CHAPTER 2

Review of literature

This chapter includes comprehensive literature review of the present study. It covers the nutritional and health benefits of edible flowers, along with their safety considerations. Additionally, this chapter provides a detailed review of novel extraction techniques, with a particular emphasis on microwave-assisted extraction and supercritical extraction, for obtaining bioactive compounds from edible flowers and other plant materials. Furthermore, the effects of various processing treatments on enhancing the shelf life of edible flowers and their impact on their physicochemical properties are discussed. The chapter also reviews the ion gelation technique for the encapsulation of bioactive compounds and highlights its benefits. Finally, the development of functional food products using these encapsulated bioactive compounds is also explored.

2.1. Biochemical properties of edible flowers

2.1.1. Nutritional composition of edible flowers

Edible flowers are a great source of nutritional properties. They are comprised phenolic compounds, vitamins, fibers, protein and essential amino acids along with numerous health beneficial properties etc. Taste, delightful fragrance and visual appeal of a flower attract a consumer. Specific curiosity i.e. special smell of a flower and indirectly aroma to some extent can impact on consumer’s attitude towards acceptability of edible flowers. Different edible flowers comprise verities of tastes like bitterness, astringency and spicy etc. which are varying in concentrate from species to species. Bioactive compounds provide a major role in sensory attributes of edible flowers because; phenolic compounds are linked to a flower’s color, bitterness, and astringency. For example anthocyanin gives color to flowers, tannin and flavonoids provide astringency and bitterness respectively. Various volatile compounds such as terpenes, esters, alcohols, carbonyls, and alkane etc. together provide a distinctive flavor to a flower (Fernandes et al, 2019a). Furthermore, the volatility of aroma compounds and taste of edible flowers are also affected by non volatile compounds such as phenolic compounds, sugars, and organic acids etc. (Pereira et al., 2014). Pale purple colored chive flower were found to be a good source of unsaturated fatty acids (about 13 %), containing essential fatty acids linoleic and oleic (Grzeszczuk et al., 2011). Along with sunflower, marigold, primula flower reported to have good content of fatty acid. Takahashi et al. (2020) were found that banana flower, sunflowers comprised interesting amount of protein content. It was observed that edible flowers such as provide better content of protein content than vegetables such as banana, broccoli and cauliflower. Carbohydrates were generally found high in edible flowers in varying amount from species to species. *Centaurea* flower petals were showed 88.39 % (dry matter) carbohydrate content, which was higher than carbohydrate content of rose petals (Pires et al., 2017). Indeed, fiber was also found varying in content. Banana flower was found to contain remarkable total dietary fiber content (over 61 % dry weight) (Begum et al., 2019). Ginger family (*Zingiberaceae*) edible flowers such as *Zingiber, Hedychium, Curcuma, Amomum* and *Alpinia* were reported to have low fat content (<1 %), high amounts of potassium (max. 737.21 mg/100 g), calcium (max. 140.15 mg/100 g), and iron (~0.32 mg/100 g) along with vitamin C content (1.05 mg/100 g in *Etlingera*), total phenolic and total flavonoid contents, as well as antioxidant activity (Rachkeeree et al., 2018).

Edible flowers deliver nutritional properties along with flavor and color. Flavor is the outcome of two broad classes of compounds, with one responsible for taste and the other for odor/aroma. Together active compounds from these two classes provide the impression of flavor for food by stimulating senses in the mouth and nose. Taste, delightful fragrance and visual appeal of a flower along with organoleptic properties such as sweetness, spiciness, aroma, and bitterness etc. can attract a consumer (Knudsen et al., 2006). Implementing metabolic engineering can enhance the aroma and flavor of fruits and flowers. A flower usually contains a range of complex chemical substances including compounds like aliphatics, benzenoids, phenylpropanoids, and terpenes (mono- and sesquiterpenes) which provide a particular scent in a flower (Knudsen et al., 2006). When fresh flowers undergo various processing treatments, it affects their color and flavor. After harvesting, the retention of aroma compounds and other nutritional compounds of flowers differs from species to species. Different post-harvest treatments affect the properties of volatile compounds in flowers differently. Drying flowers might result in low retention of bioactive compounds. A study (Xu et al., 2022) conducted on blanching pretreatments, such as steam blanching, high-humidity hot air impingement blanching, and vacuum-steam pulsed blanching before drying on Peony (*Paeonia* *lactiflora Pall*.) flowers, found retention of volatile compounds after 1 minute of blanching. Abbas et al. (2021) conducted an experiment to examine the influence of various drying methods such as shade for 1 week; sunlight for 72 h; oven at 40 °C for 72 h; solar dryer for 72 h; and microwave for 5 min on the essential oil of chamomile (*Matricaria chamomilla L.)* and its chemical composition. It was reported that the highest amount of oil was observed after solar drying, and the lowest amount was found after microwave drying. Due to volatilization the loss of essential oil was occurred in Microwave drying and shade drying stood to be the best among these drying methods in terms of preserving color, appearance, and chemical oil composition.

