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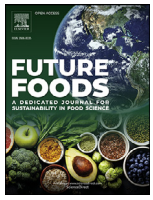

A review on nutritional, bioactive, toxicological properties and preservation of edible flowers

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ABSTRACT

Flowers that can be consumed by human being safely are known as edible flower (EF). In the fast and nutritive food thrive scenario; flowers breaking all the odds out to put their picture as the food grade material with their rich nutritive value. However, there is a strong aspiration for scientific evidences to justify positive impact of EF on health through superior nutritional and bioactive attributes. This review summarizes the outcome of various studies performed until now on edible flowers, focusing on nutritional, bioactive, preservation and toxicological properties and health effects. This article also provides valuable information through systematic compilation and interpretation of published data on edible flowers in order to increase their popularization among the food industry and consumers. Analysis of previously published outcomes revealed that the nutritional and bioactive attributes makes the EF as complete form of nutrition available for mankind and need further exploration for value added product development, without neglecting the identification and documentation of potential toxicological elements for safe and desirable application for future expansion of EF in to value added products.

1. Introduction

World Health Organization (WHO) highlighted that more than half of world's population (80%) relay on application of medicinal plants for various health care measures (WHO, 2009). Flowers are the reproductive structure of flowering plants (also known as bloom or bloosom) have been in use by mankind for various food and pharmaceutical application and thus otherwise also referred as edible flower (EF).

The south east Asian and Middle east food habits have long history of using edible flowers in regular cuisines (Cunningham, 2015). Apart from this, consumption of edible flower was also well elaborated in ancient literature of many countries with the belief that medicinal properties of EF to benefit the consumers (Melillo, 1994). However, there were very less scientific concern regarding their use in diet rather in earlier days flower were regarded as filling or flavoring elements in human. In recent years, the positive health impact assessment and nutraceutical aspects of EF has progressed well with significant interest brought in by scientific community (Mlcek and Rop, 2011).

When the discussion about EF comes in, the general perception is that EFs are some special verities of flowers, rather there are many common examples like cauliflower, broccoli, pumpkin flower as vegetables; Star anise and Javitri as spice and sun flower oil and rose water as extract etc., which gives a fair idea that how common is the usage of EF in day to day diet. Lu *et al.*, (2016) reported 97 families, 100 genera, and 180 species of EFs used globally. However, in his report many flower based vegetables, such as broccoli, cauliflower, and artichoke are not enlisted as flowers. According to Rodrigues *et al.* (2017) many flowers can also be consumed for sustenance and, some are technically edible but, far from palatable. The edible parts of flower may vary from flower to flower. In most of the cases petals are edible, but in some pollen, nectar and other parts are also used for consumption (Kopec and Balik, 2008; Henschel, 2004). More than hundred studies were summarized by Fernandes *et al.* (2017a) in their review on nutritional, antioxidant, antimicrobial properties and their effects on human health stated of edible and non-edible flowers released by any international body and no legal legislation has been laid for the marketing of the same.

While combining the word "edible" with flower, it gives a clear cut indication about the safety concern plugged with EFs. Similar to other plant segments/sources, along with above mentioned positive heal impact. However flowers (F) do possess toxic and anti-nutritional elements

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like trypsin inhibitor, hemagglutinins, oxalic acid, cyanogenic glycosides, and alkaloids (Lara-Cortes et al., 2013; Mlcek and Rop, 2011). Thus, it is very critical to discriminate between F and EF! Lim (2014) reported essential benchmarking guideline for safe and wider application of EFs, in which it was very clearly spelled out that accurate identification of the flower is the primary step in the journey of regularizing the EFs on consumers' plate. Subsequently, the flowers should be harvested during comparatively cooler time (morning) to preserve the natural color, flavor and aroma. Drying and refrigeration could be used for long term preservation of flowers, wherein lower temperature drying is expected to render better quality and bioactive properties than conventionally dried flowers. Lastly, similar to all other commodities and food ingredients there should be limitation in consumption of flower and hypersensitive consumers should avoid consumption (Lim, 2014).

Though there are some scientific inputs and communications available, still the popularity of EF is not up to the mark. Besides lack of sincere efforts for EF making widely acceptable through strategic research, scientific communication, awareness, probably poor palatability is one of the primary reasons for reluctance to adopt edible flower as regular food. Thus, it is of utmost importance that essential research pertaining applications in culinary methods or value added form, nutritional analysis, preservation study and toxicological evaluation to be done. Moreover, the sensory preferences are to be given due importance for wider acceptability of EFs by consumers. Therefore, the scope of this review is to encompass the history of edible flowers, their nutritional and health benefits, and preservation through processing methods and toxicological aspects. Furthermore in the review future prospects of EF have been outlined based on current state of usage, preservation methods, historical evidences and safety concern.

1. History, Diversity, Availability and Market of Edible Flowers

In the ancient world, flowers were used for culinary purpose, as referred in various ancient scriptures. The uses of edible flowers vary from culture to culture. Mlcek and Rop (2011) reviewed more than fifty researches to justify the statement that edible flower has been a part of the cuisines all over the world since several thousand years (**Table 1**). In China, flowers were used for culinary purpose from 3000 BC (Stradley, 2015). In Rome, violets and roses were used for the purpose of garnishing, whereas lavender was used for making sauces (McGuffin, 1997). Like China and Rome, Middle Eastern and Indian people were also using flowers, which have been traced back to civilization of antiquity (Deka and Nath, 2014). In North America, the pumpkin blossoms and squash plant were quite popular. The Zuni tribe is famous for their love and passion for squash blossoms (Murphy, 2015). During Victorian Era, edible flowers gained their popularity in England, North America and throughout Europe (Fernandes *et al.*, 2017a). Occurrence of common edible flowers throughout the world is depicted in Figure 1.

