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Review

Converting citrus wastes into value-added products: Economic and environmently friendly approaches

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ABSTRACT

Citrus fruits, including oranges, grapefruits, lemons, limes, tangerines, and mandarins, are among the most widely cultivated fruits around the globe. Its production is increasing every year due to rising consumer demand. Citrus-processing industries generate huge amounts of wastes every year, and citrus peel waste alone accounts for almost 50% of the wet fruit mass. Citrus waste is of immense economic value as it contains an abundance of various flavonoids, carotenoids, dietary fiber, sugars, polyphenols, essential oils, and ascorbic acid, as well as considerable amounts of some trace elements. Citrus waste also contains high levels of sugars suitable for fermentation for bioethanol production. However, compounds such as D-limonene must be removed for efficient bioethanol production. The aim of the present article was to review the latest advances in various popular methods of extraction for obtaining value-added products from citrus waste/byproducts and their potential utility as a source of various functional compounds.

Introduction

Citrus crops are among the most abundant popularly grown in tropical and subtropical regions worldwide. The actual origin of citrus is believed to be the warm southern slopes of the Himalayas in northeastern India and Northern Myanmar. Researchers have proposed that some species of citrus originated in the Yunnan province of China [1–3]. Citrus fruits belong to the rutaceae family, and various parts of the plant or tree are appreciated for their health benefits. Sweet orange (*Citrus sinensis*) is the major fruit in this group constituting ~70% of the total citrus production and consumption. Other citrus fruits, such as tangerine or mandarin (*Citrus reticulata*), grapefruit (*Citrus vitis*), lime (*Citrus aurantifulia*), and lemon (*Citrus limonum*), are also grown and consumed extensively [4]. Main types of citrus fruits, their byproducts and general anatomy are present in Figure 1.

It is well established that citrus fruits and its products are rich sources of vitamins, minerals, and dietary fibers (nonstarch polysaccharides) essential for nutrition, growth, and overall development of the human body [5]. Recently, citrus fruits have been examined for other nonnutrient yet biologically active compounds, such as flavonoids, carotenoids, vitamins, and minerals, which can help reduce the risk for many chronic diseases (e.g., cardiovascular diseases and age-related macular degeneration) [6]. The bioactive compounds extracted from citrus fruits are rich in therapeutic properties and act as antioxidant, anticancer, antitumor, and antiinflammatory agents. These also are known for their antiviral, antiplatelet aggregation, and antiinflammatory activities. Some of the bioactive compounds have been reported to form protective enzymes in the liver and to block the damage of the genetic materials in the cells (Table 1 [6–20]).

The geographic distribution of production of the four main types of citrus fruits varies in different countries, as shown in Figure 2. For instance, Brazil is the dominant producer of sweet orange. Brazil processes 47% of the world's citrus fruits (the main citrus-processing country in the world), followed by the United States (29%) [21]. According to US Department of Agriculture-Foreign Agricultural Service, 2010 [22], ~30% of the citrus fruit production is processed principally to make juice. China is

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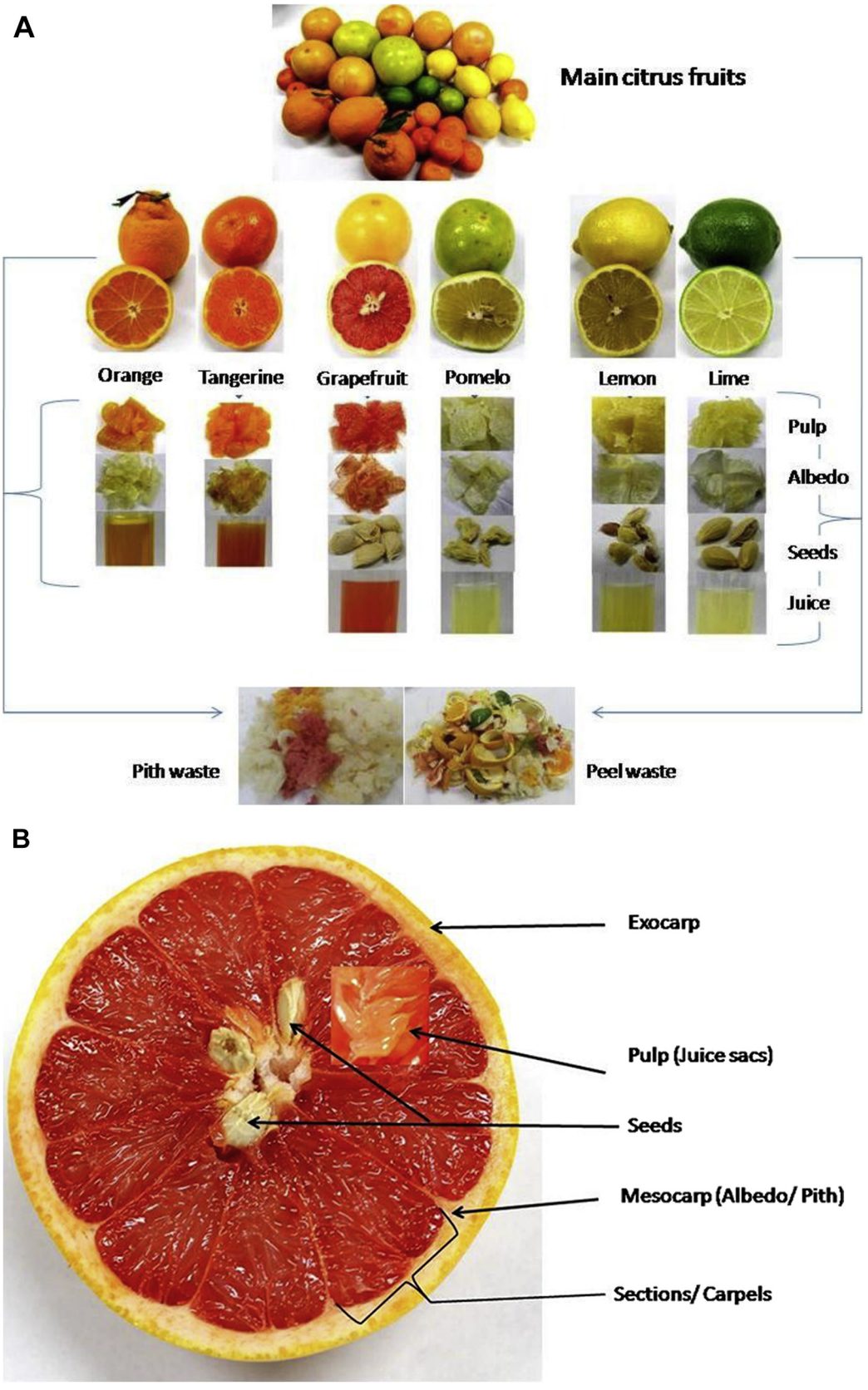

Fig. 1. (A) Main types of citrus fruits and their byproducts. (B) General anatomy of a typical citrus fruit.