Xu et al. (2022) revealed that drying methods adopted to enhance the storability of flowers could influence the aroma profile of dried flowers. It is better to adopt a suitable drying method for the optimal retention of aroma components. A study conducted on effect of different drying techniques such as hot air drying (HAD), combined infrared and hot air drying (IR-HAD), and sequential IR- HAD and HAD (IR-HAD + HAD) were performed on Chrysanthemum (*Chrysanthemum morifolium Ramat*.) cakes and found that among all the techniques IR-HAD showed the highest concentration of volatile compounds. Shi et al. (2021) found that application of combined drying technique i.e. microwave-assisted drying and air drying (MAD-AD) while processing of fresh tea flowers (*Camellia sinensis L*.) could preserved a more floral fragrance and improved the color of tea flowers. Tea flowers processed by this drying technique showed higher content of catechins, flavonol glycosides, and triterpenoid saponins, and high antioxidant activities compared to other drying techniques such as air drying and freeze drying.

2.1.2. Antinutritional properties of edible flower

According to our ancestors' view, edible flowers are those, which have alkaloids conferring pharmacological activities and mostly medicinal plants, and on the other hand, inedible flowers contained alkaloids which deliver toxic effects along with psychotropic and stimulant activities etc. (Nicolau et al., 2016). Except flowers physicochemical or biochemical properties other factors such as introduction of chemical hazards, microbiological hazards and biological hazards into edible flowers can make flowers inedible. Though some antinutrients present in edible flowers but we can consume edible flowers within a lethal dose. A dose upto 6000 mg/kg on oral administration of aqueous extract of *B. monosperma* was regarded as safe (Khan et al., 2017). Antinutrients such as phytate, oxalate, hydrocyanic acid and nitrate presented in *Gynandropsis gynandra* flowers were 1.34 mg, 0.12 mg, 0.03 mg and 0.04 mg respectively which were below the recommended antinutritional toxic level (Abubakar et al., 2014). So, there may presence of antinutrients in edible flowers but we should find out the amount of antinutrients in flowers. Antinutrients such as phytate, oxalate and tannin reported to present in *Moringa oleifera* flower were 12.6, 2.9 and 0.150 (mg/100g) respectively (Athira et al., 2021). Lachumy et al., (2010) tested toxicity of *Etlinger aelatior* (torch ginger) flowers' extract by brine shrimp bioassay (against *Artemia salina*) and found LD_{50} value of 2.52 mg/mL and considered as safe. Kunhachan et al., (2012) revealed that flower of *Jasmine sambac* is safe to use in food industry as there were no significant effects on the male ICR mice when dose of 15 mg/mouse *Jasminum sambac* flowers' extract injected and also in case of acute toxicity the LD_{50} was found to be greater than 5,000 mg/kg in both male and female wistar rats. LD50 value of methanolic extract of neem flowers was more than 12 g/kg. Doses of mehthanolic extract of neem flowers when used more than 150 mg/kg/day caused slight toxicity to rats (Kupradinun et al., 2010). A lower amount of antinutrients found in *Parkia biglobosa* flower were phytate (1.41 mg/100g), oxalate (0.03 mg/100g), hydrocyanic acid (0.17 mg/100g) and nitrate (1.32 mg/100g) which were below the toxic level or daily intake. There were no cyanogenic glycosides found in flowers of *Agave salmiana*, *Aloe vera*, *Arbutus xalapensis*, *Cucurbita pepo* (cultivated), *Erythrina americana*, *Erythrina caribaea*, *Euphorbia radians* and *Yucca filifera*; trypsin inhibitors in them were 1.11 (TUI/mg sample), 2.54 (TUI/mg sample (TUI/mg sample), 1.60 (TUI/mg sample), 1.40 (TUI/mg sample), 4.88 (TUI/mg sample), 6.32 (TUI/mg sample), 1.56 (TUI/mg sample) and 3.57 (TUI/mg sample) respectively. Among all these flowers *A. xalapensis* contains highest lecithin and in *A. salmiana* and *Y. filifera* saponins were found. It was found that flowers of *A. xalapensis*, *Erythrina americana* and *Erythrina caribaea* contained alkaloids too (Sotelo et al., 2007). Flowers of *Parkia biglobosa* (L.) had comprised of antinutrients below the toxic standard levels such as phytate (1.41± 0.24 mg %); oxalate (0.03± 0.01 mg %); hydrocyanic acid (0.17± 0.01 mg %) and nitrate (1.32± 0.10 mg %) (Hsu et al., 2016). Hence, it is a great need to identify a flower properly before consumption.

