



REVIEW ARTICLE

FROM SEED TO SHRUB: A THOROUGH REVIEW OF *BIXA ORELLANA* AND ITS DIVERSE APPLICATIONS

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The plant *Bixa orellana* (Annatto) is a botanical treasure with a complex personality that shows adaptability beyond commercial and cultural limits. Following a thorough investigation, this plant's "From Seed to Shrub" journey is revealed, considering a variety of medicinal uses. The main attraction of this plant is the vivid reddish-orange pigment, derived from its seeds, which has become a staple in the culinary sector. Vegan items and ethnic foods alike benefit from the unique color and traditional flavor that annatto adds to food preparations. *Bixa orellana* is used in traditional medicine for purposes other than coloring; its extracts are said to have medicinal qualities. Its profound cultural importance, which is ingrained in native customs and ceremonies, lends depth to its adaptable nature. Industrially, the plant is highly productive because it can produce annatto dye, a commodity that finds use in textiles, cosmetics, and pharmaceuticals. This makes annatto an important component of worldwide industrial processes. The plant's ability to adjust to many environmental circumstances adds to its allure, making it easier to cultivate and guaranteeing accessibility on a worldwide level. Further investigation into the phytochemistry of *Bixa orellana* is also pointing to possible pharmaceutical uses, which could lead to the creation of new therapeutic opportunities. Its socio-economic significance is highlighted by the fact that annatto production and commercialization considerably improve living conditions in areas where it is abundant. Overall, *Bixa orellana* is a botanical wonder that has a rich history of use in a variety of disciplines, including being a versatile plant with a wide range of uses and a bright future.

Key words: *Bixa orellana*, Annatto, Medicinal properties, Food and Cosmetic industry.

INTRODUCTION

Natural substances derived from minerals, plants or animals have long been used in medications, cosmetics, and food items. Ancient Egyptian and Chinese cultures are known to have used these goods in written chronicles. These days, people are looking for "natural" items again, even if they have always existed. Nearly half of the medications in clinical use are derived from natural chemicals, according to an examination of the chemical makeup of numerous medications. Furthermore, a variety

of food and cosmetic preparations use plants and their derivatives as flavoring agents, coloring agent, and preservatives [1].

Bixa orellana (Annatto) is a plant native to Brazil but grows in other regions of South and Central America. It is grown in tropical countries such as Peru, Mexico, Ecuador, Indonesia, India, Kenya, and East Africa [2]. One of the most commonly used colors in the world is produced by the seeds of this plant, utilized not just in food products but also in the paint, textile, and

cosmetics sectors. The World Health Organization (WHO) has approved it as one of the few harmless food dyes, and its usage has been encouraged by the ban on the use of synthetic dyes in food and cosmetics. It also does not appear to alter the nutritional content of food [3]. Another fascinating statistic is that annatto is the source of 70% of all natural coloring compounds used globally [4]. *Bixa orellana* is also available in the tropical areas of the Americas, rich in derivatives of carotenoids, terpenoids, tocotrienols, and flavonoids [5].



Fig. 1. Shrub and seeds of *Bixa orellana* [7, 8]

Chemical composition of *Bixa orellana*

The shrub *Bixa orellana* was found to contain following chemical compounds:

Bixin

The Bixin, is naturally oil soluble component and is removed from the seed covering. Bixin can be extracted from the seed coat by heating vegetable oil. Bixin is only soluble in vegetable oil at low percentage rates. Using suspensions of bixin, one can make stronger goods. This is accomplished by repeatedly extracting annatto seeds, which results in bixin concentrations of at least 4%. Bixin that is oil soluble is yellow, but bixin suspensions have a rich, vibrant red-orange hue. Bixin is a compound with the chemical formula $C_{25}H_{30}O_4$ with a chain of 25 carbons. At the endpoints of the chain, there are methyl ester and carboxylic acid groups. In nature, bixin is found in the form 16-Z (*cis*), but during the extraction process, it isomerizes to produce the 16-E form (*trans*), also known as isobixin (**Figure 2**) [14, 15].

Norbixin

Traditionally, norbixin has been used to color dairy goods where a water-soluble pigment works better, such as yogurt, ice cream, natural cheddar cheese, and dairy drinks. Norbixin gives the cheese its outstanding color and durability when it attaches to dairy protein during the

Originally, annatto was used as paprika, or food coloring, a condiment that is frequently added to meals to improve its color. However, its application has expanded to numerous industrial production sectors now-a-days. It also shows its application on the skin in the form of sunscreen and cosmetics [6].

