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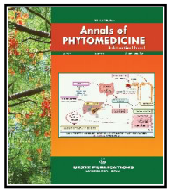

Review Article : Open Access

Phytochemicals and medicinal properties of edible flowers

Vimal Chaudhary, Bolagam Ravikumar◆, Subrat Kumar, Anant Raghunath Betkekar, Reshma Elizabath Reji and K. T. Muhammed

Department of Horticulture, Lovely Professional University, Phagwara-144411, Punjab, India

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Abstract

Every day, there is an ever growing need for delicious, high quality cuisine. The search for novel meals with beneficial impacts on human wellness has accelerated due to the growing demand for functional foods and nutraceuticals. Moreover, we view edible flowers as a novel approach to improving dietary wellness. Aside from the "alluring" aspect, edible flowers are possible sources of phytochemicals and are safe for consumption because they add new colour, texture, and freshness to any dish. The health-promoting properties of edible flowers are caused by a variety of phytochemicals, including flavonoids, anthocyanins, carotenoids, and phenolics. The most recent study on the nutritional value and health advantages of edible flowers is essential and serves as a compelling argument for their use. Few attempts have been made to use edible flowers, but those that have been made must continue to be studied to increase the employment prospects of rural populations and ensure food and nutritional security. To achieve this goal, the present review article was submitted with the goal of presenting research on edible flowers, including their various species, nutritional and phytochemical makeup, health benefits, traditional uses, pre- and postharvest technology, and functional food products integrating edible flowers, marketing, and toxicological aspects. This article promotes the use of edible flowers, a very effective source of nutrition, among consumers and the food sector.

1. Introduction

Since ancient times, flowers have been an essential component of our culture. They are also frequently described in the literature as natural wonders and symbols of beauty. They have been utilized in culinary art for several years and are not only grown for aesthetic purposes; they also have certain nutritional and biological benefits. Several regional cuisines, including Asian, European, and Middle Eastern cuisines, feature edible flowers (Grzeszczuk *et al*., 2018). Despite the good effects of blooms as another beneficial source of mineral components in the human diet, caution should be exercised in regard to the antinutritional chemicals that are present in some species. Nevertheless, many wild species and ornamentals are cultivated as edible blooms. In addition to being excellent providers of nutrients and phytochemicals, edible flowers also contain significant amounts of antioxidants, which is even more interesting (Senthilkumar *et al*., 2021). Eating edible flowers traditionally as vegetables and for their therapeutic benefits has been commonplace in the past, but more recently, scientists have focused on their nutritional and phytochemical characteristics. The results of various studies on edible flowers revealed low caloric value; high amounts of vitamins, minerals, mucilage, amino acids, fiber, carbohydrates, essential oils, and proteins; and, most importantly, phytochemicals or non-nutritive bioactive compounds, primarily phenolic compounds, more specifically flavonoids, which significantly reduce the risk of chronic illnesses such as cancer, heart disease, and obesity (Sravani, *et al*., 2024). Numerous studies have shown that edible flowers have potent medical effects, including diuretic, antidiabetic, anticancer, antianxiety, anti-inflammatory, antibacterial and immunomodulatory effects. Antioxidants are crucial for preventing several degenerative and stress-related diseases in humans. The levels of vitamin C, carotenoids, anthocyanins, and other antioxidants, as well as polyphenols, are greater in flowers than in ordinary fruits and vegetables (Sahithya *et al*., 2021). Despite its agronomic potential, the idea of eating flowers is still debated, and the majority of edible flowers are consumed by tribal residents of any nation after being harvested from natural resources (Cavaiuolo *et al*., 2013). Therefore, it is crucial to increase nutritional education to propose flowers as a common cuisine. Thus, the current work is an example of a narrative overview of scientific studies regarding different species of edible flowers, their nutritional and phytochemical composition, health benefits, traditional usage, pre- and postharvest technologies, and functional food items; marketing and toxicological factors will eventually improve edible flower acceptability as a powerful food element.