2.2. Methods for enhancing the shelf life of edible flowers and their impact on physicochemical properties of flowers

Edible flowers have a long history of contribution to human nutrition from the ancient literature of Europe, the middle east and south-east Asia (Purohit et al., 2021; Rop et al., 2012) . The term edible flower is considered as an umbrella term to encompass a wide range of diverse consumable flowers. Many cuisines considered flowers, an integral part due to their medicinal and flavoring properties (Purohit et al., 2021). Compared to other horticulture produce flowers are super perishable with a maximum shelf life of one or two days. The high water activity of flowers prevents their prolonged storage without suitable processing. Implementations of suitable processing techniques are required for the commercialization of edible flowers and the scaling up of its value-added products. Preservation of edible flowers usually progresses through three stages; pre-processing, processing and packing (Purohit et al., 2021). In addition to ease in commercialization, processing techniques ensure the safety of end products. The processing technique used in a flower can alter its chemical properties. Based on the species, some flowers change shape, colour, flavour, and dimension during processing. Even though different process conditions can affect flowers differently, conservation of its nutrients, visual appeal and bioactive compounds were given prime importance while selecting the process conditions.

2.2.1. Low-temperature

Low storage temperature can delay quality deterioration and spoilage in most food products. Cold storage and drying are the most popular methods used in the edible flower industry. In cold storage, flowers delay the rate of senescence because of a decrease in the breakdown of internal tissue, rate of respiration, water loss, wilting, and ethylene production (Fernandes et al., 2019b). Maintenance of colour integrity and moisture were considered to be important factors in the marketability of edible flowers (Kelley et al., 2001). Hence, refrigeration was identified as a common practice adopted in retail stores, where edible flowers are packed in small, rigid, plastic (or plastic-wrapped) packages to avoid desiccation and physical damage (Landi et al., 2015). A study on *Salvia* pot flowers by Landi et al. (2015) reported that the external characteristic of the flower was maintained until 6 days of cold storage (5 °C), after which the moisture content tend to decrease. Stable ascorbic acid and polyphenol content might have protected the flower from enzymatic browning and related quality deterioration.

Even though low-temperature techniques are widely used, not all flower species will react similarly. Fernandes et al. (2020) have studied the effect of freezing on flowers in their natural form and in ice cubes (Table 2.1.). The evaluation of visual appearance suggested that flowers in ice-cube had better results up to a period of 3 months, but the bioactive and antioxidant properties were decreased during this period. Ice cube storage is preferred for long periods, even though there can be incidence of cell damage, lixiviation of compounds on defrosting and gradual decrease in bioactivity (Fernandes et al., 2020).

Similarly, study Villalta et al. (2004) reports that in male and female summer squash flower (*Cucurbita pepo* 'Dixie') the visual appearance was maintained till 7 days of storage at 2.5 and 5.0 ^{0}C in vented PET containers. It was observed that the respiration rate of female flowers varies with temperature. At 5 ^{0}C the respiration rate of the flower was relatively constant but it gets reduced at around 10 ^{0}C. Landi et al. (2018) has studied the effect of cold storage in biologically active compounds of five different species (Table 2.1.). The rate of reduction in the bioactivity of flowers was found to be much lesser than its rate of loss in visual appeal. The study also concludes that flowers with comparatively low moisture content can ensure long marketability. Attempts to control water loss can significantly improve the shelf life of most edible flowers.

A Study by Demas et al. (2021) further agrees with the fact that bioactive compounds are not greatly affected by the refrigerated condition, but it's the visual appeal of flowers that get worse when kept for more than 7 days in refrigerated conditions. Decaying flowers that lost marketable visual appearance can still be used for extraction of phytochemicals. The quality depletion in most of the flowers at cold storage also depends on the type of container or film used to cover the flower on storage.

