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Edible flowers: a sustainable source of natural food ingredient

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Abstract

Edible flowers have gained popularity due to evolving dietary preferences and their recognized safety for human consumption, offering notable nutritional benefits. Utilized in culinary practices since ancient times, edible flowers are now acknowledged for their heightened health-promoting properties, expanding their market presence. Rich in nutraceutical elements like anthocyanins and antioxidants, edible flowers can be infused in beverages, incorporated into sweets or meals, and consumed in various forms. Market trends underscore the need for a comprehensive analysis of edible flowers, including their categories, origin, bioactive compounds, nutritional value, and applications in the food industry. This review explores the diverse characteristics of edible flowers, examines their functional ingredients, addresses preservation methods for extended shelf-life, and emphasizes the importance of considering potential toxicological effects. While many edible flowers offer safe consumption and health benefits, careful consideration is essential, as not all flowers are suitable for eating. This review aims to provide insights for a safe and enjoyable culinary experience.

Keywords: Edible flowers; Morphology; Health benefits; Nutritional value; Food ingredients; Flavor; Color; Antioxidants.

1. Introduction

Flowers are generally known and utilized for their radiated color and beauty. From old times, flowers have been a part of human life. Flowers are assumed as the sexual organs of a plant originating for attracting pollinators with their shape, color, and fragrance (Havananda and Luengwilai, 2019). Thus, the fundamental nature of any flower is the ornamental property. Some flowers are unique as they are secured for human consumption and thus, the flowers are termed 'edible flowers' (Shantamma et al., 2021). Consequently, the knowledge about edible flowers can relate to different streams of learning, which highlights ethnobotany, pharmacy, nutrition, aesthetics, culinary arts, and regional traditions (Chkhikvishvili et al., 2016). Compiling and documenting ancient recipes incorporating edible flowers has the potential to serve as invaluable reference material for professionals such as pharmacists, herbalists, nutritionists, chefs, and horticulturists. This resource can aid them in identifying flowers as valuable reservoirs of antioxidants and bioactive compounds (Zhou et al., 2020).

Edible flowers are utilized in different civilizations inclusive of decoration to foods regarding flavor, color, natural medicine, and art (Zhao et al., 2019). Research is being carried out to ensure the safety of edible flowers in different industries for human consumption and their safe levels are being studied. They have been conventionally applied in cooking cultures in various countries including the Middle East, Oriental, Asian, and European regions (Fragoso-Jiménez et al., 2019). Despite of under utilization of edible flowers as a part of their culinary in many countries, researchers from different fields are exploring the composition and health benefits of edible flowers. However, the safety of incorporating

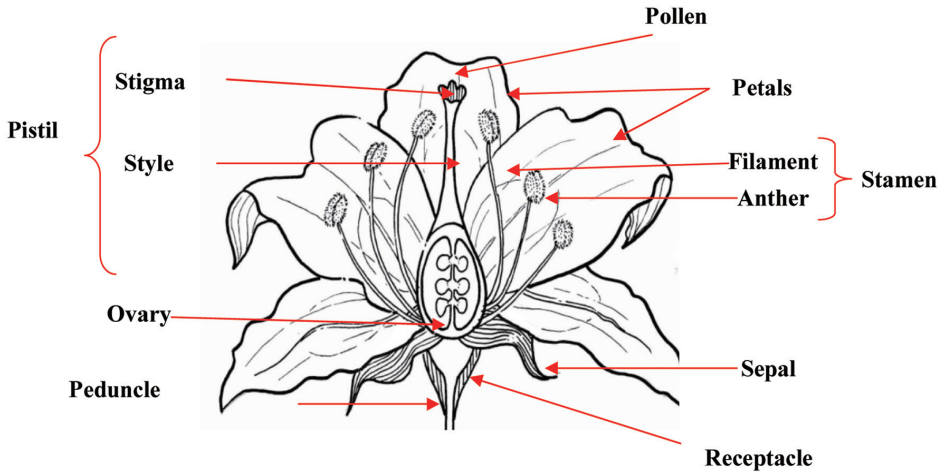

Figure 1. Standard anatomy of edible flower.

edible flowers into diets remains a challenge, primarily due to the scarcity of studies establishing safe daily consumption levels. Several species of edible flowers can be taken as a garnish or a delicacy and also as source of protein with essential amino acids. Edible flowers can play a major role in expanding the food market with unique nutritional and sensory characteristics. These flowers can be consumed in several ways as foams (molecular gastronomy), crystallized, powder, dry form (dried flowers or infusions), and fresh (Skrajda-Brdak et al., 2020). In addition to their traditional use for visual and aromatic purposes, there's a growing recognition of flowers' value as food. This shift is driven by consumers seeking natural ingredients with various health benefits. To cover the importance of edible flowers, this work discusses the major topics like morphology of flowers, nutritional value of flowers, health benefits of such flowers, their applications of edible flowers as functional food ingredients, other sources of applications, preservation of edible flowers, and toxicological effects on edible flowers. It provides a holistic understanding of the implications and considerations surrounding the consumption and utilization of edible flowers across various food and other industries.

2. Morphology of edible flowers

Over the years, the medical and nutritional properties of flowers have been identified and utilized by our human ancestors and they have been forwarded to recent generations as ethnic cuisines and herbal medicines (Harmayani et al., 2019). Before studying the functionality, and nutritional value of different edible flowers, it is required to analyze the basic anatomy of edible flowers to perform precise identification of edible flowers, distinguishing them from harmful or toxic flowers, assess the edibility of a flower, examine the medicinal and nutritional properties, and enhance culinary experiences (Navarro-González et al., 2015). The basic anatomy of an edible flower is shown in Figure 1, while its detailed structure is provided in Table 1.

Edible flowers have different parts, characteristics, and features, but here are some usual things you might find in many of them. Some of the flowers already known to be edible include species of the genus Cynodidae, *Cynodidae, Cynomysidae, R. canina, R. Gallica 'Francesa', R. canina, R. damascena* 'Alexandria', dahlia

Table 1. Functions of flower parts

Flower Part	Function	References
Petal	Attracts pollinators with its vibrant color and fragrance; enhances the aesthetic appeal of dishes.	Sindhuja (2023)
Stamen	Male reproductive organ that produces and releases pollen for fertilization.	Nicolau and Gostin (2016)
Pistil	Female reproductive organ; the ovary contains ovules, and the style connects the stigma to the ovary.	Nicolau and Gostin (2016)
Nectar Glands	Secretes nectar to attract pollinators like insects.	Jeiter et al. (2017)
Peduncle	Supports the flower and connects it to the plant.	Ganino et al. (2011)
Sepal	Protects the flower bud; resembles small leaves; sometimes edible.	Jeiter et al. (2017)
Receptacle	Base of the flower where all parts are attached.	Jeiter et al. (2017)
Ovary	Contains and protects ovules; develops into fruit post-fertilization.	Nicolau and Gostin (2016)
Anther	Upper part of the stamen that produces and releases pollen.	Chen et al. (2020)
Style	Connects the stigma to the ovary, facilitating the passage of pollen.	Zheng et al. (2018)
Stigma	Sticky surface at the pistil's tip that captures pollen during pollination.	Zheng et al. (2018)

Table 2. Functional uses and applications of edible flowers

Aspect	Flowers	Usage	References
Vibrant Colors	Marigold, Pansy, Nasturtium	Adds vibrant hues to salads, drinks, and desserts, enhancing visual appeal.	Shantamma et al. (2021)
Flavor	Hibiscus, Lavender, Chive Blossom, Rose, Jasmine, Chamomile, Dandelion, Violet, Fennel Blossom	Contributes tangy (Hibiscus), floral (Lavender), or savory (Chive) flavors to teas, desserts, sauces, and adds floral or herbal aromas to beverages.	Asif et al. (2023) Fernandes et al. (2017)
Aesthetic Enhancement	Borage, Calendula, Orchid	Used to decorate cakes, cocktails, and salads with their bright colors and intricate shapes.	Rivas-García et al. (2021)
Texture Variation	Squash Blossom, Rose Petal, Tulip Petal	Provides soft textures (Rose petals) for salads or crunchy elements (Squash blossoms) for savory dishes.	Mulík, and Ozuna (2020)
Culinary Versatility	Marigold, Lavender, Basil Blossom	Versatile in the kitchen, used raw in salads or cooked in soups, sauces, and desserts for both flavor and decoration.	Chen et al. (2020)
Health Properties	Hibiscus, Dandelion, Sunflower Petal	High in antioxidants and vitamins (e.g., Vitamin C in Hibiscus), commonly used in teas and health-focused beverages.	Fernandes et al. (2020)

(*Dahlia mignonI*), jasmine (*Ixora chinensis*), marigolds (*Tagetes erecta*), cassia flower (*Cassia siamea*), the flower of Sesbania grandiflora, Cantabria, Neem flower (*Azadirachia indica*), marshmallow (*Althea officinalis*), borage (*Borago officinalis*), dandelion (*Taraxacum officinale*), lily (*Malay sylvestris*), lotus (*Nelumbo nucifera*), turmeric (*Lilium sp*.), tulipa (*Tulipa gesneriana*), pansy (*Viola tricolor*), capuchin (*Tropaeolum majus*), mint (*Mentha sp*.), lilac (*Syringa vulgaris*), hemerocallis (*Hemerocallis sp*.), and chrysanthemum (*Chrysanthemum sp*.) (Pereira et al., 2020). Some edible flowers utilized for garnishing dishes are hibiscus, carnation, begonia, nasturtiums, Centaurea, rose, borage, and pansy. However, other edible flowers are more familiar to consumers as vegetables, like cauliflower, broccoli, and artichoke. Additionally, numerous flowers that are usually used for ornamental purposes have edible parts, which are hibiscus (*Hibiscus rosa-sinensis*), nasturtiums (*Tropaeolum majus*), rose (*Rose spp*.), borage, Centaurea (*Centaurea cyanus*), and pansy. Edible flowers from certain fruit trees can also be applied in cooking, including elderberry citrus blossoms (kumquat, grapefruit, lime, lemon, and orange) and blossoms (*Sambucus spp*.) (Fernandes et al., 2020). Furthermore, a few herb flowers are edible too, such as common sage (*Salvia officinalis*), mint (*Mentha spp*.), thyme (*Thymus vulgaris*), summer savory (*Satureja hortensis*), and alliums (garlic, chives, leeks). Although a vast range of edible flowers can be discovered around the world, only some flowers have been studied. Thus, a more comprehensive understanding of natural resources is required for increasing their acceptability as food elements and for ensuring safety. It is required to notice that not all the flowers do not meet the primary criteria of edible flowers including being, harmless, non-toxic, and giving nutritional value. Hence, flowers should have these qualities to be taken for human consumption.

