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Edible Flowers in Herbal Beverage Development

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Herbal beverages with nutraceutical benefits are becoming more widely acknowledged as healthy dietary choices among mindful consumers. There are numerous types of herbal beverages prepared from different morphological plant elements. Edible flowers, with their unique flavors, distinct aromas, vivid colors, and nutraceutical properties, have gained predominance among all the other botanical ingredients utilized in the formulation of herbal beverages. This review elaborates on applications of edible flowers used in the preparation of herbal teas, infusions, and a few other novel developments in herbal beverages. Although several commercialized herbal beverages have been developed with edible flowers, many other edible flowers with medicinal properties remain unexplored. The review further elaborates on the pharmacotherapeutic properties of these flowers, emphasizing their potential to be used in herbal beverage formulations. Additionally, ensuring the food safety aspects of innovative herbal beverages derived from edible flowers by addressing their potential toxicity and microbiological quality is vitally important. Insights presented here pave the way for incorporating edible flowers in herbal beverages, encouraging nutritious and health-promoting beverage development and consumption.

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Keywords: Edible flowers; herbal beverages; phytochemicals; extraction; preservation; health benefits.

1. INTRODUCTION

The nutraceutical segment continues to expand as a preventive approach against non-communicable diseases like hypertension, cancer, and diabetes, ultimately enhancing human life expectancy. Nutraceutical products are consumed by approximately 50-70% of the developed countries and usage among women was higher compared to men [1]. Herbal remedies are widely gaining acceptance as a complementary medical option worldwide, including in the USA and Europe [2].

Intake of nonnutritive nutraceutical compounds from dietary sources available in different palatable forms such as pharmaceutical or food supplements, food additives, and herbal beverages exhibited a marked growth in recent years. Herbal beverages have been used in traditional medicine over decades and have become a popular global beverage choice now. Therefore, herbal beverages are accepted as therapeutic carriers and a viable solution for the consumption of valuable plant nutraceuticals [3].

Traditionally edible flowers are consumed as teas or infusions; however, recent research studies have exhibited their potential to be used in novel herbal beverage developments owing to their unique taste, aroma, and colour properties. Other than utilizing edible flowers alone in herbal beverages, blending them with other plant-based ingredients with medicinal and nutritional properties has generated more palatable beverage solutions.

2. HERBAL BEVERAGE DIVERSITY AND CONSUMPTION TRENDS

The consumption of herbal beverages is embedded in the lifestyle of many Asians, Europeans, and Americans due to their health benefits, pleasant taste, and cultural influences. A wide range of herbal beverages can be identified and differentiated based on the preparation method and specific plant components utilized. In that context, herbal infusions play a vital role in traditional medicine where edible plant components with pharmacological values have been used as therapeutic agents over the years. Furthermore, it has gained popularity among health-conscious consumers who are heavily concerned about the health benefits of the beverages they consume. The term herbal drinks has multiple definitions based on the context of applications such as beverage and medicinal applications. Beverages derived specifically from the leaves, twigs, or buds of *Camellia sinesis* are frequently called "tea". The most basic definition of an herbal beverage is an infusion of fruit or herbs, excluding *Camellia sinesis* [4].

According to Rashid et al. [5], herbalism or botanical medicine are terms used to describe the preparation of plants for medicinal purposes. As per this classification, four types of herbal beverages are identified: herbal tea, herbal infusion, herbal decoction, and herbal fruit juice. From a different viewpoint, Sõukand R et al. [6] defined recreational tea as herbal beverages consumed as infusions and delivered in a food setting or as a culinary application. They are valued for their societal value, soothing effects, and widespread association as "healthy" beverages. Table 1 summarizes different types of herbal beverages and their preparation methods.

The majority of herbal teas and infusions are prepared just before drinking and often served hot. In this context, herbal teas are available in various forms: whole dried plant components, dried flakes, granules within tea bags, or sold in bulk. The plant material undergoes initial processing, involving drying, comminution, and crushing. Alternatively, instant tea, a completely soluble powder, is a concentrated tea infusion that undergoes water removal through spray drying. To preserve flavor, aroma, and nutritional quality, instant teas may undergo methods like vacuum drying and freeze-drying as well [7, 8]. However, a recent trend shows a surge in the popularity of ready-to-drink bottled herbal beverages [4]. For instance, iced tea, crafted from diluted herbal plant extracts, is marketed in bottles or cans for immediate consumption. Additionally, the realm of herbal beverage products sees innovation with carbonated herbal teas, presenting a promising avenue for commercial success. In fortified herbal beverages, a variety of ingredients are incorporated, spanning polyphenols, carotenoids (like astaxanthin, and lutein), Omega-3 oils (α-linolenic, eicosapentaenoic, docosahexaenoic acids), sterols, stimulants, and botanicals

Table 1. Different types of herbal beverages and preparation methods.

Type of Herbal Beverage	Description	Plant Components Used	Method of preparation	References
Herbal Tea	Teas that are made from plant species other than *Camellia sinensis*. (Green, black, white, and oolong teas are considered non-herbal teas). In some instances, they are also known as tisanes. Herbal teas merge recreational and therapeutic effects.	leaves, seeds, flowers, fruits, stems, or roots	The dried form of herbs (flakes or powders) is used in the making of tisanes. Approximately 2g of the dried herb is combined with 50 ml of boiling water and left to stand for around 5 minutes at ambient temperature. The resulting mixture is then filtered and decanted.	[5, 10, 11]
Herbal infusion	Herbal infusions are produced by steeping or boiling more herbs. Herbal infusions are only used for therapeutic purposes and to nourish the human body with an enormous amount of vitamins and minerals. Infusions are designed to harvest vitamins and volatile compounds.	leaves and flowers.	Initially, botanicals are chopped into chunks and hydrated. Conventionally, herbal infusions are made by immersing plant material in boiled water and allowing it to soak, then filtering the resulting liquid. This process is usually completed at room temperature and may utilize alcohol. The plant/extract ratio varies, but typically 1 part of herb generates 4-10 parts of the resulting mixture. Extraction efficacy is determined by the bulk density of the dried plant material. When fresh herbs (about 10% dry weight) are used in the same proportion as dried herbs for extraction, the final concentration is substantially reduced.	[5, 10, 12]
Herbal decoction	An herbal beverage designed to extract mineral salts and bitter compounds from plants. They require simmering for an extended period.	roots, seeds, barks, woods, rhizomes	Decoctions are often used for tougher plant components therefore it is recommended to mill or crush the plant materials before making the decoction. This is made by heating the needed amount of botanicals with water for around 30 minutes until approximately half of the water has been evaporated. As opposed to infusions, in the preparation of decoctions heat is constantly supplied. To avoid losing any vital elements this container must be closed during the thermal treatment. The extract is then filtered, and the decoction is utilized entirely or with appropriate dilution.	[5, 10, 12]
Herbal Fruit juices	Fruit juices are enriched with medicinal plant extracts to increase their nutritional value and therapeutic properties.	fruits, Herbal extracts from leaves flowers	Fruit juices are supplemented with herbal extracts, sweetened with sugar, stevia, and whey (optional), homogenized, and preserved thermally (e.g.: pasteurization) / with chemical additives / with other advanced preservation strategies.	[5, 13]

(superfruits, teas, herbal extracts). These additions synergistically amplify health benefits while ensuring palatability and balance in formulations [9].

