CHAPTER 1

Introduction

Flowers have been a part of cuisine of various countries such as India, China, Thailand, and Mexico etc. since ancient times. Edible flowers are used to garnish dishes, enhance the flavor, liqueurs, vinegar or oils, as ingredients to make jam, jellies, salads, soups, desserts, breads, cakes, cheeses, curry, syrups or tea infusions etc. (Guiné et al., 2019). There are more than 97 families belonging to 100 genera and 180 species of edible flowers available worldwide (Lu et al., 2016), where their sources are ornamental plants, fruit and vegetables trees, also medicinal and aromatic plants etc. Based on species to species, some flowers can be eaten whole and some flowers can be eaten for their specific parts only. Along with improving the appearance, taste and aesthetic value of food, edible flowers comprise both nutritional and medicinal properties. Focusing on nutritional properties, they contain protein, carbohydrates, saturated and unsaturated lipids, sugars, organic acids, antioxidants, phytochemicals (carotenoids, flavonols, alkaloids, and terpenoids), vitamins, minerals, etc. (Fernandes et al., 2017). Edible flowers have been reported to possess various medicinal properties, such as antimutagenic effects, antitumor, anti-inflammatory, antibacterial, antifungal, and antiviral effects (Rachkeeree et al., 2018 & Benvenuti et al., 2016). As research has shown that many edible flowers contain beneficial compounds, including antioxidants, polyphenols, and essential minerals, which may contribute to human health and well-being (Kim et al., 2021). Additionally, their natural colors and bioactive compounds make them attractive alternatives to synthetic food additives, aligning with consumer preferences for clean-label products (Chen et al., 2022). So, the growing need for healthy, natural functional foods can be fulfilled via edible flowers. Edible flowers are also a part of traditional delicacy of Assam (India) along with the belief that edible flowers provide both nutritional and medicinal properties. Different communities cook edible flowers differently, such as with traditional alkali (locally name is kolkhar), fish, egg, meat (pigeon, duck etc.), also eaten as curry and fritter etc. (Nongthombam et al., 2018).

Some common edible flowers of Assam are Papaya (*Carica papaya*), Gmelina or White teak (*Gmelina arboria*), Tita ful or Thyrsiformis (*Phlogacanthus thyrsiformis*),

Stinging nettle (or Sinuate nettle) (*Dendrocnide sinuate*), Malabar nut or Adhatoda (*Justicia adhatoda*), Indian trumpet tree (*Oroxylum indicum*), Night-flowering jasmine or Parijat (*Nyctanthus arbortristis*), Spiny water lily (*Lasia spinosa*), Elephant ear or Khuian (*Alocasia acuminate*), Butternut squash (*Cucurbita moschata*), Pinwheel flower or Crepe jasmine (*Tabernaemontana divaricata*), Canna lily (*Canna indica*), Orchid tree or Mountain ebony (*Bauhinia* spp.), Agathi or Sesbania (*Sesbania grandiflora*), Drumstick (*Moringa oleifera*) etc.

The incorporation of edible flowers into food products has emerged as an innovative and sustainable approach to enhancing the nutritional, sensory, and functional properties of various food categories. Edible flowers, rich in phytochemicals, antioxidants, and essential nutrients, have shown immense potential in diversifying food applications while contributing to health benefits. Their use spans multiple product categories, including rice, infant foods, meat products, bakery items, beverages, dairy products, and extruded foods, each offering unique attributes.

From improving antioxidant and sensory properties to augmenting nutritional profiles, edible flowers have demonstrated their versatility. For instance, flowers like *Clitoria ternatea* enhance the functional attributes of rice, while *Moringa oleifera* boosts the nutrient content of infant foods and meat products. Similarly, their application in bakery products, beverages, and dairy products not only adds aesthetic appeal but also increases shelf life, antioxidant capacity, and bioactive compound retention. However, the expanding market for edible flowers presents several critical challenges that demand attention from researchers, regulators, and industry stakeholders. Primary among these concerns is safety, as not all flowers are suitable for human consumption, and even edible varieties may pose risks if improperly sourced, handled, or prepared (Wilson et al., 2021). The potential presence of toxic compounds, pesticide residues, and allergenic substances necessitates rigorous safety assessments and quality control measures to protect consumer health (Thompson & Anderson, 2023). The regulatory landscape surrounding edible flowers remains complex and often inconsistent across different jurisdictions. While some regions have established clear guidelines for the commercial use of edible flowers, others lack specific regulations, creating uncertainty for producers and consumers alike (Martinez-Silva et al., 2022). This regulatory variability highlights

the need for harmonized standards and protocols to ensure safety and quality consistency in the global market for edible flowers.