2. Common edible flowers

Worldwide, edible flowers may be found in 97 families, 100 genera, and 180 species, with the number of edible flowers varying depending on location. Although, these flowers are often eaten fresh, they can also be prepared as cakes, tea, jam, salads, drinks, or even vegetables. There are many edible flowers, making it challenging to cover them all in one study (Saloni *et al*., 2022).

Corresponding author: Dr. Bolagam Ravikumar
Assistant Professor, Department of Horticulture, Lovely Professional University, Jalandhar-144411, Punjab, India
E-mail: ravikumarbolagam@gmail.com
Tel.: +91-8897277739

Table 1: The various usages of edible flowers

Scientific name	Common name	Edible use	Medicinal uses	References
Antirhinum majus	Dog flower	Flavor	Diuretic, treatment for scurvy and liver disorders	Al Snafi, 2015
Bauhinia variegate	Orchid	Vegetable	Antidiabetic	Villavicencio *et al*., 2018
Bombax ceiba	Silk cotton tree	Vegetable	Flower is used as astringent and good for skin trouble, hemorrhoids	Rameshwar *et al*., 2014
Calendula officinalis	Pot marigold	Tea, cakes and flavor	Wound healing, hepatoprotective, anti-inflammatory, anti-HIV and anticancerous	Benvenuti *et al*., 2016
Clitoria ternatea	Butterfly pea	Dessert and beverages	Brain tonic, antidepressant, anxiolytic, sedative and anticonvulsant	Havananda and Luengwilai, 2019
Coreopsis lanceolata	Lancleaf tickseed	Tea	Anticancer, anti-inflammatory, antioxidant, antiallergenic and antileukemic	Kim *et al*., 2019
Dahlia coccinea, and *D.campanulata*	Wild dahlia	Salad, sweets and cakes decorations	Increase appetite and gastric secretion	Moldovan *et al*., 2017
Yucca elephantipes	Spineless yucca	Salad and vegetable	Diuretic and treatment for kidneydiseases	Juarez-Trujillo *et al*., 2018
Jaminum sambac	Arabian jasmine	Tea	Cancer, ulceration, uterine bleeding, skin diseases and wound healing	Kalaiselvi *et al*., 2011
Hibiscus rosa - sinensis	China rose	Tea, food supplement	Cough, fever, genitourinary troubles	Kumar and Singh, 2012
Tagetes erecta and Tagetes patula	Marigold	Salad and food colorant	Antiaging, AMD diseases, anti-inflammatory, neuroprotective	Yasukawa and Kasahara, 2013
Tropaeolum majus	Nasturtium	Tea, cakes and flavor	Diuretic, chest colds, urinary tractInfections, antiseptic and expectorant	Benvenuti *et al*., 2016
Helianthus tuberosus	Sun flower	Soup	Antibacterial and antimycotic	Scariot *et al*., 2018
Cassia fistula	Golden shower	Jams, preserves curries	Diarreha and digestive problems	

2.1 Nutritional composition of edible flowers

Over 80% of edible flowers are made up of water, while the other 20% are made up of low levels of fat, protein, total carbohydrates, minerals, and dietary fiber, depending on the kind of flower (Mlcek and Rop, 2011). The nutritional characteristics of edible flowers have been studied by a number of researchers. The moisture content of the flowers ranged from 860 to 932 g kg^{-1}. The crude protein content ranged from 113 to 275 g kg^{-1} dry matter (DM), whereas the crude fiber content ranged from 104 to 177 g kg^{-1} DM. Eating flowers have nutritional components similar to those of other plants, with a high amount of total dietary fiber and water and low levels of protein and total fat (Gonzalez *et al*., 2015). The dietary composition of petals and infusions of dahlia rose, calendula and corn flowers were studied, and the results showed that the abundant macronutrients were carbohydrates, proteins and ash. Total dietary fiber and unsaturated fatty acids (palmitic, linoleic and oleic acid) were found in the carpel and petals of Izote (*Yucca elephantipes*) flowers. Due to the presence of quinic and malic acids, respectively, calendula infusions and rose petals contributed to the highest levels of organic acids. Numerous studies have shown that flowers are excellent sources of minerals, particularly potassium and phosphorus, which are abundant in edible blooms.