Monograph of *Bixa orellana*

The shrub and seeds of *Bixa orellana* are shown in **Figure 1**. Further, **Table 1** shows a detailed monograph of *Bixa orellana*.

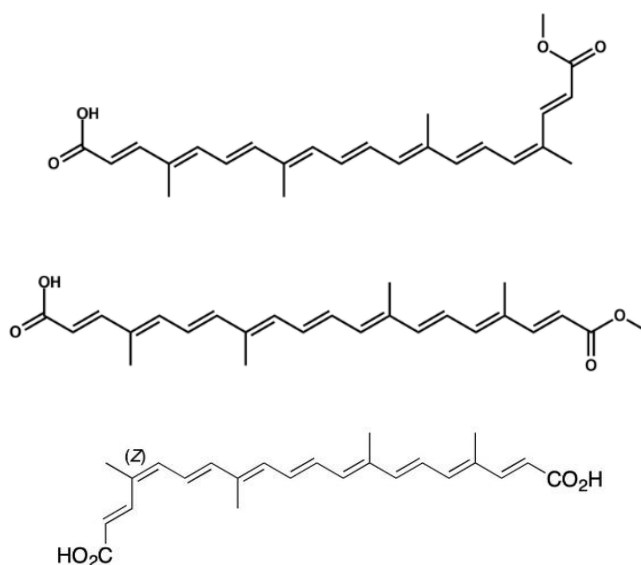
cheese-making process. Norbixin has a significant role in the food industry as well. In ice cream, it can be used to complement tropical flavors like mango or other tropical fruits at greater usage rates, or it can be used to give vanilla ice cream a pale-yellow hue. The key difference between bixin and norbixin is that bixin is insoluble in water, whereas norbixin is a water-soluble derivative of bixin. Bixin is the methyl ester of dicarboxylic acid norbixin (**Figure 2**) which is soluble in concentrated alkaline solutions, where it undergoes saponification, forming a norbixin salt. This salt when in acidic media forms dicarboxylic acid norbixin [16-18].

Geranylgeraniol

The diterpene, geranylgeraniol is present in the seeds of *Bixa orellana* together with bixin and other carotenoid diacids which are responsible for the coloring action of these seeds. *B. orellana* also contain other compounds like tocotrienols, tocopherol, terpenes and flavonoids both in seeds and in the leaves. [19, 20]. Vitamin E is the generic name given to all compounds that exerts the biological functions of α -tocopherol. However, vitamin E is a family of lipophilic compounds which includes four tocopherols and four tocotrienols (α , β , γ , δ) (**Figure 3**). The structure of these two types of compounds is very similar but tocotrienols have an isoprenoid

Table 1. Morphology of *Bixa Orellana*

Category	Subgroup	Detail	Reference
Botanical information	Scientific name	<i>Bixa orellana</i>	[9, 10]
	Common name	Annatto, Achiote, Urucum, Lipstick tree, Kumkum, Sindoor plant	
	Family	<i>Bixaceae</i>	
	Habitat	Native to tropical regions, cultivated globally	
Morphology	Plant Type	Shrub (Figure 1)	[9, 10]
	Leaves	Broad and heart-shaped	
	Flowers	Pink to lavender	
	Fruits	Spiky capsules containing seeds (Figure 2)	
Chemical composition	Pigment	Bixin and Norbixin	[9, 10]
	Phytochemicals	Carotenoids, tocotrienols	
Culinary Uses	Natural Food Coloring	Seeds used for coloring	[11, 12]
	Flavor	Traditional flavor in ethnic cuisines	
	Culinary applications	Dairy, baked goods, spice blends	
Traditional medicine	Medicinal uses	Anti-inflammatory, digestive aid	[13]
	Parts used	Seeds, leaves, roots	
Cultural significance	Rituals and customs	Symbolic and ceremonial uses	[9]
	Traditional practice	Cultural heritage	
Industrial applications	Annatto dye production	Extracted from seeds	[9]
	Textiles	Natural dye for Fabrics	
	Cosmetics	Coloring agents in cosmetics	
	Pharmaceuticals	Use in medications	
Environmental adaption	Versatility	Adaptable to various climates	[9]
	Agricultural Regions	Grown globally	

**Fig. 2.** Structures of bixin, isobixin and norbixin

tail with three unsaturated residues, whereas

tocopherols have a saturated phytol tail [21, 22].