The consumer acceptance and the preference for consuming edible flowers is location specific and EFs are generally used as aid-on for enhancing palatability. The most common flowers used in the preparation of variety of dishes have been mentioned in the **Table 2**. EFs are economic and rich source of nutrients, however remain underutilized due to several socio-economic factors. Compared to urban market, EF consumption is more popular among tribal belts. Moreover, the availability of EF is seasonal (Fernandes, et al., 2019).

As far as the production of EF is concerned, there are no statistical data in global production. However, limited data on production of selected EF (flower but not considered as flowers, such as broccoli and cauliflower, and saffron) are available (Fernendes et al., 2019). In global scenario, Asia is the largest producer of cauliflowers and broccoli (76.6%), while Europe represented only 11.9%, between 2000 and 2014. In 2014, Portugal produced 38969 tonnes of these two products (FAOSTAT, 2019). Favorable agro-climatic conditions and low labor costs are both key factors responsible for the advantageous position of Asia-Pacific in floricultural products exportation. Apart from this, Europe has shown notable demand for EFs due to the growing preference for cut flowers in some part of Germany, France and Netherland. Netherland is the leading exporter of bulbs and cut flowers in Europe. In the year 2013, Colombia has emerged as the second largest exporter of cut flowers through export of roses, carnations, chrysanthemums (Fernandes, 2019).

3. Nutritional Properties of Edible Flowers

Along with basic nutritional and sensory contributions, EF also contributes towards health improvement through bioactive potential (Alasalvar et al., 2013; Lara-Cortes et al., 2013). Studies have reported that chronic diseases, such as, hyperglycemia, carcinoma and neurodegenerative diseases are greatly influenced by benefit of antioxidant in food consumed (Liu and Hotchkiss, 1995). Various research reports evident about presence of potential bioactives like carotenes (Niizu and Rodriguezamaya, 2005), isothiocyanates (Pintão et al., 1995), essential oils (Martínez et al., 2009), and cyclotides (plant peptides) (Hellinger et al., 2014) in EFs. EFs being a plant source, there is very similar phenolic compound profile, which act as antioxidants against oxidative tissue damage (Thomasset et al., 2007). Moreover, the superior reducing ability (antioxidant) to tackle free radical damage has also been reported by Song et al. (2011). The free radical reducing capacity of edible flowers has been reported to be more as compared to most fruits and vegetables due to superior bioactive profile (Benvenuti et al., 2016).

Edible flowers can be divided into their different parts such as; Pollen, petals, nectar, stigma and other parts. It is highly recommended to consume the flowers after the removal of styles and stamens of the flowers before eating. The pollen is considered as rich source of proteins, carbohydrates, amino acids, flavonoids and carotenoids but is least recommended to have in diet because of the various allergic reactions associated with it (Mlcek and Rop, 2011). EF contain various therapeutic and pharmaceutic components in them, such as natural antioxidants in the form of Vitamin E (Tocopherol) (Kaur *et al.*, 2006), natural pigments (anthocyanins, betalains, lycopene, anthoxanthin) and various phenolic compounds in the form of flavones (acaciin, luteolin), glycosides, coumarins, flavonoids (epicatechin, catechin, cyanidin-3, rutin, quercetin, catechin), phenolic acids (vanillic acid and p-hydroxybenzoic acid, homogentisic acid, protocatechuic acid, gallic acid, ferulic acid), hydroxycinnamic acid, tannins and anthocyanidins (malvidin-3-glucoside, malvidin-3-galactoside), proanthocyanins (condensed tannins) (Skrajda, 2017).

Edible flowers serve as a great source of antioxidants and for the same reason they have been a part of both food and medicine. They act as a potential protective agents which are responsible for conferring antioxidative activities by eliminating reactive oxygen species produced during the endogenous metabolic processes. It was observed in an experimental research conducted (Castelino *et al.*, 2016) that authentication of the Ayurveda claim were tested for the Indian edible flower *Madhuka indica* and proximate analysis was performed. For this flower, it is said that it possesses many therapeutic properties which is very justified with the results of the experiments, which disclosed that they are rich in both reducing (31.25% w/w) and non-reducing sugars (20.62% w/w) and have rich pharmaceutical and nutritional profile. Similar results were reported from a research conducted by Zheng *et al.*, (2018) in which the aim was to determine the total phenolic content (TPC), total flavonoids content (TFC) and the antioxidant capacity of 65 flowers collected from China, from commercial sources and parks; and found a high correlation between TPC and antioxidative values and low correlation values were recorded for TFC and the antioxidative values.

