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Beyond beauty: Therapeutic, nutraceutical and industrial potential of edible flowers

Dr. Sujan Singh Paikra[1*], Dinkal Chaudhary[2], MD Thajuddin[3], Dr. D Nagaraju[4], Dr. Alka Minz[5], Dr. K Michael David[6]

[1] Assistant Professor, Department of Horticulture, College of Agriculture and Research Station, Janjgir Champa, Chhattisgarh, India

[2] Division of Floriculture and Landscaping, ICAR-Indian Agricultural Research Institute, New Delhi, India

[3] Assistant Professor, Department of Botany, SRR Govt Art's & Science Degree PG College Autonomous, Karimnagar, Telangana, India

[4] Associate Professor and Head, Department of Botany, Government City College (A) Nayapul, Hyderabad, Telengana, India

[5] Guest faculty, Department of Vegetable Science, Indira Gandhi Krishi Vishwavidyalay, Raipur, Chhattisgarh, India

[6] Associate Professor, Department of Botany, SML Government Degree College, Yemmiganur, Kurnool, Andhra Pradesh, India

Corresponding Author: Dr. Sujan Singh Paikra

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Abstract

Because of their rich bioactive qualities and visual appeal, edible flowers have long been a mainstay of traditional Asian diets. Edible flowers are becoming more and more popular as possible components for food fortification and nutraceutical uses. Flavonoids, phenolics, and antioxidants are only a few of the many bioactive found in edible flowers' nutritional makeup that greatly enhance their linked health advantages. Edible flowers are positioned as a tasty addition and a crucial part of functional meals that support general health due to these chemicals' antibacterial, anti-inflammatory, and anticancer qualities. Eco-friendly edible flower cultivation promotes rural livelihoods and biodiversity conservation. Policymakers and businesses should concentrate on sustainable practices, such as carbon-neutral supply chains and water-efficient irrigation, to guarantee ethically produced materials. Asian edible flower innovation and heritage provide scalable solutions for the world's food and wellness markets.

Keywords: Edible, flower, health, bioactive, nutraceutical

Introduction

Edible flowers have long been a mainstay of many cultures' culinary customs. As a reflection of their rich cultural legacy, Asian customs have skillfully used a variety of flowers, including lotus, chrysanthemum, and hibiscus, into culinary creations. These flowers are valued for their aesthetic appeal, delicate tastes, and compounds that promote health. Despite being used for centuries, they are becoming more and more popular in contemporary cooking techniques. Research on both medicinal and non-medicinal edible plants has identified over 1729 kinds of edible flowers worldwide, belonging to 133 botanical families and 631 genera. Due to their wide range of bioactive chemicals and possible health benefits, edible flowers which were previously only used as decorations in culinary presentations have been the focus of scientific research. Edible flowers have long been a staple of many culinary traditions, enhancing dishes visual appeal and subtle flavor nuances (Kumari *et al*., 2021) [9]. Although edible flowers have been used for millennia in gastronomy, scientific interest in them has only recently increased due to improvements in analytical methods and growing knowledge of their nutritional and therapeutic qualities. Edible flowers are frequently frozen into ice cubes or used as floaters to improve the visual presentation when adding floral essences to mocktails and drinks. The fragrances, colors, textures, and tastes of edible flowers enhance the sensory experience. Due to the abundance of bioactive components found in various species, edible flowers are becoming more and more popular as functional or nutraceutical foods in addition to being regarded as a traditional culinary item. The production and processing of edible flowers included a number of crucial procedures (Jadhav *et al*., 2023) [7]. Because the blooms are completely open and at their best, harvesting is mostly done in the morning. Numerous techniques, such as wine steeping, sugaring, salting, or candying the petals, have been used to eliminate the bitter taste of many flowers. Indian traditional foods like Vazhapoo vadai (banana blossom fritters) and herbal beverages depend on flowers like marigold, jasmine, hibiscus, and banana blooms. In a similar vein, edible flowers are being included into modern fusion cuisines in South Korea and Japan, demonstrating a tasteful marriage of innovation and tradition. Edible flowers are becoming more and more popular, particularly among people who prefer natural and nutrient-rich ingredients. The market for edible flowers is expected to grow significantly across a number of culinary industries as customer preferences move more and more toward wholesome and organic options. This trend has been exacerbated by the growth of social media platforms, as customers are drawn to visually appealing displays of edible flowers (Takahashi *et al*., 2020) [12]. With their harmonious combination of sensory pleasure and nutritional richness, edible flowers hold a special place in the food and health industries. Their significant quantity of bioactive chemicals gives them possible health benefits, and their