Edible flowers have general characteristics like taste, health benefits, attractive nature, colors, better nutritional values such as antioxidants, minerals, vitamins, and sensory values, safer to eat as not having harmful allergens or toxins, cultural diversity, and ornamental use. Customers may reject flowers that have visual flaws. Thus, the acceptability of edible flowers by consumers depends on several factors like consumer profiles, flower characteristics, species, and social groups and how they are recommended. Edible flowers come in a wide variety of shapes, sizes, colors, and flavors, yet they share several common characteristics, as described in Table 2.

These features impact whether the flower is appropriate for consumption or not. However, individuals will accept the food based on factors like psychological state, religion, ethnicity, health conditions, location, income, gender, and age (Rivas-García et al., 2021). Edible flowers are usually featured in gourmet dishes, but the gender, income, and education of persons will affect their willingness to consume edible flowers. In general, the color and appearance of the flowers play a major role in getting consumer's interest whereas their probable health benefits are generally observed as lower significant. To conclude, the acceptability of edible flowers can vary among individuals and different groups based on their experiences, beliefs, and attitudes toward unconventional or novel food sources. Researchers and the food industry need to understand and study these factors to promote the broader use of edible flowers in culinary applications (Kumari et al., 2021).

3. Nutritional value of edible flowers

The edible flowers have a better nutritional profile, providing dietary features like protein and fiber when including lower fat. Thus, they accomplish several dietary requirements, inclusive of vegans and vegetarians (Fernandes et al., 2017). Edible flowers come up with health improvements via bioactive compounds, and sensory and nutritional contributions. As discussed before, edible flowers have diverse parts like stigma, nectar, petals, pollen, and so on. It is suggested to eat the flowers after removing the stamens and styles of the flowers before consumption. Pollen is assumed as a rich source of carotenoids, flavonoids, amino acids, carbohydrates, proteins, and fat (Sotelo et al., 2007). However, it is consumed at a lower rate owing to the several allergic reactions correlated with it. The majority of edible flowers consist primarily of water (over 80%). The amount of total sugars, minerals, and dietary fiber varies across different flower types. Additionally, their fat and protein content is notably low. Flowers predominantly consist of moisture, including a huge portion by weight. Macronutrients like fibers and proteins are comprised of flowers (Grzeszczuk et al., 2014). This nutritional value changes among diverse parts of the flower. For example, pollen has unsaturated and saturated fatty acids, carbohydrates, and protein. Petals are identified for their richness in an-

tioxidants, minerals, and vitamins, whereas nectar is loaded with terpenoids, alkaloids, and sugar (Navarro-González et al., 2015). The nutrient value of edible flowers can vary significantly depending on the specific type of flower and its growing conditions. However, a general overview of the potential nutrients found in edible flowers is provided in Table 3.

It's important to note that the nutrient content of edible flowers can vary depending on factors such as species, growing conditions, and preparation methods. Additionally, edible flowers are often consumed in small quantities as garnishes, flavorings, or decorative elements rather than as primary sources of nutrition. As such, their contribution to overall nutrient intake may be relatively small compared to other foods in the diet.

The nutritional value of certain edible flowers is assessed based on energy, ash, protein, fat, fiber, carbohydrate, and moisture content. The energy of edible flowers denotes the overall calory consumption to offer different levels of energy (Rop et al., 2012). The mineral concentration in edible flowers is reflected by ash content comprising required nutrients. Most of edible flower has protein that is required for tissue growth and repair. Edible flowers often have lower fat content contributing to their complete nutritional profile. Some dietary fiber is included in edible flowers, which promotes gut health and aids digestion. Edible flowers offer a source of energy known as carbohydrates. The amount of water that exists in the flowers is referred to as the moisture content, which impacts their overall texture composition.

The nutritional composition of different edible flowers is discussed in Table 4. Aloe vera has 8.6 g of ash, 16.4 g of protein, 4.2 g of fat, 13.8 g of fiber, 56.8 g of carbohydrates, and a moisture content of 89.5 g (Asif et al., 2023). Aloe vera has a bit of ash, which contains important minerals that help our body work well. Aloe vera has lots of moisture and thus, it keeps hydrated. It has higher carbohydrates and offers a quick energy boost. The fiber content in aloe vera increases the digestive benefits whereas the lower fat in aloe vera may not be utilized as the dietary fat. Similarly, the nutritional value of some flowers is explained here. Saffron contains approximately 5–7 g of ash, 12–13 g of protein, 5–8 g of fat, and 4–5 g of fiber, and the carbohydrate content is not specified. Its moisture level falls between 10–12 g. These nutritional values provide insights into the nutritional components of each edible flower to give a better nutrientional value.

4. Health benefits of edible flowers

Edible flowers contain bioactive compounds that offer various health benefits, such as antioxidant, anti-inflammatory, anticancer, and neuroprotective effects. Their mineral content, antioxidant activity, and nutritional value make them important for human health (Mulík and Ozuna, 2020). These flowers help combat oxidative stress, which contributes to conditions like cancer, diabetes, and heart disease. Rich in fiber, amino acids, minerals, and vitamins, edible flowers have long been part of diets to boost health (Harmayani et al., 2019). This review explores the benefits of edible flowers, detailing their scientific names, origins, bioactive compounds, and food industry applications, as summarized in Table 5.

A detailed description of the attributes and benefits of some edible flowers is listed as follows. Aloe Vera, known scientifically as *Aloe barbadense miller*, originates from Asian countries. It contains essential proteins, amino acids, anthraquinone, and anthrone, along with carbohydrates and vitamins. Aloe vera finds use in the food industry for prolonging shelf life and preservation. Moreover, it contributes to maintaining healthy body weight, cholesterol levels, and blood sugar levels (Asif et al., 2023; Shantamma et al., 2021). The Mango Flower, *Mangifera indica*, hailing from Southern Asia, boasts gallotannins, polyphenols (including phenolic, xanthones, and flavonoid acids), and carotenoids. Culinary applications include its incorporation in pickles. Medicinally, mango flower juice addresses various health conditions like heat exhaustion, dehydration, diarrhea, high cholesterol, and diabetes (Martin and He, 2009).

The Lotus Flower, *Nelumbo nucifera*, originating from Asia and Australia, offers carotenoids, amino acids, organic acids, and alkaloids. It features prominently in salads, soups, and desserts. Traditionally, it has been used for its beneficial effects on the spleen, and kidneys, and as a cardiotonic agent (Wang et al., 2003). The Purple Coneflower, *Echinacea purpurea*, native to North America, contains polyacetylenes, Rosmarinus acid, phenolic acid, aklomides, caffeic acid, and dichroic compounds. It extends to the tea industry and imparts protective attributes against cancer, inflammation, anxiety, and sugar irregularities. It strengthens the immune system, potentially reducing the risk of various diseases (Chiou et al., 2017). The Paris Daisy, scientifically known as *Argyranthemum frutescens*, hails from East Asia and Northeastern Europe. Rich in flavonoids and phenolic acids, it enhances the nutritional value of food products and holds a place in traditional medicine for conditions like diabetes and high blood pressure (Rop et al., 2012). These edible flowers offer a variety of bioactive compounds that come with potential health benefits and can be used in a range of culinary creations (Figure 1). Nonetheless, it's important to consult with a healthcare professional before making major changes to your diet, even though these flowers show promising advantages.