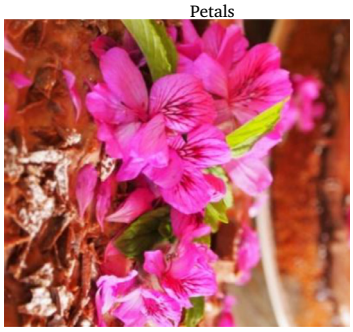
Devi *et al.*, (2009) conducted survey on edible flowers found in the valley districts of Manipur, India, in which flowers of 63 species have been taken from commercial and local sources and found that there were some culinary flowers which had exceptionally high antimicrobial and polyphenol activity. In a similar research, where the effect of cold stor-

Table 1
Common edible flowers, consumable part and their uses in different continent

Name of the Continent	Name of the Flower (Scientific name)	Figure	Edible Parts	Flavors	Uses	Reference
Asia	Chrysanthemums		Except stamens whole	Slightly Sweet	Medicinal + Cooking	Tai & Chen, 2000
	Daylilies (*Hemerocallislilioasphodelus)*		Whole	Citrus	Garnishing + Cooking	Fernandes et al, 2019
	Moringa (Moringa oleifera)		Whole	Little bitter	Cooking + Medicinal	Gopalakrishnan et al., 2016
	Banana(*Musa paradisiaca*)		White parts inside the flower	Slightly sweet	Cooking + Medicinal	Nadumane and Timsina, 2014
	Pumpkin(*Cucurbita maxima)*		Whole	Sweet	Cooking	Muruganantham et al., 2016

(*continued on next page*)

Table 1 (*continued*)

Name of the Continent	Name of the Flower (Scientific name)	Figure	Edible Parts	Flavors	Uses	Reference
Africa	**Wildmalva** (Pelargonium culallatum)		Petals	Sweet	Medicinal + Garnishing	Volschenk et al., 1982
	Peppermint-scented pelargonium (Pelargonium tomentosum)		Whole	Peppermint	Garnishing + Cooking	Demarne and Van der Walt., 1990
	Wild sorrel (Oxalis pes-caprae)		Petals	Sharp Taste	Cooking + Garnishing	Roets et al.,2014
	African wormwood (Artemesiaafra)		Whole	Strong flavor	Medicinal + Cooking	Liu et al., 2009
Australia	Nasturtium(*Tropaeolummajus)*		Whole	Slightly sour	Medicinal + Garnishing	Silva et al., 2011

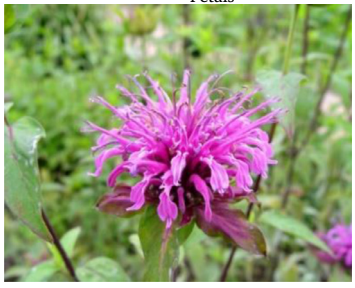
(*continued on next page*)

Table 1 (*continued*)

Name of the Continent	Name of the Flower (Scientific name)	Figure	Edible Parts	Flavors	Uses	Reference
	Viola (*Viola* sp.)		Whole	Sweetish Vanilla taste	Medicinal + Garnish-ing	Thiele & Prober, 2006
	Purslane (*Portulacaoleracea)*'		Whole		Medicinal+Garnishing	Jessop et al., 1986
	French marigold (*Tagetespatula)*		Petal	Spice	Cooking	Kanwar et al., 2016
Europe	Chives *(Allium schoenoprasum)*		Whole	Mild Onion	Medicinal + Cooking	Grzeszczuk et al., 2011
	Borage (*Boragoofficinalis*)		Blossoms and leaves	Honey like taste	Medicinal + Cook-ing + Garnishing	Gilani et al., 2007

(*continued on next page*)

Table 1 (*continued*)

Name of the Continent	Name of the Flower (Scientific name)	Figure	Edible Parts	Flavors	Uses	Reference
	Calendula *(Calendula officinalis)*		Petals	Bitter	Medicinal + Cooking	Hamad et al., 2011
	Cornflower (*Centaureacyanus)*		Petals	Sweet to Spicy	Medicinal + Garnishing	Jauron et al., 2013
	Chamomile (*Matricariachamomila*)		Whole	Sweet	Medicinal	Srivastava et al., 2010
North America	Beebalm (Monardadidyma)		Petals	Sweet and aromatic	Garnishing + Cooking	Mlcek&Rop, 2011
	Red Clover (*Trifoliumpratense*)		Whole	Sweet	Cooking + garnishing	Nelsen et al., 2002
	Althaea (Althaea officinalis)		Whole	Sweet	Cooking	Banaee et al., 2017

(*continued on next page*)

Table 1 (*continued*)

Name of the Continent	Name of the Flower (Scientific name)	Figure	Edible Parts	Flavors	Uses	Reference
	Anise Hyssop (*AgastachEdible Floweroeniculum*)		Petals	Sweetish Sour	Cooking	Hashemi et al., 2017
	Black Locust (*Robiniapseudoacacia*)		Petals	Sweet	Fresh	Sabo, 2000
South America	Begonia (*Begonia tuberhybrida*)		Flowers,leaves and stems	Slightly sour	Garnishing (Presence of oxalic acid which is harmful for taking in large amount)	Mlcek&Rop, 2011
	Pansy(Viola wittrockiana)		Petals	Sweet	Cooking + Garnishing	Agnieszka and Holubowicz., 2008
	Snapdragon (Antirrhinum)		Petals	Sweet	Medicinal + Garnishing	Al-Snafi, 2015