vivid colors, delicate textures, and subtle aromas make them highly valued elements in culinary creations. Additionally, edible flowers have historical and cultural value as representations of fertility, abundance, and life that transcend culinary limits to become symbols of culinary inventiveness and cultural legacy. In health, edible flowers represent a promising source of bioactive compounds with diverse physiological effects, including antioxidant, anti-inflammatory, antimicrobial, and cardioprotective properties.

Nutritional Composition and Phytochemical Diversity

The nutritional composition of edible flowers varies according to species, cultivar, geographical location, environmental conditions, developmental stage and postharvest management. Generally, edible flowers contain moisture, carbohydrates, proteins, dietary fibre, essential minerals and several vitamins. Important minerals reported in different edible flowers include potassium, calcium, magnesium, phosphorus, iron and zinc. These nutrients contribute to normal physiological functions, metabolic activities and overall nutritional requirements. Flowers such as pumpkin, moringa, banana and drumstick blossoms are traditionally consumed in different regional cuisines and can contribute valuable nutrients to daily diets. Some species also contain appreciable quantities of vitamin-C, carotenoids and other antioxidant vitamins. Their relatively low caloric contribution, attractive colours and distinctive flavours make them suitable ingredients for developing diversified food products. The phytochemical composition of edible flowers is particularly important because it determines their antioxidant potential, colour characteristics, aroma and biological activities. Major phytochemical groups includes:

Phenolic compounds: Phenolic acids such as gallic acid, caffeic acid, ferulic acid and chlorogenic acid contribute to antioxidant activity by neutralizing free radicals and influencing oxidative processes. *Chrysanthemum morifolium* and *Clitoria ternatea* contain ferulic and caffeic acids, which have important anti-inflammatory and neuroprotective benefits. These substances are essential to human health because they improve food fortification, efficiently lower oxidative stress, and prevent chronic diseases. According to research conducted in India, Vinca Red and Vinca Pink flower extracts had the highest antioxidant capacity, whereas Gomphrena flowers had the lowest.

Flavonoids: Flavanols, a subclass of flavonoids, are abundant in edible flowers found throughout the Asian region and offer significant health benefits. Flavanols, built on a hydroxylated fla van-3-ol backbone, exhibit potent antioxidant, anti-inflammatory, neuroprotective, and cardioprotective properties due to their hydroxyl groups on C3/C5/C7/A-ring and a meta-dihydroxy B-ring. Quercetin, kaempferol, rutin, catechin and related compounds are widely distributed in edible flowers. These compounds are associated with antioxidant, anti-inflammatory and metabolic regulatory activities. Epicatechin, epicatechin gallate, procyanidins, catechin, and derivatives of epigallocatechin gallate were the flavanols most frequently found in edible flowers.

