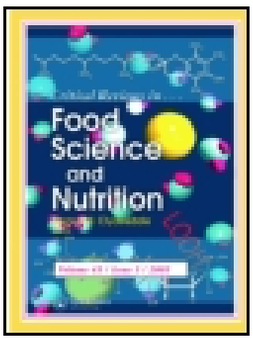

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Phytochemical Content, Health Benefits, and Toxicology of Common Edible Flowers: A review (2000-2015)

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ABSTRACT

Edible flowers contain numerous phytochemicals which contribute to their health benefits, and consumption of edible flowers has increased significantly in recent years. While many researches have been conducted, no literature review of the health benefits of common edible flowers and their phytochemicals has been compiled. This review aimed to present the findings of research conducted from 2000 to 2015 on the species, traditional application, phytochemicals, health benefits, and the toxicology of common edible flowers. It was found in 15 species of common

edible flowers that four flavonols, three flavones, four flavanols, three anthocyanins, three phenolic acids and their derivatives were common phytochemicals and they contributed to the health benefits such as anti-oxidant, anti-inflammatory, anti-cancer, anti-obesity, and neuroprotective effect. Toxicology studies have been conducted to evaluate the safety of common edible flowers and provide information on their dosages and usages.

Keywords

flavonoids; phenolic acids; anthocyanins; bioactivity; safety

1 Introduction

Edible flower is defined as non-toxic, innocuous flowers with health benefits consumed in human diet (Alasalvar, 2013)；(Lara-Cortés, 2013). They have kept playing an important role in providing nutrients to human body for centuries. Many places, such as Asia (Cichewicz, 2002), ancient Greece and Rome (Melillo, 1994), medieval France, Europe (Kopec, 2004) have been proved to have the traditional habit of eating flowers. Recently, there is an increasing demand for edible flowers worldwide(Mlcek, 2011) because edible flowers render unique odor, flavor, and color that contribute not only to their appearance but also to their health benefits. Meanwhile researches have paid more and more attention to edible flowers, more than 1880 studies in food science technology and pharmacology focused on edible flowers in the last 15 years (Da-Costa-Rocha, 2014); (Shang, 2011); (Zhang, 2011). Most of these studies were conducted in China, South Korea, Mexico, USA, Japan, India, Taiwan, Italy, Nigeria, and Germany.

This review aimed to present the findings on the phytochemical components, health benefits, and toxicology of edible flowers, and ultimately increase the acceptability of edible flowers as potential food ingredients.

2 Application and species of common edible flowers

2.1 Application of edible flowers

Edible flowers have been used in human diet since 2000 years ago. The consumption of edible flowers was documented in many places, such as Asia, ancient Greece and Rome, medieval

France, Europe, Victorian England, and in the Middle Eastern region. In Asian countries, flowers have been consumed for centuries (Cichewicz, 2002). In particular, edible flowers in ancient China served not only as food ingredients but also as components in herbal medication (Krasaekoopt, 2005; Wongwattanasathien, 2010). In ancient Rome, the flowers of various rose species were used as ingredients of purees and omelets (Melillo, 1994). In medieval France, the flowers of calendula (*Calendula officinalis*) were used as a salad ingredient. In Central Europe, the inflorescences of breaded elder (*Sambucus nigra*) were often consumed (Kopec, 2004). Currently, edible flowers are used as garnish or ingredients of dishes, such as salad and light curry, and even consumed directly as vegetables. Some flowers can be stuffed or used in stir-fried dishes.

2.2 Common edible flowers species

Various kinds of edible flowers are commercially available, and demand for them are considerably large. Edible flowers are obtained from 97 families, 100 genera, and 180 species worldwide, and the number of edible flowers varies in different places. Most of these edible flowers are potential sources of pharmaceuticals. For example, the Thai pharmaceutical handbook of the School of Traditional Medicine Association mentions 92 kinds of medicinal flowers that were traditionally used as herbs in local communities in Thailand to cure diseases. The number of edible flowers is so extremely large that they can hardly be covered in one study. Table 1 summarized the most common edible flowers including 15 species (*Hibiscus sabdariffa*,

Hibiscus rosa sinensis, *Paeonia suffruticosa*, *Rosa rugose*, *Rosa chinensis*, *Lonicera japonica*, *Hemerocallis fulva*, *Chrysanthemum morifolium*, *Chrysanthemum indicum*, *Matricaria chamomilla*, *Opuntia ficus indica*, *Magnolia denudate*, *Osmanthus fragrans*, *Jasminum sambac*, and *Nelumbo nucifera*) from 10 different families. Most of the edible flowers originated from Asia (Da-Costa-Rocha, 2014); (Tai, 2000) and now they widely distribute in tropical and subtropical regions especially in Asia, America and Africa (Mohamed-Yasseen, 1995); (Sharma, 2000). Traditionally, these edible flowers were used to make beverage, teas, cakes, jams, salads (Hopkins, 2013); (Cutler, 2003); (Chu, 2004); (Lai, 2007); (Zhang, 1995) or directly used as vegetables (Tai, 2000) as well as used as herbs to cure diseases (Shang, 2011); (Chau, 2006); (Yuan, 2009); (Singh, 2011); (Ammar, 2012); (Li, 2005); (Nakamura, 2013). Other edible flowers such as *Robinia pseudoacacia*, *Rhododendron simsii*, *Prunus serrulata*, *Amygdalus persica*, *Gardenia jasminoides Ellis*, and *Celosia cristata* were also studied but are not listed here.

3 Phytochemicals in edible flowers

Before the year of 2000, researches on edible flowers concentrated mainly on the nutrients, fragrance and volatile oils (Awad, 2000; Bouic, 2001). However, recent studies have paid more attention to phytochemicals, the main bioactive compounds of edible flowers. Liu (2003, 2004) defined phytochemicals as the bioactive non-nutrient compounds in fruits, vegetables, whole grains, and other plant foods that strongly reduce the risk of major chronic diseases, such as

cancer, cardiovascular diseases, and obesity. This researcher categorized phytochemicals into five major subgroups, namely, carotenoids, phenolics, alkaloids, nitrogen-containing compounds, and organosulfur compounds. Table 2 showed that flavonols, flavones, anthocyanins, phenolic acids, and flavanols were the most common phytochemicals found in edible flowers and Figure 1 showed their chemical structures.

3.1 Flavonols

Flavonols including quercetin, kaempferol, isorhamnetin and myricetin as well as their derivatives were a major class of flavonoids that were abundantly distributed in edible flowers. They existed in various forms in rose (Zhang, 2014), Hangzhou white chrysanthemum (Sun, 2010), Wild chrysanthemum (Wu, 2010), roselle (Alarcon-Alonso, 2012), water lily (Samee, 2007), day lily (Kao, 2015), Xibei tree peony (Wang, 2004), Chinese rose (Pei, 2013), magnolia flower (Yoon, 2014), sweet-scented osmanthus (Hung, 2012), honeysuckle (Seo, 2012), and cactus (Benayad, 2014). For example, Li et al. (2009) identified 26 flavonoids in 14 cultivars of yellow tree peony (*Paeonia suffruticosa*) flowers and found that 19 of these flavonoids were flavonols. The diversity of the major flavonols in phenolic flavonoids was also observed in honeysuckle (Seo, 2012). Dried honeysuckle contained six kaempferol derivatives and two quercetin derivatives as its major flavonols. Besides, flavonols have a relative high content in some edible flowers. Wu et al. (2010) found that the content of flavonols maily in the form of quercitrin (52.88 mg/g), myricetin (37.81 mg/g), quercetin-3-galactoside (12.55 mg/g),

quercetin-3-glucoside (9.88 mg/g) was much higher that of flavones in wild chrysanthemum. These findings suggested that flavonols were widely distributed in various types of edible flowers.