Table 2
Common flowers and dishes used

Name of the flower	Local Name	Prepared Dish
Banana Flower or Blossoms	Mocha, Vazhaipoo	
Pumpkin Flower (*Cucurbitaceae* family)	KumroFul	
Moringa Flower (*Moringa oleifera*)	Sajina	
Hummingbird (*Sesbania grandiflora*)	Bok ful	
Star Lotus (*Nymphaea nouchali*)	Sapla	
Kachnar flower (*Bauhinia variegata*)	Kachnar	
Rose *(Rosa rubiginosa)*	Padma	

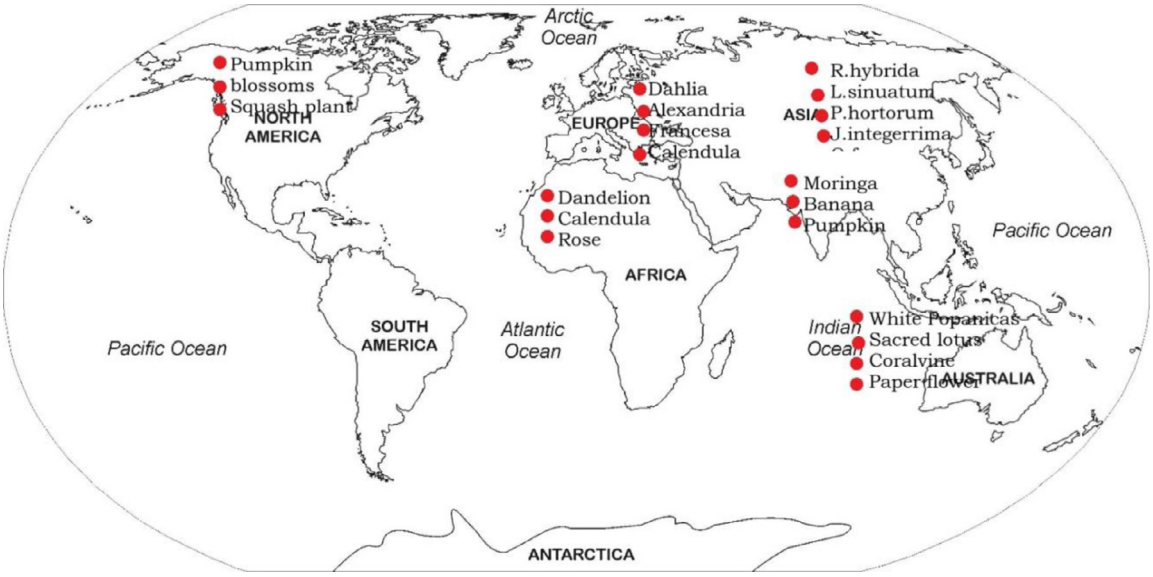


Fig. 1. Available Edible flowers throughout the world

age has been studied on the edible flowers, it has been reported that the fresh edible flowers in Italy contain significant amount of anthocyanins, ascorbic acid, flavonoids and polyphenols (Landi *et al.,* 2015).

Edible flower samples of 14 Different generas were evaluated to determine total antioxidant activity, total phenolic content and plant pigments by Dhiman et al. (2017). The EF with specific phytochemicals composition were also investigated for their in-vitro antioxidant assay and antioxidant potential. The report showed that extracts of Vinca Red and Vinca Pink flower have the highest antioxidant capacity among all. However, least was observed in Gomphrina flower. Pusa Narangi flower had the highest total phenolic content (TPC). It was concluded from the results, that most of the flowers are rich in antioxidants, phenols, carotenoids and lycopene thus they are a potential source of phytonutrients.

The lipid profile and nutritional combinations of edible flowers have been found to have exceptionally interesting compositions from a health point of view. The results of research indicate that most of the edible flowers are highly rich in their fatty acid profiles and specifically essential fatty acids. The vitamin E which is mostly present in them and called as tocopherol is found to have a very high biological activity. The carotenoids which are mostly found in these edible flowers are xanthophylls, such as lutein and carotene are also found in some. β – carotene and Lycopene are also reported with very good health attributes (Fernandes *et al.,* 2018b). Matyjaszczyk and Śmiechowska, (2019) reported that health benefits associated with edible flower and the active compounds occurring in most of the edible flowers where it was found that the edible flowers are very rich in bioactive components in which polyphenols and their specific antioxidant properties are the most frequently occurring ones.

Extracts of 19 edible flowers of China were studied for their antioxidant activities by (Zheng *et al.,* 2018) and it was found that upon using the flowers as herbal tea extract for the study and it was found that the varieties of edible flowers tested had a stronger antioxidant activity and polyphenolic activity than that of black and green tea. However, in vivo studies are needed to confirm the health-promoting potential of these herbs. Similarly, the biological values of 12 edible flowers was compared by Grzeszczuk et al., (2016) who concluded that: edible flowers are rich sources of nutritional and bioactive compounds and among the tested edible flowers the flower *Tagetestenui folia* had the highest content of biologically active compounds such as L- ascorbic acid, total carotenoids, total polyphenols, and highest antioxidant activity.

4. Potential Health Benefits of EFs

Presently the flowers are regaining popularity due to their health benefits and consumer acceptance (Patel and Naik, 2010; Rop et al., 2012). The presence of micronutrients in the edible flowers in large quantities helps in prevention of several diseases. Among these, some are useful for treating cardiovascular diseases, cancer, diabetes, microbial infections, cold, cough, jaundice, pox etc. (Jucá et al., 2020, Sharma et al., 2018).