5. Edible flowers as functional food ingredients

Edible flowers are becoming well-known as unique foods, which are better for human health. These flowers contain phenolic compounds, which help to boost immunity and also cure stress-related issues (Domínguez-Perles et al., 2010). It also helps to protect the heart, liver, and brain, which assists in fighting against cancer and also boosts metabolism. Few flowers have medicinal properties to kill bad bacteria. These flowers might also assist in anti-aging properties for handling stress and inflammation. Due to the potential health benefits, high pigment concentration, bioactive properties, nutritional characteristics, and unique composition and concentration of antioxidant compounds, edible flowers are assumed to be functional foods (Rezende et al., 2019). It is also recognized as a functional food owing to its medicinal properties, culinary experimentation with the infusion of special colors, textures, and flavors into dishes, boosting the immune system, diabetes management, protection against neurodegenerative diseases, anti-inflammatory conditions, and weight management. The benefits of edible flowers are outlined as follows:

5.1. Low cost

Edible flowers acquire promising functions for serving as practical and affordable functional elements results in several advantages because they increase their existence in easy and natural accessibility that cooperatively locates them as a cost-efficient choice for incorporating into a wide range of products (Trivellini et al., 2007). The flowers are easily available as there are a lot of flowers around. It makes it simpler to use or grow them with a lot of resources. Thus, the overall cost related to attaining flowers can be

Table 3. Overview of nutrients and health benefits in edible flowers

Nutrient Category	Nutrient	Edible Flower Examples	Key Functions and Benefits	References
Antioxidants	Anthocyanins	Red, Purple, and Blue Flowers: Pansy, Violet, Blue Butterfly Pea	Protect against chronic diseases, provide anti-inflammatory benefits, and support cardiovascular health.	Teixeira et al. (2023)
	Carotenoids	Bright-Colored Flowers: Marigold, Calendula, Nasturtiums	Support eye health, reduce oxidative stress, and improve immune function.	Crupi et al. (2023)
	Flavonoids	Rose, Hibiscus, Lavender	Provide anti-inflammatory properties, improve cardiovascular health, and reduce the risk of chronic diseases.	Janarny et al. (2021)
	Polyphenols	Chamomile, Dandelion, Elderflower	Reduce inflammation, protect cardiovascular health, and prevent oxidative damage.	Maleš et al., (2022)
Vitamins	Vitamin C	Roses, Hibiscus, Elderflower	Acts as a powerful antioxidant, protecting cells from free radical damage and boosting overall immunity.	Mercola (2021)
	Vitamin E	Sunflower Petals, Pansy	Protects cellular membranes from oxidative damage, promotes skin health, and improves immune response.	Uniyal and Kumar (2024)
	Vitamin A	Calendula, Nasturtiums	Essential for promoting healthy vision, immune function, skin health, and cell growth.	Bohra and Visen, (2022)
	Vitamin B (Folate - B9)	Chive Blossoms, Nasturtiums	Necessary for DNA synthesis, cell division, and fetal development during pregnancy.	Socha et al., (2021)
	Vitamin E	Sunflower Petals, Pansy	Protects cells from oxidative damage, supports immune function, and maintains healthy skin and eyes.	Uniyal and Kumar (2024)
	Vitamin K	Borage, Chamomile	Vital for blood clotting, bone metabolism, and regulating calcium in the body.	Maleš et al., (2022)
Minerals	Calcium	Borage, Chamomile	Essential for bone health, muscle contraction, and blood vessel function.	Franklin (2024)
	Copper	Rose Petals, Violets	Aids in connective tissue formation, energy production, and brain health.	Reddy and Pullaiah (2024)
	Iron	Nasturtiums, Pansy	Vital for hemoglobin formation, oxygen transport, and preventing anemia.	Matejić et al., (2024)
	Magnesium	Calendula, Sunflower Petals	Involved in energy production, muscle function, nerve function, and reducing inflammation.	Bohra and Visen, (2022)
	Potassium	Hibiscus, Elderflower	Regulates fluid balance, supports muscle contractions, and helps maintain normal nerve function.	Maleš et al., (2022)
	Zinc	Chive Blossoms, Nasturtiums	Important for immune function, wound healing, and DNA synthesis.	Socha et al., (2021)
Other Nutritional Benefits	Dietary Fiber	Dandelion, Violet, Hibiscus	Supports digestion, promotes healthy cholesterol levels, and helps regulate blood sugar.	Jakubczyk et al., (2022)
	Fatty Acids	Sunflower Petals, Nasturtiums	Low in fatty acids but may contain small amounts of heart-healthy unsaturated fats.	Shukla et al., (2019)
	Calories	Marigold, Chamomile, Pansy	Adds flavor, color, and texture to dishes without contributing significant calories.	Janarny et al. (2021)
	Protein	Dandelion, Nasturtiums, Pansy	Contains small amounts of protein (1–4%), contributing to muscle repair, tissue building, and overall growth.	Teixeira et al. (2023)

Table 4. Nutritional value of diverse edible flowers

Flower name	Nutritional value (g/100 g dry weight)							Reference
	Energy	Ash	Protein	Fat	Fiber	Carbohydrate	Moisture	
Aloe vera	–	8.6	16.4	4.2	13.8	56.8	89.5	Asif et al. (2023)
Saffron	–	5–7	12–13	5–8	4–5	–	10–12	Cardone et al. (2020)
Pansies	197	4.4	16.8	5.0	9.3	64. 5	87.2	Kozicka and Hallmann (2023).
Coral tree	–	10.73	12.53	1.69	13.69	56.64	87.6	Mulík and Ozuna (2020)
Agave	–	5.65	11.58	1.58	9.65	71.58	88.1	Mulík and Ozuna (2020)
Artichoke	47	1.13	3.27	0.15	5.4	10.51	84.94	Zayed et al. (2020)
Fuchsia (Dancing lady)	–	–	–	–	–	–	91.6	Benvenuti et al. (2016)
Mexican marigold	117	4.8	7.9	1.9	55.4	85.2	83.4	Singh et al. (2020)
French marigold	–	–	–	–	–	–	90.6	Chkhikvishvili et al. (2016)
Rugosa rose	465	4.2	4.3	1.3	–	90.2	71.6	Kim et al. (2022)
Tea Rose	–	–	2.6	–	–	–	89.9	Lijun et al. (2020)
Jasmine	35–40	1–2	1	0.5	1–2	6–8	90	Kalemba and Cierniak (2019)
Chamomile	–	9.5	15.3	7.8	–	54.74	9.6	Helal et al. (2021)
Lavender	100–120	10–15	3–5	0.5–1	20–30	20–30	15	Mélanie et al. (2022)
Hibiscus	35–40	10–15	2–3	1	6–8	7–8	85	Bahuguna et al. (2018)
Rosemary	–	11.78	14.3	–	14.26	45.84	–	Moliner et al. (2020)
Broccoli	84	15.4	52.3	0.2	28.0	10.0	92.6	Domínguez et al. (2010)
Cauliflower	75	13.9	8.0	2.9	21.7	43.6	93.4	Rezende et al. (2019)

considerably lower and distinguished from other unique ingredients. Therefore, the widespread availability of edible flowers gives the cost-efficiency. The requirement for transportation and distribution networks is minimized owing to the availability of flowers in local environments, which minimizes extra costs (Rezende et al., 2019). Edible flowers are inexpensive and useful because they are everywhere, easy to get, and can fit into different things. Using them in products can make things better for customers without making things too expensive to make. But it's important to be careful when getting the flowers and using them in case some people are allergic.

5.2. Easy Availability

Edible flowers can be widely spread around the world, which has increased the potential of using edible flowers for different purposes and applications (Fernandes et al., 2020). They are easily available because they can be seen in various locations without many complications. This accessibility is increased owing to their natural existence in gardens, fields, and also in the wild. They sometimes grow naturally in diverse regions and can be pursued in open fields or gardens.

5.3. Antioxidant effect of edible flowers

Edible flowers have several pharmaceutic and therapeutic components in them like natural antioxidants in the type of proanthocyanins (condensed tannins), anthocyanidins (malvidin-3-galactoside, malvidin-3-glucoside), tannins, hydroxycinnamic acid, hydroxycinnamic acid, phenolic acids (p-hydroxybenzoic acid and vanillic acid, ferulic acid, protocatechuic acid, gallic acid, homogentisic acid), flavonoids (catechin, quercetin, rutin, cyanidin-3, catechin, epicatechin), coumarins, glycosides, several phenolic compounds regarding flavones (luteolin, acaciin), natural pigments (anthoxanthin, lycopene, betalains, anthocyanins), and Vitamin E (Tocopherol) (Benvenuti et al., 2016; Kalemba-Drożdż et al., 2019). In general, edible flowers act as a huge source of antioxidants and thus, it has been a segment of both medicine and food. It serves as a probable protective agent that is accountable to confer antioxidative effects through the elimination of reactive oxygen species generated during metabolic endogenous activities. Edible flowers exhibit antioxidant activity that is considered to be dependent on the compositions of phytochemicals like anthocyanins, alkaloids, flavonoids, and phenols (Fernandes et al., 2018; Kozicka and Hallmann, 2023). Along with these compounds, the edible flowers can explore neuroprotective, anti-cancer, anti-obesity, and anti-inflammatory effects. Although flowers contain better natural nutrients, it is not verified explicitly and needs careful evaluation. The value range acquired for the antioxidant activity differs broadly among flowers. Though, it is complicated for comparing the antioxidant activity outcomes among flowers while using a similar technique (Siriamornpun et al., 2012). Through the valuable sources of antioxidants in edible flowers, they are utilized in the diet for increasing the health benefits of humans.