2.2.2. Drying

Drying is considered the oldest preservation technique practiced for storing food materials. Drying can inhibit enzymatic changes and microbial growth in the food; it can also facilitate cheap transport and storage by reducing weight. Traditional methods of drying i.e., sun drying, and shade drying, have been used in edible flowers, but the emergence of new drying techniques like hot/dehumidified air drying, freeze-drying, vacuum drying, microwave drying and hybrid drying lead to its adaptation in edible flower industry (Table 2.1.) (Fernandes et al., 2019b; Purohit et al., 2021). Conventional drying techniques have a longer duration and slow drying rate that can negatively affect the physicochemical and sensorial properties of flowers (Shantamma et al., 2021). The long drying hours used in conventional techniques increase the chances of contamination and nutrient deterioration. The temperature used in the study has an impact on the nutrient profile of flowers, Stefaniak & Grzeszczuk, (2020) have evaluated the effect of three drying temperatures (25 ºC, 35 ºC and 70 ºC) in *Mimulus hybridus* L., *Hemerocallis hybrid* Hort., *Monarda didyma* L., *Paeonia lactiflora* Pall. Parameters like L-ascorbic acid, total carotenoids, total polyphenols and antioxidant activity of flowers were considered to select best drying temperature. The authors report that total polyphenols, total carotenoids and antioxidant activity is high in dried flowers. They also conclude 35 ºC as the ambient temperature for the flowers *M. hybridus* L., *M. didyma* L. and *H. hybrid* Hort and 25 ºC for *P. lactiflora* Pall.

Like temperature differences, different drying methods also affect flower properties. Fernandes et al., (2018a) studied the effects of hot-air convective drying, shade drying and freeze-drying on Centaurea (*Centaurea cyanus* L.) petals. Regardless of the drying method used, the petals were observed as small, darker and wrinkled than fresh petals. The water activity, titratable acidity, carotenoid and hydrolysable tannin contents were decreased but total reducing capacity and antioxidant activity in terms of reducing power were increased in all the three types of treatments. On drying the water activity values of petals reach 0.86 or 0.62, below which growth of pathogenic microorganisms, yeasts and molds are inhibited. Only in freeze-dried petals, a magnitude of 0.3 was reported. Retention of monomeric anthocyanins, flavonoids, hydrolysable tannins, total reducing capacity and antioxidant activity was best in shade drying. Hot-air convective drying had the lowest retention of anthocyanin and flavonoid but carotenoid content was kept high.

Similarly, Dorozko et al. (2019) studied the effect of freeze-drying, hot air drying, and microwave on lavender, marigold and common daisy flower (Table 2.1.).They found that the drying process, in general, reduces the total flavonoid content in flowers. But the total phenolic content was observed to be higher in freeze-dried samples than in fresh flowers. The drying techniques used have a negative impact on the antioxidant property but microwave drying demonstrated comparatively better results. The observed rise in antioxidant property of lavender was owed to the release of bound components during treatment. Oven drying on mahua flowers (*Madhuca indica syn. Bassia latifolia*) powdered with liquid nitrogen retained their nutrients (reducing and nonreducing sugars, amino acids, proteins, lipids, ascorbic acid and ash contents) for almost a year of preservation in a deep freezer at 0 ^{0}C (Das et al., 2010).

Another study on the effectiveness of different drying techniques on *Rosa rugosa* flower suggests that Infra-red freeze drying (IRFD) is the most economical method for retaining flavour, nutrition and molecular structure in rosa flower (Qiu et al., 2020). A better technique for rosa flowers was later suggested by Hnin et al. (2021). They compared Novel infrared pulse-spouted freeze drying (IRPSFD) along with much accepted techniques like freeze-drying and Infra-red freeze drying (IRFD) used in edible flowers. The new technique was found to have reduced the processing time associated with the process.

2.2.3. Edible films and coatings

Edible coatings can extend shelf life by acting as a protective barrier on flower surfaces. They help to reduce the rate of respiration, lower gaseous and moisture transmission, retain colour, flavour, and minimize enzymatic degradation (Fernandes et al., 2018b). The technique of edible coating was prominent in the preservation of fruits and vegetables but limited information is available on its application in edible flowers. Biomaterials like protein, polysaccharides and lipids are generally used for making these edible barriers (Shantamma et al., 2021; Zhao et al., 2019). These edible layers when enriched with other bioactive constituents can increase the nutrient profile of flowers. The technique of edible coatings is often found in combination with other preservation technique (e.g: refrigeration) hence, it gives a synergistic effect on maintaining flower quality.