In a research reported by Yamamoto and Kono, (2018) the physiological functions of 70% ethanol extracts of six edible flowers locally found in Japan was evaluated in-vitro for their antioxidant activity (based on radical scavenging properties), anti-hypersensitive activity, anti-diabetic activity (based on amylase reduction ability) and anti-adiposity activity (based on lipase inhibitory activity). According to the results of this study, the extracts represented a 2-3 higher antioxidative activity than α-tocopherol. The anti-diabetic, anti-hypersensitivity and anti-adiposity activity have also represented a good biological value. Kumar et al, (2018) outlined some specific health benefits of edible flowers such as being nearly calorie free, great source of bioactive compounds such as polyphenols, very good source of antioxidants, anti-inflammatory nature, potentially active compounds which act against various diseases of liver, prostate, bladder, colon and breast.

In an elaborate research conducted by Chensom *et al.,* (2019) thirteen edible flowers, which are used as food ingredients in Japan, were evaluated as possible sources of antioxidants and biological compounds. The nutritional composition, total polyphenol content (TPC), carotenoid content, and antioxidant activity of the edible flowers were determined based on the oxygen radical absorbance capacity (ORAC). This study highlighted that edible flowers are a potential source of antioxidants, and the addition of edible flowers to the human diet provide health benefits. In the same study, it was also found, that the edible flowers exhibited similar nutritional profile to that of vegetables generally grown in Japan. Among all the 13 edible flowers tested, cosmos yellow was found to be the best source of polyphenols and antioxidants. Moreover, some of the selected edible flowers also contain a provitamin. A precursor, β-carotene and β-cryptoxanthin, which may enhance human health. Therefore, the results concluded that consuming edible flowers everyday would help in preventing diabetes, hypertension, adipose accumulation and oxidation reactions in body.

In another study, various reviews related to edible flower from a perspective of nutraceutical ingredients was done and it was concluded that

the components of edible flowers which are proteins, saccharides, fats and vitamins is somehow similar to that of the other green portions of the plant (Mlcek and Rop, 2011). They also studied the chemoprotective effects of consuming edible flowers for curative effects and for reducing the risk of occurrence of various diseases. They claimed that there are substantial researches to establish the nutritive and chemoprotective impact of edible flowers on health. Moreover, it was also mentioned that the edible flowers should be put under medicinal or nutraceutical category because of their bioactive properties. However, the ornamental flowers are not recommended to include in the study.

It was reported by Kaur *et al.*, (2006) that the extract of *Cassia siamea* Lam. (Fabaceae) flowers contains large amount of polyphenols and exhibits strong reducing and oxygen scavenging ability in oxygen, nitrogen oxide, hydrogen peroxide and proteins as well, which justifies the statement "edible flowers having strong antioxidative activity". The reported extract of edible flower has also been found very effective in acute oxidative tissue injury, hepatic enzyme balance, protection against histopathological changes such as necrosis, fatty changes, ballooning degeneration etc. Thus, found to be very effective in liver health management. Ethanolic extract, of the edible flower *P. mume* of China, was tested for its claim of providing health benefits in traditional Chinese medicinal system since very long and. it was found that the flower does have a medicinal basis as antioxidant, because of the reason that it contains a high concentration of biologically active chlorogenic acids, which established its pharmacological properties (Shi *et al.,* 2017).

Anti-hyperglycemic and anti-cholinergic effects on natural antioxidant in flowers was studied in selected 16 edible flowers by Nowicka and Wojdyło (2019) where they checked the bioactive compounds such as polyphenols, carotenoids, triterpenoids and for anti-diabetic qualities of edible flowers inhibition of amylases by edible flowers were studied. It was found that the edible flowers like haw thorn and primrose were having an exceptionally high content of biologically active polymeric procyanidins. There was above 50% of the polyphenol content recorded in these flowers. Anti-aging effect was also studied and was found that edible flowers possess anti-aging effects on skin. Flowers like marigold, lavender, arnica and daisy were found to have a strong addictive feature which can be used for patients like senile dementia as an alternative to sedative drugs. They have also been reported for containing high levels of carotenoids, triterpenoids and for having anti-hyperglycaemic properties (Chitrakar et al., 2019).

Anti-obesity activity was also reported in some flowers such as Water lily, roselle and magnolia flower. Anti-aging and neuro-generative diseases were also reported to have lessened in the populations consuming edible flowers since ages. Flowers like Roselle and Chinese hibiscus have been reported to have hepatoprotective and gastro protective effects on body. Whereas, In vivo trails of roselle outlined its activity as an anti-cholesterol, anti-hypertensive and anti-diabetic functions also and on the other hand Chinese hibiscus has been found to have an exertion on anti-convulsive, contraceptive for acting as anti-nociceptive drug with honeysuckle as well as in showing anti-diabetic effect (Fernandes et al., 2017a), wound healing, hair growth and on increasing immunity also. Rose extract was found to have a decreasing effect on blood pressure in both acute and chronic cases in animal studies. Chrysanthemum has been found to have an effect on sleep regulation and Chamomile has been reported.