5.4. Color

Consumers recognize flowers by different attractive properties like color, smell, taste, shape, size, and appearance. From the existing

Table 5. Bioactive compounds and health benefits of various edible flowers

Flower Name	Scientific Name	Origin	Bioactive Compounds	Application in the Food Industry	Health Benefits	Clinical Trials	References
Aloe Vera	Aloe barbadensis miller	Asian countries	Proteins, amino acids, anthraquinones, carbohydrates, vitamins	Preserves food and packaging, increases shelf life	Maintains body weight, cholesterol, blood sugar levels, and supports skin health.	Tested on HaCaT and NHDF cells, showing reduced inflammation and improved skin health.	Razia et al. (2022), Asif et al. (2023), Shantamma et al. (2021)
Mango Flower	Mangifera indica	Southern Asia	Gallotannins, polyphenols, carotenoids	Used in pickles and culinary applications	Treats heat exhaustion, dehydration, high cholesterol, and diabetes.	Antioxidant activity and cholesterol reduction demonstrated in mouse trials.	Masibo and He (2009)
Banana Flower	Musa sapientum L	Asian countries	Glutathione reductase, ascorbate peroxidase, catalase, phenols, flavonoids	Used in curry, soups, and pickles	Improves bowel movements, gut health, and alleviates diabetes, heart pain, asthma, and ulcers.	Tested on BPH-1 cell line, showing antiviral and antioxidant effects.	Ara and Chandra (2019)
Rose	Rosa spp.	Asia	Tannins, carotenoids, flavonoids, phenolic acids	Jams, syrups, beverages, nutritional supplements	Reduces inflammation, supports tumor reduction, and combats age-related macular degeneration.	Clinical trials on human blood cells showed significant reduction in inflammation.	Wang (2023), Maria et al. (2018)
Lotus Flower	Nelumbo nucifera	Asia and Australia	Carotenoids, amino acids, organic acids, alkaloids	Salads, soups, desserts	Treats spleen and kidney disorders, supports heart health, and is used as a cardiotonic agent.	Skin-soothing, antioxidant, and anti-inflammatory properties confirmed in human trials.	Ho et al. (2023)
Cape Jasmine	Gardenia jasminoides	Asia	Iridoids, crocin, gardenoside, genipin, geniposide	Tea products	Treats hypertension, hepatic disorders, inflammation, and jaundice.	Anti-inflammatory, anti-diabetic, and anti-tumor properties confirmed in animal studies.	Yin and Liu (2018), Chen et al. (2020)
Moringa Flower	Moringa oleifera	Northwestern India	Flavonoids (kaempferitrin, rhamnetin, kaempferol), quercetin, alkaloids	Dietary supplements, health products	Treats urinary infections, rheumatism, common cold, and improves skin health.	Effective in treating urinary infections in clinical trials.	Maurya and Singh (2014)
Tuberose Flowers	Polianthes tuberosa L	Mexico	Heptacosene, pentacosene, methyl anthranilate, benzyl benzoate, methyl isoeugenol	Essential oil extraction	Relieves coughs, cramps, depression, convulsions, nervous afflictions, anger, anxiety, diarrhea, and stress.	Anticancer and antibacterial activities tested with silver nanoparticles on A431 cell lines.	Alghuthaymi et al. (2023), Fragoso-Jiménez et al. (2019)

(continued)

Table 5. *(continued)*

Flower Name	Scientific Name	Origin	Bioactive Compounds	Application in the Food Industry	Health Benefits	Clinical Trials	References
Butterfly Pea	Clitoria ternatea	Tropical Asia	Phenols, flavonoids, saponins, steroids, glycosides, tannins, alkaloids	Beverages, desserts	Fights cancer, reduces inflammation, improves memory function.	Flavonoid-rich extracts inhibited cancer cell growth and reduced inflammation in mice.	Adhikary et al. (2018), Havananda and Luengwilai (2019)
Purple Coneflower	Echinacea purpurea	North America	Polyacetylenes, rosmarinic acid, phenolic acids, alkaloids	Tea products	Boosts immune system, reduces anxiety, inflammation, and helps fight colds.	Anti-inflammatory effects demonstrated in mouse macrophage cell line trials.	Chiou et al. (2017)
Paris Daisy	Chrysanthemum (Argyranthemum frutescens)	East Asia, Northeastern Europe	Flavonoids, phenolic acids	Enhances nutritional value in food products and nutraceuticals	Treats swelling, dizziness, headaches, cold, and type-2 diabetes.	Potential inhibition of cancer cell growth in human colon and lung carcinoma cell lines.	Pehlivan Karakas et al. (2017), Rop et al. (2012)
Sunflower	Helianthus annuus L	Asia and North America	Polyphenols, amino acids, fatty acids	Treats kidney diseases, asthma, rheumatism, pulmonary troubles	Supports digestion, brain function, bone health, and speeds up wound recovery.	Topical application for diaper rash demonstrated faster wound recovery and reduced inflammation.	Liang et al. (2013)
Hibiscus	Hibiscus rosa-sinensis	China, Japan, Pacific islands	Polysaccharides, flavonoids, anthocyanins	Natural food colorant for syrups, cocktails, and tea	Lowers blood pressure, supports heart health, and is rich in antioxidants.	Antioxidant effects and improved heart health confirmed in cell line trials.	Bahuguna et al. (2018)
Marigold	Tagetes erecta	Southern America	Carotenoids, zeaxanthin, lutein	Garnish for pasta, salads, soups, and natural food coloring	Heals wounds, reduces age-related macular degeneration, improves skin health, and has anti-inflammatory properties.	Anti-inflammatory effects confirmed in colon and lung cancer cell line trials.	Vallisuta et al. (2014), Siriamornpun et al. (2012)
Lavender	Lavandula spp.	Mediterranean region	Chlorophylls, anthocyanins, carotenoids	Natural flavoring for chewing gum, baked goods, candy, ice cream, beverages	Treats insect bites, skin sores, burns, digestive problems, headaches, and has anti-inflammatory effects.	Anti-inflammatory and antioxidant properties demonstrated in prostate cancer cell line trials.	Zhao et al. (2017)
Pansies	Viola × wittrockiana	South America	Rosmarinic acetate, linalool, linalyl acid	Used in cocktails, tea, and baked goods	Calming, helps relieve headaches, and improves digestion.	Positive results in relaxation and digestive aid observed in Caenorhabditis elegans model.	Kozicka and Hallmann (2023)
Chamomile	Matricaria recutita	Europe, Africa, Asia	Phenolic acids, quercetin, apigenin	Oils, extracts, flavored tea blends, baked goods	Improves digestive health, sleep quality, and reduces anxiety.	Anticancer and antioxidant effects demonstrated in rat trials.	Helal et al. (2021)

studies, the color of edible flowers plays a major role in preparing food (Zayed et al., 2020). Mostly, consumers often choose blue, orange, and yellow flowers. Color plays a major role in food and nutrition, which is an essential organoleptic property of edible flowers. The existence of anthocyanins and carotenoids is essential for the color of flowers. In these flowers, it is generally observed that the levels of total flavonoids also aim to increase while the amount of anthocyanins goes up. Edible flowers have a considerable impact on the color of food (Begum and Deka, 2019; Chen et al., 2020). While using edible flowers in the food recipes, their natural pigments depict beautiful and better colors, which increases the attractiveness of food. Flower color also imparts antioxidant ability to the flowers. Moreover, the natural colors produced by edible flowers do not harm human health and so, it is highly recommended.

5.5. Taste

Taste is the primary factor of the food industry, which influences the overall satisfaction, choices, and preferences of consumers. The edible flowers play a major role in increasing taste and enhancing the culinary experience in diverse ways (Liang et al., 2013). The composition of edible flowers comprises compounds, which increase the taste of food regarding phytochemical and phenolic compounds. These properties offer a pleasant and unique flavor to the food by edible flowers. in addition, the taste provided by edible flowers increases the refreshing and pleasant sensation regarding higher antioxidant ability (Massantini et al., 2022). To conclude, the taste of foods is increased by edible flowers, which increases the better food industry applications.

5.6. Antimicrobial activity of flowers

The edible flowers can fight against harmful microorganisms affected by particular compounds that trouble their growth. Antimicrobial properties originate from the phenolic compounds along with the specific compounds (Chen et al., 2020). In addition, antimicrobial effects are displayed by proteins. It gives a promising performance in human health and also extends the shelf life of preserved foods. Some edible flowers are recognized for their antimicrobial attributes, attributed to substances that inhibit the growth of particular microorganisms (Takahashi et al., 2020). Moreover, the existence of specific microorganisms exhibiting compounds decides the antimicrobial activity in edible flowers. Generally, those compounds show from the phenolic group. It is more probable for edible flowers to consider as a source of antimicrobial compounds for both the food and the human body, which serves to prevent food from deteriorating rapidly (Bahuguna et al., 2018). The presence of antimicrobial activity in edible flowers offers several advantages inclusive of food preservation, minimized growth of viruses, bacteria, and other pathogens to handle diseases, natural preservation of foods, less food waste, and enriching culinary experience.

5.7. Production of value-added products using edible flowers

In recent decades, edible flowers have primarily noticed their place as a culinary ingredient in food, owing to their bright colors, soft textures, unique flavors, and powerful nature (Petrova et al., 2020). Edible flowers have been added to beverages and salads like wines and tisanes. Extracts from these flowers have been used for enhancing flavors and aromas in several products. In addition, flowers and their extracts have maximized their roles to make spreads like dressings, marinades with vinegar, and also create food preserves or butter (Takahashi et al., 2020). It is highlighted that edible flowers are vastly considered in terms of culinary elements and also sources of value-added goods. Consequently, innovative products like flower-infused yogurt are also made (Pires et al., 2018). Several products like honey, liquors, vinegar, sauces, jellies, and jams have been produced from these edible flowers (Mlcek and Rop, 2011). Moreover, a vast range of beverages, candies, salads, ice cubes, and teas are prepared in diverse flavors based on the properties of edible flowers. Some flowers like Cardoon (*Cynara cardunculus*) are used for making cheese-related processes (Rampanti et al., 2023). The vegetable rennet is served from the enzymes extracted from these flowers. This collaborative usage of these flowers gives better probable applications and versatility of edible flowers across several product and culinary practices.

To conclude, edible flowers are taken as functional ingredients of foods owing to several properties like low cost, easily available, antioxidant effect of edible flowers, color, taste, polyphenols present in flowers, antimicrobial activity of flowers, and produce several value-added products.