3.2 Flavones

Flavones, which mainly existed as luteolin, apigenin, acacetin, chrysoeriol, and their glucoside, formed the second major class of flavonoids found in edible flowers. Flavones was abundant in the three edible flowers from Asteraceae family (Sugawara, 2009); (Sun, 2010); wild chrysanthemum (Wu, 2010); (Choi, 2007); (Peng, 2005). Lin et al. (2010) identified a total of 63 phenolic compounds in chrysanthemum flowers, a traditional Chinese medicine and food, and revealed that apigenin, acacetin, luteolin, diosmetin, and eupatorin were the major flavones in chrysanthemum flower extracts. Luteolin and chrysoeriol derivatives were also found in the methanolic extract of honeysuckle, an herb growing in East Asian countries (Choi, 2007). In addition, luteolin was detected in extracts of Hangzhou white chrysanthemum (0.0149 mg/g) (Tsuji-Naito, 2009), wild chrysanthemum (7.29 mg/g) (Wu, 2010), honeysuckle (24.6 mg/g) (Peng, 2005), sweet-scented osmanthus (Wu, 2009), tree peony (Li, 2009), and roselle (Salah, 2002). Other flavones including apigenin (Tsuji-Naito, 2009), (Wu, 2010), (Li, 2009), (Avallone, 2000), acacetin (Lin, 2010), chrysoeriol (Choi, 2007) and their derivatives existed in a relatively lower content.

3.3 Flavanols

Flavanols found in edible flowers were catechin, epicatechin, epicatechin gallate, and epigallocatechin gallate derivatives (Zhang, 2014). Among the reported edible flowers, rose was most rich in flavanols. Catechin was found in extracts of water lily (7.03 mg/g) (Samee, 2007), day lily (3.93-5.47 mg/g) (Kao, 2015), rose (80.8 mg rutin/g) (Zhang, 2014) and roselle (0.267 mg/mL) (Yang, 2010). Epicatechin was found in day lily extract (2.25-5.08 mg/g) (Kao, 2015) and rose (180.0 mg rutin/g) (Zhang, 2014). Epicatechin gallate, epigallocatechin gallate (28.0, 131.0 mg rutin/g extract respectively) was found in rose (Zhang, 2014). In addition, day lily was rich in (-)-epigallocatechin-3-gallate (2.80-6.23 mg/g) (Kao, 2015).

3.4 Anthocyanins

Anthocyanins and their derivatives were flavonoids that appear red, purple, or blue depending on the pH. Roselle, tree peony, and Chinese rose were typical edible flowers containing anthocyanin. Roselle was rich in delphinidin-3-sambubioside and cyanidin-3-sambubioside (56.5, 20.8 mg/g extract respectively) (Alarcon-Alonso, 2012); tree peony was abundant in glycosides of peonidin, pelargonidin, cyanidin and the content varied in 39 cultivars of Xibei tree peony (Wang, 2004) as well as in 48 cultivars of Zhuongyuan tree peony (Fan, 2012), and Chinese rose was abundant in glycosides (Cai, 2005) and rutinosides (Mikanagi, 2000) of pelargonidin and cyanidin. Different cultivars of the same species of flower contained varied anthocyanin compositions. For instance, 90.50% anthocyanin was identified in

the form of peonidin-3,5-di-O-glucoside in the red ócaihuiô tree peony (Zhao, 2015), whereas 93.83% anthocyanin was identified in the form of pelargonidin-3,5-di-O-glucoside in the ógui Fei Cha Cuiô tree peony (Fan, 2012).

3.5 Phenolic acids

Phenolic acids was another major phytochemicals in edible flowers. Phenolic acids identified in roselle (Huang, 2009), honeysuckle (Choi, 2007), day lily (Kao, 2015), Hangzhou white chrysanthemum (Tsuji-Naito, 2009), and rose (Nowak, 2014) were reported. These phenolic acids included chlorogenic acid (Kao, 2015; Alarcon-Alonso, 2012; Peng, 2005), caffeic acid (Huang, 2009; Choi, 2007; Kao, 2015; Tsuji-Naito, 2009; Nowak, 2014; Peng, 2005), caffeyolquinic acid (Ramirez-Rodrigues, 2011; Lin, 2010; Peng, 2000), protocatechuic acid (Choi, 2007), and gallic acid (Zhang, 2014). Among these phenolic acids, caffeic acid, chlorogenic acid, and caffeyolquinic acid and their derivatives were the most ubiquitous. Caffeic acid was found in extracts of honeysuckle (6.4 mg/g) (Peng, 2005), roselle (1.985 mg/mL) (Huang, 2009), day lily (0.56-0.1386 mg/g) (Kao, 2015), Hangzhou white chrysanthemum (0.0337 mg/g) (Tsuji-Naito, 2009), and rose. Chlorogenic acid was identified in extracts of roselle (106.5 mg/g) (Herranz-Lopez, 2012), day lily (0.586-0.129 mg/g extract) (Kao, 2015), and Hangzhou white chrysanthemum (0.291 mg/g) (Tsuji-Naito, 2009). Caffeyolquinic acid existed in different forms; roselle contained 3-caffeoylquinic acid, 4-caffeoylquinic acid, and 5-caffeoylquinic acid (Ramirez-Rodrigues, 2011), whereas Hangzhou white chrysanthemum

contained 1-caffeoylquinic acid, 3-caffeoylquinic acid (Lin, 2010), 1,3-dicaffeoyl-epi-quinic acid, and macranthoin F, 3,5-dicaffeoylquinic acid (Xie, 2009).

3.6 Others

Other phytochemicals distributed in edible flowers included carotenoids (ϐ-carotene) (Fu, 2009), phytosterols (ϐ-sitosterol) (Mckay, 2009; Nakamura, 2013), alkaloids (Nakamura, 2013), lignans (Lee, 2011; Seo, 2010; Kong, 2011), neolignans (Li, 2005), coumarins (Petrulova-Poracka, 2013), and bisabolol oxides A and B (Avonto, 2013). However, these phytochemicals had relatively lower contents and weaker bioactivities.

4 Health benefits of edible flowers

4.1 Anti-oxidant activity

Overproduction of free oxidative radicals induces oxidative stress, aging, neurodegenerative diseases (e.g., Parkinsonϐs disease), stroke, diabetes mellitus, coronary heart disease, and cancers. The anti-oxidant capacity of edible flower extracts was evaluated by in vitro methods such as DPPH, ABTS, and ORAC assays (Xiong, 2014) and in vivo methods such as lipid peroxidiant assay (Adetutu, 2013). Almost every edible flower exhibited high anti-oxidant activities (Kaisoon, 2011; Li, 2014; Navarro-González, 2014; Zeng, 2014). Extracts of some edible flowers exhibited even stronger ability to scavenge free oxidative radicals than those of other plant organs (Mato, 2000) and bioactive plants, including tea plant (Mato, 2000; Zeng, 2014). Researches revealed that phytochemicals such as anthocyanins, flavonoids, phenolic acids,

alkaloids, and glycosides in edible flowers exerted high anti-oxidant activities (Cichewicz, 2002; Li, 2009). Further study showed that the amount of phenolic compounds, especially total flavonoids, may explain the higher anti-oxidant capacity of flowers than other plant organ (e.g., leaves) (Ksouri, 2009). Besides, the total amount of phenolic compounds significantly, positively correlated with anti-oxidant activity (Navarro-González, 2014; Vandavasi, 2015). Furthermore, the presence of flavonoids, alkaloids, triterpenoids, steroids, and carbohydrates in combination was possibly responsible for the observed anti-oxidant potential of edible flowers (Navarro-González, 2014).

The phytochemicals in edible flowers exerted anti-oxidant activities through multi-signaling transduction pathways. Wu et al. (2011) discovered using in vitro and in vivo approaches that *Chrysanthemum zawadskii* extract exhibited inhibitory effects through Nrf2-ARE antioxidative stress signaling pathways. Meanwhile, Ajiboye et al. (2011) suggested that roselle flower extract activates phase II drug detoxification enzymes through Nrf2-ARE-antioxidative stress signaling pathways. Further studies should focus on elucidating the mechanism underlying the anti-oxidant activities of edible flowers.

4.2 Anti-inflammatory

Inflammation is an essential and beneficial physiologic response designed to defend the host both from toxins and from invading pathogens. Begining as an acute inflammation, inflammation may then develop into chronic inflammation resulting in lethal damage to the health of the host.