Table 1: Bioactive compounds in edible flowers and their associated health benefits

Scientific name	Bioactive compounds	Benefits
Rosa rubiginosa	Anthocyanins, flavonols, carotenoids, flavanols	Anti-inflammatory, anti-cancerous, and anti-aging
Tagetes spp.	Flavonoids, triterpenes, phenolic acids, quinones, and carotenoids	Antioxidant, gastroprotective, hepatoprotec tive, anti-inflammatory, sedative, antispasmod ic, bactericidal. Treatment of injuries, ulcers, and skin afflictions. Measles, smallpox
Chrysanthemum morifolium	Flavonoids, alkaloids, phenolic compounds	Anti-inflammatory, antimicrobial, anti human immunodeficiency virus, antioxidant, antidiabetic
Carthamus tinctorius	Flavonoids, phenylethanoid glycosides, coumarins	Lowering cholesterol, enhancing blood sugar control
Celosia cristata	Flavonols glycosides, myricetin, quer cetin, phenolic acids	Antidiabetic, anticancer, antimicrobial

Anthocyanins: These water-soluble pigments are responsible for red, purple and blue floral colours. They are particularly abundant in coloured varieties of butterfly pea, rose and pansy.

Carotenoids: Carotenoids, produced by photosynthetic organisms, are fat-soluble plant pigments. Commonly present in fruits, vegetables, and flowers, they add vivid yellow, orange, and red colors. Carotenoids contribute yellow, orange and red pigmentation and include compounds such as lutein, beta-carotene and related xanthophylls. Carotenoids also contribute to the plant's photoprotective mechanisms. Carotenoids are composed of polyene tetraterpenoid chains featuring conjugated double bonds and cyclic or oxygenated end groups. This structure imparts strong antioxidant, anti-inflammatory, anticancer, and immunomodulatory properties.

Terpenoids and Volatile Compounds: These substances contribute characteristic floral aromas and may exhibit antimicrobial and other biological activities. Chen *et al.* (2015) [2] evaluated the phenolic, flavonoid and antioxidant properties of 23 edible flowers and identified considerable variation among species. Their findings demonstrated that edible flowers represent diverse sources of bioactive compounds, although their antioxidant potential differs substantially.

Therapeutic Potential of Edible Flowers

The therapeutic importance of edible flowers is associated with their diverse phytochemical composition. Several experimental studies have investigated their potential role in protecting biological systems against oxidative stress, inflammation and metabolic disturbances. Nevertheless, most reported therapeutic effects are based on laboratory

and animal studies, and further clinical research is necessary to establish their effectiveness in humans.

Antioxidant Activity

Oxidative stress occurs when the production of reactive oxygen species exceeds the antioxidant defence capacity of biological systems. It is associated with cellular damage and contributes to the development of several chronic disorders. Edible flowers contain phenolic compounds, flavonoids and anthocyanins that may help neutralize free radicals and reduce oxidative damage. Rose, marigold, hibiscus, chrysanthemum and butterfly pea are particularly interesting because of their diverse antioxidant constituents. Coloured flowers frequently demonstrate considerable antioxidant activity due to their anthocyanin and polyphenol concentrations. Oxidative stress occurs when the production of reactive oxygen species exceeds the antioxidant defence capacity of biological systems. It is associated with cellular damage and contributes to the development of several chronic disorders. Edible flowers contain phenolic compounds, flavonoids and anthocyanins that may help neutralize free radicals and reduce oxidative damage. Rose, marigold, hibiscus, chrysanthemum and butterfly pea are particularly interesting because of their diverse antioxidant constituents. Coloured flowers frequently demonstrate considerable antioxidant activity due to their anthocyanin and polyphenol concentrations. Benvenuti *et al*. (2016) [1] reported substantial differences in antioxidant capacity and anthocyanin content among edible flower species. Their findings also indicated that highly pigmented flowers frequently exhibited greater antioxidant potential. These properties make edible flowers promising ingredients for antioxidant-rich beverages, functional foods and natural food formulations.