6. Applications of edible flowers

As edible flowers are loaded with more nutrients and health benefits, they are being used for different applications since ancient times for various purposes (Mlcek and Rop, 2011) which are discussed in detail.

Cultural Traditions: Diverse cultures and civilizations had unique usage for edible flowers by considering their practices, values, and beliefs (Singh et al., 2020). These traditional values generally reflect the local resources and environment. *Aesthetic Practices*: Edible flowers are utilized in several aesthetic and personal adornment practices for body art, accessories, and garlands (González-Barrio et al., 2018). *Beverages*: Flowers were infused into beverages like wines and teas for lending specific fragrances and flavors. These infused-floral drinks are beneficial for both health improvements and taste. *Garnishes and decorations*: Edible flowers are utilized as decorative elements for ancient gatherings and feasts. These are applied for embellishing banquets, food displays, and tables to create visually stunning appearances (Kelley et al., 2003). *Natural Dyes*: Natural dyes are created for artworks, textiles, and fabrics, where their attractive colors add aesthetic value to crafts and clothing. *Fragrances and aromatics*: Flowers are employed for creating fragrant waters, scented oils, and perfumes, which aid to enhance living spaces and personal grooming. *Symbolism and Rituals*: Edible flowers are useful in religious and cultural practices to signify renewal, fertility, and purity. *Medicinal Practices*: The edible flowers mostly have medicinal properties for addressing several diseases and promoting health. *Culinary Delights*: Edible flowers are incorporated into ancient cultural cuisines for adding flavor, color, and visual enchantment to dishes. These flowers are utilized as ingredients in desserts, teas, salads, and soups to increase the sensory experience of food (Takahashi et al., 2020). *Edible flowers as food additives*: Flowers are utilized as flavorants and preservatives. They are commonly applied for tasting and for imparting aroma to pickled goods, vinegar, and oils. Throughout history, people have used edible flowers in different ways, including in their culture, cooking, and everyday life.

Edible flowers are widely being used in cosmetic and perfumery industries, as natural food colorants, used to garnish dishes due

to their beauty, attractiveness, and pleasant color, also added as new food additives due to different nutraceutical and non-toxicity properties, they are also used in pharmaceutical industry because of phenolic compounds present in them, used in industry of confectionary for decorating cakes, cookies, and so on for different reasons, daily meal preparations owing to diverse and potent smells, colors, textures for increasing scent and flavors, and in beverage industries for making wines, sauces, and tisanes for flavoring beverages (dos Santos et al., 2018). Edible flowers are also beneficial as non-food applications as raw materials for creating cosmetic products, natural dyes, and perfumes. Especially, Jasmine flowers (*Oleaceae* family) are utilized in the fragrance industry owing to their rich composition of several aromatic compounds. Moreover, the edible flowers play an vital role in preparing essential oils (Zhao et al., 2019). Additionaly flowers that are rich in pigments usually results in producing vibrant colors by promoting the dye industries, and synthetic dyes in cosmetics like lipsticks.

7. Preservation techniques of edible flowers inorder to increase their shelflife

Consumers are hugely adopting natural food products owing to concerns regarding probable artificial compounds or harmful effects. Edible flowers possess a biodegradable nature, generally owing to their higher water content and the issues related to the preservation of them over long durations (Zhao et al., 2019). Though, handling this issue focuses on integrating efficient processing techniques. Strengthening the production of edible flowers and their preservation in natural or better ways requires suitable methodologies, which focus on increasing the basic nutritional attributes, bioactive qualities preservation, managing costs, prolonging shelf life, and upholding freshness. Another major issue is their restricted availability due to their short lifetime and seasonal cycles (Shantamma et al., 2021). Regarding these complications, innovations are highly required. Some studies show that dehydrated or crystallized methods are suggested as the new solution. Even though new techniques give better preservation of perishable foods, their incorporation gives higher cost implications and also restricts their commercial viability. On the other hand, inventive drying schemes such as drying, microwave drying, dehumidified drying, vacuum drying, and hybrid drying are appearing as more suitable ways to retain the nutritional values and bioactive components in edible flowers. In general, edible flower preservation is performed with three major stages like pre-process, processing, and packaging methods.

- *Pre-processing*: It aims for handling and storing the flowers from the point of harvest until they reach the processing unit.
- *Processing*: During this stage, appropriate methods are employed to process the flowers, giving utmost importance to retaining their freshness and quality.
- *Packaging*: Finally, post-processing storage is complemented by suitable packaging methods to ensure extended shelf life and preservation.

Despite various attempts to extend the shelf life of edible flowers, they remain delicate and prone to sensitivity towards heat and other processing methods. The major complication lies in the preservation of edible flowers with their "fresh-like" qualities regarding the maintenance of freshness with traditional physical, biological, and chemical preservation techniques. These methods can impact the nutritional properties and sensory attributes of flowers. These preservation techniques are classified into two major groups of traditional and modern methods. Traditional methods involve processes like dehydration and osmosis, while modern methods encompass refrigeration, freezing, and freeze-drying (Falla et al., 2022). These methods can be further categorized based on their outcomes like preserving flavor, preservation of color and flavor while altering shape, and preserving shape, color, and flavor. Moreover, methods can be divided into short-term, medium-term, and long-term preservation methods considering the duration of preservation. Each approach has its advantages and considerations, with the ultimate goal of preserving the distinct qualities of edible flowers while extending their use and availability. Non-thermal techniques like pulsed electric field technology, ultrasound, high hydrostatic pressure (HHP), and irradiation have increased the interest as efficient alternatives for edible flower preservation (Siriamornpun et al., 2012). More recently, a range of advanced extraction techniques has emerged, including enzyme-assisted extraction, pulsed-electric field extraction, ultrasound-assisted extraction, microwave-assisted extraction, pressurized liquid extraction, and supercritical fluid extraction. These new techniques are being studied for solving the intricacies of preserving the unique qualities of edible flowers amidst the demands of food processing and preservation.

A few preservation techniques are discussed as follows. *Drying*: It is a simpler way of preserving flowers. Dried flowers are used in making infusions and tea-like beverages, which give colors to baked goods. It is used as decorative substances on candies, cookies, or cakes. While the drying process may cause a change in the flower's appearance, it succeeds in partially maintaining both the color and flavor of the flowers over extended durations, sometimes lasting up to a year or even longer (Harmayani et al., 2019). Several drying techniques are used in the preservation of edible flowers, which are osmotic drying, sun drying, cool wind drying, vacuum microwave drying, freeze drying, and hot-air drying. Also, a combination of these techniques can be used. The traditional way of preparing tea petals is heat-based drying techniques like sun-drying and hot-air drying schemes. Though, it comes with several challenges of probable unrequited modifications in the nutritional and biochemical composition of edible flowers. Yet, the impact of these changes can be mitigated by strategically designing and selecting the appropriate drying process, considering specific flower attributes, available technology, and economic considerations. *Cold preservation*: Recently, cold preservation techniques like refrigeration and freezing are often utilized in preserving edible flowers. Refrigeration serves as a means to extend the longevity of flowers. Frozen edible flowers are utilized in application in bakery items and ice creams, contributing to a range of culinary delights. Cold storage or refrigeration assumes to a possible tool for increasing the shelf life of edible flowers (Kelley et al., 2003). Though, there is a possibility of occurring chilling injuries in some flowers. It helps in bacterial cell destruction and preserving the nutritional, chemical, and physical properties of flowers. Although the freezing process does reduce the activity of autolytic enzymes, it doesn't completely deactivate them. To enhance preservation, a pre-treatment like blanching can be applied to render enzymes inactive before freezing. *Low-temperature storage*: Storing flowers at low temperatures can efficiently delay their aging process by slowing transpiration and respiration rates. In addition, it reduces enzymatic activities, which thus postpones microbial and autolytic spoilage. *High hydrostatic pressure technology*: HHP is a non-thermal technology, which is the primary preservation method used for operating in the pressure range of 200–800 MPa, and the process conditions may differ depending on the applications like the development of organic or preservative-free products, nutritional and functional characteristics of the product, microbial inactivation in raw and fresh commodities, and inactivation of the enzymes (Falla et al.,

Table 6. Analysis of different preservation techniques of edible flowers with their respective uses.