Roselle, Hangzhou white chrysanthemum, wild chrysanthemum, honeysuckle, and day lily showed high anti-flammation effect. The anti-inflammatory property of edible flower extracts on acute inflammation was evaluated using cell models including lipopolysaccharide (LPS)-induced RAW 264.7 macrophage activation and animal models including dimethylbenzene-induced ear vasodilatation, acetic acid-induced capillary permeability enhancement, and carrageenan-induced paw edema. Hangzhou white chrysanthemum flower extracts reduced 12-O-tetradecanoylphorbol-13-acetate (TPA)-induced acute inflammation in mice (Ukiya, 2001). Similarly, honeysuckle flower water extract inhibited proteinase-activated receptor 2-mediated mouse paw edema (Kang, 2010). The effects of this extract on chronic inflammation was observed through granuloma formation in rats subjected to cotton pellet implantation (Su, 2012). A traditional Chinese medicine consisting of wild chrysanthemum extracts, patchouli oil, and zedoary turmeric oil reportedly regulated important inflammatory factors, such as prostaglandin E2, interleukin-1ϐ, tumor necrosis factor-ὰ, and nitric oxide (NO) (Su, 2012). Edible chrysanthemum flower extracts also reduced TPA-induced inflammation in mice (Ukiya, 2001). Other in vitro and in vivo experiments revealed that edible flowers such as cactus (Benayad, 2014), day lily (Kao, 2015; Ukiya, 2001; Su, 2012), and roselle (Beltran-Debon, 2010) also exhibited strong anti-inflammatory activities. Recent studies have suggested that flavonoids (Kao, 2015), anthocyanins (Beltran-Debon, 2010), and phenolic acids (Beltran-Debon, 2010) were the active compounds responsible for the anti-inflammatory properties of these edible flowers.

The anti-inflammatory activities of edible flowers involved the mitogen-activated protein kinase (MAPK) and NF-əB signaling pathways, which predominantly regulated the expression of inflammatory mediators such as inducible NO synthase (iNOS) and cytokines (Laskin, 2001; Lee, 2005). For instance, delphinidin 3-sambubioside, a *Hibiscus* anthocyanin isolated from the dried calices of roselle, reduced the amounts of several LPS-induced inflammatory mediators, such as iNOS, NO, interleukin-6 (IL-6), monocyte chemoattractant protein-1 (MCP-1), and tumor necrosis factor-Ŭ(TNF-Ŭ) in RAW264.7 cells as well as inhibited the expression of IL-6, MCP-1, and TNF-Ŭ and attenuated LPS-induced mouse paw edema in male ICR mice in vivo. These results indicated that roselle delphinidin 3-sambubioside exhibited potential anti-inflammatory properties (Sogo, 2015). Similarly, luteolin isolated from honeysuckle also inhibited inflammatory cytokines through the NF-əB signaling pathway (Kang, 2010).

4.3 Anti-cancer

One third of all cancer deaths in the United States are associated with inappropriate diet (Willett, 2002). Epidemiological studies have consistently shown that a high dietary intake of fruits and vegetables is strongly associated with reduced risk of chronic diseases (Davies, 2013). Edible flowers exerted potent activities against cancers of the liver, bladder, prostate, breast, and colon; these flowers include roselle (Lin, 2005; Lo, 2007; Chang, 2005; Hou, 2005a), Hangzhou white chrysanthemum (Xie, 2009), wild chrysanthemum (Wang, 2010; Yang, 2011), jasmine (Kalaiselvi, 2011b), rose (Hu, 2013; Gao, 2013), and honeysuckle (Yip, 2006). Phytochemicals

highly contributed to the anti-cancer activities of edible flowers. Luteolin (Xie, 2009; Yip, 2006), rugosaflavonoids A, rugosaflavonoids B, rugethanoids B (Hu, 2013; Gao, 2013), gallic acid (Nowak, 2014), protocatechuic acids (Nowak, 2014; Yip, 2006), and chorogenic acid (Yip, 2006) showed significantly anti-proliferative effect against cancer cells (Xie, 2009; Hu, 2013; Gao, 2013; Nowak, 2014; Xie, 2009). Therefore, these edible flowers were potential sources of anticancer drugs. The major components of roselle extract included bioactive compounds such as protocatechuic acid and delphinidin 3-sambubioside. These compounds may induce cell apoptosis via the p53 signaling and p38 MAPK/FasL cascade pathways (Lin, 2005; Lo, 2007; Chang, 2005) and moderated the ROS-mediated mitochondrial dysfunction pathway (Lin, 2005; Lo, 2007; Chang, 2005; Hou, 2005a).

4.4 Anti-obesity

Obesity, resulting from a disequilibrium between energy intake and expenditure (Woods, 1998), always triggers several metabolic and chronic ailments, including obstructive sleep apnea, hypertension, hyperlipidemia, and type 2 diabetes (Wickelgren, 1998; Muñoz, 2004).

Among the 15 edible flowers, roselle, magnolia flower, and water lily showed inhibition effect on obesity. The *Hibiscus* acid from roselle (Preuss, 2007; Kim, 2007; Hansawasdi, 2001), and (+)-epimagnolin A and (+)-magnolin from magnolia flower (Kong, 2011) reportedly participated in weight control in animal model and cell model. These phytochemicals mediated fat metabolism-related enzymes and pathways. In particular, roselle extract inhibited adipocyte

differentiation by modulating the PI3K and MAP-kinase pathways (Kim, 2007) or mediated energy intake and expenditure by inhibiting Ŭ-amylase activity and blocking sugar or starch absorption (Hansawasdi, 2001). Similarly, water lily methanol extract inhibited lipid storage in adipocytes by promoting lipolysis; it also exhibited agonist and antagonist activities toward 5-HT2C and CNR2 receptors (Hansawasdi, 2001; Kong, 2011; Lee, 2010; Velusami, 2013).

4.5 Neuroprotective effect

Neuronal degradation is highly associated with aging. Alzheimerôs and Parkinsonôs diseases, the most frequent causes of dementia, are characterized by a loss of dopaminergic neurons in the substantia nigra (Kim, 2009). Similarly, ischemic stroke, a leading cause of death and long-term disability, results from neuronal degeneration (Lin, 2010). The potential neuroprotective effect of edible flowers including Hangzhou white chrysanthemum, roselle, honeysuckle was evaluated using a rat model of glutamate, arachidonic acid, 6-hydroxydopamine (6-OHDA)-induced injury (Lee, 2007); a rat model of middle cerebral artery occlusion-induced focal cerebral ischemia/reperfusion (Lin, 2010); and a human neuroblastoma cell model of neurotoxin 1-methyl-4-phenylpyridinium (MPP^+)-induced cytotoxicity (Kim, 2009). Ruteolin, apigenin, dicaffeoylquinic acids, and triterpene from Hangzhou white chrysanthemum (Kim, 2009) inhibited MPP^+-induced cytotoxicity in human neuroblastoma. Loganin and chlorogenic acid isolated from honeysuckle protected SH-SY5Y cells from H_2O_2. Previous studies found that sweet-scented osmanthus ethanol extract demonstrated neuroprotective activity at EC50 values

of 66-165 μg/mL in a Wistar rat model of glutamate, arachidonic acid, and 6-OHDA-induced injury (Lee, 2007; Kim, 2009; Lee, 2009; Kwon, 2011). These researches also suggested that Hangzhou white chrysanthemum extract exhibited positive effects on neurodegenerative diseases by exerting anti-oxidant activities (Lin, 2010), inhibiting the mitochondrial apoptotic pathway (Kim, 2009), while sweet-scented osmanthus by upregulating glutamate and 6-OHDA expression, and downregulating AKT expression (Lee, 2007).

4.6 Visceral injury prevention effect

Roselle and Chinese hibiscus of the Malvaceae family displayed nephroprotective (Alarcon-Alonso, 2012), hepatoprotective (Lee, 2012), and gastroprotective effects (Phani Kumar, 2014). The water extract of roselle respectively exerted nephroprotective and hepatoprotective effects on streptozotocin-induced diabetic nephropathy in rats (Lee, 2009; Lee, 2009; Mossalam, 2011; Wang, 2011; Laikangbam, 2012; Alarcon-Alonso, 2012) and on acetaminophen paracetamol- or CCl_4-induced hepatotoxicity (Wang, 2000; Ali, 2003; Amin, 2005; Liu, 2006; Asagba, 2007; Olaleye, 2008; Ajiboye, 2011; Yin, 2011; Lee, 2012). Clinical trials (Herrera-Arellano, 2004; Prasongwatana, 2008) obtained similar results and suggested anthocyanins as the bioactive ingredient. Chinese hibiscus extract (250 mg/kg) mainly contain flavonoids, alkaloids, and tannins exhibited gastroprotective effect in aspirin- or ethanol-induced ulcer in rats (Kumar, 2014; Khandelwal, 2011). Dried pulverized Chinese hibiscus flower (250 mg/kg) in 2% carboxy methyl cellulose demonstrated cardioprotective effect (Gauthaman, 2006).