5. Processing and Preservation Methods

Edible flowers are perishable due to higher water activity and difficulties to preserve them for longer time significant. However, proper processing could be the solution to above problem. The possibilities for scaling up the production of edible flowers and preserving in native or value added form requires interventions with ability to address freshness retention, shelf life, cost and retention of bioactive attributes along with basic nutritional properties. Another biggest issue with EF is seasonal availability and short life span. Though consumption of EF in native form renders many advantages but to tackle with the challenges related to its availability novel interventions are very much essential. Fernandes et al. (2019) opined that dehydrated or crystallized form may be a good option. Application of emerging technologies are getting greater importance in many preserving perishable food, however, cost associated with them has become the major limiting factor and restricting commercial use. On the other hand, novel drying methods like vacuum drying, dehumidified drying, microwave drying, hybrid drying are being considered as a better option with the potential of preserving bioactive components present in edible flowers (Chitrakar at al., 2019).

Several processing and preservation techniques have been mentioned in detail by Zhao et al., 2019 (**Table 3**). The preservation of EF can be achieved through three main segments as mentioned below

- Pre-processing: Firstly, during pre-processing storage till the EF reaches processing unit from farm.
- Processing: Secondly, processing through suitable methods while giving due emphasis to freshness and quality retention.
- Packaging: Lastly, post processing storage with proper packaging.

5.1. Pre-processing

Nitric oxide fumigation treatment can be used as post-harvest quarantine treatment (Liu, 2015). Kelley et al., 2001 have conducted a storage study on five different species of flowers at different temperatures. The flowers had been stored in polyethylene bags with temperature ranging from -2.5 to 20°C. Flowers namely Viola, Pansy and Nasturtium were marketable after 2 weeks when stored at a temperature of -2.5°C. But, flowers like Borage and Scarlet Runner Bean have shown marketable appearance only on week 1 at temperature of zero to -2.5°C. On the other hand, chlorine dioxide fits well in this demand, showing strong oxidant power over microorganisms. This chemical can be applied alone or combined with other preservatives, in aqueous or gaseous form, to extend shelf life of several substrates including edible flowers (Ran, et al., 2019).

5.2. Processing

There are several products made with EF apart from being used as fresh. But due to increasing demand the processing and preservation techniques have been introduced to preserve the EF with retention of quality parameters. Few of the processing methods like, Irradiation, High pressure Processing (HPP), Ultrasound, Edible coating and drying have been used for preservation.

5.2.1. Irradiation

Viola tricolor L. flower treated with gamma irradiation and electron beam irradiation to check the antioxidant activity. Several dosages have been applied and it was noticed that irradiated flowers showed highest phenolic content and antioxidant activity. Treatment with electron beam and gamma irradiation in low dosages (1.0 kGy) have also proved to be able to preserve both integrity and chemical components of edible flowers such as Dianthus chinensis (Koike et al., 2015). However, fungal infestation is common in EF and irradiation dose required to encounter fungal infestation imparts negative effect on quality of edible flower (Fjeld et al., 1994). Thus, a lower irradiation dose is desirable in order to preserve functional properties of EF. Under this circumstances, combining irradiation treatment with other method could be the solution. Cia et al. (2007), suggested clubbing the UV-C treatment and gamma irradiation could ensure lower gama ray dosage and quality retention. In addition above treatment could be effective in fungal inactivation as well.

5.2.2. High Pressure Processing (HPP)

From a research on the influence of HPP on cauliflower and broccoli (Fernandez et al., 2006; Fernandez et al., 2017c). it has been reported that blanching and high-pressure processing can be used as an

Table 3
Different preservation methods of edible flowers

Name of the flower	Preservation Method	Reference
All flowers	Small and hard Plastic wraps	Newman and O'Conner, 2009
Snap Dragon, Carnations, Crutaurea	Modified Atmospheric Packaging (MAP)	Kou et al,, 2012; Gude et al,, 2011; Aros et al., 2017
Crutaurea, Pansies, Camellia, Borage	High Hydrostatic Pressure (HHP)	Fernandes et al., 2017b, 2017c
Night Fragrant, Pansy	Edible Coating	Xie, 2015; Fernandes et al., 2018a
Optima flowers	Breathable film + 1 MCP	Asil and Mahnaz, 2013
Orchid, Viola, Cut- rose	Irradiation	Fjeld et al., 1994; Chu et al., 2015; Koike et al., 2015; Kikuchi, 2000; Hallman, 2011; Fan, 2003
Walnut male flower	Shade Drying and Oven Drying	Zhang et al., 2008, 2016
Day Lily, Dried Rose, Magnolia liliflora	Microwave Drying	Li et al., 2015; Chunfang et al., 2011; Ding et al., 2012
Marigold, Day Lily	Freeze Drying	Mao et al., 2006; Sirithon et al., 2012
Orchid, Rose, Carnation, Jasmine, Loquat Flower	Hybrid Drying	Zheng et al., 2015; Sirithon et al., 2012; Visalakshi et al., 2015

aid in frozen storage of EF. High pressure processed and frozen broccoli exhibited better texture, less drip losses, and minimum cellular damage than that of conventionally frozen broccoli. In a similar research, McInerney et al. (2007) highlighted that HPP at 400-600 MPa had minimum effect on the β-carotene and Lutein of broccoli juice. However, in a comprehensive study pertaining to HPP of four EF-centaurea, pansies, camellia and borage, the shelf life extension was found to be flower specific Fernandes et al. (2017b). HHP treatment of pansy at 75 MPa (holding 5 or 10 min) was found as a promising condition to extend shelf life up to 20 days from 6 days for untreated. On the other hand, no shelf life extension was observed for other three flowers. Thus, application of HPP flower dependent.