Fernandes et al. (2018a) studied the effect of alginate coating on Pansies (*Viola wittrockiana*) (Table 2.1.), for enhancing shelf life in refrigerated storage. Pansies of four different colours red, white, violet, and yellow were used in the study. It was observed that compared to uncoated counter parts, coated flowers had a longer shelf life irrespective of the flower colour. Yellow and white coloured flowers showed comparatively high water loss, an excess water loss on storage can negatively affects the economic revenue and appearance of flowers. Water activity measurement has insignificant variation from fresh flowers. In terms of size, due to water loss and shrinkage, all the pansies decreased their dimension in storage. The authors suggest that a combination of suitable coating and packaging design can delay weight loss and shrinkage thus improving shelf life in pansies. A study on borage flower petals also reported a similar conclusion which agrees that alginate coating on a flower can increase the shelf life (Fernandes et al., 2018b).

2.2.4. Irradiation

Food irradiation is a physical process used for extending the shelf life, disinfecting insects, maintaining quality and improving the safety of edible flowers. Factors like moisture content, treatment dose, substance composition and conditions determine the effectiveness of irradiation treatment (Zhao et al., 2019). Ionizing radiation builds oxidative stress in food by the production of peroxides, these will delay cell death by altering biochemical properties (Shantamma et al., 2021).Villavicencio et al., (2018) studied the effect of radiation at doses 0.5, 0.8 and 1 kGy on *Bauhinia variegate* L var. *candida alba* Buch.-Ham white flower (Table 2.1.). It was observed that 0.5 kGy increased the phenolic content and resulting antioxidant activity in the flower without causing much difference in its nutrient profile. Other than nutrient and bioactive compounds, irradiation treatment can also affect the sensorial properties of flowers. Irradiation study on *Tropaeolum majus* L also demonstrated an increase in antioxidant activity after irradiation and in another study it was found that upto a limit of irradiation dose there were no significant changes to its sensorial properties (Koike et al., 2015a, 2015). A similar trend in phenolic content was also observed in the study on *Viola tricolor* L (Koike et al., 2015b).

A sensory evaluation study conducted on irradiated *Bauhinia variegates* flowers showed that the flavour of the flowers gets improved with irradiation. Whereas, the colour and texture of irradiated flowers got a lower score compared to irradiated flowers in terms of consumer preference. The observed improvement in flavour can be due to the breaking of a glycosidic bond by radiation (N.Simoni, F.Santos,T.Andrade et al., 2018). Both gamma radiation and electron beam radiations can be used in the processing of edible flowers. Koike et al. (2021) have studied the effect of gamma radiation and electron beam doses on the carotenoid lutein content of *Dianthus chinensis*. They reported that the carotenoid content is positively influenced by the radiation treatment at 1.0 kGy. They also suggest that the electron beam irradiated sample at 1.0 kGy is better than the gamma radiated sample. Selection of proper dose is very important in irradiation treatment of flowers as high doses can cause petal withering, browning and other physical injuries in edible flowers.

2.2.5. High hydrostatic pressure (HHP) processing

High hydrostatic pressure (HHP) is a novel non-thermal processing technology that gained acceptance in the food industry due to its efficiency to maintain safety and quality. HHP treatments work in the pressure range of 200-800 MPa and are uniform, eco-friendly, independent of the product geometry and can extend the shelf life of products without chemical additives. HHP treatment requires a medium (water or fluid) to transfer the pressure into the foods. In HHP treated samples certain macromolecular components undergo changes like starch gelatinization, protein denaturation, enzyme inactivation, and microbial cell damage whereas micronutrients remain unaffected, this help in preserving the food without disturbing the nutrient profile of food (Fernandes et al., 2019b; Shantamma et al., 2021; Zhao et al., 2019). Edible flowers are highly perishable commodities, comparatively few studies have worked on the effect of high-pressure treatment on edible flowers, edible flowers of broccoli and cauliflower are among the most studied groups (Fernandes et al., 2017).