Other edible flowers such as chamomile, Hanghou white chrysanthemum also exhibited similar results. For example, in chamomile, a relatively higher dosages (300 mg/kg) of apigenin-7-methoxy-8-O-arabinopyranoside, apigenin-7-O-ƀ-glucoside-6òacetate, apigenin-7-O-galactoside-6òacetate, and apigenin-7-O-ƀ-glucoside showed gastroprotective effect (El Souda, 2015). Luteolin and luteolin-7-O-(6ò-O-malonyl)-glucoside from Hangzhou white chrysanthemum extract prevented CCl_4-induced liver injury in mice (Sugawara, 2009). However, the mechanisms underlying the visceral injury prevention effect of these compounds remained unclear.

4.7 Others

Edible flowers contain numerous phytochemicals which qualify them various health benefits. In addition to the ones mentioned above, other edible flowers such as roselle, Chinese hibiscus, chamomile, Hangzhou white chrysanthemum, wild chrysanthemum, rose, and honeysuckle showed special effects. Both roselle and Chinese hibiscus from Malvaceae family have a good deal of health benefits. In vivo and clinical trials revealed that roselle demonstrated anti-cholesterol (Wang, 2011; Oppliger, 2012), anti-hypertensive (Ajay, 2007; Inuwa, 2012), and anti-diabetic properties (Peng, 2011), in which delphinidin-3-O-sambubioside and cyanidin-3-O-sambubioside were indispensable, but the underlying mechanisms remained unclear (Ochani, 2009; Yang, 2010). Chinese hibiscus exerted anti-convulsive (Kasture, 2000) and contraceptive effects (Kumar, 2014a, 2014b). It also promoted hair growth (Adhirajan, 2003),

wound healing (Shivananda, 2007), and immunity (Gaur, 2009). . Recent studies have revealed that two Chrysanthemum species in bovine serum albumin (BSA)/glucose and BSA/fructose systems strongly inhibited the formation of various advanced glycation endproducts; this finding opened new avenues to explore pharmacological treatments to prevent glycation and related diseases (Tsuji-Naito, 2009; Yagi, 2012). In addition, rose extract (20 g/kg) reduced blood pressure both in acute and chronic cases in an animal model (Xie, 2012). Edible species of rose also exerted anti-HIV-1 effects (Fu, 2006; Gao, 2013). Chamomile ethanolic extract (20-100 mg/kg) shows effective antidiabetic effect by stimulating the utilization of peripheral glucose and/or by restoring enzyme activity and increasing the activities of serum superoxide dismutase and catalase (Cemek, 2008). Chamomile (Abad, 2011; Hajjaj, 2014; Nouri, 2012) together with wild chrysanthemum (Shi, 2011), and honeysuckle (Kang, 2010; Yoo, 2008) are also good sources of anti-nociceptive drugs. Other effects such as sleep patterns regulation effect of Hangzhou white chrysanthemum (Kim, 2011) and anti-depression effect of day lily (Cichewicz, 2002; Lin, 2013) were also reported. The health benefits of phytochemicals in edible flowers has been extensively investigated, but information about edible flowers remains incomplete.

5 Toxicology

The toxicology of edible flowers extracts was evaluated primarily through Ames mutagenicity assay and acute, subacute, chronic, and subchronic toxicity analysis in animals. Compared with fruits and vegetables, fewer studies explored the toxicology of edible flowers. A study on the

possible risk of using the extracts of flowers grown in Thailand showed that all extracts were not mutagenic even at their highest concentrations; this result indicated that these flowers were safe for consumption and that their extracts may be used in food product development (Wongwattanasathien, 2010).

Flowers whose toxicology were further assessed include honeysuckle (Yoo, 2008; Zhang, 2003; Kang, 2010), Hangzhou white chrysanthemum (Chen, 2007; Li, 2010; Yagi, 2012), Chinese hibiscus (Shivananda, 2007; Ali, 2010; Singh, 2014), and roselle (Ndu, 2011; Ali, 2012; Mahmoud, 2012), shown in Table 4. Most of the studies revealed that edible flowers were non-toxic at an appropriate dosage. For example, cytotoxicity study revealed that a 1.0 mg/mL ethanol extract of honeysuckle exhibited no-observed adverse effect on the viability of RAW264.7 macrophage cells (Yoo, 2008), acute toxicity study in mice showed that the LD50 for honeysuckle flower bud exceeded 15 g/kg bw. Moreover, the micronucleus test for bone marrow cell, the microsomal enzyme test for *Salmonella typhimurium*/mammals, and the antifertility test for Sprague-Dawley (SD) female mouse showed that the extract is nontoxic (Zhang, 2003). Similar results were also found in Hangzhou white chrysanthemum and Chinese hibiscus.

However, roselle was potentially hazardous (Akindahunsi, 2003). Prolonged exposure to this high extract dosage caused liver injury in Wistar rats, poisoned the hepatic system, mimiced chronic hepatitis, and eventually triggered muscular dystrophy (Fakeye, 2009). The extract could also induce testicular toxicity in adult rats (Orisakwe, 2004; Mahmoud, 2012) and affect the

development of the reproductive system of male rats when exposed to pregnant and lactating mothers (de Arruda, 2015). Furthermore, potential interaction may occur between roselle and other drugs, such as hydrochlorothiazide (Ndu, 2011) and acetaminophen (Kolawole, 2004).

6 Conclusion

Edible flowers are abundant natural resources worldwide and most of them contain numerous phytochemicals with health benefits which has attracted more and more attention. While many edible flowers are traditionally used as herbs to cure diseases, recent studies confirmed their health benefits, revealed the bioactive components and the related mechanisms. Also, researches have concentrated on the safety of common edible flowers and clarified the usages and dosages. However, there are so numerous edible flowers all over the world that only a small part of them have been studied. We suggest that more researches should be conducted to fully utilize edible flowers, ultimately increase the acceptability of edible flowers as potential food ingredients and avoid the potential hazards.

Author Disclosure Statement

No competing financial interests exist.

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Table 1 Species, distribution, traditional application of common edible flowers

Edible flower	Latin Name	Family	Origin	Distribution	Traditional Application		Reference
					Edible	Medical	
roselle	*Hibiscus sabdariffa*	Malvaceae	Africa	tropical and sub-tropical regions	beverage, jams	abscesses, dysuria, fever, hypertension and scurvy	(Da-Costa-Rocha, 2014)
Chinese hibiscus	*Hibiscus rosa sinensis*	Malvaceae	Africa	tropical and sub-tropical regions	teas, food su	fever, cough, genito-urinary troubles and bronchial catarrh	(Kumar, 2012)
tree peony	*Paeonia suffruticosa*	Ranunculaceae	China	China, Japan, America and	casseroles, cakes, teas,	womenôs diseases	(Huang, 2001)

				Europe	and drinks		
rose	*Rosa rugose*	Rosaceae	China	from temperate regions to the subarctic zone	jams, teas, cakes and natural pigment	stomachache, diarrhoea and womenôs diseases	(Li, 2009)
Chinese rose	*Rosa chinensis*	Rosaceae	China	from temperate regions to the subarctic zone	jams, teas, flavor extract	catamenia disorder, trauma, hemostasia, and diarrhea	(Lu, 2003)
honeysuckle	*Lonicera japonica*	Caprifoliaceae	East Asian	East Asian, Argentina, Brazil,	teas	exopathogenic wind-heat, epidemic febrile	(Shang, 2011)