Anti-inflammatory Properties

Inflammation is a protective biological response, but prolonged inflammatory activity can contribute to several chronic health conditions. Certain phytochemicals present in edible flowers may influence inflammatory pathways and regulate the production of inflammatory mediators. Flavonoids, phenolic acids and other plant-derived compounds have been investigated for their ability to modulate inflammatory responses. Calendula, hibiscus and rose are traditionally used in different medicinal preparations because of their perceived soothing and anti-inflammatory properties. Lu *et al*. (2016) discussed the potential health-promoting activities of phytochemicals present in edible flowers, including their anti-inflammatory effects. However, the identification of active compounds, effective dietary concentrations and mechanisms of action requires further investigation.

Antidiabetic Potential

The increasing prevalence of diabetes mellitus has encouraged research into natural dietary ingredients that may support metabolic health. Certain edible flower extracts have demonstrated potential inhibitory effects against carbohydrate-digesting enzymes, particularly alpha-amylase and alpha-glucosidase, under experimental conditions. These enzymes participate in carbohydrate digestion and influence the release and absorption of glucose. Inhibition of their activity may help moderate postprandial glucose responses. Flowers such as hibiscus, rose and selected varieties of marigold have attracted research attention because of their polyphenolic constituents. Loizzo *et al*. (2016) [10] investigated the antioxidant and hypoglycemic properties of edible flower phytochemicals and highlighted their potential relevance to metabolic health. Nevertheless, these findings should not be interpreted as evidence that edible flowers can replace conventional diabetes treatment.

Antimicrobial and Antifungal Activities

Edible flowers contain various secondary metabolites that may exhibit antimicrobial activities against selected microorganisms. Phenolic compounds, flavonoids and essential oil constituents can interfere with microbial cell membranes, enzyme activities and other cellular processes. Extracts obtained from hibiscus, marigold, rose and other medicinally important flowers have demonstrated antimicrobial potential in laboratory investigations. These properties are particularly relevant to the development of natural food preservatives, antimicrobial packaging and botanical formulations. Fernandes *et al.* (2017) [5] reviewed the antimicrobial properties of several edible flowers and highlighted their possible applications in food preservation and health-related products. However, antimicrobial activity observed in laboratory extracts does not automatically establish effectiveness when flowers are consumed as ordinary foods.

Cardioprotective and Hepatoprotective Potential

Cardiovascular and liver-related illnesses are linked to oxidative stress, lipid metabolism, and inflammatory reactions. Through metabolic regulation and antioxidant pathways, several flower phytochemicals may have an impact on these processes. The potential effects of anthocyanins and flavonoids on oxidative pathways and vascular function make them especially intriguing. Traditionally taken as an infusion, hibiscus has drawn significant scientific interest due to its bioactive components. The cardioprotective and hepatoprotective potential of phytochemicals found in edible flowers was covered by Janarny *et al*. (2021) [8]. Even if these results encourage more research, human clinical investigations and species-specific assessment are still required.

Nutraceutical Potential of Edible Flowers

Nutraceuticals are food-derived products that provide nutritional value alongside potential physiological benefits. Edible flowers are increasingly investigated as natural sources of nutraceutical ingredients because they contain diverse phytochemicals and attractive sensory characteristics. The nutraceutical potential of flowers depends on their bioactive composition, bioavailability, processing stability and physiological effects. Anthocyanins, flavonoids, carotenoids and phenolic acids are particularly important in this context. Butterfly pea flowers are rich in characteristic blue anthocyanin pigments known as ternatins. These pigments are being explored for applications in functional beverages, natural colourants and antioxidant-rich food formulations. Hibiscus flowers contain anthocyanins and other phenolic constituents, making them suitable for herbal infusions and functional beverage development. Rose petals provide aromatic compounds and phenolic constituents and are traditionally used in syrups, beverages, confectionery and herbal preparations. Marigold flowers are important sources of carotenoid pigments,

particularly lutein, which has attracted interest in nutritional and food applications. Flavonoids, phenolic acids, and anthocyanins are the main dietary phytochemicals found in edible flowers, according to Janarny *et al.* (2021) [8]. These compounds have shown a variety of biological actions in experiments. Therefore, there may be chances to create novel functional foods by including carefully chosen edible flowers into food preparations.