3. INCORPORATING PLANT ELEMENTS INTO HERBAL BEVERAGES

There are many edible plant varieties but, in most species, the edible portion is restricted to one or few morphological plant parts. Phytochemical compounds can be isolated from some of these edible plant varieties, but they may most probably be not from the edible portion of the plant [14]. Different plant elements including leaves, seeds, fruits, stems, roots, peels, barks, and flowers, and their plant extracts are used in the preparation of herbal beverages.

Flowers which are mostly recognized for their ornamental value due to their attractive colors, shapes, and exotic aroma are now gaining more attention for their medicinal properties in food and pharmaceutical applications. Some flowers are technically edible but less palatable. Petals are the most consumed component in edible flowers although pollen, nectar, and other parts are also consumed [15]. Flowers, being more delicate but rich in bioactive compounds, flavor properties, characteristic aroma, and colour make a significant contribution mainly to herbal infusions and other novel applications in the herbal beverage industry.

There are 97 families, 100 genera, and 180 species of edible flowers found around the world excluding flowers based on vegetables such as broccoli, cauliflower, and artichoke [16]. Two types of edible flowers can be identified namely fruit flowers and non-fruit flowers. Fruit flowers such as Papaya, Apple, Peach, and Banana require to undergo a pre-heat treatment process before consumption. Non-fruit flowers such as Butterfly pea flower, Hibiscus, Rose, and Lotus are commonly categorized as ornamental flowers. Usually, this category of flowers has vividly colored petals & stamens [17]. There are several naturally occurring tree flowers such as *Corymbia calophylla, Butea monosperma, Bauhinia variegata, Rhododendron arboretum, Madhuca longifloia, Morigna oleifera, Delonix regia, Bombax cieba, Sessbania grandiflora, Woodfordia fructicosa* which are rich in phytochemical properties but still not widely explored for the applicability in the preparation of herbal beverages. Utilization of tree flowers in herbal beverages is restricted because of the short blooming period and availability in a limited geographical region. Furthermore, due to the short post-harvest life, these flowers are utilized mostly by the local tribes as a food ingredient or for medicinal purposes only during their respective flowering times [18].

4. HERBAL BEVERAGE FORMULATIONS WITH EDIBLE FLOWERS

Edible flowers provide competitive advantages to the production of herbal beverages. Their distinctive flavors, colourful pigments, and inherent medicinal properties make them an excellent addition to various formulations. By incorporating edible flowers and their extracts, alongside other compatible ingredients, a diverse array of visually stimulating herbal beverages can be developed to cater to both gustatory and sensory experiences. These flowers harbor valuable bioactive compounds that hold the potential to positively impact overall well-being. Moreover, the integration of edible flowers into herbal beverages amplifies their phytochemical composition, thereby contributing to enhanced health benefits. Fig. 1 illustrates commercialized and vividly coloured herbal beverages prepared with these edible flowers.

A functional beverage incorporated with *Clitoria ternatea* flower extract was developed with two other constituents, natural sweetener (Stevia extract) and a flavor (lime). This functional beverage possessed a significantly higher ($p<0.05$) antioxidant potential for total phenolic content and oxygen radical absorbance capacity compared to pure *Clitoria ternatea* extract. The total flavonoid content of *Clitoria ternatea* extract incorporated functional beverage & extract was 43.67 mg quercetin equivalents (QE)/L of sample & 42.75 mg QE/L of sample respectively. Antioxidant activity of the functional beverage was quantified by ferric reducing antioxidant power, DPPH radical scavenging activity, and ABTS radical scavenging activity resulting values were 14.99 mg Trolox equivalents (TE) per liter of sample, 35.07 mg TE/L, and 185.81 mg TE/L respectively. As per the evaluation of quality parameters of the functional natural beverage it was concluded that the beverage can be effectively utilized to manage oxidative stress associated with chronic diseases [19].