				Mexico, Australia, New Zealand and United States		diseases, sores, carbuncles, furuncles and some infection diseases	
day lily	*Hemerocallis fulva*	Liliaceae	Asia	from southern Europe to the temperate zone of Asia	vegetables	depression, inflammation, and indigestion	(Tiejun, 1997)
HangZhou white chrysanthemum	*Chrysanthemum morifolium*	Asteraceae	China	China	teas, food supplement	dysentery, inflammation, hypertension,	(Chau, 2006)

						hyperlipidemia	
wild chrysanthemum	*Chrysanthemum indicum*	Asteraceae	China	China, Japan and Korea	teas	inflammation, hypertension, colitis, pneumonia and carbuncle	(Yuan, 2009)
chamomile	*Matricaria chamomilla*	Asteraceae	Europe	Europe, Egypt and North America	teas, cakes	hypoglycemia, hypertension, immunomodulatory, analgesic, fever, inflammatory, ulceration	(Singh, 2011)

cactus	*Opuntia ficus indica*	Cactaceae	Mexico	arid and semi-arid regions of South and Central America, Africa and the Mediterranean area	vegetables	as depurative and in particularly diuretic and relaxant of renal excretory tract	(Ammar, 2012)
magnolia flower	*Magnolia denudata*	Magnoliaceae	China	east and southeastern Asia, northeastern and central America,	cakes, salads, food supplement	emphyema, nasal congestion, sinusitis, allergic or chronic rhinitis	(Li, 2005)

				west Indies, and South America			
sweet-scented osmanthus	*Osmanthus fragrans*	Oleaceae	China	China, Japan and southern area of Korea	teas, cakes, wine, food supplement	hair and skin diseases	(Lee, 2011)
jasmine	*Jasminum sambac*	Oleaceae	India or Pakistan	tropical, subtropical and temperate zones	teas	cancer, uterine bleeding, ulceration, leprosy, skin diseases and wound healing	(Kalaiselvi, 2011a)

water lily	*Nelumbo nucifera Gaertn*	Nymphaeaceae	China	Asia and Oceania	teas, food garnish, vegetables	bloody discharge, skin diseases, inflammatory, hypertension, cancer, diarrhea, fever, infection and body heat imbalance	(Nakamura, 2013)

Table 2 Phytochemicals in common edible flowers

Phytochemicals	**Main components**	**Edible flower**	**Content**	**Method**	**Reference**
Flavonols	quercitrin	rose	36.64 mg rutin/g extract DW	HPLC	(Zhang, 2014)
		Hangzhou white chrysanthemum	21.38mg/g extract DW	HPLC, GC-MS	(Sun, 2010)
		wild chrysanthemum	52.88 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
		roselle	3.2 mg/g extract DW	HPLC	(Alarcon-Alonso, 2012)
		water	0.68mg/g	HPLC	(Samee,

		lily	extract DW		2007)
		day lily	0.0052-0.0231mg/g extract DW	HPLC	(Kao, 2015)
		Xibei tree peony	ND	HPLC	(Wang, 2004)
		Chinese rose	ND	LC-ESI-MS/MS, LC-MS/MS	(Pei, 2013)
	quercetin-3-rutoside	roselle	2.1 mg/g extract DW	HPLC	(Alarcon-Alonso, 2012)
		wild chrysanthemum	0.16 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
		day lily	0.0052-0.0	HPLC	(Kao,

			231mg/g extract DW		2015)
		rose	ND	LC-ESI-MS/MS	(Nowak, 2014)
		magnolia flower	ND	LC-MS	(Yoon, 2014)
		sweet-scented osmanthus	ND	HPLC, UV, H and C-NMR, 2D-NMR, MS	(Hung, 2012)
	quercetin-3-galactoside	Hangzhou white chrysanthemum	2.46 mg/g extract DW	HPLC, GC-MS	(Sun, 2010)
		wild chrysanthemum	12.55 mg/g extract	HPLC, GC-MS	(Wu, 2010)

			DW		
		water lily	0.68mg/g extract DW	HPLC	(Samee, 2007)
	quercetin-3-glucoside	roselle	3.072 mg/g extract DW	HPLC-ESI-TOF-MS	(Herranz-Lopez, 2012)
		Hangzhou white chrysanthemum	1.33 mg/g extract DW	HPLC, GC-MS	(Sun, 2010)
		wild chrysanthemum	9.88 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
	quercetin-3-O-hexoside	honeysuckle	0.0873 mg/g FW	HPLC-MS/MS	(Seo, 2012)
	quercetin-3-O-ɓ-D-glucopyranoside	honeysuckle	1.047 mg/g	H and C-NMR,	(Choi, 2007)

			extract DW	FAB-MS	
	quercetin-7-O-rutoside	cactus	0.101 mg GAE/g extract DW	HPLC-DAD -ESI-MS	(Benayad, 2014)
	quercetin-3-O-(2ò-O-ɓ-D-glucosyl)-ɓ-dxyloside	rose	3.04-9.58 mg/g extract DW	UPLC, H and C-NMR, HR-ESI-TOF-MS	(Ochir, 2010)
	quercetin-3-O-sophoroside	rose	1.16-20.13 mg/g extract DW	UPLC, H and C-NMR, HR-ESI-TOF-MS	(Ochir, 2010)
	quercetin-3-sambioside	roselle	7.674 mg/g extract	HPLC-ESI-TOF-MS	(Herranz-Lopez, 2012)

			DW		
	kaempferol	Hangzhou white chrysanthemum	0.0012mg/g extract DW	HPLC-DAD, HPLC-APCI-MS/MS, HPLC	(Tsuji-Naito, 2009)
		wild chrysanthemum	0.22 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
		rose	8.14 mg rutin/g extract DW	HPLC	(Zhang, 2014)
		Chinese rose	ND	LC-ESI-MS/MS, LC-MS/MS	(Pei, 2013)
		roselle	ND	HPLC	(Peng, 2011)
		Xibei	ND	HPLC	(Wang,

		tree peony			2004)
	kaempferol-3-O-rutoside	roselle	2.186 mg/g extract DW	HPLC-ESI-TOF-MS	(Herranz-Lopez, 2012)
		honeysuckle	0.019 mg/g FW	HPLC-MS/MS	(Seo, 2012)
		rose	ND	LC-ESI-MS/MS	(Nowak, 2014)
		cactus	ND	RP-HPLC-UV-PDA, ESI-MS	(Yeddes, 2013)
	kaempferol-3-O-hexoside	honeysuckle	0.132 mg/g FW	HPLC-MS/MS	(Seo, 2012)
Flavonols	kaempferol-3-O(2ò-O-ɓ-D-glucosyl)-ɓ-dxyloside	rose	10.06-20.59 mg/g DW	UPLC, H and C-NMR, HR-ESI-TO	(Ochir, 2010)

				F-MS	
	kaempferol-3-O-glucoside	honeysuckle	0.0611 mg/g FW	HPLC-MS/MS	(Seo, 2012)
	kaempferol-3-O-ɓ-D-glucopyranoside	honeysuckle	0.227 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)
	isorhamnetin-3-O-glucoside	honeysuckle	0,0249 mg/g FW	H and C-NMR, FAB-MS	(Choi, 2007)
	isorhamnetin-3-O-ɓ-D-glucopyranoside	honeysuckle	0.187 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)
	isorhamnetin-3-O-rutoside	cactus	1.517 mg GAE/g extract DW	HPLC-DAD-ESI-MS	(Benayad, 2014)
	isorhamnetin-7-O-rhamnos	cactus	1.044 mg	HPLC-DAD	(Benayad,

	yl-3-O-rutoside		GAE/g extract DW	-ESI-MS	2014)
	myricetin	whild chrysanthemum	37.81 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
	myricetin-3-arabinogalactose	roselle	4.756 mg/g extract DW	HPLC-ESI-TOF-MS	(Herranz-Lopez, 2012)
Flavones	luteolin	Hangzhou white chrysanthemum	0.0149mg/g extract DW	HPLC-DAD, HPLC-APCI-MS/MS	(Tsuji-Naito, 2009)
		wild chrysanthemum	7.29 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
		honeysu	0.240	H and	(Choi,

		ckle	mg/g extract DW	C-NMR, FAB-MS	2007)
		honeysuckle	24.0-24.6 mg/g extract DW	CE-ED	(Peng, 2005)
		sweet-scented osmanthus	ND	LC-MS	(Wu, 2009)
		tee peony	ND	HPLC-DAD, HPLC-ESI-MS	(Li, 2009)
		roselle	ND	HPLC	(Salah, 2002)
	luteolin-7-glucoside	Hangzhou white	50.59 mg/g	HPLC, GC-MS	(Sun, 2010)