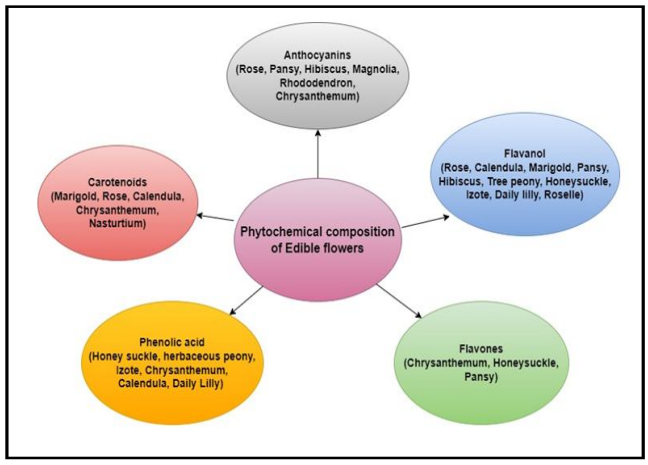


Figure 1: Phytochemical composition of edible flowers.

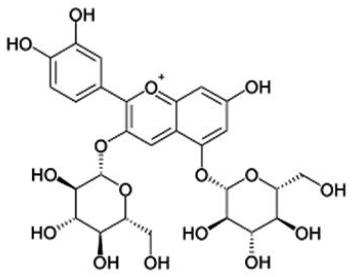
Bioactive, naturally occurring, nonnutritive chemical molecules called phytochemicals are present in plants and have therapeutic properties that are beneficial to human health. They also enhance the plant's color, smell, and flavor while protecting it from disease and

environmental damage (Moliner *et al*., 2018). The most prevalent physiologically active substances in edible flowers are phenolic acids, carotenoids, flavonoids, and anthocyanins. The presence of carotenoids and flavonoids, which also provide flowers with antioxidant activity, is responsible for floral color. Marigold phytochemicals, particularly lutein and flavonoids, are said to exert cytotoxic, anti-inflammatory, and free radical scavenging effects on a variety of malignant cells. Anthocyanins, flavonoids, carotenoids, and phenolic acids are the most prevalent phytochemicals detected in edible flowers.

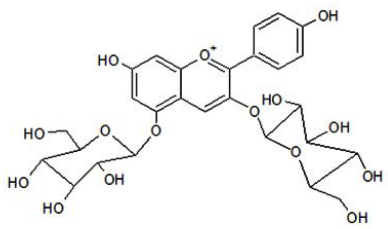
Table 2: Phytochemical constitution of edible flowers