Edible flowers of different plants behave differently in HHP treatment, a detailed study is required to determine the best combination of pressure and holding time for each flower. Fernandes et al., (2017) evaluated the effect of high pressure between 75 and 450 MPa with holding time 1, 5 and 10 minutes on pansies (*Viola wittrockiana*), blue centaurea (*Centaurea cyanus*), blue borage (*Borago officinalis*) and rose camellia (*Camellia japonica*) (Table 2.1.). It was observed that best visual appearance in pansies was obtained in treatment 75/5 MPa min^{-1} and 75/10 MPa min^{-1}, at a combination of

150/5 M Pa min^{-1} the flower became fragile. In centaurea, all combinations other than 75/5 and 100/5 M Pa min^{-1} result in damaging the flower whereas, the flowers camelia and borage were found to be unsuitable for high-pressure treatment. The evaluation of colour parameters reveals that under HHP treatment, pansies of different colours behave differently. Excess weight loss in flowers is undesirable for its economic revenue, the study showed that higher pressures induced higher changes in pansies but insignificant changes in Centaurea. Further, the storage evaluation suggests that in pansies HHP treatment induces the production of bioactive compounds that help to increase its shelf life. HHP treated Centaurea gave unsatisfactory results on HHP treatment hence it is not recommended for shelf life extension in Centaurea flowers. The authors concluded that in pansies lower pressure and short holding time are better for shelf life extension whereas this treatment is not recommended for other flowers used in the study.

2.2.6. Modified and controlled atmosphere packaging

Packaging ensures the quality and safety of food during storage, handling and transport. In the current scenario, consumer experience expectations from the package have increased which lead to novel innovations in packaging techniques. Modified atmosphere packaging is an advanced technology where the internal atmosphere of the packet is modified to improve the shelf life of the product it contains (Shantamma et al., 2021). Many of the fresh produce continue to respire after harvesting, by altering the gas composition inside the package the freshness and quality can be maintained for a longer period. This technique was successfully used in many fruits and vegetables. Kou *et al*. (2012) in their study suggest that the shelf life of carnation (*Dianthus caryophyllus*L.) and snapdragon (*Antirrhinum majus* L.) flowers can be extended by using a controlled release of 1-methylcyclopropene with modified atmosphere packaging stored at 5 ^{0}C. Flowers stored in modified atmosphere packaging conditions lower the dehydration, thus maintaining good quality and prolonging the shelf life of flowers. Unlike modified atmosphere packaging, a controlled atmosphere package enables continuous monitoring of the atmosphere throughout the storage period. Aquino-Bolaños et al. (2013) proposed that a controlled atmosphere with high CO_2 and low O_2 concentrations can enhance the shelf life *Cucurbita pepo* flower. In their study the conditions were 5 % O_2 + N_2 (CA1); 5 % O_2 + 10 % CO_2 + N_2 (CA2); 10 % CO_2 + air (CA3); and control was air. It was found that these controlled atmospheric conditions can maintain total sugars, total soluble solids, pH, titratable acidity and lower physiological weight loss. Most importantly, 5% O_2 + 10% CO_2 + N_2 (CA_2); 10% CO_2 + air (CA3) treatments can extend shelf life up to 16 days, where mostly ascorbic acid (49.5 %), polyphenols (65.2 %) and carotenoids (72.8 %) was retained by 5 % O2 + 10 % CO_2 + N_2 (CA2) treatment. Finally, it was proved that a controlled atmosphere with high CO_2 and low oxygen can enhance the shelf life of *Cucurbita pepo* flower.

The type of processing, packaging and storage conditions can influence the shelf life of edible flowers. Different species of flowers behave differently towards different processing conditions hence, the selection of processing technique for flowers are highly specific.

Table 2.1. Preservation techniques and their effects on flowers' properties

Flower Name	**Methods of preservation with conditions**	**Effect on quality of flower**	**Reference**
Borago officinalis	Freezing in natural form and ice cubes (-18ºC)	• On prolonged storage chilling injury and browning of petals • loss of brightness	(Fernandes et al., 2020)
Viola tricolor	Freezing in natural form and ice cubes (-18ºC)	• Loss of texture and brightness • Significant decrease in total flavonoids and total reducing capacity	(Fernandes et al., 2020)
Taraxacum officinale	Freezing in natural form and ice cubes (-18ºC)	• Medium level of visual appearance • Significant decrease in total flavonoids and total reducing capacity	(Fernandes et al., 2020)
Kalanchoe blossfeldiana	Freezing in natural form and ice cubes (-18ºC)	• Maintained fresh appearance and rigid structure of flower • Increased bioactivity	(Fernandes et al., 2020)
Begonia semperflorens L. (white, pink, and dark-pink)	Refrigeration 4ºC	• Tissue darkening and browning of flowers • Oxidation of phenolics • Reduction in total flavonoids • Increase in antioxidant activity on storage	(Landi et al., 2018)
Salvia discolour Kunth,	Refrigeration 4ºC	• Decrease in anthocyanin content • Browning • Reduction in total phenols	(Landi et al., 2018)
Tropaeolum majus L	Refrigeration 4ºC	• Browning of flowers • Reduction in total phenols • Increase in antioxidant activity on storage	(Landi et al., 2018)
Acmella oleracea L	Refrigeration 4ºC	• Increase in antioxidant activity on storage	(Landi et al., 2018)
TulbaghiacominsiiVosa	Refrigeration 4ºC	• Reduction in total phenols	(Landi et al.,