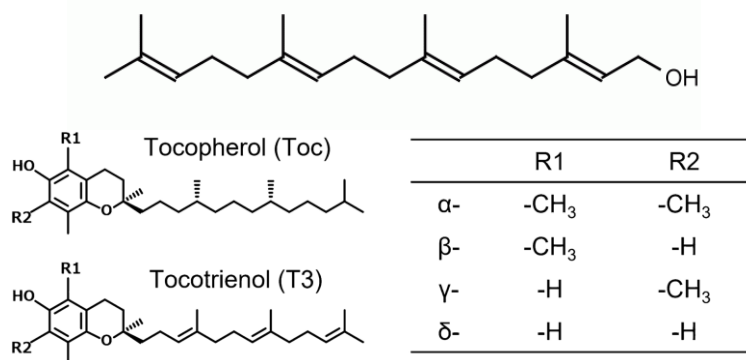


Fig. 3. Structures of geranylgeraniol, tocopherols and tocotrienols

Applications

Bixa orellana has applications in medicines, cosmetic and textile industries. Different parts of *B. orellana* used in medicines and other industries are shown in **Figure 4**. Plants that naturally produce dyes, such as *Bixa orellana*,

are used in the leather, textile, cosmetic, and solar cell industries. Artificial Neural Networks (ANNs) have the potential to improve the dye extraction process by optimizing the dye extraction from *Bixa orellana* seeds, hence leading to increased efficiency.



Fig. 4. Different parts of *Bixa orellana* used in medicines and other industries

Medicinal properties

Although annatto is mainly used in industry and cuisine, new studies indicates that it may also have therapeutic benefits [23-25]. It is significant to remember that annatto's medical applications are still being investigated, and additional studies are required to determine the plant's therapeutic value.

Anti-mutagenic activity

According to the literature, *Bixa orellana* extracts might have anti-mutagenic properties. When *B. orellana* was given in conjunction with recognized mutagens in tests, anti-mutagenic effects were seen [26].

Anti-inflammatory effect

Some cultures have long used anchovy in traditional medicine because they think it has anti-inflammatory qualities. Native American tribes have used annatto extracts to treat inflammatory illnesses. Bioactive substances found in abundance in *Bixa orellana* and carotenoids have been shown to have anti-inflammatory and antioxidant properties. Examples of these chemicals are bixin and

norbixin. According to certain animal research, *B. orellana* extracts might have anti-inflammatory properties. These studies show a decrease in inflammatory markers, suggesting a possible function in controlling inflammatory reactions [27, 28].

Antioxidant activity

Bixin and norbixin are the two main carotenoids found in abundance in *Bixa orellana* seeds. Strong antioxidants called carotenoids aid in the body's defense against reactive oxygen species (ROS) and free radicals. *B. orellana* antioxidants are essential for scavenging free radicals, which are unpaired electron molecules that can harm cells and induce oxidative stress. Anthocyanins are neutralized by annatto, which enhances cellular defense. *Bixa orellana*'s antioxidant qualities may be linked to several health advantages, such as defense against oxidative stress-related chronic illnesses like heart disease and some malignancies [29, 30].

Wound healing

Because of the anti-inflammatory properties that *Bixa orellana* extracts have shown, they may

help control inflammation as wounds heal. To create an environment that is favorable for tissue repair, inflammation must be reduced. Research has indicated that annatto extracts might play a role in wound healing and tissue regeneration. This is explained by the plant's capacity to promote cellular migration and proliferation. During the wound-healing process, *Bixa orellana*'s antioxidant qualities might shield cells from oxidative damage. Antioxidants promote tissue healing by reducing the harm that free radicals inflict. Collagen synthesis and remodeling are critical processes for the strength and structural integrity of healed tissue, and *Bixa orellana* extracts may have an impact on these processes. Scar development and wound closure depend heavily on collagen [31].

Antimicrobial activity

Bixa orellana, popularly referred to as annatto, has been investigated for its antibacterial qualities. Some investigations indicate that *B. orellana* extracts may have an antibacterial effect against specific microbes, although more research is needed. Antibacterial activity of *Bixa orellana* extracts has been demonstrated against a range of bacterial species including both Gram-positive and Gram-negative bacteria. It is believed that the presence of bioactive substances like norbixin and bixin is responsible for the antibacterial actions. Further, research has shown that extracts from *Bixa orellana* have antifungal properties against specific types of fungi [32].

Antiparasitic activity

Research has also been done on the possible antiparasitic effects of *Bixa orellana*. Research points to activity against certain parasites, suggesting a wide range of antimicrobial properties [33].