Phytochemical	Edible flower	Main constituents
Anthocyanins	Rose	Cyanidin 3,5-diglucoside, pelargonidin 3,5-diglucoside, cyanidin 3,5-di-O-glucoside
	Pansy	Delphinidin-3-(4γ-p-coumaroyl)-rutinoside-5-glucoside (violanin), petunidin3-(4γ-p-coumaroyl)-rutinosid e-5-glucoside
	Hibiscus	Delphinidin-3-O-sambubioside and cyanidin-3-osambubioside
	Magnolia	Cyanidin-glucosyl-rhamnoside, cyanidinglucosyl-rhamnosyl-glucoside, peonidinglucosyl rhamnoside
	Rhododendron	Delphinidin, cyanidin and malvidin 3-O-arabinoside-5-O-glucosides, cyanidin3,5-di-O-glucoside
	Chrysanthemum	Cyanidin 3-glucoside and cyanidin 3-(32 2 -malonoyl) glucoside
Carotenoids	Marigold	Lutein and its derivatives
	Rose	Luteoxanthin, violaxanthin, zeaxanthin, β-carotene, lutein epoxide, lutein,
	Nasturtium	Lutein, violaxanthin, antheraxanthin, zeaxanthin, zeinoxanthin,β-cryptoxanthin,β-carotene, and β-carotene
	Chrysanthemum	Lutein, zeaxanthin, β-cryptoxanthin, 13-cis-β-carotene, β-carotene,
Flavonol	Rose	Quercetin, myricetin 3,5-di-O-glucoside, quercetin 3,4-di-O-glucoside, kaempferol 3,4-di-O-glucoside, quercetin 3-O-glucosyl-xyloside,
	Rhododendron	Isorhamnetin, quercetin, kaempferol, and their glycosides, which includedrutinoside, rhamnose, and glucoside
	Chrysanthemum	Quercetin-3- glucoside
	Pansy	Quercetin and isorhamnetin glycosides
	Daylily	Quercetin 3-O-rutinoside,
	Izote	Quercetin 3-glucoside
Flavones	Honey suckle	Luteolin
	Chrysnathemum	Acacetin, acacetin-7-O-β-glucoside, apigenin, apigenin-7-O-β-glucoside, luteolin and luteolin-7-O-β-glucoside
	Pansy	Apigenin glycosides, apigenin-6,8-di-C-glucoside, apigenin-C-hexosyl-cdeoxyhexosid
Phenolic acid	Honey suckle	Chlorogenic acid, caffeic acid, 4,5-dicaffeoylquinic acid, 3,5-dicaffeoylquinic acid
	Day lily	3-O-caffeoylquinic acid, 5-O-caffeoylquinic acids
	Chrysanthemum	3,5-dicaffeoyl quinic acid and chlorogenic acid
	Nasturtium	Neochlorogenic acid, cis-3-p-CoQA, cis-5-p-CoQA, chlorogenic acid, p-coumaroylquinic isomer
	Calendula	Caffeic acid
	Herbaceous peony	Gallic acid, ferulic acid