			2018)
Calendula officinalis L.	Freeze drying	• Increase in total phenol content • Decrease in total flavonoid content and antioxidant activity	(Dorozko et al., 2019)
Bellis perennis L.	Freeze drying	• Increase in total phenol content • Increase in total flavonoid content • Decrease in antioxidant activity	(Dorozko et al., 2019)
Lavandula angustifolia L.	Freeze drying	• Increase in total phenol content • Decrease in total flavonoid content and antioxidant activity	(Dorozko et al., 2019)
Rosa rugosa	Hot air drying	• Damage the flavor constituents • Reduction in volatile compounds • Reduce bioactive compounds	(Qiu et al., 2020)
Borago officinalis	Alginate coating	• Flowers became fragile • Maintained good appearance and high water activity on storage	(Fernandes et al., 2018)
Viola wittrockiana	Alginate coating along with refrigerated storage at 4ºC	• Weight loss and shrinkage • Reduction in dimensions or size	(Fernandes et al., 2018b)
Bauhinia variegata L var. *candida alba* Buch.-Ham	Irradiation 0.5 kGy	• Increase in phenolic content and resulting antioxidant property	(Villavicencio et al., 2018)
Bauhinia variegate	Irradiation 1.0 k Gy	• Improvement in flavor profile of flower	(N.Simoni et al., 2018)
Centaurea cyanus	High hydrostatic pressure	• Unacceptable changes in visual appearance on storage	(Fernandes, Casal, Pereira, Pereira, et al., 2017b)
Viola wittrockiana	High hydrostatic pressure	• Increase in water loss • Increase in bioactive compounds	(Fernandes, Casal, Pereira, Pereira, et al., 2017b)

2.3. Novel Extraction of phytochemical from edible flowers

2.3.1. Supercritical fluid extraction (SFE)

Compared with other traditional extraction methods, SFE, is not only reduces the consumption of solvents, but also provides better selectivity (Płotkawasylka et al., 2017). It was reported that SFE was successful on *Hibiscus sabdariffa* and *Lonicera japonica* etc. calyces for extraction bioactive compounds more efficiently than other conventional methods (Pimentel-Moral et al., 2019) (Hsu et al., 2016). In sunflower when, 5 % methanol, water or dimethyl sulphoxide added as a modifier, this increased the efficiency of SFE process (Casas et al., 2007).

Xia et al., (2018) investigated antioxidative activity of essential oil of flowers of tea (*Camellia sinensis L*.) by using SFE and they found the optimum condition at pressure of 30 MPa, temperature of 50 ℃, static time of 10 min, and dynamic time of 90 min, resulting (based on GC-MS analysis) 59 compounds including alkanes (45.4 %), esters (10.5 %), ketones (7.1 %), aldehydes (3.7 %), terpenes (3.7 %), acids (2.1 %), alcohols (1.6 %), ethers (1.3 %), and others (10.3 %) were identified in the essential oil of tea flowers. DPPH radical scavenging activity of the essential oil of tea flowers relatively stronger than essential oils of geranium and peppermint, although it was weaker than essential oil of clove, ascorbic acid, tertiary butylhydroquinone, and butylatedhydroxyanisole. Fragoso-Jiménez et al., (Fragoso-Jiménez et al., 2019) studied the effect of pressure and temperature process of SFE on volatile composition of tuberose flowers and it was found that the chemical profile of extracts was dependent on the process conditions, mainly the pressure process. Characteristic compounds of tuberose as methyl isoeugenol, benzyl benzoate, methyl anthranilate, pentacosene, and heptacosene were obtained mainly at 18 MPa and 333 K process conditions.