Flower Name	Preservation Technologies	Processing Conditions & Storage Conditions	Uses of Edible Flowers in the Food Industry	References
Nasturtium (Tropaeolum majus)	Ionizing and Irradiation	Room temperature, 60°C (0.5, 0.8, and 1 kGy)	Used in meals, drinks, and salads	Koike et al. (2011)
Heartsease (Viola tricolor)	Low Temperature	Polyethylene bags, stored at −2.5, 0, 2.5, 5, 10, 20°C	Colorant in drinks, salads, soups	González et al. (2015)
Rose (Rose spp.)	Drying Techniques	Vacuum drying (27, 37, and 47°C, 0.004–0.007 kPa), freezing at −35°C for 2 and 4 h	Rose sugar, syrup, beverages, soups, and teas	Maria et al. (2018)
Pansies (Viola × wittrockiana)	HHP (High Hydrostatic Pressure)	75 MPa, for 5 and 10 min	Used in the tea industry	Kozicka and Hallmann (2023)
Marigold (Tagetes erecta)	Drying	Freeze Drying (FD) for 48 hours, Hot Air Drying (HA) at 60°C for 4 hours, and FIRHA Drying	Used in stews, soups, and salads	Siriamornpun et al. (2012)
Purple Coneflower (Echinacea purpurea)	Drying Techniques	Freeze drying at −55°C for 4 days, Vacuum Microwave Drying (1 kW) for 47 minutes, air drying at 70°C	Used in salads	Khallaf et al., (2022)
Borage (Borago officinalis)	Low Temperature & HHP	Polyethylene bags, −2.5 to 20°C, 75, 150, and 450 MPa, 5 and 10 min	Used in soups and beverages	Khallaf et al., (2022)
Artichoke (Cynara scolymus)	Low Temperature	Stored at 0–10°C for 14 days	Regulates blood pressure, treats fatty liver	Zayed et al. (2020)
Blue Pea Flower (Clitoria ternatea)	Drying	Dried for 45 days	Colorant in yogurts, functional beverages, drink powders	Harmayani et al. (2019)
Cornflower (Centaurea cyanus)	HHP (High Hydrostatic Pressure)	75, 100, 200, and 300 MPa, for 5 min	Used in infusions, as a garnish, and as a colorant	Fernandes et al. (2018)
Paris Daisy (Chrysanthemum spp.)	Drying	Flowers placed in water for 16 hours at room temperature, stored for 3 days	Applied in herbal teas, toppings for snacks, and creams	Fukai et al. (2018)
Lavender (Lavandula)	Drying	Dried for 0 h, 24 h, 48 h, and 72 h after harvest	Used in beverages, chewing gum, baked goods, and ice cream	Rathore and Kumar (2022)

2022; Garzón and Wrolstad, 2009). HHP can increase the shelf-life of the product while retaining its nutrients, functionality of compounds, stability, and natural freshness. While using mild HHP treatments, the sensory property may be damaged regarding the incomplete inactivation of microbes and enzymes. In these conditions, the incorporation of several methodologies can acquire synergistic advantages, which result in lower maintenance and operational costs, and shorter treatment times. *Irradiation*: The shelf-life and safety of perishable foods are enhanced by the food irradiation technique, which is an economically suitable technique. Irradiation treatments are being beneficially utilized in the food industry for microbial decontamination, delay ripening, sprout inhibition, and insect disinfestations. It delays cell death to manifest physiological and biochemical properties (Koike et al., 2011). The food is exposed to ionizing radiations in the irradiation process majorly emitting electron gamma or beam radiations. The irradiation procedure does not affect the nutritional composition. The irradiated flowers have shown higher antioxidant activity and higher phenolic content. *Photosynthetic Photon Flux Density (PPFD)*: PPFD is a metric of the amount of light energy available for photosynthesis per unit area, generally evaluated in micromoles of photons per square meter per second (μmol/m^2/s). PPFD is significant in the context of edible flower preservation because it directly impacts the metabolic processes within the flowers (Fukai et al., 2018; Janarny et al., 2021). To keep edible flowers fresh and maintain their good qualities like color, taste, and overall freshness, it's important to provide them with the right amount of light energy. This can be done by controlling how much light they get while they're stored or being prepared. Making sure they get enough light energy helps their natural processes without harming them. So, knowing and controlling the light they receive is important to make sure edible flowers stay fresh and nice.

The recent studies on edible flower preservation are discussed in Table 6 with their processing conditions, along with the uses of edible flowers. This table serves as a comprehensive reference, summarizing recent findings on how edible flowers can be effectively preserved. This information is valuable for those interested in maintaining the quality and usefulness of edible flowers over time. Flowers are in different appearances and forms and are often consumed fresh. Thus, it is required to preserve edible flowers for making different culinary dishes and also in diverse ornament applications. The most common postharvest methods applied to these edible flowers are refrigeration, drying, canning in sugar, and preservation in distillates. If preservation techniques are utilized,

then they must not harm the quality of flowers. Thus, the current research specifies that food irradiation and High Hydrostatic Pressure (HHP) technologies are utilized for extending the shelf life of edible flowers (Chen et al., 2020). The freeze-drying method is generally applied for acquiring positive outcomes in preparing culinary recipes and also in food industries as it preserves the nutritional effects and valuable bioactive compounds. In addition, it is required to analyze and consider several preservation and post-preservation techniques for consistent nutritional outcomes.

8. Toxicological effects of edible flowers

The edible flower consumption may have potential risks, which is studied in different research works as some can trigger adverse reactions or allergies whereas some edible flowers are nutritious, and safe, in which some flowers may not be appropriate for consumption (Koike et al., 2011). Identification of safe options for consumption is complicated. Generally, flowers from nurseries, florists, or garden centers are not to be consumed as they are usually treated with harmful pesticides (dos Santos et al., 2018). Few flowers could lead to conditions like asthma, allergies, and even complicated outcomes. Wild edible flowers are not a safer option for consumption owing to the contamination risks from neighbor poisonous plants. Edible flowers may have contaminants like chemical compounds and bacteria (Janarny et al., 2021). Moreover, edible flowers are assumed to be safe in some categories such as fruity flowers (e,g, vegetable, herb, citrus, and banana flowers) and ornamentals (e.g., daylilies, begonia, and calendula). Safer consumption is ensured by the identification and processing methods, where some recent studies show it is required to analyze gender, occupation, education beliefs, and knowledge about edible flowers for consumption (Bahuguna et al., 2018; Kim et al., 2000). Though, the toxic nature of some flowers is persisted. Poisonous flowers may contain harmful substances like pathogenic microorganisms, sulphite, or dimethoate.

9. Conclusion and future scope of edible flowers

For thousands of years, several cultures have prepared their food with flowers by conventional techniques. These flowers also have some medicinal values and thus, it is required to evaluate the potential of edible flowers. This review offers insights into nutritional benefits, health advantages, and better safety, preservation, and processing conditions of edible flowers. The edible flowers give a better flavor to the dishes, aromas, delightful flavors, bioactive properties, and nutrition to humans. Although flowers are used in cooking for a long time, modern approaches can produce more valuable products and increase their shelf life. Though, the study of processing and preservation has generally studied particular edible flowers alone, which leaves room for broader exploration. While edible flowers have great potential, there's not enough scientific research to fully develop value-added products using them. However, new ways of drying and packaging them could change how we use flowers in the products we buy. To ensure safe use, rules should be made. Using flowers in food has a lot of possibilities and can help both now and in the future.

Conflict of interest

The authors declare no conflict of interest in this paper.

References

Adhikary, R., Sultana, S., and Bishayi, B. (2018). Clitoria ternatea flower petals: Effect on TNFR1 neutralization via downregulation of synovial matrix metalloproteases. J. Ethnopharmacol. 210: 209–222.

Alghuthaymi, M.A., Patil, S., Rajkuberan, C., Krishnan, M., Krishnan, U., and Abd-Elsalam, K.A. (2023). *Polianthes tuberosa*-mediated silver nanoparticles from flower extract and assessment of their antibacterial and anticancer potential: An in vitro approach. Plants 12(6): 1261.

Amrouche, T.A., Yang, X., Capanoglu, E., Huang, W., Chen, Q., Wu, L., Zhu, Y., Liu, Y., Wang, Y., and Lu, B. (2022). Contribution of edible flowers to the Mediterranean diet: Phytonutrients, bioactivity evaluation and applications. Food Frontiers 3: 592–630.

Asif, M., Zahid, T., Ahmad, B., Noor, S., Naqvi, A., Yasmeen, T., Imran, M., Akhtar, M.U., Zaman, M., and Shafique, H. (2023). Therapeutics Characteristics and Application of Aloe vera: A Review. RADS J. Food Biosci. 2(1): 56.

Bahuguna, A., Vijayalaxmi, K.G., and Suvarna, V.C. (2018). Formulation and Evaluation of Fresh Red Hawaiian Hibiscus (Hibiscus rosa-sinensis) Incorporated Valued Added Products. Int. J. Curr. Microbiol. Appl. Sci. 7(08): 4282–4290.

Begum, Y.A., and Deka, S.C. (2019). Chemical profiling and functional properties of dietary fibre rich inner and outer bracts of culinary banana flower. J. Food Sci. Technol. 56(12): 5298–5308.

Benvenuti, S., Bortolotti, E., and Maggini, R. (2016). Antioxidant power, anthocyanin content and organoleptic performance of edible flowers. Sci. Hortic. 199: 170–177.

Bohra, M., and Visen, A. (2022). Nutraceutical Properties in Flowers. Research Anthology on Recent Advancements in Ethnopharmacology and Nutraceuticals. IGI Global, pp. 1036–1054.

Burlou-Nagy, C., Bănică, F., Jurca, T., Vicaș, L.G., Marian, E., Muresan, M.E., Bácskay, I., Kiss, R., Fehér, P., and Pallag, A. (2022). *Echinacea purpurea* (L.) Moench: Biological and pharmacological properties. A review. Plants 11(9): 1244.

Cardone, L., Castronuovo, D., Perniola, M., Cicco, N., and Candido, V. (2020). Saffron (Crocus sativus L.), the king of spices: An overview. Sci. Hortic. 272: 109560.

Chen, L., Li, M., Yang, Z., Tao, W., Wang, P., Tian, X., Li, X., and Wang, W. (2020). *Gardenia jasminoides* Ellis: Ethnopharmacology, phytochemistry, and pharmacological and industrial applications of an important traditional Chinese medicine. J. Ethnopharmacol. 257: 112829.

Chen, Q., Xu, B., Huang, W., Amrouche, A.T., Maurizio, B., Simal-Gandara, J., Tundis, R., Xiao, J., Zou, L., and Lu, B. (2020). Edible flowers as functional raw materials: A review on anti-aging properties. Trends Food Sci. Technol. 106: 30–47.