Food and Beverage Applications

Edible flowers have significant potential in food processing because they provide natural colours, distinctive flavours, fragrances and nutritional components. Their incorporation into conventional and novel food products can improve sensory characteristics and create opportunities for product diversification.

Functional Beverages

Flower-based beverages represent one of the most promising applications. Hibiscus tea, rose water, butterfly pea tea and chrysanthemum infusions are examples of traditional preparations that have gained popularity in contemporary markets. Butterfly pea extracts are particularly attractive because their colour changes according to pH conditions, making them suitable for innovative beverage formulations. Hibiscus extracts provide characteristic red pigmentation and a pleasant sour flavour, while rose-based beverages contribute distinctive fragrance and sensory appeal.

Bakery and Confectionery Products

Dried petals and flower powders can be incorporated into biscuits, cakes, breads, chocolates, candies and other confectionery products. Rose petals, lavender, calendula and chrysanthemum are examples of flowers used in decorative and flavouring applications. Flower powders may also provide natural pigments and phytochemicals, although their stability during baking and storage must be evaluated.

Dairy and Fermented Products

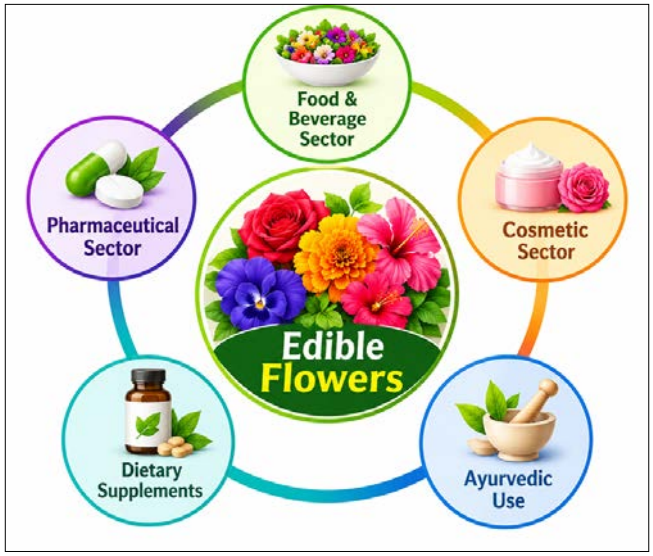
Yogurt, ice cream, flavored milk, fermented drinks, and other dairy products can all contain edible floral extracts. Their inclusion could enhance the product's novelty, color, and flavor. The potential of edible flowers as useful components in dairy, beverage, and baking formulations was highlighted by Chetia *et al.* (2025) [3]. The significance of comprehending the flavor traits and safety specifications of distinct flower species was also highlighted in their review.

Traditional and Ethnic Foods

Several edible flowers have considerable cultural and culinary importance. Pumpkin blossoms are used in stuffed and fried preparations, banana flowers are consumed in vegetable dishes, and drumstick flowers are incorporated into traditional recipes. These practices demonstrate the potential of edible flowers as components of diversified and sustainable diets.

Industrial Applications of Edible Flowers

Beyond their direct consumption, edible flowers offer opportunities for several industrial sectors, particularly food processing, pharmaceuticals, cosmetics and natural ingredient manufacturing.



N**atural Food Colourants:** The food industry is increasingly exploring plant-derived pigments as alternatives to synthetic colouring agents. Anthocyanins, carotenoids and betalains obtained from selected floral materials can provide different colour shades. Butterfly pea is particularly promising for blue pigmentation, while marigold and calendula provide yellow and orange pigments. Hibiscus and rose offer red and pink colour characteristics. These pigments can be incorporated into beverages, confectionery, desserts and other food products. However, sensitivity to temperature, light, oxygen and pH can influence pigment stability and commercial performance.

