



Citrus waste derived nutra-/pharmaceuticals for health benefits: Current trends and future perspectives



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ABSTRACT

Citrus are one of the most widely cultivated fruit crops. Citrus fruits are rich source of essential vitamins, minerals, fibers and bioactive phytochemicals, such as alkaloids, carotenoids, nitrogenous compounds and polyphenolics. The by-products derived from citrus wastes are considered to be an economic and renewable source for valuable compounds which can be used in pharmaceutical, nutraceutical, food and cosmetic industries. The review presents a detailed description on the recent advances with emphasis on the citrus derived nutraceuticals as potential source for various biological properties and physiological roles, such as anti-carcinogenicity, anti-mutagenicity, anti-allergenicity, anti-ageing activity, and natural as well as important constituent in synthetic antioxidants. A comprehensive description on the citrus derived food and drinks as well as nutritious feed for animals has also been included.

1. Introduction

Large amount of by-products are generated after the processing of fruits, such as citrus, mangoes, and bananas; which contains valuable compounds. The global production of different types of citrus fruits in the fiscal year 2016/17 for orange, tangerine/mandarin, grapefruit, lemons/limes are 50,186, 28.5, 934 and 7209 million metric tons, respectively (USDA, 2017). Many reports are published related to the processing of citrus waste for the recovery of natural value-added compounds, such as fiber (Martínez, Yáñez, Alonso, & Parajó, 2010), bioactive compounds like flavonoids (Casquete et al., 2014), additives and colorants (Sharma, Mahato, Cho, & Lee, 2017). In South Korea, more than 60 thousand tons of citrus pomaces (CPs) are annually produced after processing of citrus fruits. Consumer demand for non-synthetic and more natural food raw materials has increased the research work on for the recovery of natural value-added compounds from citrus waste (Marangoni, 2016).

1.1. Citrus fruit structure: anatomy and composition

Citrus belongs to the genus *citrus* of the family Rutaceae and are well known for fragrance and thirst quenching ability. It is also recognized for its medicinal values since ancient times. The anatomy of different

citrus fruits varies with type, variety, quality, and degree of maturity. The pictorial representation of the physical composition of a typical citrus fruit is shown in Fig. 1. The figure displays the main citrus varieties which are widely cultivated across the globe and their internal parts in the category of edible and non-edible parts and the labels are self-explanatory. The anatomy of a typical citrus fruit and its quantitative physical composition is shown in Fig. 2a. The chemical composition of the different non-edible parts of the citrus fruits, also called as citrus waste, such as peel flavedo, albedo and seeds are shown in Fig. 2b. The chemical composition of the macro- and micronutrients are shown in Fig. 2c. The utilization of citrus fruits is based on above factor and are of great importance while considering the problems caused in the preparation of citrus juices. Citrus waste contains soluble sugar, starch, fiber including cellulose, hemicellulose, lignin and pectin, ash, fat and protein and many bioactive compounds. This waste is very harmful to the environment as it contains many bioactive compounds and must be treated carefully before disposal. Because of insufficient infrastructure to handle the huge quantity of biomass and lack of knowledge and awareness, disposal of citrus wastes is a major problem in developing countries. Citrus peel and pulp are the by-products of the citrus juice processing industries and account for ~55–60% of the fresh fruit weight and the wastes from process industries is estimated to be more than 15×10^6 tons worldwide (Kalra, Grewal, & Kahlon, 1989;