Chiou, S.Y., Sung, J.M., Huang, P.W., and Lin, S.D. (2017). Antioxidant, Antidiabetic, and Antihypertensive Properties of Echinacea purpurea Flower Extract and Caffeic Acid Derivatives Using in Vitro Models. J. Med. Food 20(2): 171–179.

Chkhikvishvili, I., Sanikidze, T., Gogia, N., Enukidze, M., Machavariani, M., Kipiani, N., Vinokur, Y., and Rodov, V. (2016). Constituents of French Marigold (*Tagetes patula* L.) Flowers Protect Jurkat T-Cells against Oxidative Stress. Oxid. Med. Cell. Longevity 2016: 216285.

Crupi, P., Alba, V., Gentilesco, G., Gasparro, M., Ferrara, G., Mazzeo, A., and Coletta, A. (2023). Viticultural climate indexes and their role in the prediction of anthocyanins and other flavonoids content in seedless table grapes. Horticulturae 10(1): 28.

Domínguez-Perles, R., Martínez-Ballesta, M.C., Carvajal, M., García-Viguera, C., and Moreno, D.A. (2010). Broccoli-derived by-products - a promising source of bioactive ingredients. J. Food Sci. 75(4): C383–C392.

dos Santos, A.M.P., Silva, E.F.R., dos Santos, W.N.L., da Silva, E.G.P., dos Santos, L.O., Bruna, B.R., Maria, M.C., and dos Santos, W.P.C. (2018). Evaluation of minerals, toxic elements and bioactive compounds in rose petals (Rosa spp.) using chemometric tools and artificial neural networks. Microchem. J. 138: 98–108.

Falla, N.M., Caser, M., Demasi, S., and Scariot, V. (2022). Heat Pump Drying of Lavender Flowers Leads to Decoctions Richer in Bioactive Compounds. Agronomy 12(12): 3162.

Fernandes, L., Casal, S., Pereira, J.A., Saraiva, J.A., and Ramalhosa, E. (2017). Edible flowers: A review of the nutritional, antioxidant, antimicrobial properties and effects on human health. J. Food Compos. Anal. 60: 38–50.

Fernandes, L., Casal, S., Pereira, J.A., Saraiva, J.A., and Ramalhosa, E. (2018). Effects of different drying methods on the bioactive compounds and antioxidant properties of edible Centaurea (*Centaurea cyanus*) petals. Braz. J. Food Technol. 21: e2017211.

Fernandes, L., Casal, S., Pereira, J.A., Saraiva, J.A., and Ramalhosa, E. (2020). An Overview on the Market of Edible Flowers. Food Rev. Int. 36(3): 258–275.

Fragoso-Jiménez, J.C., Tapia-Campos, E., Estarron-Espinosa, M., Barba-Gonzalez, R., Castañeda-Saucedo, M.C., and Castillo-Herrera, G.A. (2019). Effect of supercritical fluid extraction process on chemical composition of Polianthes tuberosa flower extracts. Processes 7(2): 60.

Fukai, S., Yasukouchi, M., and Kawasaki-Narumi, T. (2018). Postharvest quality management of cut marguerite flowers. Acta Hortic. 1213: 67–73.

Ganino, T., Rapoport, H.F., and Fabbri, A. (2011). Anatomy of the olive inflorescence axis at flowering and fruiting. Sci. Hortic. 129(2): 213–219.

Garzón, G.A., and Wrolstad, R.E. (2009). Major anthocyanins and antioxidant activity of Nasturtium flowers (Tropaeolum majus). Food Chem. 114(1): 44–49.

Ghasemi, S., and Yousefbeyk, F. (2024). A Review on Phytochemicals and Biological Properties of Golden Chamomile (Matricaria aurea). Res. J. Pharmacogn. 11(4): 79–91.

Goldberg, K.H., Yin, A.C., Mupparapu, A., Retzbach, E.P., Goldberg, G.S., Liu, L.-C., Lin, Y.-H., Lin, Y.-C., Ho, C.-T., Hung, C.-M., Way, T.-D., and Bau, D.-T. (2018). Banana flower extract suppresses benign prostatic hyperplasia by regulating the inflammatory response and inducing G1 cell-cycle arrest. In Vivo 32: 1373–1379.

González-Barrio, R., Periago, M.J., Luna-Recio, C., Garcia-Alonso, F.J., and Navarro-González, I. (2018). Chemical composition of the edible flowers, pansy (Viola wittrockiana) and snapdragon (Antirrhinum majus) as new sources of bioactive compounds. Food Chem. 252: 373–380.

Grzeszczuk, M., Wesołowska, A., and Jadczak, D. (2014). Nutritional value of chive Edible Flowers. Acta Sci. Pol., Hortorum Cultus 10(2): 85–94.

Harmayani, E., Anal, A.K., Wichienchot, S., Bhat, R., Gardjito, M., Santoso, U., Siripongvutikorn, S., Puripaatanavong, J., and Payyappallimana, U. (2019). Healthy food traditions of Asia: Exploratory case studies from Indonesia, Thailand, Malaysia, and Nepal. J. Ethnic Foods 6: 1.

Havananda, T., and Luengwilai, K. (2019). Variation in floral antioxidant activities and phytochemical properties among butterfly pea (*Clitoria ternatea* L.) germplasm. Genet. Resour. Crop Evol. 66(3): 645–658.

He, F.J., and MacGregor, G.A. (2008). Beneficial effects of potassium on human health. Physiol. Plant. 133(4): 725–735.

Hudson, J.B. (2012). Applications of the phytomedicine Echinacea purpurea (purple coneflower) in infectious diseases. J. Biomed. Biotechnol. 2012: 769896.

Janarny, G., Gunathilake, K.D.P.P., and Ranaweera, K.K.D.S. (2021). Nutraceutical potential of dietary phytochemicals in edible flowers—A review. J. Food Biochem. 45(4): e13642.

Jakubczyk, K., Koprowska, K., Gottschling, A., and Janda-Milczarek, K. (2022). Edible flowers as a source of dietary fibre (total, insoluble and soluble) as a potential athlete's dietary supplement. Nutrients 14(12): 2470.

Jeiter, J., Hilger, H.H., Smets, E.F., and Weigend, M. (2017). The relationship between nectaries and floral architecture: a case study in Geraniaceae and Hypseocharitaceae. Ann. Bot. 120(5): 791–803.

Kalemba-Drożdż, M., Modrzewski, A.F., and Frycz, A. (2019). Antioxidant and genoprotective properties of extracts from edible flowers. Agnieszka Cierniak. J. Food Nutr. Res. 58(1): 42–50.

Kaulmann, A., and Bohn, T. (2014). Carotenoids, inflammation, and oxidative stress. Curr. Nutr. Food Sci. 10(2): 144–151.

Kelley, K.M., Cameron, A.C., Biernbaum, J.A., and Poff, K.L. (2003). Effect of storage temperature on the quality of edible flowers. Postharvest Biol. Technol. 27: 341–344.

Kim, H.O., Durance, T.D., Scaman, C.H., and Kitts, D.D. (2000). Retention of caffeic acid derivatives in dried Echinacea purpurea. J. Agric. Food Chem. 48(9): 4182–4186.

Kim, E., Mok, H.K., and Hyun, T.K. (2022). Variations in the antioxidant, anticancer, and anti-inflammatory properties of different Rosa rugosa organ extracts. Agronomy 12(2): 238.

Koike, A.C.R., Araújo, M.M., Costa, H.S.F., Almeida, M.C., Lúcia, A., and Villavicencio, C.H. (2011). Tolerance of edible flowers to gamma irradiation. 2011 International Nuclear Atlantic Conference.

Kozicka, M., and Hallmann, E. (2023). Identification and Quantification of Bioactive Compounds in Organic and Conventional Edible Pansy Flowers (Viola × wittrockiana) and Their Antioxidant Activity. Plants 12(6): 1264.

Kumari, P., Ujala, and Bhargava, B. (2021). Phytochemicals from edible flowers: Opening a new arena for healthy lifestyle. J. Funct. Foods 78: 104375.

Liang, Q., Cui, J., Li, H., Liu, J., and Zhao, G. (2013). Florets of sunflower (Helianthus annuus L.): Potential new sources of dietary fiber and phenolic acids. J. Agric. Food Chem. 61(14): 3435–3442.

Martin, M., and He, Q. (2009). Mango bioactive compounds and related nutraceutical properties-A review. Food Rev. Int. 25(4): 346–370.

Maleš, I., Pedisić, S., Zorić, Z., Elez-Garofulić, I., Repajić, M., You, L., Vladimir-Knežević, S., and Dragović-Uzelac, V. (2022). The medicinal and aromatic plants as ingredients in functional beverage production. J. Funct. Foods 96: 105210.

Massantini, R., Cardarelli, M., and Frangipane, M.T. (2022). Quality, Sensory Analysis and Shelf Life of Ready-To-Use Fresh-Cut Zucchini Flowers Stored in Different Film Packaging. Agriculture (Switzerland) 12(11): 1818.

Matejić, J.S., Dragićević, A.V., Jovanović, M.S., Žarković, L.D., Džamić, A.M., Hinić, S.S., and Pavlović, D.R. (2024). Plant Products for Musculoskeletal, Respiratory, Circulatory, and Genitourinary Disorders in Eastern and South-Eastern Serbia–Folk Uses Comparison with Official Recommendations. Rec. Nat. Prod. 18(1): 1–52.

Maurya, S.K., and Singh, A.K. (2014). Clinical efficacy of Moringa oleifera Lam. stems bark in urinary tract infections. Int. Scholarly Res. Not. 2014(1): 906843.