A. Anthocyanins



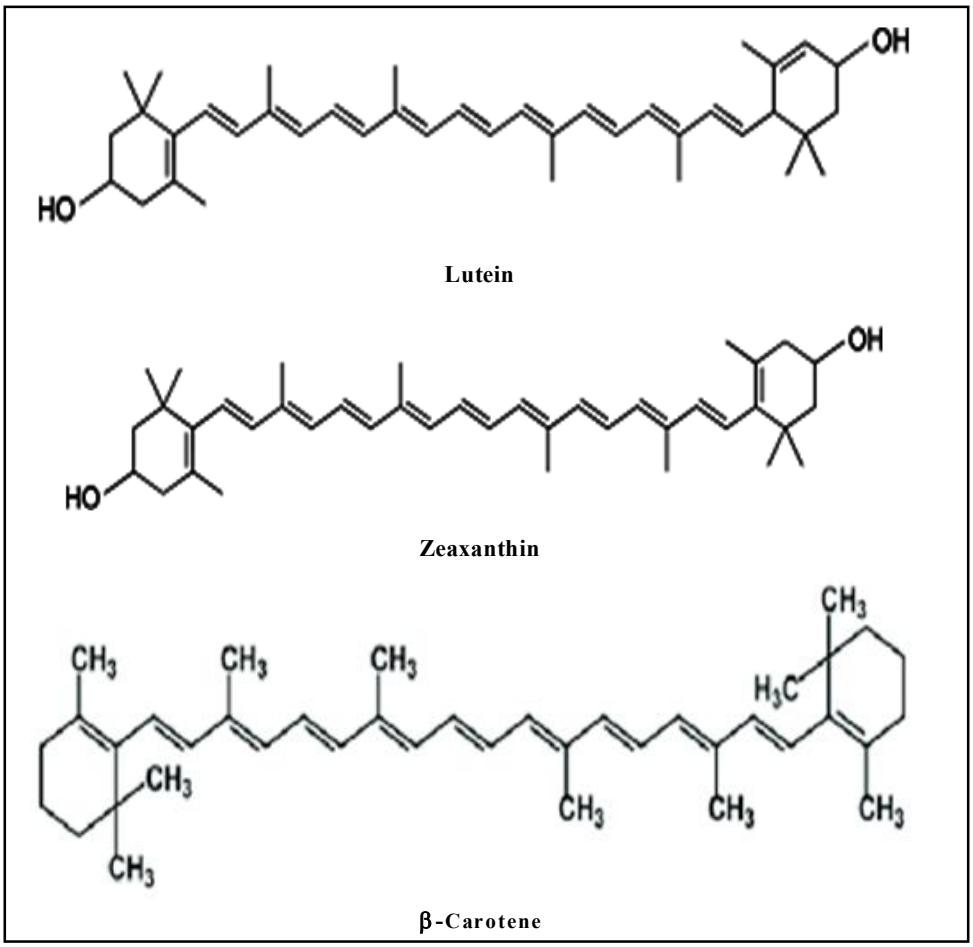
Cyanidin 3,5-O-diglucoside



Pelargonidin 3,5-diglucoside

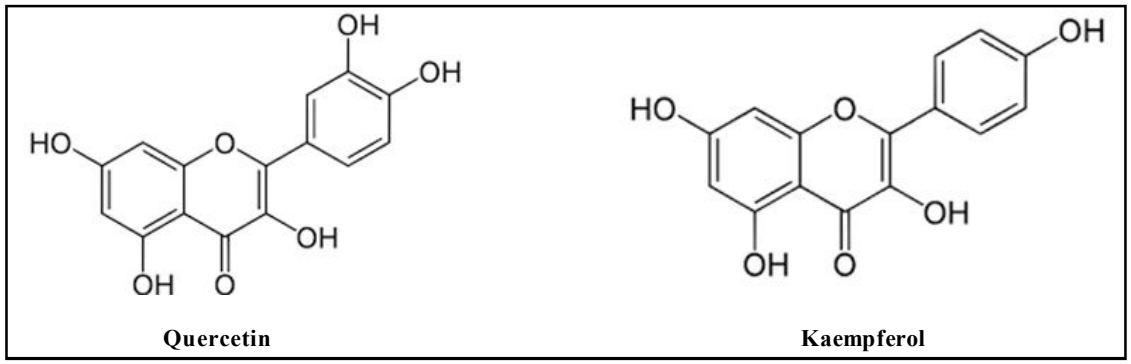
The water-soluble plant pigments known as anthocyanins, which are part of the flavonoid family, are what give flowers their stunning hues. Their unique color is influenced by pH, metal ions, and copigments (Tanaka *et al*., 2008). Anthocyanin molecules have strong potential to scavenge free radicals, and studies have demonstrated their importance in the prevention of cancer, cardiovascular disease, obesity, diabetes, and other disorders. Anthocyanin pigments are abundant in rose, chrysanthemum, hibiscus, pelargonium, petunia, and pansy flowers.

B. Carotenoids



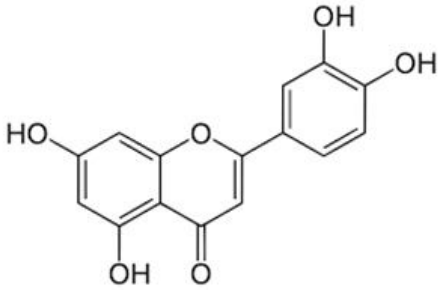
Carotenoids, which are natural pigments and are members of the isoprenoid family, give plants yellow, orange, and red hues (Wan *et al*., 2019). The amount of carotenoids in flowers varies significantly between plant species and cultivars. Since de novo carotenoids cannot be synthesized, they must be ingested through natural foods and supplements, where they play a crucial role in human and animal nutrition. Research has demonstrated that carotenoids help lower the risk of vitamin A insufficiency, cataracts, age-related macular degeneration (AMD), cancer, and cardiovascular disorders. According to several studies, marigold flowers may be a source of lutein and its derivatives, which are part of the carotenoid pigments (Paramita *et al*., 2021).