		chrysanthemum	extract DW		
		wild chrysanthemum	17.24 mg/g extract DW	HPLC, GC-MS	(Wu, 2010)
	luteolin-7-O-(6ò-O-malonyl)-glucoside	Hangzhou white chrysanthemum	1.02 mg/g FW	HPLC, H and C NMR	(Sugawara, 2009)
	luteolin-7-O-ɓ-D-glucopyranoside	honeysuckle	3.229 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)
	apigenin	Hangzhou white chrysanthemum	0.0186mg/g extract DW	HPLC-DAD, HPLC-APCI-MS/MS	(Tsuji-Naito, 2009)
		wild	0.09 mg/g	HPLC,	(Wu, 2010)

		chrysanthemum	extract DW	GC-MS	
		tree peony	ND	HPLC-DAD, HPLC-ESI-MS	(Li, 2009)
		chamomile	ND	HPLC-ESI-MS/MS	(Avallone, 2000)
	apigenin-7-O-glucoside	Hangzhou white chrysanthemum	0.0101 mg/g FW	HPLC, H and C NMR	(Sugawara, 2009)
		tree peony (red (ócaihuiô))	ND	HPLC-ESI-MS	(Zhao, 2015)
		rose	ND	LC-ESI-MS/MS	(Nowak, 2014)

	apigenin-7-O-(6ò-O-malonyl)-glucoside	Hangzhou white chrysanthemum	1.56 mg/g FW,	HPLC, H and C NMR	(Sugawara, 2009)
	apigenin-7-O-hexoside	honeysuckle	0.0097 mg/g FW	HPLC-MS/MS	(Seo, 2012)
	apigenin deoxyheso-hexoside	tree peony (red (ócaihuiô))	ND	HPLC-ESI-MS	(Zhao, 2015)
		Zhongyuan tree penoy	ND	HPLC-DAD-ESI-MS	(Fan, 2012)
	acacetin	Hangzhou white chrysanthemum	ND	H and C NMR, LC-DAD-ESI-MS	(Lin, 2010)
	acacetin-7-O-(6ò-O-malony	Hangzho	1.41 mg/g	HPLC, H	(Sugawara,

	l)-glucoside	u white chrysanthemum	FW	and C NMR	2009)
	chrysoeriol	honeysuckle	0.248 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)
	chrysoeriol-7-O-ɓ-D-glucopyranoside	honeysuckle	0.200 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)
Anthocyanins	delphinidin-3-sambubioside	roselle	56.5 mg/g extract DW	HPLC	(Alarcon-Alonso, 2012)
	cyanidin-3-sambubioside	roselle	20.8 mg/g extract DW	HPLC	(Alarcon-Alonso, 2012)
	Pn3G5G, Pg3G5G, Cy3G5G, Pn3G, Cy3G	Zhongyuan tree	VR	HPLC-DAD-ESI-MS	(Fan, 2012)

		penoy			
		Xibei tree peony	VR	HPLC	(Wang, 2004)
	Pn3G5G	tree peony (red (ócaihui ô))	ND	HPLC-ESI-MS	(Zhao, 2015)
	Pg3Gy5Gy, Cy3Gy5Gy	Chinese rose	ND	LC-ESI-MS, MALDI-QIT-TOF-MS	(Cai, 2005)
Phenolic acids	caffeic acid	roselle	1.985 mg/mL extract	HPLC	(Huang, 2009)
		honeysuckle	0.132 mg/g extract DW	H and C-NMR, FAB-MS	(Choi, 2007)

		day lily	0.056-0.138 6mg/g extract DW	HPLC	(Kao, 2015)
		Hangzhou white chrysanthemum	0.0337mg/g extract DW	HPLC-DAD, HPLC-APCI-MS/MS	(Tsuji-Naito, 2009)
		rose	ND	LC-ESI-MS/MS	(Nowak, 2014)
		honeysuckle	6.4 mg/g extract DW	CE-ED	(Peng, 2005)
	chlorogenic acid	day lily	0.59-1.29 mg/g extract DW	HPLC	(Kao, 2015)
		roselle	2.7 mg/g extract	HPLC	(Alarcon-Alonso,

			DW		2012)
		honeysuckle	8.8-58.0 mg/g extract DW	CE-ED	(Peng, 2005)
	3-CfA, 4-CfA, 5-CfA	roselle	49.7-73.0, 13.5-18.8, 38.2-43.6 mg/mL extract	HPLC-DAD, LC-MS	(Ramirez-Rodrigues, 2011)
	1-CfA, 3-CfA	Hangzhou white chrysanthemum	ND	H and C NMR, LC-DAD-ESI-MS	(Lin, 2010)
	3-CfA, 3,5-diCfA and their derivatives	honeysuckle	0.0422, 0.156 mg/g FW	H and C-NMR, FAB-MS	(Peng, 2000)
	protocatechuic acid	honeysuckle	0.173 mg/g	H and C-NMR,	(Choi, 2007)

			extract DW	FAB-MS	
	Hibiscus acid	roselle	3.66-4.07 mg/mL extract	HPLC-DAD, LC-MS	(Ramirez-Rodrigues, 2011)
	gallic acid	rose	83.2 mg rutin/g extract DW	HPLC	(Zhang, 2014)
Flavanols	catechin	rose	80.8 mg rutin/g extract DW	HPLC	(Zhang, 2014)
		roselle	0.267 mg/mL extract	HPLC	(Huang, 2009)
		water lily	7.03 mg/g extract DW	HPLC	(Samee, 2007)

		day lily	3.93-5.47 mg/g extract DW	HPLC	(Kao, 2015)
	epicatechin	rose	180.8 mg rutin/g extract DW	HPLC	(Zhang, 2014)
		day lily	2.25-5.08 mg/g extract DW	HPLC	(Kao, 2015)
	epicatechin gallate	rose	28.0 mg rutin/g extract DW	HPLC	(Zhang, 2014)
	epigallocatechin gallate	rose	131.0 mg rutin/g extract	HPLC	(Zhang, 2014)

			DW		
		roselle	2.798 mg/mL extract	HPLC	(Huang, 2009)
	(-)-epigallocatechin-3-gallate	day lily	2.80-6.23 mg/g extract DW	HPLC	(Kao, 2015)

2D NMR: 2 Dimensional nuclear magnetic resonance spectrum; 3G: 3-O-Glucoside; 5G: 5-O-Glucoside; 3G5G: 3,5-di-O-Glucoside; 3Gy5Gy: 3,5-di-O-Glycoside; APCI: Atmospheric pressure chemical ionization; CE: Capillary electrophoresis; CfA: Caffeoylquinic acid; DAD: Detection and tandem; DW: dry weight; ED: Electrochemical detection; ESI: Electrospray ionization; FAB: Fast Atom Bombardment; FW: flower weight; GAE: gallic acid equivalent; H and C NMR: 1H and 13C nuclear magnetic resonance spectrum; HPLC: High performance liquid chromatography; HR: High resolution; GC-MS: Gas chromatography; LC: Liquid chromatography; MS: Mass spectrometer; Pg: Pelargonidin; Pn: Peonidin; TOF: Time-of-flight; VR: Varied in different cultivars.

Table 3 Health benefits of common edible flowers

Bioactivities	**Edible flower**	**Method**	**The inhibitory concentration**	**Main Functional Components**	**Reference**
Antioxidant	sweet-scented osmanthus	DPPH	EC50: 304.9 mg ascorbic acid eq/g extract	luteolin	(Wu, 2009)
		DPPH	IC50: 19.1, 10.3, 6.2 εM respectively	phillygenin, rutin, verbascoside	(Hung, 2012)
		ABTS	EC50:	luteolin	(Wu,

			516.3 mg trolox eq/g extract		2009)
		H_2O_2 scavenging ability	IC50: 10.5, 23.4, 13.4 εM respectively	phillygenin, rutin, verbascoside	(Hung, 2012)
	Hangzhou white chrysanthemum	DPPH	2.2, 2.3, 0.06, 0.03 mol trolox eq/mol respectively	luteolin-7-O-glucoside, luteolin-7-O-(6ò-O-malonyl)-glucoside, apigenin-7-O-(6ò-O-malonyl)-glucoside, acacetin-7-O-(6ò-O-malonyl)-glucoside	(Sugawara, 2009)
	water	haemoglobin	500	alkaloids, phenols and	(Durairaj,

	lily (white and pink)	glycosylation	µg/mL extract 55.5%, 41.6% inhibition	flavonoids	2014)
		DPPH	IC50: 350, 400 µg/mL extract	alkaloids, phenols and flavonoids	(Durairaj, 2014)
		$O_2^{Å}$scavenging assay	IC50: 310 µg/mL extract (white)	alkaloids, phenols and flavonoids	(Durairaj, 2014)
		NO scavenging activity assay	IC50: 325, 410 µg/mL extract	alkaloids, phenols and flavonoids	(Durairaj, 2014)