5.2.3. Edible coating of EF

The major role of edible coating is to provide desirable barrier properties for moisture control, manage gaseous exchange, retaining colour and flavor, and minimizing enzymatic oxidation in agricultural products (Ju et al. 2019; Shigematsu et al., 2018). Based on the results of edible coating of fresh fruits and vegetables, edible coating technology could be a promising method to preserve EF. However, limited information is available in this context. In a study, effect of simple alginate coating on various microbiological and physicochemical properties of Pansy flower was investigated under refrigerated condition (Fernandes et al. 2018b). Hydrolysable tannin, anthocyanins and flavonoids and antioxidant activities of pansy flower were found higher in coated flowers than in those uncoated ones. Moreover, the shelf-life of it was extended to 14 days, which was 7 days longer than the untreated ones. Xie (2015) reported that, soy protein-alginate-chitosan based composite edible coating could be suitable to inhibit enzymatic browing, shedding rate, vitamin C loss, while it retains the sensory qualities Night-Fragrant flower. In another study, effect of edible coating in association with packaging of pansy flower was evaluated by Fernandes et al. (2018a). Compared to uncoated sample, coated and packaged sample showed significant difference in shelf life under refrigerated storage (from 3-4 days to 2 weeks).

5.2.4. Drying

Drying is very common method of preservation since ages. Drying of EF has been showcased to be most efficient method for preservation through inhibition of spoilage caused by microbes and enzymes (Ahrné et al. 2007; Pan at al. 1998). Traditional drying methods such as sun drying, solar drying, and shade drying have been tested for drying of EF. However, with progression of time various modern method of drying have evolved which includes, hot/dehumidified air drying, freeze drying, vacuum drying, microwave drying and hybrid drying (combination of two or more types of drying) (Zhao et al., 2019). Above drying methods have been widely tested for drying of fruits and vegetables and hybrid drying method could be promising for preservation of EF. Solar drying, shade drying and vacuum drying of *T. erecta* flower was attempted by Ahluwalia et al. (2014). As per this research, though the nutritional content increased due to drying but the anti-oxidant activity and total phenol content was noted to goes down the scale. However, among all these methods, vacuum drying was adjudged to be superior due to higher retention of β-carotene. In another study, far infrared drying of *T. erecta* was conducted, which showed maximum retention of carotenoids and phenolic compounds (Siriamornpun et al., 2012).

5.3. Packaging

Post processing storage is most important factor to justify the processing method used and to witness the expected shelf life. Modified atmosphere packaging (MAP) is the method to modify the gas composition within closed polymeric film either actively or passively. Generally, the atmosphere inside the packaging is altered in order to slow down the rate of respiration, which further control the metabolic heat generation by the living food. Similar to other vegetables, fresh cut flowers do consume O_2 and produces CO_2, inside packaging the closed packaging. This is commonly known as passive modification of the atmosphere naturally through the respirational exchange caused by the product itself. The reduced O_2 concentration and elevated level of CO2 concentration inhibits the mold growth, which is further help in slow down the food decay (Falagán and Terry, 2018).

MAP has been very commonly used and scientifically proven method to retain the quality and freshness of fresh fruits and vegetables (Sing et al., 2018). Aros et al. (2017) evaluated the application of MAP of carnation, lily and rose, which gave promising results related to shelf life extension, however, efficacy of MAP for preservation of long stem EF was found inferior. Remarkably, shelf-life of several kinds of flower bulbs and herbaceous perennials showed greater shelf life of 2-3 months, which was significantly higher than 2-3 weeks for control. Use of 1-Methylcyclopropene (1-MCP) as ethylene binder has been presented by Kou et al. (2012). They evaluated the impact of MAP in combination with 1-MCP treatment on storage-life of carnations and snapdragons in which it was worthy to note that there was 248 time increase in shelf life and other quality attributes were retained.

Various gas mixtures of 92% N2, 3% O2 and 5% CO2 in polypropylene (PP) and polyethylene (PE) pouches stored at 4 ± 1°C were tested for preservation of cauliflower (Khaled et al. 2019). The cauliflower packed with above mentioned gas mixture in PE pouch had a shelf-life of more than 30 days, which was more than cauliflower stored in PP with above gas mixture. Thus, above findings strongly support the affirmation that MAP could be the suitable method for preservation of EF.