Consumer acceptance of edible flowers varies significantly across different demographic groups and cultural contexts. While some consumers embrace these ingredients for their novelty and perceived health benefits, others remain hesitant due to safety concerns or unfamiliarity with their use (Wang & Johnson, 2023). Understanding these varying perspectives is crucial for developing effective marketing strategies and educational initiatives to promote safe and appropriate consumption of edible flowers. Furthermore, edible flowers are effective natural alternatives for artificial additives, such as coloring agents, and can significantly reduce harmful compounds during thermal processing. The broad applicability across diverse culinary and functional domains underscores their potential in the food industry as valuable natural ingredients. This growing trend highlights the need for further research and development to unlock the full potential of edible flowers in creating innovative, functional, and sustainable food products.

Flowers of Night jasmine *(Nyctanthus arbortristis),* Drumstick *(Moringa oleifera),* Pumpkin (*Cucurbita sp.*) and Nongmangkha *(Phlogacanthus thyrsiflorus)* are commonly consumed in Assam, India. Pumpkin belongs to *Cucurbitaceae* family (genus *cucurbita*) and bears a bright color (between yellow and orange color) and it starts to bloom from February to March. This flower was traditionally believed to be used for treating cold, male infertility, eye problems, bone formation and improving immunity (Ghosh et al., 2021). Specially, Pumpkin flower is rich in sodium, potassium and calcium and is a good source of oleic acid, myristic acid and stearic acid. Santos et al. (2022) mentioned in their study that addition of Pumpkin (*Cucurbita maxima*) flower powder in chicken patties could improve the antioxidant and sensorial properties. The yellowish white flowers of Drumstick have fragrance and belong to family *Moringaceae* under the genus *Moringa* and generally bloom from Januray to March. Also, these flowers are a source of protein, amino acid (Sánchez-Machado et al., 2018), potassium, calcium, antioxidant (α, γ tocopherol) (Liu et al., 2018). It was reported that they act as antioxidative agent, exhibits anti-inflammatory activity, have diuretic actions, offers hepatoprotective effects, prevent asthma, muscle and spleen diseases, and effect on

tumors (Patriota et al., 2020) etc. Studies found that extracts of drum stick flower reduced the lipid oxidation in cooked chicken nuggets (Madane et al., 2019).

The small, delightful fragrance bearing flower Night jasmine belongs to the family Oleaceae, native to Southern Asia which blooms at night during September to January. It has a bitter, astringent taste (Sasmal et al., 2007) and is a good source of flavonoids, anthocyanins and an essential oil (Jain et al., 2016), potassium, calcium, magnesium, sodium, iron and zinc etc. (Haque et al., 2019). This plant is regarded as a medicinal plant traditionally and the flowers have been reported to deliver antibilious, antifilarial, anti-inflammatory, antioxidant acitivity, diuretic, dyspepsia, ophthalmic, sedative effects, cytotoxic activity (Khatune et al., 2001), antibacterial and hepatoprotective (Pal et al., 2019). Night jasmine flowers comprising delightful fragrance which belong to family *Oleaceae*, native to Southern Asia and bloom at night. They have bitter, astringent taste (Sasmal et al., 2007) and a good source of flavonoids, anthocyanins and an essential oil (Jain et al., 2016), potassium, calcium, magnesium, sodium, iron and zinc (Haque et al., 2019). Also, other chemical constituents were found such as essential oil, nyctanthin, D-mannitol, arborside C, 6-b-hydroxyloganin, nyctanthoside, D-mannitol and carotenoids, cyclohexylethanoid etc. (Agrawal et al., 2013). This plant is regarded as a medicinal plant traditionally and the flowers were delivered antibilious, antifilarial, anti-inflammatory, antioxidant, diuretic, dyspepsia, ophthalmic, sedative effects and cytotoxic activity (Khatune et al., 2001), antibacterial, hepatoprotective, cytotoxic activity, antioxidant activity (Pal et al., 2019). Sasmal et al. (2007) reported that graying of hairs and baldness could be stopped by using juice of this flower and could be used for the treatment of constipation, intestinal worms, and piles (Nagavani et al., 2010).

