ABSTRACT

Edible flowers have been consumed from ancient times, and it was believed to deliver medicinal properties. In this study some common edible flowers such as Night jasmine *(Nyctanthus arbortristis)*, Drumstick *(Moringa oleifera)*, Pumpkin *(Cucurbita sp.)* and Nongmangkha *(Phlogacanthus thyrsiflorus)* of Assam, India were taken for studying their different nutritional, phytochemical, antioxidant activity, minerals analysis and screening of phenolic compounds by HPLC etc. In this study phenolic compounds from this flower were extracted by employing microwave assisted extraction (MAE) technique with an ultrasound pretreatment. The optimized extract was taken for encapsulation. Finally functional food products such as gummies and RTS beverages were developed.

The thesis is divided into 7 chapters that are discussed below

Chapter 1 provides an introduction to the overall present research work. It includes a brief overview of edible flowers and their health benefits. Additionally, the extraction of bioactive compounds using novel extraction techniques is highlighted. The benefits of encapsulation of flower extract using the ion gelation technique, along with its application in the development of functional food products, are also discussed.

Chapter 2 presents a 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.

Chapter 3 presents data and discusses the findings on the biochemical properties of various edible flowers, including Night jasmine, Nongmangkha, Pumpkin, and Drumstick flowers. These flowers were analyzed for their nutritional composition,

phytochemical content, antioxidant activity, mineral composition, and phenolic compound profiling using HPLC. Among the studied flowers**,** Drumstick flowers exhibited the highest ash content and DPPH radical scavenging activity**,** while Nongmangkha flowers recorded the highest total phenolic content (TPC) at 115.117 mg GAE/g**.** HPLC analysis of night jasmine flowers identified the presence of several phenolic compounds, including gallic acid, resorcinol, caffeic acid, p-coumaric acid, and ferulic acid. Additionally, Nongmangkha flowers were found to contain resorcinol, 3,4-dihydroxybenzoic acid, rutin, ellagic acid, and salicylic acid**,** further emphasizing their rich phytochemical profile. Based on its higher phenolic content**,** Nongmangkha flower was selected for further study. The cell viability was observed to be different on the basis of the species of flowers. Cell viability of Nongmangkha flower extract was found to be 82.62 % at extract concentration of 200 µg/mL for 24 h.

Chapter 4 discusses the effects of microwave-assisted extraction (MAE) and supercritical fluid extraction (SFE) on the extraction of phytochemical compounds from edible flower. The study highlights that MAE and SFE exhibit significant potential for extracting phytochemicals compared to conventional extraction techniques. Among these, SFE demonstrated superior extraction of total phenolic content (TPC) compared to conventional methods. In the case of MAE, optimization of process parameters resulted in the highest extraction of TPC, TFC and DPPH radical scavenging activity, with TPC content found to be higher in microwave-assisted extracts than in conventional extract. The statistical analysis showed a coefficient of determination (R^2) value of 0.8424 and an F-value of 7.98, indicating a significant model fit. The optimized extraction conditions were determined to be 700 W and 5 minutes, under which MAE successfully extracted 30.20 (± 4.42) mg GAE/g of TPC, 81.26 % (±0.288) DPPH radical scavenging activity, and 22.50 (±5.029) mg QAE/g of total flavonoid content (TFC) from Nongmangkha flower. These findings indicate that the extract can be considered safe for use at lower concentrations, making it a promising natural source for functional food formulations.

Chapter 5 comprises the study on exploring the encapsulation of Nongmangkha flower extract using the ion gelation technique to enhance its stability and controlled release. The optimized encapsulation conditions, consisting of 3% sodium alginate and 5 % calcium chloride, resulted in high encapsulation efficiency. The encapsulation efficiency improved with optimized polymer concentration, reducing the migration of phenolic

compounds. After that when beads were prepared by using various concentrations of flower extract, it was observed that TPC increased with higher concentrations of flower extract. The thermal transitions of the optimized encapsulates exhibited enhanced stability. The intestinal release kinetics of total phenolics from beads and crude extract followed a biphasic and monophasic pattern, respectively. For encapsulates, two distinct phases were observed: an initial rapid release (Phase 1) with a higher rate constant followed by a slower, sustained release (Phase 2) with a lower rate constant**.** This suggests initial burst diffusion from the encapsulates' surface, followed by a controlled release from within the encapsulates. In contrast, the crude extract exhibited only a single-phase release with no secondary phase, indicating immediate and complete dissolution in the intestinal fluid. The findings confirm that the release follows first-order kinetics**,** where the rate is concentration-dependent, supporting a diffusion-controlled mechanism.

Chapter 6 includes the study of development of functional food products by incorporating encapsulated phytochemical extracts from Nongmangkha flower and assessing their physicochemical and nutritional properties. Encapsulation using ion gelation enhanced the stability and controlled release of phenolic compounds, which were then incorporated into gummies and ready-to-serve (RTS) beverages. The gummies containing encapsulated extracts exhibited improved nutritional properties, with increased total phenolic content and flavonoid content, as well as enhanced DPPH radical scavenging activity. Textural analysis indicated that the addition of encapsulated extract influenced the gummies' hardness, cohesiveness, and chewiness. Water activity increased slightly with encapsulates, though moisture content remained stable. Color analysis revealed increased redness and yellowness in treated samples due to bioactive compound incorporation. In RTS beverages, the inclusion of crude extract (CERTS) led to the TPC of 3.81 mg/mL and antioxidant activity of 57.17 %, while encapsulated extract (BRTS) maintained a controlled release of phenolic compounds. The pH and acidity of RTS samples remained within acceptable ranges for beverage stability. Color variations among RTS samples suggested that crude extract contributing to darker, reddish hues and encapsulated beads enhancing yellow tones. The findings confirm that encapsulation successfully preserves bioactive compounds while allowing their incorporation into functional food products without compromising sensory and physicochemical properties. This approach enhances the antioxidant potential and

nutritional quality of gummies and RTS beverages, supporting their role as viable functional food products. Further research could explore consumer acceptance and large-scale production feasibility.

Chapter 7 deals with the summary and future scope of the present research study. This study provides important insight into the composition of the nutritional compounds, antioxidant activity, minerals and phenolic profiles of the investigated edible flowers i.e, Night jasmine, and Nongmangkha, Pumpkin and Drum stick flowers. HPLC analysis for the screening of phenolic compounds, where various phenolic standards were used, showed that flowers of Nongmangkha and Night jasmine exhibited a better presence of phenolic compounds compared to Pumpkin and Drumstick flowers. The findings indicated that these edible flowers could be a good source of nutrients, mineral, phenolic compounds and antioxidants etc. Extraction of phenolic compounds such as TPC, TFC and DPPH capacity of Nongmangkha was done by using ultrasound pretreatment and microwave assisted extraction (MAE) technique and RSM, CCD showed successful and efficient application for this optimization of the selected MAE conditions. Both Microwave power and irradiation time showed impact on TPC, TFC and DPPH capacity. MAE extract showed better results of phenolic compounds in HPLC than conventional extract. Also ion gelation can be successful technique to encapsulate edible flower extract and also by incorporating these encapsulates various functional food products can be developed. Further research is needed to investigate the antinutritional properties of flowers and to develop processes to eliminate them for safe consumption. Moreover, further exploration is needed to identify, characterize and isolate bioactive compounds, along with further scientific investigations to understand their potential health benefits for human. This phenolic compounds rich flower extract could pave a way to researchers for novel utilization of flowers extract. These results signified that the Nongmangkha flowers extract could be a useful in functional food product development.