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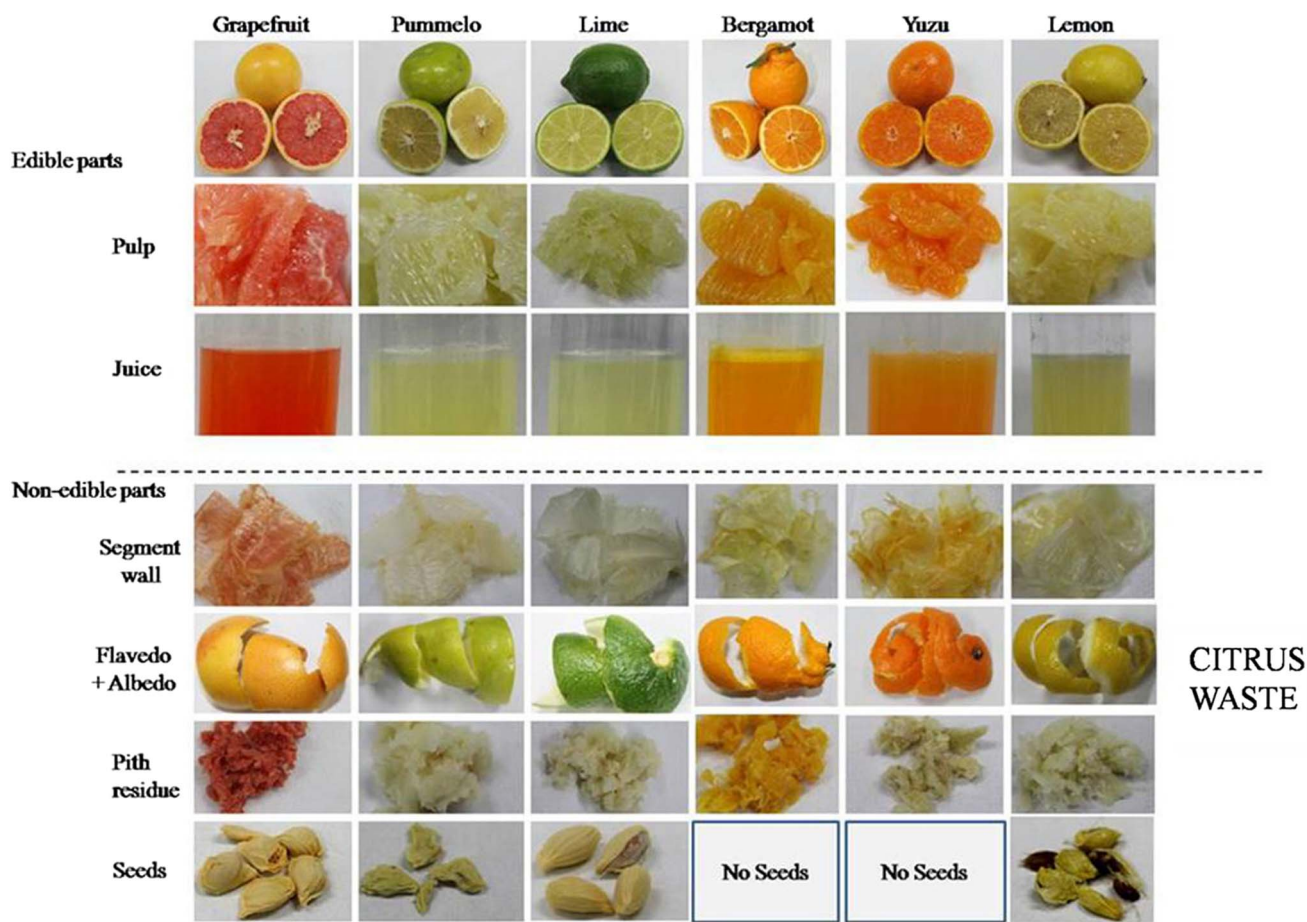


Fig. 1. Edible, non-edible and waste proportions of the main citrus fruit varieties commercially grown across the globe.

Marín, Soler-Rivas, Benavente-García, Castillo, & Pérez-Alvarez, 2007).

1.2. Recovery of value added compounds from citrus wastes

Recovery of the value added product from the citrus waste includes steps such as extraction, isolation, purification, identification, and characterization. The selection of methods in these steps depends on the nature of the compounds, such as hydrosolubility, liposolubility. The overall process of utilization citrus waste as value added product is represent in Fig. 3. Different extracting solvents such as polar and non-polar nature are used on the basis of the bioactive compounds to be extracted. After extraction, the bioactive compounds are recovered and purified using different methods. After purification, the compounds are characterized incorporating different analytical techniques. Furthermore, these compounds are tested for its bioaccessibility and bioavailability and later the refined compounds are utilized in food industries. By-products are valued sources of various nutrients and offer a variety of valuable opportunities in the technological and health promoting domains. When there is no refining step involved during the processing of waste, in that cases waste-management process is cheaper and more efficient (Schieber, 2017). The by-products obtained from citrus waste consists of pith, albedo, seed and flavedo, main compounds present within, and their applications in different fields are presented in Fig. 4. Different kinds of by-products are obtained from different processing industries, such as chemical industries produce lower contents of pectin and flavonoids, and higher contents of lignin and ash as compared to the food industries. The chemical industries use hydroalcoholic solvents for the processing which enables the extraction of flavonoids and pectins. Canning industry showed lower contents of flavonoids because it uses hot chemical such as NaOH for peeling (Marín et al., 2007).

Polyphenols, carotenoids and essential oils are considered to be the most biologically active compounds (BAC) in the citrus by-products. The polyphenols and carotenoids are known to have numerous health benefits, mostly attributed to their antioxidant activity (Anagnostopoulou, Kefalas, Papageorgiou, Assimopoulou, & Boskou, 2006; Levaj, Dragović-Uzelac, BursaćKovačević, & Krasnići, 2009). In addition, polyphenols possess significant potential as a lucrative raw material for the production of functional foods, pharmaceuticals and cosmetics.

In recent years, tremendous progress in research on the nutraceutical benefits and pharmacological effects of the phytochemicals found in *C. aurantium* and *Citrus reticulata* has been carried out. Researchers are looking forward to exploring new drugs from the development and utilization of the active ingredient found in other citrus fruits as well (Seki et al., 2013; Zhang, Li, Ma, & Ma, 2015).

2. Citrus waste derived phytochemicals for human health

Citrus wastes derived phytochemicals and value added compounds are utilized in designing healthy foods, nutrient supplements, flavouring agents in foods processing, preservatives, health and power drinks. These help in enhancing the quality of taste and aroma of the food and curing deficiencies. Citrus waste derived phytochemicals are also utilized in cosmetic formulations for skin, hair and nails, antifungal and antibacterial lotions, soaps, perfumes and toiletries.

Nutrition and food scientists, dieticians and medical practitioners are researching on functional foods and nutritional supplements that can reduce the risk of diet related disorders and diseases. Foods containing antioxidants have proven to provide protective effects against degenerative processes caused by oxidative stress (Kaur & Kapoor,

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