C. Flavanols

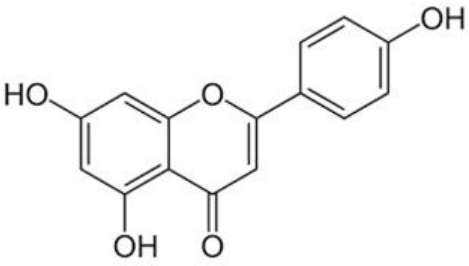


Edible flowers are filled with flavanols, a group of flavonoids that includes myricetin, quercetin, isorhamnetin, and kaempferol. (Cendrowski *et al*., 2017). They occurred in a variety of floral types, including rose, day lily, Chinese rose, roselle, magnolia flower, honeysuckle, and chrysanthemum.

D. Flavones



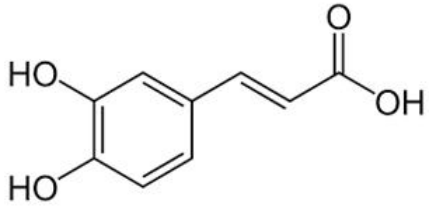
Luteolin



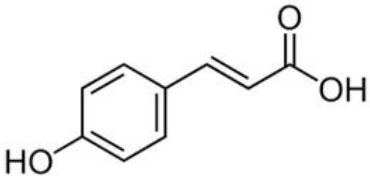
Apigenin

Edible flowers include flavones in a variety of forms, including acacetin, chrysoeriol, apigenin, luteolin, and related glucosides. Different edible flowers contain many flavones. The flowers of chrysanthemum morifolium contained large amounts of luteolin-7-glucoside. Recently, a few other flavones were discovered in chrysanthemum flowers, including acacetin, acacetin-7-O-glucoside, apigenin, apigenin-7-O-glucoside, luteolin, and luteolin-7-O-glucoside. (Ryu *et al*., 2019). Numerous studies have demonstrated that honeysuckle blossoms contain luteolin. Additionally, luteolin was found in the extracts of *Yucca* and maize flowers. Another important class of phytochemicals present in edible flowers is phenolic acids (Juarez-Trujillo *et al*., 2018). Izote (*Yucca elephantipes*) flowers contain 4-coumaric acid, rutin, ferulic acid, 4-hydroxybenzoic acid, caffeic acid, and trans-cinnamic acid. The main phenolic acids present in honeysuckle blossoms include caffeic acid, 4,5-dicaffeoylquinic acid, chlorogenic acid, and 3,5-dicaffeoylquinic acid.

E. Phenol



4-Coumaric acid



Caffeic acid

3. Health benefits of edible flowers

The health benefits of edible flowers include antioxidant, hypoglycemic, anticancer, antidiabetic, antiobesity, neuroprotective, hepatoprotective, and antimicrobial effects.

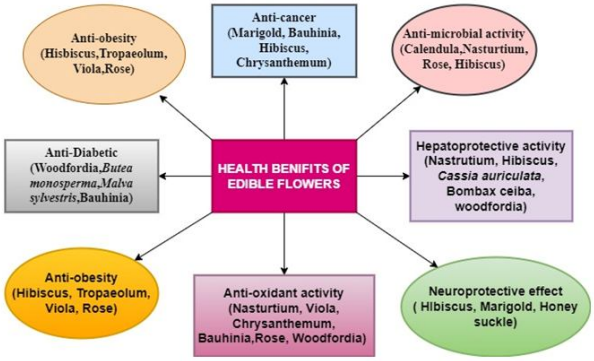


Figure 2: Phytochemicals found in flowers are what cause these effects.