Pharmaceutical and Herbal Industries: Phytochemicals found in edible flowers can be used as raw materials to create standardized botanical extracts. Their antibacterial, anti-inflammatory, and antioxidant qualities have prompted research into possible medicinal uses. Among the flowers that are typically connected to medicinal treatments are calendula, rose, and hibiscus. The recovery and characterisation of their bioactive components can be made easier with the use of contemporary extraction procedures. However, thorough toxicological testing, consistent extraction techniques, active ingredient identification, and clinical validation are all necessary for pharmaceutical development.

Cosmetic and Personal Care Products: Floral extracts and essential oils are widely used in cosmetic and personal care formulations. Rose, calendula, chamomile and lavender are valued for their fragrance and botanical constituents. Potential applications include skin-care creams, facial cleansers, soaps, shampoos, lotions and aromatic preparations. Natural floral pigments and extracts may also provide opportunities for developing plant-based cosmetic formulations.

Natural Preservatives and Active Packaging: Certain edible flower extracts possess antimicrobial and antioxidant properties that may be useful in food preservation. Their incorporation into edible coatings, biodegradable films and active packaging materials is an emerging research area. Such materials may help delay oxidation and reduce microbial deterioration when appropriately formulated.

However, compatibility, migration, stability and effectiveness must be established before commercial application.

Agricultural and Entrepreneurial Opportunities: Commercial cultivation of edible flowers can provide additional income opportunities for horticultural growers, small-scale food processors and rural entrepreneurs. High-value flowers can be cultivated in protected environments, kitchen gardens, vertical farming systems and specialized horticultural units. The production of dried flowers, floral teas, powders, extracts and value-added food products can support agricultural diversification. In India, traditional consumption of banana blossoms, pumpkin flowers, moringa flowers and other locally available floral resources provides opportunities for developing region-specific products. Gupta *et al*. (2024) [6] discussed the medicinal and culinary importance of edible flowers of Indian origin, highlighting their potential as valuable natural resources for food and health-related applications.

Processing, Extraction and Preservation Technologies

The commercial utilization of edible flowers requires suitable processing technologies to retain their nutritional and functional properties. Fresh flowers are highly perishable because of their delicate tissues, high moisture content and susceptibility to microbial deterioration.

- **Shade drying:** A traditional technique used for reducing moisture while limiting direct sunlight exposure.
- **Hot-air drying:** Provides controlled moisture reduction but may affect heat-sensitive phytochemicals.
- **Freeze drying:** Helps preserve colour, structure and several heat-sensitive bioactive constituents.
- **Vacuum drying:** Reduces exposure to oxygen and may improve the retention of sensitive compounds.
- **Ultrasound-assisted extraction:** Enhances the recovery of selected phytochemicals by improving mass transfer.
- **Microwave-assisted extraction:** Offers rapid extraction and reduced processing time under optimized conditions.
- **Supercritical fluid extraction:** Provides opportunities for recovering selected non-polar and volatile compounds.

Chitrakar *et al.* (2019) [4] highlighted the therapeutic value and processing potential of marigold flowers, emphasizing the importance of suitable processing methods for obtaining valuable ingredients. The selection of processing technology should consider the target compound, intended application, production cost, product quality and food safety requirements.

Conclusion

Edible flowers have been employed as natural cures for a variety of illnesses by ancient societies, and contemporary science has started to recognize and validate their therapeutic potential. In conclusion, there are numerous options when investigating edible flowers as a great source of natural chemicals for culinary and medical uses. In addition to providing therapeutic benefits, these botanical resources improve food's sensory attributes and aesthetic appeal. Nonetheless, it is essential to put safety first and follow rules when producing and consuming them. Edible flowers have a great deal of culinary and therapeutic promise. They provide a wide range of tastes, textures, and nutritional profiles that enhance food while offering health advantages like anti-inflammatory and antioxidant properties, stress reduction, and digestive assistance.

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