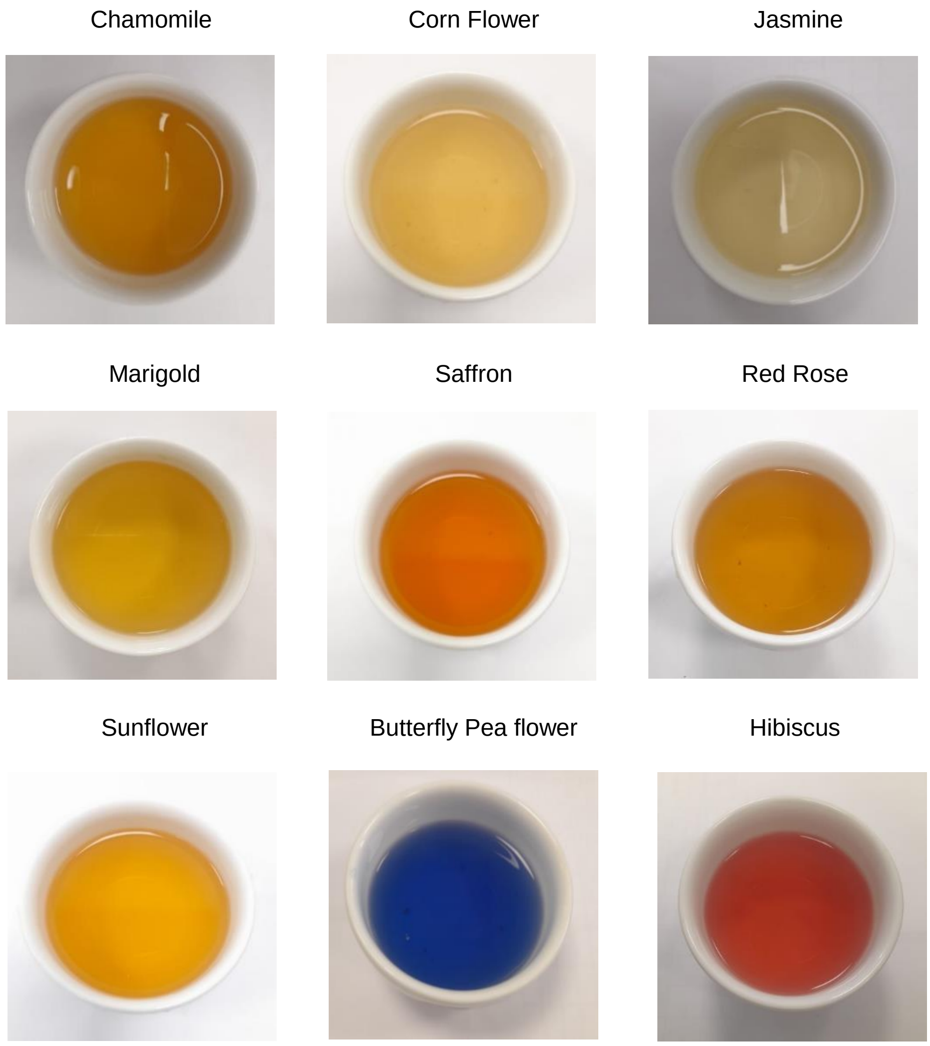


Fig. 1. Herbal beverages prepared with common edible flowers

"Kombucha" is a traditional fermented beverage that is made commonly using black tea, green tea, and oolong tea. However, a study was conducted replacing the original raw material with a *Clitoria ternatea* infusion as the base material in the preparation of Kombucha. Variations in Total flavonoid content & antioxidant activity of Butterfly pea Kombucha were examined. Total flavonoid content indicated a marked growth over the fermentation period, however, antioxidant activity values remained almost stable [20].

Powder drink from Butterfly pea flower was developed using co-crystallization, agglomeration, and drying methods by Marpaung et al [21] and the prepared drink was evaluated over 28 days at three different storage temperatures. (27^0 C, 40^0 C, and 50^0 C). Although a significant decrease in the stability of Anthocyanins was seen as the storage temperature increased, the decrease in antioxidant activity of the powder drink was minimal.

More than 20,000 Chrysanthemum cultivars are found in the world and about 7000 cultivars are present in China [22]. Chrysanthemum tea is one of the most popular herbal infusions widely consumed mainly in China & Japan. Chrysanthemum flower with yellow petals is frequently used as a tea material, a coolant, and an antioxidant in the Korean herbal tea industry.

Two types of Chrysanthemum flower teas are produced and commercialized in China. Tea prepared from flower buds is named "Taiju" and another type of tea prepared from blooming flowers is named "Hangbaiju". Keneko et al. [23] carried out an experiment using the aroma extract dilution analysis (AEDA) technique to identify the compounds responsible for characteristic floral/sweet odor in Chinese Chrysanthemum flower tea infusion. Studies revealed that flower buds are rich in four compounds (verbenone, ethyl 3-phenylpropanoate, propyl 3-phenylpropanoate, and ethyl cinnamate) which give four floral/sweet aroma peaks.

However, to develop chrysanthemum teas in different appealing colors and fragrances suitability of the new flower tea cultivar with a dark purple petal over the commercial yellow Chrysanthemum cultivar was evaluated under different infusing time and temperature conditions. Both cultivars exhibited strong ABTS radical scavenging activity and moderate DPPH radical scavenging activity. However purple Chrysanthemum tea contained anthocyanins and linamarin, which were not detected in the yellow Chrysanthemum tea and the content of chlorogenic acid, acacetin-7-O-β-glucoside, and luteolin was higher compared to the yellow Chrysanthemum tea. On the other hand, yellow Chrysanthemum tea had higher luteolin-7-O-β-glucoside, 3, 5-dicaffeoylquinic acid, apigenin-7-O-β-glucoside, and apigenin contents compared to the purple Chrysanthemum tea [24].

Tea aroma formation is a novel aspect in herbal beverage manufacturing to enhance the sensory properties. Therefore, tea volatiles generation and retention, irrespective of the rigorous treatment conditions are important to deliver herbal teas with the finest quality. It was concluded that dry tea could adsorb substantial amounts of volatiles from jasmine flowers to improve the aroma profile of scented green tea [25].

Chamomile tea is one of the most popular herbal beverages all around the world and approximately a million cups of chamomile tea are consumed each day. German Commission E recommends the oral consumption of herbal infusions derived from Chamomile. Chamomile flowers can be used in the preparation of herbal beverages in their pure form after blending with other medicinal herbs. It is available as a powder and dried flower as a whole or flakes in tea bags. Chamomile tincture is prepared by mixing one part of chamomile flower in four parts of water having 12% grain alcohol. Herbal beers are made from the whole herb including the Chamomile flower. Chamomile wine, another derivative is prepared by adding dried Chamomile flowers to White wine and then followed by steeping and filtration [26, 27].

Lotus pollens are gaining much attention as an ingredient in natural health supplements. They have exhibited antioxidant properties when brewed in hot water. Lotus pollen tea was chosen as a viable consumer product considering the high pollen yield, potent antioxidant activity, favorable aroma, flavor, and color of *Nelumbo nucifera* tea [28]. Out of the four varieties of lotus evaluated (Sattabongkutt, Buntharik, Sattabutt, and Patum), Buntharik reported the highest antioxidant capacity at a trolox equivalent of 499.48 µg/ml and total polyphenols equivalent of gallic acid of 63.26 µg/ml. The stamen of *Nelumbo nucifera* is used in dried or powdered form in herbal teas and as a main ingredient in traditional remedies in Asian countries such as China, Thailand, Japan, and India [29].

Rose petal teas are considered a caffeine-free beverage with high antioxidant capacity. Yakov et al. [30]. studied the antioxidant activity and total phenolic contents of Rose petal tea. Hot water infusions prepared from air-dried petals of twelve different Rose cultivars were analyzed and the study concluded that teas from different Rose cultivars possess significantly different sensory properties, and they are accepted to be used as an herbal beverage alone or in combination with other herbal materials.