3.1 Antioxidant activity

The byproducts of physiological processes occurring inside the human body are free radicals. They cause the oxidative destruction of lipids, proteins, and ultimately DNA since they are extremely reactive chemicals. This increases the likelihood of a protracted illness and causes tissue damage as well as an overall inflammatory response. To counter this activity, a healthy antioxidant defense system is beneficial. Edible flowers are recognized as sources of a number of bioactive substances, including vitamins, phenolics, and the well-known antioxidant carotenoids (Chensom *et al*., 2019). Phenolics are particularly important natural food sources because of their antioxidant potential, which has a favorable influence on chronic health issues, including diabetes, obesity, cardiovascular disease, and neurodegenerative illnesses. The antioxidant properties of *Nasturtium officinale* reduce superoxide anion, cellular lipid peroxidation, and free radical scavenging activities. Additionally, it was shown that healthy individuals who consume it regularly have less DNA damage and higher blood antioxidant levels. *Delonix regia* has antioxidant activity and phytochemicals that are best for antioxidant therapy. Extracts of flowers such as *Rosa macdub*, *Clitoria ternatea* and *Nasturtium officinale* possess high antioxidant activity (Ramakrishnan, 2018).

3.2 Anti-inflammatory activity

The human body is constantly in contact with outside elements that might harm it in many ways, irritate it, or trigger allergies that frequently result in inflammation. Any tissue can develop an intricate web of interactions between soluble substances as a protective

reaction to a traumatic, viral, postischemic, toxic, or autoimmune insult. Although, microbial infections are usually the cause, trauma or tissue damage that occurs naturally, can also cause microbial infections (Lasselin and Capuron, 2014). In most cases, the inflammatory process promotes healing and infection recovery. It is a crucial physiological reaction that protects the host against invasive infections and toxins. Symptoms of inflammation that are initially acute turn chronic and eventually cause deadly damage to host health. Some edible flowers, including honeysuckle, day lilies, chrysanthemums, and *Portulaca oleracea*, have been shown to have strong anti-inflammatory effects (Sun *et al*., 2018). The properties of the edible floral extracts were assessed utilizing a cell modeling system. The symptoms of effectively decreased asthma include eosinophil infiltration and peribronchial irritation.

3.3 Digestive health

Edible flowers contain dietary fiber, which is essential for maintaining a healthy digestive system. They help to regulate bowel movement. Flowers such as chamomile (*Matricaria chamomilla*) have anti-inflammatory properties that help to soothe the digestive tract. It can alleviate indigestion and calm an upset stomach (Arya *et al*., 2015). Edible flowers such as fennel (*Foeniculum vulgare*) are known for their carminative properties, which means that it can help to reduce the formation of gas in the digestive system. They contain prebiotic compounds that promote the growth of beneficial gut bacteria. Dandelion (*Taraxacum officinale*) flowers have been used in traditional medicine to stimulate digestion and support liver health (Tian *et al*., 2019).

3.4 Hypoglycemic effect

A metabolic condition known as diabetes mellitus is caused by a total or partial lack of insulin secretion or action. In the end, blood glucose levels rise because the body is unable to metabolize carbohydrates. Comparing edible flower extracts to glibenclamide and insulin, these extracts were able to reduce blood glucose levels that were too high (Kumar *et al*., 2015). Extracts of flowers of *Woodfordia fructicosa, Malva sylvestris, Catharanthus roseus, Butea monosperma* and *Bauhinia variegate*a have a stimulatory effect on glucose uptake. These flowers have antidiabetic properties because they block enzymes that breakdown carbohydrates, manipulate glucose transporters, regenerate beta cells, and increase insulin release.

3.5 Anticancer activity

The use of edible flowers is growing and is receiving increased attention in the therapeutic field. In the context of cancer therapy, edible flowers are essential regulators of oxidative stress and associated apoptotic/inflammatory pathways. Skin diseases such as photoaging and skin cancer have become universal concerns. The extract of wild chrysanthemum showed potential for preventing cell death and photoaging, and the bioactive compounds may halt skin disease. Petal extracts of *Bauhinia tomentosa* flowers and *Tagetes erecta* petals were found to be effective against liver cancer cell lines. *Hibiscus sabdariffa,* which is rich in flavonoids, is known for its cytotoxic potential on T47D breast cancer cells (Kaulika and Febriansah, 2019). Aqueous and ethanol extracts of rose and pea flowers have been found to have *in vitro* antioxidant and antitumor activity.

