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Review

Edible flowers: A review of the nutritional, antioxidant, antimicrobial properties and effects on human health

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ABSTRACT

Edible flowers have been traditionally used for human consumption in various cultures. They improve the appearance, taste and aesthetic value of food, aspects that consumers appreciate, justifying the increasing trend of fresh top quality flowers' sales worldwide. However, consumers also demand foods with beneficial health properties, in addition to the nutrients they contain, looking for functional qualities such as antioxidant and antimicrobial properties. This review summarizes the data of more than 100 studies performed until now on edible flowers, focusing on nutritional, antioxidant and antimicrobial activities, as well as health effects. This review provides valuable information on edible flowers in order to better characterize them and to increase their popularization among the food industry and consumers.

1. Introduction

Edible flowers have been used in culinary arts for flavor and garnish for hundreds of years. Early reports indicate that Romans used flowers in cooking, as did Chinese, Middle Eastern and Indian cultures. During Queen Victoria's reign, edible flowers were popular, as well as in North America and Europe (Newman and O'Connor, 2013). Presently, edible flowers are regaining popularity, as evidenced by the increasing number of edible flower cookbooks, culinary magazine articles and dedicated television segments (Barash, 1993; Creasy, 1999; Jacobs, 1999; Roberts, 2014; Rusnak, 1999). Despite being a niche market, attention to this kind of product has been raised by the recent highlights on their potential as a source of nutrients as well as a source of several bioactive compounds, supporting an increased worldwide demand (Patel and Naik, 2010).

Many flowers are edible but proper identification is essential because some are poisonous. Popular edible flowers include chrysanthemum, daylily, lilac, mint, nasturtium, pansy, rose, tulip and violet (University of Kentucky, 2012). Until now, there are no official lists of edible and non-edible flowers emitted by any international body, including Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO), Food and Drug Administration (FDA), or European Food Safety Authority (EFSA). However, the European Regulation (EC) No. 258/97, concerning novel foods and novel food ingredients, provides some information on the safety of these flowers. Accordingly, there are not any legal requirements for edible flowers marketing. Nevertheless, foodborne-disease outbreaks involving edible flowers have already been reported in the Rapid Alert System for Food and Feed (RASFF) (Table 1). The main problems are associated with the presence of unauthorized chemical compounds such as dimethoate and sulphite, and/or pathogens such as *Salmonella* spp (RASFF). This fact highlights for the necessity to take adequate measures for a safe cultivation and preservation, and therefore increased knowledge on these food products, from producers to food processors and consumers. Therefore, the aim of this review is to assemble the current knowledge on the edible flowers most studied until now and normally consumed in fresh or used in infusions. Thus, it is reported some of the most important aspects related to those edible flowers, including acceptability, nutritional, antioxidant and antimicrobial activities, effects on human health and safety issues. Nutritional composition, mainly macronutrients and micronutrients, is discussed and summarized in tables. The whole ranges of nutrient and minerals contents reported in the original papers are provided. Due to values reporting, in the studies reviewed, on fresh and dry weight basis, we decided to convert fresh weight to dry weight-based values. Antioxidant methods applied to edible flowers and the values obtained are also one

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Table 1
Foodborne-disease outbreaks attributed to some flowers and reported in the Rapid Alert System for Food and Feed (RASFF).
Source: RASFF Portal, Rapid Alert System for Food and Feed. https://webgate.ec.europa.eu/rasff-window/portal.

Flower	Country of origin	Detected problem	States notification	Year
Tilia tomentosa flowers	Albania	Dimethoate	Italy	2014
Hibiscus flowers	Egypt	Infested with insects and moulds, rodent excrements	Poland	2008
Cinnamon and cinnamon tree flowers (*Cinnamomum verum*)	Sri Lanka	Sulphite unauthorised	Spain	2005
Fresh edible flower	Thailand	*Salmonella mbandaka*	Finland	2005
Dried marigold flowers/*Calendula officinalis*	Egypt	*Salmonella hadar*	Poland	2004

of the focus of the present review, as well as, the identification of individual phenolic compounds (flavonoids and phenolic acids). Antimicrobial activities against some pathogenic microorganisms, as well as the effects on human health, are subjects also discussed in the present review.

2. Edible flowers: general characteristics and acceptability

There is a wide range of flowers, but only some are edible. Therefore, their proper identification is essential. Table 2 describes some edible flowers used for culinary purposes. According to Lu et al. (2016), edible flowers are obtained from 97 families, 100 genera and 180 species worldwide. Edible flowers are part of the cuisine of many countries. Examples include *Hemerocallis disticha* (Tai and Chen, 2000) and *Prunus mume* blossoms in China (Shi et al., 2009), *Carica papaya*, *Gmelina arboria*, *Phlogacanthus thyrsiformis*, *Dendrocnide sinuate*, *Justicia adhatoda*, *Oroxylum indicum* and *Nyctanthus arbortristis* in India (Deka and Nath, 2014), *Antigonon leptopus*, *Bougainvillea hybrida*, *Cassia siamea*, *Clitorea ternatea*, *Cosmos sulphureus* and *Malvaviscus arboreus* in Thailand (Kaisoon et al., 2011), *Curcubita pepo*, *Erythrina americana* and *Erythrina caribaea* in Mexico (Sotelo et al., 2007) and *Sambucus nigra* inflorescences in Central Europe (Kopec, 2004).