Edible flowers can be used with other plant-based ingredients to produce herbal beverages with improved palatability other than using them alone in beverage preparations. A study was conducted to evaluate how different concentration levels (1.5%, 3%, 4%) of natural flavors (mint leaves, ginger, and lemon juice) affect the sensory and functional properties of the rose-extract-based drink. Water extract of Rose petals was obtained by maceration with 1% citric acid. Rose extract was concentrated by evaporating the filtrate of water extract in a rotary evaporator at 50-60^0 C until the desired volume was achieved. The functional beverage was produced by mixing the prepared rose extract, natural flavor materials, citric acid, and sugar and heating it at 80-85 ^{0}C. Before filling the mixture was cooled up to 60-65 ^{0}C. A marked increase in the total anthocyanin content and antioxidant activity resulted from adding natural flavoring ingredients. The addition of mint leaves, ginger, and lemon increased the total anthocyanin content by 46.48%, 34.50%, and 16.07%

respectively. Rose extract-based drink flavored with 3% mint leaves which gave 84.44% antioxidant activity and favorable flavor properties was selected as the best formulation [31].

Sylvia et al. [13] developed a functional fruit-herbal beverage and evaluated the physiochemical properties and consumer acceptance of the beverage. Fruit –herbal beverage was prepared with fruit juices (80%) obtained from Aronia (*Aronia melanocarpa Michx*.), Rugosa Rose (*Rosa rugosa Thumb.*), Acerola *(Malpighia glabra L.)*, Sea buckthorn (*Hippophaë rhamnoides L*.), and Cranberry (*Oxycoccus palustris Pers., Vaccinium Oxycoccus L.*). and supplemented with herbal extracts prepared from different combinations of Nettle leaves (*Urtica dioica*), Siberian ginseng (*Eleutherococcus senticosus*), Ginger (*Zingiber officinale*), Purple Coneflower (*Echinacea purpurea*), Aloe (*Aloe vera*), Horsetail (*Equisetum arvense*), Lingonberry (*Vaccinium vitis-idaea*), Silver birch (*Betula pendula*), and Chamomile (*Matricaria chamomilla*) (20%) in different combinations. The juice mixture sweetened with sucrose was heated up to 80 ^{0}C, filtered, and then pasteurized at 85–87 ^{0}C for 10 minutes. The study concluded that all the developed fruit herbal beverages showed a high antioxidant potential and were accepted by consumers in sensory evaluations. Highest carotenoid content, polyphenols content (807 mg GA/L), vitamin C content (3439 mg/l), and antioxidant activity (DPPH assay:75.7 µM Trolox/g and ABTS assay: 63.2 µM Trolox/g) was reported in the formulation made with Rosehip−acerola, Siberian ginseng, Ginger, Purple Coneflower, and Aloe.

Oluwatoyin et al. [32] studied the synergistic effect of fruit/vegetable (Pineapple/Carrot/Orange) based beverages blended with *Hibiscus sabdariffa* extracts (HSE). The objective of the study was to formulate a functional beverage with optimized antioxidant properties. Juice formulation with 40% Pineapple, 16.5% Carrot, 17.2% Orange, and 26.3% HSE extract reported total phenolic content as 512.82 mg GAE 100 g^{-1}, Vitamin C content as 3.37 mgg^{-1}, and DPPH inhibition potential as 51.34% and found to be the blend with optimum nutraceutical quality and sensory properties. Blends with increased ratios of HSE exhibited the highest antioxidant activity and the study concluded all the ingredients used in the experiment are accepted to be utilized in herbal beverage preparations.

Another low-caloric beverage with high antioxidant capacity which can be used as an alternative option for popular industrialized beverages was produced and examined by Elizabeth et al. [33] This plant-based beverage included aqueous extracts of medicinal plants: Melissa (*Melissa officinalis*) and Lemon verbena (*Aloysia triphylla*), flowers: Chamomile (*Matricaria chamomilla*) and Bougainvillea (*Bougainvillea glabra*), fruits: (Guava, Pineapple, Strawberry, Orange, and Tangerine). Experimental results indicated that flower bougainvillea improved the sensory quality of the product by providing an appealing colour along with improved bioactive properties to the beverage.

A mixed beverage was prepared from Hibiscus and Coconut water using three different combinations, HA 1 (50% Hibiscus and 50% Coconut water), HA 2 (70% Hibiscus and 30% Coconut water), and HA 3 (90% Hibiscus and 10% Coconut water). Three mixes were pasteurized at 90 ^{0}C for 3 minutes, hot filled into glass bottles, and stored at refrigeration temperature (4 ^{0}C) for 35 days. Physiochemical, microbiological, sensory, and phytochemical properties of the mixed beverage were assessed throughout the storage period. The highest retention of total phenolic compounds (decreased from 177.74 to 153.71 mg GAE/g) and antioxidant activity (reduced from 174.23 to 20.81 µm Ferrous sulfate/g) was achieved in the HA2 beverage mix. Processing temperatures applied were capable of inactivating microorganisms and retardation of polyphenol oxidase enzymatic activity for 35 days. Most acceptable chemical and sensory features were achieved from the blend HA2, hence concluded to be the most viable formulation in the development of herbal beverages [34].

Dabbagh et al. [35] developed a Saffron-based probiotic beverage fermented by lactic acid bacteria. Air-dried Saffron petals were powdered, and water extract was prepared. Then it was sweetened with a mixture of sucrose, glucose, and fructose before sterilization at 121 ^{0}C for 15 minutes. Then the prepared beverage was fermented by probiotic strains including *Lactococcus lactis*, *Lactobacillus plantarum, Lactobacillus brevis,* and *Lactobacillus casei*. Total phenolic compounds, DPPH scavenging capacity, and total monomeric anthocyanin of fermented saffron beverages ranged from 69.1-99.1 mg GAE/g, 105.7- 160.6 EC_{50} mg/100 g mass, 5.6-12.1 malvidin-3-O-glucoside equivalents/g dry sample respectively. Unfermented saffron beverage contained 51.8 mg GAE/g of total phenolic compounds and 18.2 malvidin-3-O-glucoside equivalents/g of total monomeric anthocyanins. Therefore, the study concluded that saffron-based fermented beverage is accepted as a health-promoting non-dairy beverage.

Ashwani et al. [36] conducted a study to investigate the physicochemical, phytochemical, sensorial, and storage properties of a cereals and milk-based functional beverage supplemented with Marigold powder and Rose syrup functional beverage produced from finger millet, oats, and double-toned milk. Marigold powder was prepared by grinding dehydrated flower petals at 40^0 C in a hot air cabinet dryer. Rose syrup, also known as rose petal preserves, was produced by macerating fresh rose petals with sugar for 2 days at room temperature and then heating the solution at 70-100 ^{0}C for 1 hour until the complete dissolution of sugar to optimize the extraction of colour and flavor.

