurance frameworks must evolve accordingly [24,25].

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Conclusion

The applications of standardized herbal pigments span diverse industries, reflecting their multifunctional nature and consumer demand for natural alternatives. Ensuring consistent quality through rigorous standardization and quality assurance practices is critical for harnessing their full potential. From enhancing the safety and efficacy of pharmaceuticals to delivering vibrant, healthful food colors and enabling eco-friendly textiles, standardized herbal pigments contribute significantly to sustainable product development. Continued innovation in extraction, formulation, and analytical methods will further expand their applications, supporting global trends toward natural, safe, and environmentally responsible products.

References

- Aher A, Wahi A. Herbal drug standardization: An overview. *International Journal of Pharmaceutical Sciences and Research*. 2011. 2: 2566-2574.
- Alum EU, Manjula VS, Uti DE, Echegu DA, Ugwu OP, et al. Metabolomics-driven standardization of herbal medicine: Advances, applications, and sustainability considerations. *Natural Product Communications*. 2025. 20: 1934578X251367650.
- Bhat SV, Nagasampagi BA, Sivakumar M. Natural products. 2009.
- Devi S. Advancements in Quantitative and Qualitative Methods for Quality Control of Herbal Drugs: A Comprehensive Review. *Pharmacognosy Research*. 2025. 17.
- Chan, K. Some aspects of toxic contaminants in herbal medicines. *Chemosphere*. 2003. 52: 1361-1371.
- Chandra S, Lata H, Varma A, Sharma A. Herbal pigment standardization and quality control parameters. *Pharmacognosy Reviews*. 2012. 6: 124-132.
- Manach C, Scalbert A, Morand C, Rémésy C, Jiménez L. Polyphenols: Food sources and bioavailability. *American Journal of Clinical Nutrition*. 2004. 79: 727-747.
- Eltayeb EA, Ali EHA, Fadlelmoula AA. Extraction and applications of natural dyes from plants: A review. *International Journal of Environment*. 2014. 3: 23-31.
- Nisha P, Singhal RS, Pandit AB. A study on the degradation kinetics of bioactive compounds in tomato juice during processing. *Journal of Food Science and Technology*. 2011. 48: 485-491.
- Rymbai H, Sharma RR, Srivastav M. Bio-colorants and its implications in health and food industry – a review. *International Journal of Pharmaceutical and Biological Archives*. 2011. 2: 1397-1406.
- Wang H, Chen Y, Wang L, Liu Q, Yang S, et al. Advancing herbal medicine: enhancing product quality and safety through robust quality control practices. *Frontiers in Pharmacology*. 2023. 14: 1265178.
- Zuberi SA, Tasleem F, Malik N, Jaffar F, Aamir N.. Drug Standardization and its Applications to Herbal/Skin Care Formulations: A Review. *Journal of Population Therapeutics and Clinical Pharmacology*. 2024. 31.
- Joshi K, Chavan P. Natural colorants and their applications: A review. *Journal of Pharmacognosy and Phytochemistry*. 2019. 8: 1243-1252.
- van Breemen RB. The role of quality assurance and standardization in botanical dietary supplements.
- Kumar S, Pandey A. Chemistry and biological activities of flavonoids: An overview. *The Scientific World Journal*. 2013. 162750.
- Jadhav R. Regulations, current development, and future prospects of phytopharmaceuticals. 2025.
- Li S, Han Q, Qiao C, Song J, Xu H. Chemical markers for the quality control of herbal medicines: An overview. *Chinese Medicine*. 2008. 3: 1-16.
- Edo GI. The use of quality control parameters in the evaluation of herbal products. 2024.
- Patel PM, Patel NM, Goyal RK. Quality control of herbal products. *Indian Pharmacist*. 2006. 5: 26-30.
- Sashidhara KV, Kumar A, Kumar M, Srivastava A. Natural colorants in food applications: A brief review. *Natural Product Radiance*. 2009. 8: 134-140.
- Standardizing Herbal Cosmetics: Analytical Approaches, Regulatory Complexities and Emerging Trends (recent). 2025.
- World Health Organization (WHO) Quality Control Methods for Medicinal Plant Materials. WHO Press, Geneva. 1998.
- Lindenmaier MP, Bernart MW, Brinckmann JA. Advanced Methodologies for the Quality Control of Herbal Supplements and Regulatory Considerations. *Phytochemical Analysis*. 2025.
- Harborne JB. *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis* (3rd ed.). Springer. 1998.
- Sharma AK, Pandey AK. Quality Assurance in the Herbal Drug Industry under Current Good Manufacturing Practices (cGMP). *International Journal of Innovative Science and Research Technology*. 2025. 10: 2099-2102.