3.6 Antimicrobial activity

Nasturtium officinale plant extract is used for manufacturing fungicidal compounds. The antimicrobial activity of extracts of *Calendula officinalis* against both Gram-negative and Gram-positive bacteria has been shown (Chaudhary *et al*., 2018). Extracts of *Hibiscus rosa-sinensis* are effective against several foodborne bacterial pathogens. Ethanol, butyl alcohol and aqueous extracts of *Pedalium murex, Senna auriculate, Millingtonia hortensis and Catharanthus roseus* were found to be effective against postoperative pathogens found on wounds, such as *Pseudomonas aeruginosa, Staphylococcus aureus, Haemophilus influenzae, Streptococcus pyogenes* and *Enterococcus faecalis.*

3.7 Antiobesity effects

Obesity is caused by the accumulation of additional body fat, lipogenesis, and energy imbalance. It is linked to adipogenesis and is associated with an increase in health related issues (Ojulari *et al*., 2019). The use of bioactive substances can help people lose weight. Studies have shown that bioactive chemicals derived from *Hibiscus sabdariffa* are beneficial for combating obesity, as evidenced by an apparent decrease in body weight, a reduction in adipogenesis, and the inhibition of lipid buildup. *Portulaca oleracea* methanolic extract was shown to have antiobesity effects because it decreased glucose intake and fat accumulation.

3.8 Neuroprotective effect

The majority of neurodegenerative illnesses in humans, including Parkinson's disease (PD) and Alzheimer's disease (AD), are linked to biological aging processes. Stopping the build-up and escalation of oxidative damage is one of the ageing processes (Kim *et al*., 2009). Additionally, it has been connected to preventing neurodegenerative illnesses. Reactive oxygen species, such as hydrogen peroxide (H_2O_2) and superoxide, damage normal cells in the body, increasing oxidative stress and decreasing the activity of antioxidant enzymes. Reduced intracellular generation of reactive oxygen species (ROS) and malondialdehyde, elevated glutathione levels, and enhanced antioxidant activity of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) are all linked to antioxidant processes. These antioxidant enzymes are vital for preventing AD and PD caused by lipid peroxidation in the brain because they prevent the build-up of oxidative damage and the increase in OS (Moliner *et al*., 2018). *Lonicera japonica* has neuroprotective effects, and *Tagetes erecta* flower extracts are promising antioxidants. Rosemary (*Rosmarinus officinalis*), which contains rosmarinic acid and other antioxidants, may help protect the brain from oxidative stress and inflammation. Chrysanthemum and hibiscus contain antioxidants that exhibit potential neuroprotective effects that protect the brain from oxidative stress and inflammation.

4. Conclusion

Due to their extraordinary nutraceutical potential, edible flowers are receiving increased amounts of attention. Flowers that can be eaten are a wonderful source of phytochemicals and nutrients. In terms of phytochemical composition, phenolic acids, carotenoids, flavonoids, and anthocyanins, which are widely known for their health advantages, are the most prevalent substances found in edible flowers. Strong medicinal effects, including antidiabetic, anticancer, antianxiety, anti-inflammatory, antibacterial, hepatoprotective, and neuroprotective

effects, are found in edible flowers. The worldwide food and pharmaceutical industries are increasingly using edible flowers to create functional meals, which has created enormous opportunities for the growth of the edible flower industry. Thus, the use of edible flowers has created new opportunities for reducing hunger, diversifying agriculture, creating new sources of revenue, and saving wild edible flower species that are in danger due to human activity. The current study offers a thorough understanding of all these elements of edible flowers and will thus be a significant resource for academics working in the field of edible flowers and their application. The use of edible flowers has created new opportunities for reducing hunger, diversifying agriculture, creating new sources of revenue, and saving wild edible flower species that are in danger due to human activity. The current study offers a thorough understanding of all these elements of edible flowers and will thus be a significant resource for academics working in the field of edible flowers and their application.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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