The bioactive potential of the functional beverage was significantly improved by blending with flower extracts. Anthocyanins & total phenolic content significantly increased by 78.82 & 119.18% in the beverage mixed with marigold powder and by 230.58% &145.23% in the Rose syrup-supplemented functional beverage respectively. Beta carotene (0.37 mg/100 ml) was detected only in the functional beverage blended with Marigold powder. In Rose syrup supplemented beverage 12.65 % of DPPH radical scavenging activity was observed while Marigold powder supplemented beverage reported 10.46 % of DPPH radical scavenging activity. Functional beverage supplemented with Rose syrup was the most acceptable formulation in sensory analysis. At refrigerated temperature shelf stability of the developed beverage was limited to 50 days [37].

A novel tea infusion was prepared with dried *Hibiscus calyces* petal powder, Ginger powder, and Cocoa powder mixed in different ratios and was analyzed by Folashade et al. [38] Beverage powder was packed in tea bags with an average weight of 1.5 g. To prepare the tea by hot water extraction tea blend was infused at 70 ^{0}C for 1 minute and to prepare by cold water extraction tea bags were dipped in distilled water at 25 ^{0}C for 5 minutes. Infusions prepared from both extraction methods had total phenolic content varied from 11.61 to 22.01 mg GAE/g; ferric reducing activity varied from 10.84 to 26.88 mg/g, vitamin C content varied from 1.77 to 4.82 mg/g and DPPH inhibition varied from 38.60 to 87.53%. The study concluded that the beverage blend has complimentary effects and beneficial antioxidant properties.

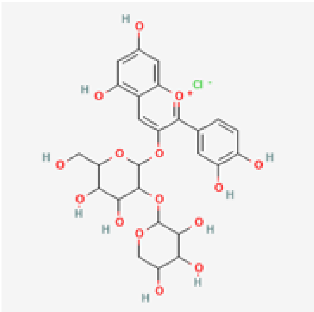
Rodrigues et al. [39] coupled Sea lavender (*Limonium algarvense*) and Green tea (*Camellia Sinensis*) to produce an herbal beverage with improved inhibitory properties towards enzymes related to Alzheimer's (acetyl- and butyrylcholinesterase) and type-2 diabetes mellitus (α-amylase and α-glucosidase). Powders obtained from dried plant material were mixed in different combinations to prepare the infusions for further analysis. Both the plant species are rich in antioxidant properties, however, the experimental results concluded that when they are coupled together radical-scavenging and anti-lipid peroxidation activities of the prepared herbal beverage improved synergistically. Although Lavender had a stronger inhibition capacity regarding anti-cholinesterase activity compared to green tea, the herbal mixture exhibited a greater synergistic effect. Green tea is rich in epicatechin and caffeic acid was the main contributor to α-glucosidase inhibition, but the herbal blend induced an antagonistic effect.

5. PHYTOCHEMICALS AND PHARMACOTHERAPEUTIC POTENTIAL OF EDIBLE FLOWERS IN HERBAL BEVERAGES

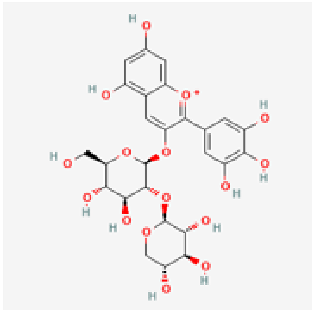
The prime advantage of incorporating edible flowers into herbal beverages lies in their abundance of bioactive compounds, encompassing carotenoids, phenolic acids, flavonoids, coumarins, alkaloids, polyacetylenes, saponins, and terpenoids [4, 40]. The chemical structures of key phytochemicals abundantly found in edible flowers are illustrated in Fig. 2.

α-carotene, β-carotene, β-cryptoxanthin, lutein, lycopene, fucoxanthin, and zeaxanthin are the key bioactive compounds belonging to carotenoids. Vitamin A precursors include α-carotene, β-carotene, and β-cryptoxanthin. Lutein, lycopene, and fucoxanthin act as powerful antioxidants whereas lutein is crucial in healthy eyesight. Zeaxanthin is a fat-soluble pigment and antioxidant found in the retina's macula, where it is responsible for fine feature eyesight. Carotenoids have numerous medicinal properties, including gene transcription regulation by lutein, α-carotene, and β-carotene, improved gap junction communication by β-carotene, enhancement of the immune system by β-carotene and lutein, and defense against lung and prostate cancers by α-carotene, β-carotene, lycopene, and zeaxanthin. Fucoxanthin is reported to have anticancer, anti-inflammatory, radioprotective, antihypertensive, and antiobesity properties [42].

Anthocyanins



Cyanidin 3-sambubioside



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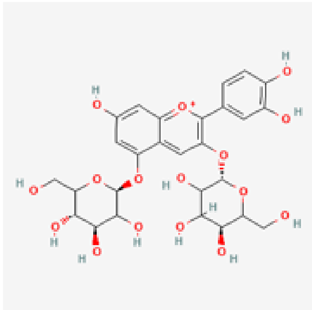
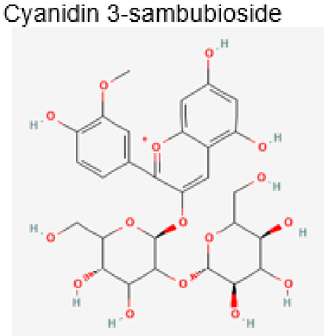
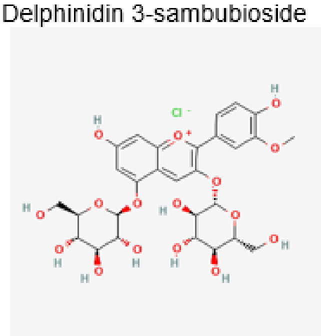


Cyanidin 3, 5-diglucoside



Peonidin 3-sophoroside



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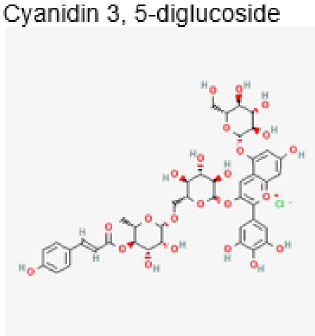
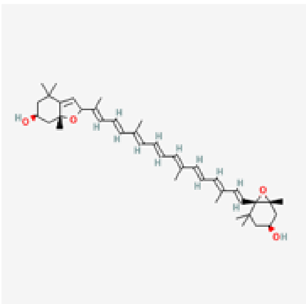
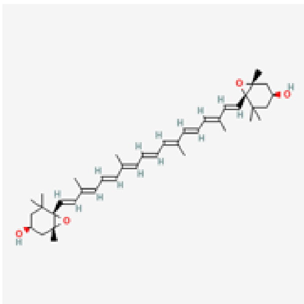