		^{Å}OH scavenging activity assay	IC50: 360, 450 µg/mL extract	alkaloids, phenols and flavonoids	(Durairaj, 2014)
		H_2O_2 scavenging activity assay	IC50: 330, 440 µg/mL extract	alkaloids, phenols and flavonoids	(Durairaj, 2014)
	roselle	Total antioxidant activity	4.6, 8.6 mM eq of Vitamin C for HSCF and HSEA	protocatechuic acid	(Farombi, 2005)
		$O_2^{Å}$scavenging assay	IC50: 130, 98 µg/mL	protocatechuic acid	(Farombi, 2005)

			for HSCF and HSEA		
		$^{\cdot}OH$ scavenging activity assay	IC50: 100, 90 µg/mL for HSCF and HSEA	protocatechuic acid	(Farombi, 2005)
		H_2O_2 scavenging activity assay	IC50: 110, 91µg/mL for HSCF and HSEA	protocatechuic acid	(Farombi, 2005)
	Chinese	DPPH	IC50:	2,3-hexanediol, n-hexadecanoic	(Bhaskar,

	hibiscus		45µg extract /mL	acid, 1,2-benzenedicarboxylic acid, squalene	2011)
	Chinese rose	DPPH	IC50: 0.015, 0.016, 0.013, 0.010 mM respectively	3,4,8,9,10-pentahydroxydibenzo [b,d]pyran-6-one kampferol-3-O-(6ő-galloyl)-ɓ-D -glucoside kampferol-3-O-(2ő,6ő-digalloyl)-ɓ-D-glucoside quercetin-3-O-(2ő,6ő-digalloyl)- ɓ-D-glucoside	(Pei, 2013)
	rose	DPPH	IC50: 0.08-1.33 mg extract/ mg DPPHÅ	flavonoids, phenolic acids	(Nowak, 2014)
		TBARS	50 ε g extract/	gallic acid	(Ng, 2004)

			mL inhibition 87.79%		
	magnolia flower (white and violet)	DPPH	IC50: 262.05, 246.99 ε g extract/ mL	gallic acid	(Jo, 2012)
		ABTS	IC50: 353.55, 336.07 ε g extract/ mL	gallic acid	(Jo, 2012)
		FTC	IC50: 204.06, 204.94	gallic acid	(Jo, 2012)

			ε g eatract/ mL		
	tree peony	DPPH	32.71-18 .72 mmol of Trolox eq/g of DW	quercetin glycoside	(Li, 2009)
		FRAP	1.04-3.0 3mmol of Trolox eq/g of DW	quercetin glycoside	(Li, 2009)
		ABTS	1.19-3.5 8 mmol of Trolox	quercetin glycoside	(Li, 2009)

			eq/g of DW		
	honeysuckle	DPPH	IC50: 17.68, 3.38µg extract/ mL	loganin and chlorogenic acid	(Kwon, 2011)
		ABTS	IC50: 3.38µg extract/ mL	loganin and chlorogenic acid	(Kwon, 2011)
		DPPH	IC50: 5.72, 11.76, 9.97, 7.21, 4.60 ε M	caffeic acid, isorhamnetin-3-O-ϐ-D-glucopyranoside, luteolin-7-O-ϐ-Dï glucopyranoside, protocatechuic acid, quercetin-3-O-ϐ-D-glucopyranoside	(Choi, 2007)

Anti-inflammation	day lily	LPS-induced RAW 264.7 macrophages	IC50: 1.60, 0.45,0.24, 0.40εg/mL respectively	rutin, epigallocatechin gallate, procyanidin, pelargonidin	(Kao, 2015)
	Hangzhou white chrysanthemum	terephthalic acid-induced inflammation ear edema in mice	ID50: 0.03-1.0 mg extract/ear	triterpene diols and triols	(Ukiya, 2001)
	wild chrysanthemum	rat lens aldose reductase assay	IC50: 2.1, 1.5 9.7 εM	(2S)-eriodictyol-7-O-ɓ-D-glucopyranosiduronic acids (2R)-eriodictyol-7-O-ɓ-D-glucopyranosiduronic acids (2S,3S)-1-phenyl-2,3-butanediol-3-O-b-D-glucopyranoside	(Matsuda, 2002)

	roselle	clinical studies in health men and women	10 g extract DW	anthocyanins, hydroxycitric acid, *Hibiscus* acid, chlorogenic acids	(Beltran-Debon, 2010)
	honeysuckle	HMC-1 cells	50 ε M	luteolin	(Kang, 2010)
		LPS-induced RAW264.7, the vascular permeability and air pouch models in mice	oral doses of 30, 100 and 300 mg/kg^{-1} showed inhibition of 7.9%, 18.8% and 27.2% in the	caffeic acid and luteolin	(Yoo, 2008)

			vascular permeability assay, 0.3 mg/pouch showed an inhibition in the air pouch model as positive control		
		formalin test, hot plate test, tail-flick	oral 100, 200, 400 mg/kg	chlorogenic acid, 9Ŭ-hydroxypinoresinol, sweroside, secologanin, rutin,	(Kang, 2010)

		test, hargreaves test, carrageenan/ acetic acid/croton oil/ MIA -induced mice model	bw	3,5-di-O-caffeoylquinic acid, 4,5-di-O-caffeoylquinic acid and quecertin	
Anti-cancer	roselle	HL-60 cells	IC50: 0.95 mg extract/ mL	phenolic compounds (protocatechuic acid)	(Lin, 2005)
		HL-60 cells	IC50: 75 εM	delphinidin-3-sambubioside	(Hou, 2005)
	Hangzhou white chrysanthemum	Colon 205 cells	IC50: 96.9, 82.9 mM	luteolin, diosmetin	(Xie, 2009)

			respectively		
	wild chrysanthemum	DU145 Cells, U266 cells	IC50: 40 εg/mL	acacetin, chrysoeriol, hesperetin, sudachitin	(Kim, 2013)
	rose	NB4, SHSY5Y, MCF7 cells	IC50: 2.2, 2.5, 2.3 εM	rugosaflavonoids A	(Hu, 2013)
		A549, MCF7 cells	IC50: 1.2, 2.8 εM	rugosaflavonoids B	(Hu, 2013)
		HeLa, T47D cells	100 μg extract/ mL	flavonoids, gallic acid, protocatechuic acids, tannins	(Nowak, 2014)
		HL-60, Hep-G2, KB, MDA-MB-231 cells	IC50: 3.10, 2.15, 2.82, 3.57	rugethanoids B	(Gao, 2013)

			µmol/L		
	honeysuckle	HepG2 cells	IC50: 55, 40, 60 µmol/L	chlorogenic acid, luteolin, protocatechuic acid	(Yip, 2006)
Anti-obesity	water lily	3T3-L1 preadipocyte cells	IC50: 47 µg extract/ mL	quercetin and kaempferol glycoside	(Velusami, 2013)
	roselle	monosodium glutamate induced neurotoxicity model in rats	33.64 mg anthocyanins/kg bw/day	delphinidin and cyanidin	(Alarcon-Aguilar, 2007)
	roselle	Ŭ-amylase-added Caco-2 cell model system	IC50: 3.8mM extract	*Hibiscus* acid	(Hansawasdi, 2001)
	magnoli	3T3-L1	50 µM	(+)-fargesin,(+)-eudesmin,	(Kong,

	a flower	adipocytes cells	extract	(+)-epimagnolin A, (+)-magnolin	2011)
Neuroprotection	Hangzhou white chrysanthemum	MPP^+-induced cytotoxicity in human neuroblastoma SH-SY5Y cells	1, 10 or 100 εg extract/ mL	ruteolin, apigenin, dicaffeoylquinic acids, triterpene	(Kim, 2009)
	roselle	streptozotocin induced diabetic nephropathy model in rats	100 or 200 mg extract/kg bw/day	protocatechuic acid, catechin, epigallocatechin, epigallocatechin gallate	(Lee, 2009)
		streptozotocin-induced type 1 diabetic	100 or 400 mg extract/kg	flavonoids, anthocyanins, polyphenolic acid	(Wang, 2011)

		model in rats	bw/day		
	honeysuckle	H_20_2 induced SH-SY5Y cell model	1, 5, 10 µg extract/ mL	loganin and chlorogenic acid	(Kwon, 2011)
Hepatoprotection	roselle	t-BHP-induced cytotoxicity in rat model	50-100 mg extract/kg bw	protocatechuic acid	(Liu, 2002)
		CCl_4-induced liver fibrosis in rats	200 mg extract/kg bw	anthocyanins, polyphenolic acid, flavonoids	(Liu, 2006)
		acetaminophen-induced hepatic steatosis model in mice	100, 200 or 300 mg extract/kg bw	catechin, protocatechuic acid, epigallocatechin, epigallocatechin gallate, caffeic acid	(Lee, 2012)