2.3.2. Microwave assisted extraction (MAE)

Microwave assisted extraction can offer the advantage of effective internal heating and ability to shorten the reaction time (Leonelli et al., 2010). It was reported that the temperature and solvent concentration were potential factors in MAE for obtaining bioactive compounds (Pimentel-Moral et al., 2018)**.** Indeed, in case of *Hibiscus sabdariffa* flower the optimum extraction condition was found at 164 ℃ for 12.5 min with 45 % ethanol. MAE was compared with ultrasound assisted extraction (UAE) for extraction of essential oil, and found that in case of rose, UAE showed optimum result *i.e.*, proanthocyanidins of 96.94 mg/g in 17 min and 59 ℃ and MAE showed best result proanthocyanidins of 100.81 mg/g, in 44 s and 61 ℃ (Xu et al., 2018). Tran et al. (2022) recommended that at a radiation time of 70 min and power of 700 W could give a better extraction of bioactive compounds from Coffee Pulp (*Coffea canephora*) waste. Bonomini et al. (2018) were conducted study on microwave-assisted extraction process with ethanol and ethyl acetate at different time, power and temperatures, in order to extract plumieride from *Allamanda cathartica* flowers. It was found that yield of plumieride reached 43 % in the extracts under the optimal MAE conditions (10 min, 300 W). Plumieride recoveries by conventional extraction method were 12 % with ethanol and 22 % with ethyl acetate. It was concluded that MAE process showed actual advantages over the conventional extraction method in terms of shorter time and higher efficiency to recover plumieride from *A. cathartica* flowers. Also, ethanol was found to be the best extractor solvent and it was possible to obtain high contents (52 mg g^{-1} of dry flowers) at optimized conditions.

2.3.3. Encapsulation of bioactive compounds

Bulatao et al. (2017) studied on ten different varieties of defatted bran of black rice to extract anthocyanin and encapsulate using chitosan-alginate nanoparticles. The variety yielding the highest amount of anthocyanin was taken in consideration for encapsulation. The crude anthocyanin extract was encapsulated using i.e. ionic pre-gelation and polyelectrolyte complex formation. After that, freeze dried at -110 °C for 48 h. The final encapsulated capsule was analysed on the basis of chemical properties, surface morphology, particle size, polydispersive index, encapsulation efficiency, and 2,2-diphenyl-1-picrylhydrazyl radical scavenging activities. The capsule with 30 mg crude anthocyanin extract was found to be highest in encapsulation efficiency with 68.9 % and antioxidant scavenging activity with 38.3 %. The authors found chitosan-alginate nanoparticles as best encapsulating material for anthocyanin with nano size of (<1000 nm). Moura et al. (2019) produced Microparticles containing anthocyanin extract from *Hibiscus sabdariffa L.* (HE) were produced by the ionic gelation method by dripping-extrusion and atomization. Double emulsion (HE/rapeseed oil/pectin) and a cross-linked solution ($CaCl_2$) were used and microparticles applied into pectin candy. This microencapsulation of hibiscus anthocyanin resulted in improved enteric protection of bioactive compound, mainly in microparticles generated by dripping-extrusion. It was concluded that application in jelly candy has shown to be technically feasible, with retention of up to 73 % of bioactive compounds and mean sensorial acceptance of 70 % tasters.

2.3.4. Functional food products by using encapsulates

Taghadosi et al. (2024) explored the addition of curcumin-loaded nanocapsules (CLN) into functional stirred yogurt (CLN-Y). The study found that CLN significantly enhanced antioxidant activity, viscosity, hardness, and water holding capacity during storage. However, increasing the levels of CLN resulted in lower scores for taste, color, and overall acceptability. Based on these findings, a 3 % CLN concentration is recommended for yogurt formulation, as it improves yogurt quality, offers antioxidant benefits, supports probiotic viability, and ensures high consumer acceptance over time. Tanganurat et al. (2020) developed a functional food product by encapsulating probiotics in fruit juice bubbles. The study focused on the encapsulation of *Pentosaceus ARG MG12* in pure orange juice bubbles using sodium alginate and calcium chloride. The results showed that the survival rates of the bacterial cells in acidic conditions and bile salts were 83.27 % and 94.24 %, respectively. Additionally, the probiotic-infused orange juice bubbles exhibited a stiffness of 390.71 g/sec, DPPH radical-scavenging activity equivalent to 294 µg ascorbic acid per mL, and an L-ascorbic acid content of 0.095 mg/mL. There was no taste difference according to sensory panelists in between non-probiotic and probiotic orange bubbles. Tolve et al. (2018) developed various dark chocolates containing 64 %, 72 %, and 85 % cocoa, each fortified with 0 %, 5 %, 10 %, and 15 % microencapsulated phytosterols. From a chemical perspective, the chocolates were stable. The antioxidant activity was found to be 92 µg trolox per gram of chocolate (for the 85 % cocoa variety). Additionally, sensory evaluations indicated that the functional chocolates produced had a positive impact on consumer acceptability.

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