Violanin

Carotenoids



Luteoxanthin



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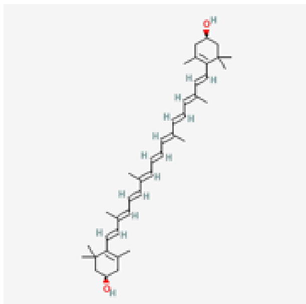
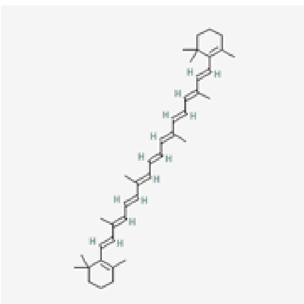
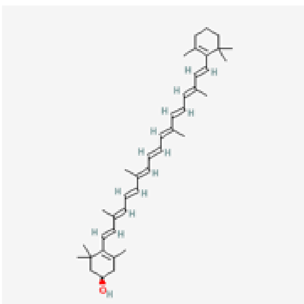


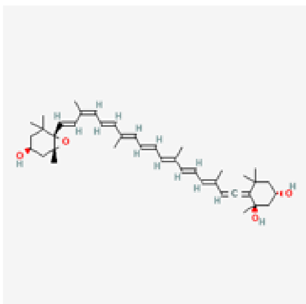
Zeaxanthin



β-Carotene



Cryptoxanthin



Neoxanthin

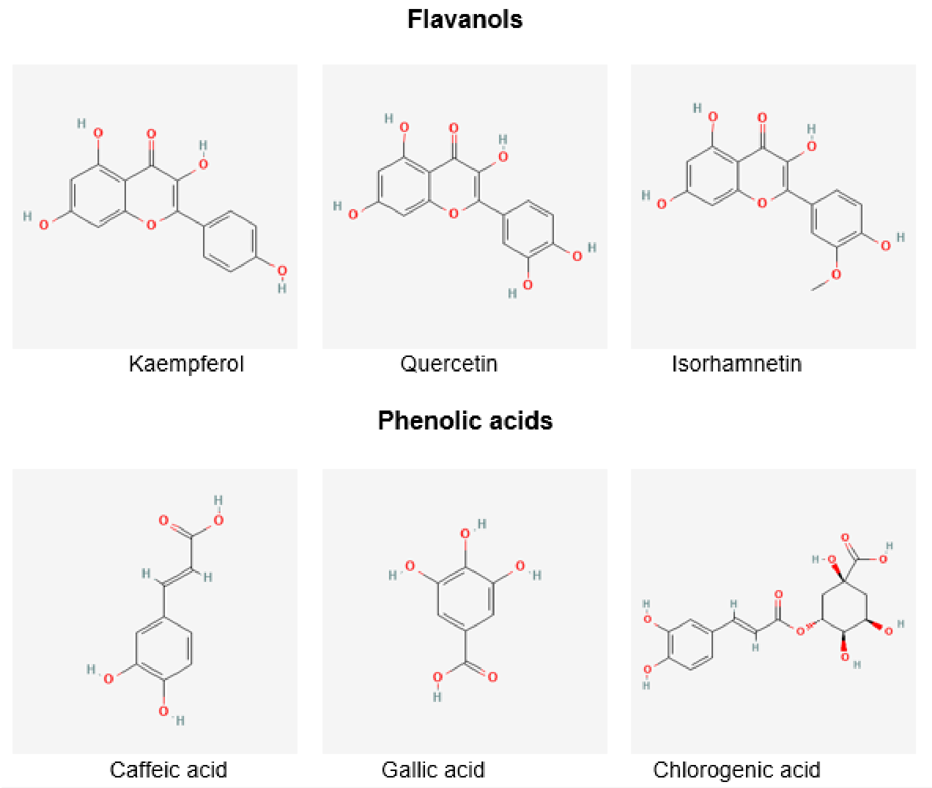


Fig. 2. Chemical structures of key phytochemicals in edible flowers [41]

Polyphenols can be categorized into four main groups: phenolic acids, flavonoids, stilbenes, and lignans [43]. Phenolic acids are known for health-protective effects such as antimicrobial, anticancer, anti-inflammatory, and anti-mutagenic properties. They are readily absorbed through the intestinal tract and they act as antioxidants, preventing cell damage from free radicals. Regular consumption of phenolic acids enhances the body's anti-inflammatory capacity [44].

Flavonoids have a variety of therapeutic applications, including antioxidant, anticancer, anti-inflammatory, and antiviral effects and neuroprotective and cardioprotective benefits [45]. Anthocyanins are colorful, water-soluble pigments in the flavonoids class. Experimental evidence, including cell culture experiments, animal models, and clinical tests on humans, has revealed that anthocyanidins and anthocyanins have antioxidative and antibacterial characteristics. They possess anti-angiogenic properties, improve visual and neurological health, and protect against a variety of noncommunicable illnesses, including cardiovascular disease, cancer, diabetes, and obesity [46].

Coumarins are members of the benzopyrone family and are known to exhibit a variety of pharmaceutical effects, including anti-inflammatory, anticoagulant, anticonvulsant, anticancer, antibacterial, antifungal, antiviral, antimalarial, casein kinase-2 (CK2) inhibitory, Alzheimer's disease suppression, neuroprotective, phytoalexins, ulcerogenic, and antihypertensive properties [47].

Consumer interest is shifting towards safe natural origin products other than relying on conventional pharmaceuticals to cure the pathologic conditions negatively affecting the health status [48]. Furthermore, recent research explored the synergistic potential of phytochemicals found in herbal beverages on effective management of medical conditions when used parallel to conventional medicines [49]. Edible flowers rich in phytochemicals deliver a plethora of health benefits for consumers, offering antioxidant, antibacterial, antiviral, anti-inflammatory, antifungal, antidiabetic, neuroprotective, antiallergic, antithrombotic, and vasodilatory actions. Additionally, they exhibit antimutagenic, anticarcinogenic, and anti-aging effects, making them valuable contributors to overall well-being [4, 50].