	Hangzhou white chrysanthemum	CCl_4-induced liver injury in Mice	12 mg luteolin or 22 mg the other flvonoids	luteolin, luteolin-7-O-(6ò-O-malonyl)-glucoside	(Sugawara, 2009)
Gastroprotection	Chinese hibiscus	global ischemia/ reperfusion induced lethal injury in rats	minimum dose: 180 µg extract/ mL	quercetin, cyanidin, kaempferol	(Khandelwal, 2011)
	chamomile	indomethacin-induced ulcer in rats	500 mg extract/kg bw	apigenin-7-methoxy-4ô-O-ß-arabinofuranoside apigenin-7-[O-(6öö-acetyl)-glucoside] apigenin-7-[O-(6öö-acetyl)-galactoside] apigenin-7-O- ß-glucoside	(El Souda, 2015)

DW: Dried weight; EC50: Median effective concentration for radical-scavenging activity; eq: Equivalent; HSCF: Chloroform soluble fraction of roselle ethanolic extract; HSEA: Ethyl acetate soluble fraction of roselle ethanolic extract; IC50: Half maximal inhibitory concentration; ID50: Half inhibitory dose; LPS: Lipopolysaccharide; t-BHP: Tert-butyl hydroperoxide;

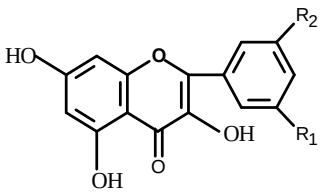
Table 4 Toxicology of common edible flowers

Edible flower	Method	Result	Reference
cactus	acute toxicity study in rats model	a single oral dose of 3000 mg/kg bw has no observed adverse-effect	(Alimi, 2011)
honeysuckle	cytotoxicity in RAW264.7 macrophage cells	1.0 mg/mL ethanol extract has no effect on cell viability	(Yoo, 2008)
	acute toxicity study in mice model	LD50 (median lethal dose) > 15 g/kg bw	(Zhang, 2003)
	acute toxicity study in rats model	1.25, 2.5, 5 g/kg bw has no observed adverse-effect	(Kang, 2010)
Hangzhou white Chrysanthemum	acute toxicity study in rats model	a single oral dose of 200 mg/kg bw has no observed adverse-effect	(Chen, 2007)
		a single oral dose of 15g/kg bw has no observed adverse-effect	(Li, 2010)
	chronic toxicity study in rats model	320, 640, 1280 mg/kg bw/d for 26 weeks has no observed adverse-effect	(Li, 2010)
	randomized controlled clinical	150mg powder/day for over 8 weeks has no observed adverse-effect	(Yagi, 2012)

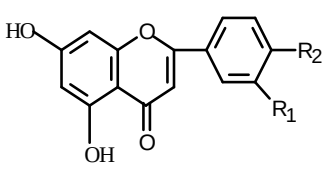
	trial in healthy female		
Chinese hibiscus	acute toxicity study in mice model	LD50 (median lethal dose): 150 mg/kg bw	(Kasture, 2000)
		a single oral dose of 1600 mg/kg bw showed 20% mortality	(Singh, 2014)
	acute toxicity study in rats model	4 g/kg bw/d for 14days has no observed adverse-effect	(Shivananda, 2007)
	cytotoxicity test in *Allium cepa* L.	5-10g dry and milled þowers /L distilled water has cytotoxicity	(Ali, 2010)
	genotoxicity test in mice model	oral dose of 200, 400mg/kg bw for for 15 days has no observed adverse-effect	(Singh, 2014)
roselle	acute toxicity study in rats model	average consumption of 150-180 mg/kg/day has no observed adverse-effect	(Akindahunsi, 2003)
		oral dose of 50-200 mg/kg bw for 5 days has no observed adverse-effect	(Ali, 2012)
	subchronic toxicity study in mice model	oral dose of 1150-4600 mg/kg bw for 12 weeks has testicular toxicity	(Orisakwe, 2004)
		oral dose of 250, 1000 mg/kg/day for 30	(Prommetta,

		days has no observed adverse-effect	2006)
		10%, 15% and 20% aqueous extracts in drinking water for 10 weeks has no observed adverse-effect	(Ali, 2012)
		oral dose of 2000 mg/kg bw for 90 days has lethal effect	(Fakeye, 2009)
		oral dose of 250 or 500 mg/kg bw from gestational day 12 until day 21 of lactation affect the productive development of offsprings	(Mahmoud, 2012)
	mice, rats and rabbits model	a single oral dose of 20-40mg/kg bw has interaction potential with hydrochlorothiazide within 24h	(Ndu, 2011)
	clinical trial in healthy young men	30g dried hibiscus calyces/L boiling water has possible interaction potential with acetaminophen	(Kolawole, 2004)

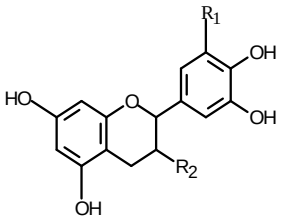
Aglycones of flavonol, flavone, flavanol and anacyanin



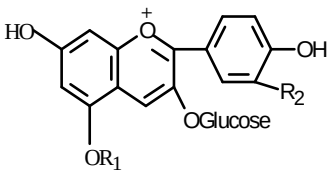
	R_1	R_2
keampferol	H	H
quercetin	OH	H
isorhamnetin	OCH_3	H
myricetin	OH	OH



	R_1	R_2
apigenin	H	H
luteolin	OH	H
chrysoeriol	OCH_3	H
acacetin	H	OCH_3

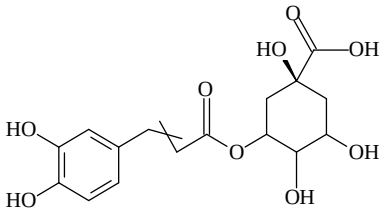


	R_1	R_2
chtechin	H	(¦ÁOH
epicatechin	H	(¦ÂOH
epicatechin gallate	H	$C_7H_6O_5$
epigallocatechin gallete	OH	$C_7H_6O_5$

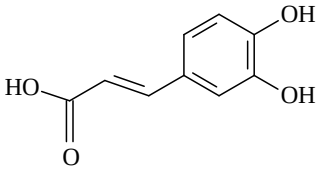


	R1	R2
Cy3G	H	OH
Cy3G5G	G	OH
Pg3G	H	H
Pg3G5G	G	H
Pn3G	H	OCH3
Pn3G5G	G	OCH3

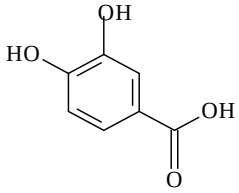
Phenolic acids



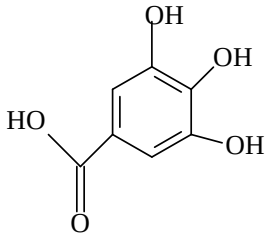
chlorogenic acid



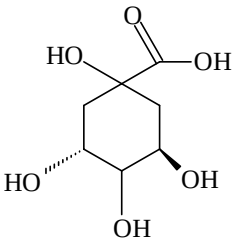
caffeic acid



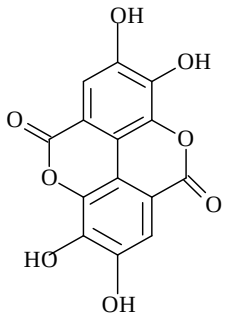
protocatechuic acid



gallic acid



quinic acid



ellagic acid

Figure 1 Chemical structures of the identified phytochemicals in edible flowers