Red brick colored Nongmangkha flowers belong to acanthaceae family and an important medicinal plant that blooms from February to April. These flowers were reported to deliver beneficial health effects on hyperlipidemia (Chakravarty et al., 2014), antioxidant and radical scavenging activities (Nongthombam et al., 2018), and possessed hypoglycemic and hypolipidemic properties (Ahmed et al., 2016). Nongmangkha flowers were believed to cure pox; prevent skin diseases like sores, scabies, have anti-allergic effects, treat wounds and tumors, act as a blood purifier (Koushik et al., 2020),

kidney stones, and liver disorders (Das et al., 2017). The flowers contain steroids, terpenoids, flavonoids, phenols, etc. (Nongthombam et al., 2018).

Novel extraction techniques are employed due to its advantage over conventional extraction methods as conventional extraction methods such as maceration, decoction, percolation, infusion, digestion, serial exhaustive extraction, and soxhlet extraction etc. which had been practiced for extraction of phytochemicals were proved to be labourious, time consuming, and usage of high amount of organic solvents etc. High hydrostatic pressure, ultrasound, pulsed electric field, supercritical fluid, microwave-assisted extraction etc. were considered as novel extraction techniques and these techniques provide advantages over conventional extraction techniques by many research studies.

Microwave assisted extraction is regarded as green and novel efficient extraction technique which provide advantages over conventional extraction methods by higher extraction rate, less capital cost, good performance under atmospheric condition (Filip et al., 2017), lower consumption of solvent and sample preparation time than conventional methods (Sun & Lee, 2003) etc. But extraction time, liquid-to-solid ratio, extraction power, and type of extraction solvent etc. influence on the efficiency of microwave assisted extraction technique (Liu et al., 2016). Microwave assisted extraction technique utilizes microwave energy to migrate active compounds or target compounds from the sample matrix into the solvent. Microwave is electromagnetic field having frequency range from 300 MHz to 300 GHz (Ridlo et al., 2019). Due to ion conduction and bipolar rotation heat is generated and as a result cell wall disruption and release of target compounds occurs in solvent from plant samples or sample matrix (Mandal et al., 2015). In case of ultrasound extraction, the waves of ultrasound causes cavitation and bubbles are formed due to pressure and finally they are collapsed when reaching peaks of compression and expansion and resulted sonoporation in the disruption of the plant cell matrix (Rocha & Noreña 2020).

Disruption of cell wall is most important for the release of phenolic compounds from plant materials in both cases of UAE and MAE treatment. The deformation of cell matrix is more in combined UAE and MAE treatment leading to an effective and higher yield of phenolic compounds then solely UAE treatment. Combination of ultrasound and microwave extraction treatment could lead to an effective and higher yield of phenolic

compounds. Both ultrasound and microwave techniques help to disrupting the cell walls of plant sample. Supercritical fluid extraction (SFE) also has advantages that help to overcome various limitations of conventional extraction methods. SFE relies on the solvent properties of supercritical fluids, which are achieved by applying pressure and temperature above the critical point of a substance, mixture, or element (Ahmed et al., 2019).

Ethanol is less toxic, environment friendly and provides good potency for extraction of phenolic compounds, here in this study 80 % ethanol was used as sample solvent for extraction process. Solvent concentration and solvent polarity affects the extraction and purification of phytochemical. Based on chemical nature of target compound to be extracted, the solvents of different polarity are selected for better extraction (Nawaz et al., 2020).