Table 2. Major bioactive compounds and pharmacotherapeutic properties of edible flowers used in herbal beverages

Crop Name	Major Bioactive Compounds	Pharmacotherapeutic Properties	Refs
Hibiscus	Polyphenols (Delphinidin 3-sambubioside,3-Caffeoylquinic acid) Anthocyanins (Cyanidin-3-O-sambubioside, Delphinidin-3-O-sambubioside)	Antibacterial, antioxidant, nephro-and hepato-protective, renal/diuretic, anti-diabetic and anti-hypertensive effects, lowering blood pressure in pre and mildly hypertensive adults, lowering blood pressure in type II diabetic patients with mild hypertension, increasing antioxidant capacity of both the enzymatic and non-enzymatic systems in the plasma of the MSF (Marfan syndrome) patients, reducing total cholesterol, low-density lipoprotein-cholesterol (LDL-C), triglycerides, increasing high-density lipoprotein-cholesterol (HDL-C).	[51-66] [67]
Rose	Anthocyanins (Cyanidin 3, 5-di-O-glucoside, peonidin 3-O-sophoroside, peonidin 3, 5- di-O-glucoside, peonidin 3-O-glucoside), Carotenoids (Luteoxanthin, violaxanthin, zeaxanthin, β-Carotene, lutein epoxide, lutein, antheraxanthin, neoxanthin), Flavanols (Kaempferol 3-O-rhamnoside, qeuercetin 3-O-glucosid)	Antioxidants, anticancer, anti-inflammatory, antimutagenic, and antidepressant properties, moderate anti-HIV activity, anti-viral, anti-diabetic activities, antifungal properties, neuropharmacological, alleviate constipation.	[68-78]
Lotus	Flavonoids (Anthocyanin, myricetin 3-O-glucoside, quercetin, kaempferol, isohamnetin, diosmetin)	Strong antibacterial activity against *Escherichia coli, Bacillus Subtilis, Staphylococcus aureus* and moderate inhibition against *Klebsiella pneumonia* and *Pseudomonas aeruginosa*, prevention of degenerative diseases, treating bleeding disorders, fever, diarrhea, hyperdipsia, cholera, and hepatopathy, improving circulatory system, decrease blood glucose and lipid levels, treatment of diabetes mellitus.	[79-85]
Chrysanthem um	Carotenoids (Lutein, zeaxanthin, β-cryptoxanthin, 13-cis-β-carotene, α-carotene, trans-β-carotene, and 9-cis- β-carotene.)	Antioxidant, anti-inflammatory, antitumor, antiosteoporotic effects, easing stress and anxiety, protection against oxidative damage, enhancing the immune function, improving eye health, cardiovascular health, dispelling pathogenic heat, improving liver function and detoxification, antiviral activities against Herpes simplex virus type 1 (HSV 1).	[24, 86-89]
Marigold	Carotenoids (Lutein, lycopene, beta carotene, zeaxanthin, rubixanthin, flavoxanthin, neoxanthin, auroxanthin, luteoxanthin, (9Z)-antheraxanthin, violaxanthin), terpenoids, terpenes (bisabolol, faradiol, chamazulene, arnidiol, esters), flavonoids, (quercetin, isorhamnetin, kaempferol, aglycones), polyunsaturated fatty acids (calendic acid), coumarins (scopoletin, umbelliferone, esculetin)	Angiogenic, vascular regeneration, analgesic, antibacterial, antiprotozoal activity, antifungal, antioxidant and immunomodulatory effects, wound healing properties, anti-inflammatory, cytotoxic, antiseptic, anti-viral, hepatoprotective, antidiabetic, anthelmintic activity.	[90-94]
Magnolia	Flavanols (Kaempferol, quercetin, isorhamnetin) alkaloids, sesquiterpenes, phenolic constituents, glycosides)	Treatment of diarrhea, abdominal diseases, rheumatic arthritis, heart disturbances, high blood pressure, epilepsy, infertility and fever, anti-inflammatory properties, anti-melanogenic and antioxidant properties	[95, 96]

Crop Name	**Major Bioactive Compounds**	**Pharmacotherapeutic Properties**	**Refs**
Butterfly pea	Polyphenols (ternatin anthocyanins), flavanol glycosides of kaempferol, rutin, quercetin, and myricetin,	Antimicrobial, antioxidant, anti-inflammatory, anti-diabetic properties, tranquilizing effect, antipyretic activities, anti-proliferative properties inhibiting cancer cell lines, diuretic, nootropic, anti-asthmatic, analgesic, antilipidemic, anti-arthritic, antioxidant, and wound-healing properties.	[97-103]
Chamomile	Terpenoids (sesquiterpenes and α bisabolol), flavonoids (apigenin, quercetin, patuletin, luteolin), coumarins (herniarin and umbelliferoneolin), cinnamic acid derivatives (ferulic acid and caffeic acid)	Antioxidant, antimicrobial, antidepressant, anti-inflammatory, antidiarrheal activities, angiogenesis activity, anti-carcinogenic, hepatoprotective, and antidiabetic properties and beneficial impacts on knee osteoarthritis, ulcerative colitis, premenstrual syndrome, and gastrointestinal disorders, wound healing properties, protective effect on hematological parameter disorders, erythrocytes-induced oxidative stress after the acute alcohol administration, neuroprotective agent against oxidative brain damage, anti-allergic activity, alleviating depression and sleep quality problems in post-partum women, beneficial effects on glycemic control and serum lipid profile in type 2 diabetes mellitus patients, relieving the intensity of premenstrual syndrome associated symptomatic psychological pains.	[104-114]

Both *in vitro* and *in vivo* studies are carried out to assess their pharmacotherapeutic properties, clinical efficacy, and safety concerns related to toxicity and microbiological quality. Table 2 presents a concise overview of the essential bioactive compounds and therapeutic effects found in common edible flowers, often utilized in the preparation of herbal beverages.

6. SAFETY ASPECTS OF THE CONSUMPTION OF EDIBLE FLOWERS

Many edible flowers such as Hibiscus, Chamomile, Butterfly pea flower, Lotus, Jasmine, Marigold, Chrysanthemum, Corn Flower, Saffron, and Magnolia are rich in phytonutrients and safe for human consumption. However, some edible flowers can be contaminated by dimethate, sulphite, and pathogenic microorganisms (*Salmonella spp*) that have been identified by Rapid Alert System for Food and Feed (RASFF) during the last years [115]. Hazardous agents may originate from the plant itself or at the various steps in the food chain.

Pathogenic bacteria and residues from agricultural production are the two main external impurities found in edible flowers. The microbiological quality of the edible flowers depends on several factors such as soil quality, irrigation waters, fertilization, crop protection techniques, and harvesting equipment. Subsequently, after the harvesting, edible flowers may be contaminated during processing, transport, and distribution, by processing water or ice, and due to lack of personal hygiene of the food handler [116]. In an experiment carried out by Aleksandra et al. [117] microbial quality of 5 selected edible flowers namely Nasturtium (*Tropaeolum L.*), Calendula (*Calendula officialis L*.), Daylily (*Hemerocallis L.*), Daisy (*Bellis*), Pink (*Dianthus caryophyllus L*.) were assessed. At the end of the experiment, it was concluded none of the flowers were contaminated by *Salmonella sp.,* but *Staphylococcus aureus* was detected in all flower samples at >3 log CFU g^{-1}. Total yeast and mould counts were less than 6 log CFU g^{-1} and *E. coli* was detected only in Nasturtium flowers.