Mavandi, P., Abbaszadeh, B., Emami Bistgani, Z., Barker, A.V., and Hashemi, M. (2021). Biomass, nutrient concentration and the essential oil composition of lavender (Lavandula angustifolia Mill.) grown with organic fertilizers. J. Plant Nutr. 44(20): 3061–3071.

Mercola, J. (2021). Upgrade Your Immunity with Herbs: Herbal Tonics, Broths, Brews, and Elixirs to Supercharge Your Immune System. Hay House, Inc.

Mlcek, J., and Rop, O. (2011). Fresh edible flowers of ornamental plants - A new source of nutraceutical foods. Trends Food Sci. Technol. 22(10): 561–569.

Moliner, C., López, V., Barros, L., Dias, M.I., Ferreira, I.C., Langa, E., and Gómez-Rincón, C. (2020). Rosemary flowers as edible plant foods: phenolic composition and antioxidant properties in Caenorhabditis elegans. Antioxidants 9(9): 811.

Mulík, S., and Ozuna, C. (2020). Mexican edible flowers: Cultural background, traditional culinary uses, and potential health benefits. Int. J. Gastronomy Food Sci. 21: 100235.

Navarro-González, I., González-Barrio, R., García-Valverde, V., Bautista-Ortín, A.B., and Periago, M.J. (2015). Nutritional composition and antioxidant capacity in edible flowers: Characterisation of phenolic compounds by HPLC-DAD-ESI/MSn. Int. J. Mol. Sci. 16(1): 805–822.

Nicolau, A.I., and Gostin, A.I. (2016). Safety of edible flowers. Regulating safety of traditional and ethnic foods. Academic Press, pp. 395–419.

Pehlivan Karakas, F., Ucar Turker, A., Karakas, A., Mshvildadze, V., Pichette, A., and Legault, J. (2017). *In vitro* cytotoxic, antibacterial, anti-inflammatory and antioxidant activities and phenolic content in wild-grown flowers of common daisy—a medicinal plant. J. Herb. Med. 8: 31–39.

Pereira, A.M., Cruz, R.R.P., Gadelha, T.M., Silva, Á.G.F. da, Costa, F.B. da, and Ribeiro, W.S. (2020). Edible flowers: beauty, health and nutrition. Agric. Biol. Sci. 9(7): e336972994.

Petrova, I., Petkova, N., Ivanov, I., and Todorova, M. (2020). Phytonutrients and Antioxidant Activity of Extracts from Five Edible Flowers Used in Culinary. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Food Sci. Technol. 77(2): 26–33.

Pires, T.C.S.P., Dias, M.I., Barros, L., Barreira, J.C.M., Santos-Buelga, C., and

Ferreira, I.C.F.R. (2018). Incorporation of natural colorants obtained from edible flowers in yogurts. LWT 97: 668–675.

Rampanti, G., Raffo, A., Melini, V., Moneta, E., Nardo, N., Saggia Civitelli, E., Bande-De León, C., Tejada Portero, L., Ferrocino, I., Franciosa, I., Cardinali, F., Osimani, A., and Aquilanti, L. (2023). Chemical, microbiological, textural, and sensory characteristics of pilot-scale Caciofiore cheese curdled with commercial *Cynara cardunculus* rennet and crude extracts from spontaneous and cultivated *Onopordum tauricum*. Food Res. Int. 173(Pt 2): 113459.

Razia, S., Park, H., Shin, E., Shim, K.-S., Cho, E., Kang, M.C., and Kim, S.Y. (2022). Synergistic effect of *Aloe vera* flower and Aloe gel on cutaneous wound healing targeting MFAP4 and its associated signaling pathway: *In-vitro* study. J. Ethnopharmacol. 290: 115096.

Ren, X., Chen, H., Wang, H., Wang, Y., Huang, C., and Pan, H. (2024). Advances in the pharmacological effects and mechanisms of *Nelumbo nucifera* Gaertn. extract Nuciferine. J. Ethnopharmacol. 331: 118262.

Rezende, F.A.G.G., Sande, D., Coelho, A.C., Oliveira, G.P., Boaventura, M.A.D., and Takahashi, J.A. (2019). Edible flowers as innovative ingredients for future food development: Anti-Alzheimer, antimicrobial and antioxidant potential. Chem. Eng. Trans. 75: 337–342.

Rivas-García, L., Navarro-Hortal, M.D., Romero-Márquez, J.M., Forbes-Hernández, T.Y., Varela-López, A., Llopis, J., Sánchez-González, C., and Quiles, J.L. (2021). Edible flowers as a health promoter: An evidence-based review. Trends Food Sci. Technol. 117: 46–59.

Rop, O., Mlcek, J., Jurikova, T., Neugebauerova, J., and Vabkova, J. (2012). Edible flowers - A new promising source of mineral elements in human nutrition. Molecules 17(6): 6672–6683.

Shantamma, S., Vasikaran, E.M., Waghmare, R., Nimbkar, S., Moses, J.A., and Anandharamakrishnan, C. (2021). Emerging techniques for the processing and preservation of edible flowers. Future Foods 4: 100094.

Sindhuja, S. (2023). Edible flowers-A supplementary source for human nutrition: A review Suram Sindhuja. J. Pharm. Innov. 12(9): 2961–2967.

Singh, Y., Gupta, A., and Kannojia, P. (2020). Tagetes erecta (Marigold)-A review on its phytochemical and medicinal properties. Curr. Med. Drug Res. 4(1): 201.

Siriamornpun, S., Kaisoon, O., and Meeso, N. (2012). Changes in colour, antioxidant activities and carotenoids (lycopene, β-carotene, lutein) of marigold flower (Tagetes erecta L.) resulting from different drying processes. J. Funct. Foods 4(4): 757–766.

Skrajda-Brdak, M., Dąbrowski, G., and Konopka, I. (2020). Edible flowers, a source of valuable phytonutrients and their pro-healthy effects–A review. Trends Food Sci. Technol. 103: 179–199.

Socha, R., Kałwik, J., and Juszczak, L. (2021). Phenolic profile and antioxidant activity of the selected edible flowers grown in Poland. Acta Universitatis Cibiniensis. Series E: Food Technol. 25(2): 185–200.

Sotelo, A., López-García, S., and Basurto-Peña, F. (2007). Content of nutrient and antinutrient in edible flowers of wild plants in Mexico. Plant Foods Hum. Nutr. 62(3): 133–138.

Takahashi, J.A., Rezende, F.A.G.G., Moura, M.A.F., Dominguete, L.C.B., and Sande, D. (2020). Edible flowers: Bioactive profile and its potential to be used in food development. Food Res. Int. 129: 108868.

Teixeira, M., Tao, W., Fernandes, A., Faria, A., Ferreira, I.M.P.L.V.O., He, J., de Freitas, V., Mateus, N., and Oliveira, H. (2023). Anthocyanin-rich edible flowers, current understanding of a potential new trend in dietary patterns. Trends Food Sci. Technol. 138: 708–725.

Trivellini, A., Vernieri, P., Ferrante, A., and Serra, G. (2007). Physiological characterization of flower senescence in long life and ephemeral hibiscus (Hibiscus rosa-sinensis L.). Acta Hortic. 755: 457–463.

Uniyal, A., and Kumar, A. (2024). Minor flowers of European and American Countries. Edible Flowers. Academic Press, pp. 385–430.

Vallisuta, O., Nukoolkarn, V., Mitrevej, A., Sarisuta, N., Leelapornpisid, P., Phrutivorapongkul, A., and Sinchaipanid, N. (2014). In vitro studies on the cytotoxicity, and elastase and tyrosinase inhibitory activities of marigold (Tagetes erecta L.) flower extracts. Exp. Ther. Med. 7: 246–250.

Wang, H. (2024). Beneficial medicinal effects and material applications of rose. Heliyon 10(1): e23530.

Wang, L., Yen, J.H., Liang, H.L., and Wu, M.J. (2003). Antioxidant effect of methanol extracts from lotus plumule and blossom (Nelumbo nucifera Gertn.). J. Food Drug Anal. 11(1): 60–66.

Yang, C.F. (2017). Components in aqueous Hibiscus rosa-sinensis flower extract inhibit in vitro melanoma cell growth. J. Tradit. Complementary Med. 7(1): 45–49.

Zheng, Y.Y., Lin, X.J., Liang, H.M., Wang, F.F., and Chen, L.Y. (2018). The long journey of pollen tube in the pistil. Int. J. Mol. Sci. 19(11): 3529.

Yin, F., and Liu, J.-H. (2018). Research and application progress of *Gardenia jasminoides*. Chin. Herb. Med. 10(4): 362–370.

Zayed, A., Serag, A., and Farag, M.A. (2020). *Cynara cardunculus* L.: Outgoing and potential trends of phytochemical, industrial, nutritive and medicinal merits. J. Funct. Foods 69: 103937.

Zhao, Y., Chen, R., Wang, Y., Qing, C., Wang, W., and Yang, Y. (2017). *In vitro* and *in vivo* efficacy studies of Lavender angustifolia essential oil and its active constituents on the proliferation of human prostate cancer. Integr. Cancer Ther. 16(2): 215–226.

Zhao, L., Fan, H., Zhang, M., Chitrakar, B., Bhandari, B., and Wang, B. (2019). Edible flowers: Review of flower processing and extraction of bioactive compounds by novel technologies. Food Res. Int. 126: 108660.

Zhou, L., Yu, C., Cheng, B., Han, Y., Luo, L., Pan, H., and Zhang, Q. (2020). Studies on the volatile compounds in flower extracts of Rosa odorata and R. chinensis. Ind. Crops Prod. 146: 112143.