6. Innovative Value Added Products

Since long time, EFs are mostly used as culinary ingredients in food because of their powerful and unique flavors, soft textures and bright colors. EFs are also used as salads, and to make beverages such as tisanes and wines. In addition, flowers extracts are also introduced as aroma or flavor enhancer (Fernandes *et al.*, 2017a). Other possible uses of flowers and their extracts are to make spreads such as butter or fruit preserves, vinegar, marinades, and dressings. Thus, EF is not only a candidate for culinary preparation but also possess immense potential to be a source of value added products. Similarly comparison of bioactive compounds and sensory evaluation of edible flower infused tea was done by Hussain *et al.*, (2019) where the 3 common edible flowers France Rose Buds, Jasmine Flower, and Osmanthus Flower of Malaysian market were taken and compared and it was found that the Osmanthus flower preceded the other two in terms of caffeine and polyphenolic content.In a study conducted by Matyjaszczyk and Śmiechowska, (2019) advantages and risk pertaining to edible flower and their consumption was analyzed. The results of the survey showed a very positive attitude among consumers associated with food products containing flowers with "health benefits"; whereas, yoghurt with flowers was considered as an innovative product. Several products also used to make from the flower such as jam, jellies, sauce, vinegars, liquors, honey etc. These flowers are also used for making tea, ice cubes, salads, candies and several beverages. In the Mediterranean countries Cardoon (*Cynaracar dunculus*) flower was used to make cheese as well. The extracted enzyme from the flower is also used as vegetable rennet (Colombo et al., 2010).

7. Toxicological effect of edible flowers

Some reports have been given for the food allergens where consumption of flower causes diseases and allergies. Apart from many safe and nutritious edible flowers, there are few which are not considered as safe for consumption purposes. Therefore, there is a need for identification of each variety of edible flowers open to consumption. By the researches reviewed, it is not recommended to consume or garnish with flowers bought from garden centers, florists or nurseries because there are very high chances of them being treated with pesticides and containing harmful toxins naturally. There are very high chances of people undergoing conditions like asthma, hay fever, allergies and can even lead to death when consumed. Some edible flowers come from wild plants, collected from wild stands (Kumar et al, 2018). Contamination of flowers with similar but poisonous relatives growing in the neighborhood is therefore not unlikely. The hazardous compounds may come from the plant or from the different levels of food chain. The two most important groups of external impurities occurring in edible flowers are bacteria and chemical compounds. Hazardous bacteria may come both from agricultural production and the food chain, while the sources of chemical impurities are mostly agricultural production and the environment. Relevant safety requirements and guidelines are scarce (Matyjaszczyk and Śmiechowska, 2019).

It has also been reported that despite of having rich pigments, nutrients and health benefits, few edible flowers (e.g. *Connavalariamajalis, Anemone ranunculoides* etc) are associated with presence of some harmful chemical compounds and pathogens as well such as dimethoate, sulphites and salmonella. Edible flowers which are consumable are categorized under ornamentals such as calendula, begonia, daylilies, honeysuckle and hibiscus. Other than ornamentals there are fruity flowers which are consumable such as banana flower, citrus flower, various herb flowers and vegetable flowers (Ebert, 2013). Therefore, there is a need of proper identification and processing techniques for edible flowers, in order to consume the same. In a study conducted by Guine *et al.*,(2017) beliefs and awareness about the consumption was studied in Portuguese adults and it was found that the there was many factors which were governing the same such as gender, education and area of work and some of the consuming habits related to edible flowers. However, there were many confusion related to the consumption because of the toxic nature of few of the edible flowers. Therefore, the flowers for consumption purpose should never be bought from the ornamental flower shops because they have been reported to be high in herbicides, fertilizers and pesticides and are from the non-tested cultivars.

Table 4
Safety Issue identified by RASFF for edible flowers (Matyjaszczyk and Śmiechowska, 2019)

Name of the impurities	Flower Name	Year	Country
Microorganism (*Salmonella spp.*)	Cornflower blossoms	2018	Albania
	Magosa Flower	2017	Thailand
	Dried Marigold	2004	Egypt
Rodents	Chamomile flower	2016	Egypt
	Hibiscus Flower	2008	Egypt
Chemicals	Tilia Flower	2015	Bulgaria
	Tilia Flower	2014	Albania
	Cinnamon Flower	2005	Sri Lanka

Worldwide many flowers are edible but there is no certain rule or division by the governing bodies to classify them. Some of the flowers are poisonous mainly due to the presence of dimethoate, sulphite and pathogenic microorganism mainly *Salmonella* spp identified by Rapid Alert System for Food and Feed (RASFF). The identified few flowers detected by RASFF has been mentioned in **Table 4**. According to European Regulation (EC) No.258/97, there are no legal requirements for edible flower marketing. But no official food safety and security laws and discrimination has not given by any international bodies. Also, most of the studies revealed that edible flowers were nontoxic at an appropriate dosage which therefore marks this as a discussed issue amongst scientists and researchers.

8. Future Scope and Concluding Remarks

Flowers were cooked from thousands years in many cultures in their traditional cooking methods. Vedas and traditional knowledge has mentioned about medicinal uses of flowers and in recent years modern science is taking significant interest to explore the potential of EF. Above review gives a fair idea about nutrition, health benefits, processing, preservation and toxicological aspect of EF. Due to superior nutritional and bioactive properties along with flavor and aroma, EF could be an ideal candidate in various products. Though, there were many culinary uses of edible flowers but modern processing interventions have the potential for value added product development along with techniques to preserve them for longer than usual. However, processing and preservation aspect has been explored for selected edible flowers only and wider application could be promising. Commercialization of value added EF product is far away due to lack of scientific reports. Among the tested preservation methods novel drying methods and innovative packaging methods could be the game changer in promoting edible flower for commercial practices. Moreover, there is a need to bring in strategic regulation to ensure safe use of edible flowers. There is a huge potential of using flowers in food. It will not only help the present but also be a potential food for future generation.

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Declaration of Competing Interest

The authors declare no competing interests.

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