The most frequent way to consume edible flowers is in fresh but they can also be consumed dried, in cocktails (in ice cubes), canned in sugar and preserved in distillates (Mlcek and Rop, 2011). Edible flowers are usually used to add color, fragrance and flavor to food such as salads, soups, entrees, desserts and drinks (Mlcek and Rop, 2011; Rop et al., 2012; Kelley et al., 2001a). In this order, edible flowers have attracted the curiosity of some researchers and professional chefs, but there is still high potential to improve their usage and knowledge (Basso and Papalia, 2014).

Pansy (*Viola* × *wittrockiana*), centaurea (*Centaurea cyanus*), borago (*Borago officinalis*), rose (*Rose* spp.), nasturtiums (*Tropaeolum majus*) and hibiscus (*Hibiscus rosa-sinensis*) are examples of edible flowers that are normally used to garnish dishes. Nevertheless, others are more known by consumers as vegetables, such as artichoke (*Cynara scolymus*), broccolis and cauliflower (*Brassica oleracea*), even though these are inflorescences. Moreover, some herb flowers are edible, namely: alliums (leeks, chives, garlic), thyme (*Thymus vulgaris*), summer savory (*Satureja hortensis*), marjoram (*Origanum majorana*), mint (*Mentha* spp.) and common sage (*Salvia officinalis*), which are used to improve the flavor of dishes. Flowers of some fruit trees can also be used in cuisine as syrups such as elderberry blossoms (*Sambucus* spp) and citrus blossoms (orange, lemon, lime, grapefruit, kumquat).

In general, edible flowers are eaten whole, but depending on the flower species, only some parts should be consumed. For example, only the petals of *Tulipa*, *Chrysanthemum, Rosa* spp. or the flower buds of daisies (*Bellis perenis*) or garden nasturtium (*T. majus*) are consumed. Furthermore, in some flowers it is necessary to remove some parts due to their bitterness such as the white portions of the roses and chrysanthemums petals base.

Kelley et al. (2001b) observed that acceptability of edible flowers by consumers and professional Chefs, varied in accordance to some attributes and flower specie among both groups. In this study the opinion and preferences regarding three edible-flower species (viola, borage and nasturtium) in what regards three attributes, namely taste, fragrance and visual appeal, were registered. Regarding viola, consumers and chefs expressed similar perceptions in what concerns fragrance and visual appeal; however, the first group preferred taste and were more likely to purchase and use viola than the second. In a similar way, consumers also liked more borage than chefs, except for fragrance. In contrast, in nasturtium the three attributes evaluated were rated higher by the chefs. In this way, the decision to purchase and taste a flower can be different for both participant groups. Moreover, within the group of consumers some variables may influence purchase and use of edible flowers. Consumers from USA with higher college education, female, larger households, and highest annual income were more likely to purchase and use edible flowers (Kelley et al., 2002a). Furthermore, Kelley et al. (2002b) also found that, according to the variables described above, consumers have different attitudes and behavior in relation to how they like to consume the edible flowers (garnish, meal and salad) and the way edible flowers were obtained (grown organically or if they grew the flowers themselves). Generally, participants preferred to purchase edible flowers to eat as garnish, followed by salad and meal, independently of the variables mentioned. Concerning the way edible flowers are obtained, people less than 50 years old, with college/technical graduation and with two or more adults in the household, were more likely to grow their edible flowers. Older people (more than 50 years), female, without university studies, single-family household and with one or more children, were more likely to purchase edible flowers if grown organically. Some properties of edible flowers can also influence consumers at the time of purchase. Kelley et al. (2001a) reported that color was the most influential factor when consumers have to decide which package they would purchase. Price was the next most important factor and container size was the least important. Furthermore, consumers preferred a mix of flower colors over single colors, and some specific color contrasts were preferred over others. Consumers usually preferred most yellow and orange colors, while blue and combinations of other colors were less favored. For example, consumers preferred containers of edible flowers with more than one color of nasturtium and/or containers of nasturtiums with additional types of flowers (Kelley et al., 2001a).

In conclusion, acceptability of edible flowers depends on a number of factors, namely: social group (chefs *versus* consumers), species of flowers and their characteristics (taste, texture and appearance), personal characteristics of consumers (education, gender, annual income) and the packaging for sale (composition of flowers, size and price).

3. Properties of edible flowers

3.1. Nutritional value

Few studies were carried out on the nutritional composition of edible flowers, but most of them reported that the content of common components is not different from the composition of other plant organs (Mlcek and Rop, 2011). Mlcek and Rop (2011) reported that, from the nutritional point of view, flowers can be divided in pollen, nectar, petals and other parts. Pollen is a source of proteins and carbohydrates, saturated and unsaturated lipids, carotenoids and flavonoids. Nectar