Toxic compounds and their possibility to cause allergic reactions are one of the main risks associated with the consumption of edible flowers. The availability of toxic compounds depends on factors such as the type of flower, the cultivation of the flowers, and the presence of toxic compounds in the floral tissues. Edible flowers may contain phytotoxins and ingestion of them can lead to health implications such as nausea, vomiting, diarrhea, and even DNA damage in exceptional situations. Thujone, three alkenylbenzenes-methyl eugenol, 1, 8 cineole (eucalyptol), and safrole are the three phytotoxins frequently reported in edible flowers [118].

In a study conducted by Akindahunsi et al. [119] wistar albino rats were orally administrated with an aqueous fraction of an aqueous-alcoholic extract of H*ibiscus sabdariffa* L. calyces to examine the toxicological impact. Results of the study demonstrated that prolonged usage of 15 doses of 250 mg/kg of this extract caused liver injury and mild effects were given at 1-10 dose levels. Also, the average consumption of 150–180 mg/kg per day was considered to be safe. Another study conducted by Sireeratawong et al. [120] revealed that at the doses of 50, 100, and 200 mg/kg body weight for 270 days, *H. sabdariffa* extract did not produce chronic toxicity in rats. In the amount of 5,000 mg/kg body weight oral administration of a single dose of *H. sabdariffa* extract also did not generate acute toxicity in rats. Hopkins et al. [67] reported that Hibiscus extracts have an LD_{50} value ranging from 2,000 to over 5,000mg /kg/day indicating minimal toxicity. There is no indication of hepatic or renal toxicity from Hibiscus extract ingestion, except for potentially harmful hepatic effects at high dosages. Njinga et al. [121] conducted a study to evaluate the acute toxicity study (LD_{50}) of aqueous extract of *Hibiscus sabdariffa* calyces and stipulated the acute oral toxicity to be higher than 2000 mg/kg according to OECD 2001 guidelines. A single oral dose of aqueous extract of *Hibiscus sabdariffa* calyces (2000 mg/kg) resulted in the death of one of three Wistar rats in the first test. However, when the dose was repeated in another set of three rats, there was no toxicity, mortality, or modifications to behavior or physiological functions. A single dose of 300 mg/kg aqueous extract of *Hibiscus sabdariffa* calyces did not result in mortality in any of the three Wistar rats used in the first experiment or the second experiment utilized for confirmation. In an experiment conducted by Onyenekwe et al. [122] in mice, administering 1000, 3000, and 5000 mg/kg body weight of *Roselle calyx* extract intraperitoneally resulted in decreased activity, which appears to be influenced by dose. All of the animals recovered within around 30 minutes. No mice died throughout the 14-day monitoring period. Therefore, the study concluded that LD_{50} is expected to be more than 5000 mg/kg.

However, the study also discovered that hypertensive rats died when exposed to concentrations as high as 1000 mg/ kg.

Wu et al. [123] evaluated the acute oral toxicity of Marigold flavonoids extracted from defatted Marigolds to assess the comprehensive utilization possibilities. As per the study results, the LD_{50} value for marigold flavonoids oral toxicity in Sprague Dawley rats and ICR mice was determined to be 5000 mg/kg body weight.

Hwang et al. [124] investigated the safety of *Chrysanthemum indicum* flower oil using acute oral toxicity, bone marrow micronucleus, and bacterial reverse mutation assays. No mortality and clinical indications of toxicity were observed at 2,000 mg/kg body weight/day of *Chrysanthemum indicum* floral oil for 15 days. Micronucleated erythrocyte cell counts did not differ substantially between treatment and control groups. *Chrysanthemum indicum* oil at a concentration of 15.63~500 µg/plate did not cause mutagenicity in *S. Typhimurium* and *E. coli*. The study revealed that *Chrysanthemum indicum* flower oil does not cause bone marrow micronucleus abnormalities, mutagenicity, or chromosomal aberrations, making it a potentially useful element in food or medicine. A chronic toxicity study was carried out by feeding *Chrysanthemum morifolium* extract to rats at dose levels of 320, 640, and 1280 mg/kg body weight /day for 26 weeks. No toxicological changes in body weight, organ weight, blood chemical examination, hematologic examination, or microscopic histopathologic examination were reported in rats at the end of the study [125].

Akbari M et al. [126] assessed the toxic effects of *Rosa damascena* using an animal model using exponential doses of the infusion made with petals (90-1440 mg/kg/day) over 10 days. The Study of the results concluded that minimal nephrotoxic or hepatotoxic effects.

The concentration of metals and heavy metals in tissues is another risk associated with the usage of edible flowers in food applications. However, the possibility for metal poisoning as a result of the consumption of edible flowers is low hence edible flowers contain a relatively low concentration of metals and heavy metals (Cd, Co, Ni, Pb, and V) [127, 128].

Edible flowers harvested from wild plants may pose certain safety concerns. One potential issue is the risk of contamination with toxic plant species that grow near the edible ones. Additionally, wild plants, especially those in non-agricultural areas, may accumulate chemical impurities from the soil or airborne pollutants. Certain regions may suffer from high concentrations of heavy metals in the soil, which can be absorbed by these plants, leading to potential safety risks when consumed by humans. Furthermore, impurities from the air, such as those arising from automotive or industrial pollution, can also affect the safety of wild edible flowers. Therefore, the location where these flowers are harvested may play a significant role in determining their safety for consumption [116]. While numerous studies have been carried out to assess the safety aspects of edible flowers, there remains a need for more extensive research concerning the presence of hepatotoxic pyrrolizidine alkaloids in both nectar and pollen [129].

7. CONCLUSION

Although a wide array of edible flowers exists in various regions globally, only a handful of them have been subject to thorough investigation and exploration. It is required to conduct extensive research in this field to unveil the health advantages of these underutilized or undiscovered edible flowers. These findings can be leveraged for the development of functional beverages aimed at mitigating the risk of non-communicable diseases [130]. Furthermore, forthcoming research should center on the bioavailability and bio accessibility of edible flowers subjected to processing and preservation methods during the preparation of herbal beverages.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that generative AI technologies such as Large Language Models (Chat GPT 3.5) have been used during the writing of manuscripts to improve readability and conciseness.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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