Due to various factors such as light, pH, temperature and storage condition etc. along with simulated gastrointestinal digestion affects to decrease the levels of polyphenols or bioavailability of it or the quality of a polyphenol rich or bioactive compounds rich extract can be graded and resulting it loss of quality of an extract (Pasukamonset et al., 2016).Encapsulation technology is a process of entrapping active agents using coating materials and it is a useful tool to improve delivery of bioactive molecules and living cells into foods. Various methods of encapsulation of food ingredients are spray drying, freeze-drying, fluidized bed-coating, extrusion, cocrystallization, molecular inclusion, and coacervation etc. So, ion gelation is one of the techniques which can be adopted to preserve the quality or bioavailability of an extract. Also, encapsulation of extracts helps for the preservation and stability of the bioactive compounds during processing and storage. By harnessing encapsulation techniques of bioactive compounds from flowers, there is significant potential for research and innovation in the food industry to develop functional food products.

Functional food products are described as offering additional health benefits beyond their conventional nutritional value (Khan et al., 2013). As functional food products demands are increasing which might be due to the rising costs of health care, the steady increase in life expectancy and the interest of the elderly in the improvement of life quality etc. (Kraus, 2015). Edible flowers can be termed as functional food due to

its nutritional properties, antioxidant activity, antimicrobial activity, color, flavor, mood and stress reduction capability etc.

Night jasmine, Drum stick, Pumpkin flower and Nongmangkha flowers have been consumed traditionally since ancient times, not only as food ingredients but also to cure many diseases. But knowledge of edible flowers as food is mostly confined for traditional use, which hinders market viability. Along with these flowers, there are many flowers that are edible but due to lack of identification of edible flowers or knowledge of their uses, people cannot appreciate or visualize the novel uses of these edible flowers. A common fear regarding flowers is that there may be presence of unauthorized toxins or chemicals and some might be poisonous, and making the flower inedible. Indeed, the scientific study or the data regarding the exploration and use of edible flower as food are scanty. Therefore, it is necessary to conduct scientific studies proposing flowers as health beneficial foods to increase its awareness stimulate market growth and foster innovation in food technology. Understanding these varying perspectives is crucial for developing effective marketing strategies and educational initiatives to promote safe and appropriate consumption of edible flowers. These facts underscore the vision of this study which aims to provide valuable information on edible flowers for better utilization and innovation in food technology. Emphasizing on all these nutritional properties of edible flowers, there has been growing interest regarding the exploration and consumption of them. Edible flowers are inexpensive and abundantly available but have very low shelf life which limits the commercial viability of edible flowers and to overcome this limitation one of the ways we can follow is to extract the nutritional part from edible flowers and can utilize for further use such as formulation of functional food products. As a common fear regarding flowers is there may be presence of unauthorized toxins or chemicals and some might be poisonous and make the flower inedible and indeed, the scientific study or the data regarding the exploration and use of edible flower as food is scanty. Therefore, it is necessary to conduct scientific study proposing flowers as a health beneficial food to increase its awareness, market growth and innovation in food technology. Therefore to address these the proposed work aims to provide the effective extraction parameters by using novel extraction technique (supercritical fluid extraction and microwave assisted extraction method) for optimum yield of bioactive compounds and its encapsulation and utilization for development of functional food product. It also

aims to provide valuable information (nutritional and cell viability study) on edible flowers in order to better utilization and innovation in food technology.

Some research gaps regarding edible flowers are observed are exploration of both nutritional and antinutritional properties of edible flower is limited. There is limited study on the extraction of major phytochemicals from the edible flowers of Assam. Also, there is limited scientific study on product development and food formulation using edible flowers.

As we can observe that the scientific research on the exploration and consumption of edible flowers as food is limited. As a result, conducting studies to highlight the health benefits of flowers is essential to raise awareness, promote market expansion, and encourage innovation in food technology. Accordingly, the proposed research aims to investigate the nutritional value of edible flowers, extract phytochemical compounds from them, and explore the potential uses of these flower extracts. Accordingly, this research study is comprised of four objectives which are mentioned below.

1. To conduct a comparative study of the nutritional and phytochemical properties of edible flowers.
2. To optimize the phytochemical extraction process from an edible flower using novel techniques.
3. To encapsulate phytochemical extract of edible flower and their characterization.
4. To develop functional food products by incorporating phytochemical rich encapsulate.

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