Cosmetic and textile use

Plants that naturally produce dyes, like *Bixa orellana* (annatto), are used in the textile and cosmetics industries. An enormous amount of promise exists for artificial neural networks (ANNs) to optimize dye extraction from the plant's seeds. The cosmetic and leather industries utilize Annatto dye extensively. It is used in domestic goods including furniture polish, floor wax, brass lacquer, shoe polish, and wood stain, as well as in the cosmetics industry to make lipstick, hair oil, nail gloss, and soap [34, 35].

Annatto is used in the textile industry to dye wool, cotton, and silk. It gives these materials an orange-red color, and when combined with wood ash or sodium carbonate in a dye bath and exposed to tartaric or citric acid, it turns yellow. Some findings state that when ammonia is added to woolen yarn dyed with annatto seeds, the lightness value decreases. Although the dye is resistant to washing, acids, and alkalis, it fades in sunlight. It is also possible to color bamboo, rattan, and wood with this dye.

Food industry

The seeds contain natural colorants, such as yellow or orange, that are acceptable for use in food and are not subject to FDA or EU certification requirements. Mostly in dairy, confectionary, and bakery products, these natural colorants are employed in the food business in various countries. The dye is used to color margarine, ice cream, candies, cheese, butter, bakery goods, and oils since it is non-toxic, soluble in lipids, and contains trace amounts of vitamin A. In Latin America, annatto is used as a vegetable dye and a turmeric supplement to impart a red color to rice meals, seafood, and meat.

Other uses

Fodder is made from the seed and fruit press cake. Bark fibers are used to make cordage, and the wood makes excellent fuel. The Baoulé village of Côte d'Ivoire, in West Africa, paints toys, wooden masks, and doorposts using a paste made of crushed seeds mixed with lemon juice and water. Additionally, studies on the application of natural dye in solar cells, leather, and other industries have been reported. Compared to other plant biomass fuel sources, the fruit pericarp, a byproduct of the color extraction industry, exhibits a superior fuel value index, suggesting its potential as a biofuel [36].

Correlation between the biological activities, phytochemistry, and the traditional uses of Bixa orellana

Many South and Central American nations have the same traditional uses for *Bixa orellana*, indicating the plant's potential for use as a medicinal agent. Bioactive extracts from *B. orellana* included antioxidant, hypotensive, molluscicide, and antimalarial activity against A549 cells for lung cancer, as well as allergy, hypoglycemic, antifungal, antioxidant, insect

repellent, anti-gonococcal, and antivenom serum. Some of these activities are in line with traditional uses; for instance, in Brazil, the seeds are extracted for the purpose of repellent insecticide and antimalaria, and scientific studies conducted in the same nation have demonstrated the extract's ability to repel *Lutzomyia longipalpis* insects, and a study conducted in Cuba has demonstrated the pharmacological action of *Bixa orellana* against *Plasmodium berghei* [12]. Generally speaking, the information gathered for this research precludes drawing connections between the chemicals found in this species and the physiological activity examined in vivo or in vitro. However, *Bixa orellana* might be taken into consideration as a prospective source for the creation of phytopharmaceutical products due to related activities like the antiparasitic impact and the lack of mutagenesis and cytotoxic activity. To sum up, the research included in this review offers a wealth of information about the

properties of *Bixa orellana* and its possible applications. This suggests that the use of phytopharmaceuticals to treat certain illnesses whenever an antioxidant, hypotensor, or hypoglycemic action is required is a possibility. Despite this species' well-established commercial exploitation, very little is known about its medicinal properties. Further research should be done to verify additional biological activities that are supported by the common usage of *B. orellana*, given the necessity to create a safe and effective product.

Global market

The global *Bixa orellana* extract market size was worth around USD 214 million in 2021 and is predicted to grow to around USD 250.92 million by 2030 with a compound annual growth rate (CAGR) of roughly 4.9% between 2022 and 2030 as shown in **Figure 5**. This data clearly reveals that *B. orellana* will prove to be the researcher's focus in the coming years.



Fig. 5. Global market of *Bixa orellana* [37]

CONCLUSION

B. orellana has been used for thousands of years by many indigenous groups in tropical climates as a natural colorant. This study emphasizes how important the chemical components of the plant are in determining its commercial and therapeutic value. *Bixa orellana*'s complex chemical makeup not only makes it a popular natural dye but also shows off the plant's

potential uses in conventional medicine. The phytotherapeutic potential of this plant must be investigated in conjunction with the utilization of modern scientific methodologies. To fully realize *B. orellana*'s potential for both conventional and novel applications, it is essential to investigate its therapeutic qualities and implement contemporary propagation and conservation techniques.

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