



Valorisation of citrus processing waste: A review

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ABSTRACT

This study analyses the quantitative and qualitative characteristics of citrus peel waste and discusses the systems for its valorisation. Citrus peel waste (CPW) is the main residue of the citrus processing industries and is characterised by a seasonal production (which often requires biomass storage) as well as high water content and concentration of essential oils. The disposal of CPW has considerable constraints due to both economic and environmental factors. Currently this residue is mainly used as food for animals, thanks to its nutritional capacity. If enough agricultural land is available close to the processing industries, the use of CPW as organic soil conditioner or as substrate for compost production is also possible, thus improving the organic matter content of the soil. Recently, the possibility of its valorisation for bio-methane or bioethanol production has been evaluated by several studies, but currently more research is needed to overcome the toxic effects of the essential oils on the microbial community. Considering the high added value of the compounds that can be recovered from CPW, it has promising potential uses: in the food industry (for production of pectin, dietary fibres, etc.), and in the cosmetic and pharmaceutic industries (extraction of flavonoids, flavouring agents and citric acid). However, in many cases, these uses are still not economically sustainable.

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Contents

1. Introduction	253
2. Citrus processing systems	253
2.1. Citrus processing products	253
2.2. Processing technologies	254
3. Citrus peel waste production and storage	256
3.1. Physico-chemical characterization	256
3.2. Factors conditioning CPW valorisation: temporal production, storage, and transport costs	257
3.3. Storage techniques	257
4. Citrus peel waste valorisation systems	258
4.1. Direct use	258
4.1.1. Agronomic utilization	258
4.1.2. Animal food	259
4.2. Biorefinery valorisation approaches	261
4.2.1. Energy production	261
4.2.2. Added-value product extraction	264
5. Conclusions	268
Funding sources	269
References	269

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1. Introduction

The citrus processing industry plays an important role in the agro-industrial sector. The orange is the most widely-cultivated fruit worldwide and accounts for about 50–60% of total citrus production; however also other species (e.g. lemon, lime, mandarin, grapefruit) have industrial importance (Safari and Karimi, 2018). Brazil, China, India, Mexico, Spain, and the USA produce over two-thirds of the world's citrus fruits (Paggiola et al., 2016; Safari and Karimi, 2018). In 2016 more than 124 million Mg (Mg is the SI unit equivalent to tonne) of citrus were produced (Fig. 1a), of which about 50–60% was consumed as fresh fruit and the remaining 40–50% was destined for industrial processing (Fig. 1b) (FAOSTAT, 2017; Safari and Karimi, 2018; Sharma et al., 2017; 2018).

After processing (operated by different technologies with variable levels of automation), the citrus industry produces wastewater and solid/semisolid residues (citrus peel waste, henceforth “CPW”). The CPW production ranges from about 50% to 70% w/w of processed fruits, depending on adopted technology and fruit cultivar, and its annual world production is probably close to 10 million Mg. CPW shows a low pH and high concentrations of organic compounds; among these latter, the presence of essential oils (EO, of which D-limonene is the primary constituent) is the main problem for biological management options, due to their antimicrobial properties. The large amounts produced and the peculiar characteristics of citrus processing residues involve considerable

constraints for their management due both to economic and environmental factors (Calabrò et al., 2016). As a matter of fact, traditional CPW disposal strategies (e.g., incineration or landfilling) are nowadays insufficient and problematic in terms of environmental impacts and energy efficiency (Safari and Karimi, 2018; Wei et al., 2017). Disposal of CPW requires high costs and unauthorised disposal can potentially cause soil (due to the EO toxicity on soil microflora) and water bodies pollution; in some cases the destruction of the aquatic ecosystem is possible (Zema et al., 2018), particularly when the body of water is insufficient to properly dilute the waste (Sharma et al., 2017).

To minimize management costs and prevent environmental damage, several uses of the residues from the citrus processing industry have been evaluated in recent decades. All the treatment/valorisation options for CPW depend on a large number of factors, which affect economic viability. CPW can be used directly or after simplified treatments as animal feed or soil conditioner (for a long time the most common destination) or further processed in biorefinery industries (currently still hampered by economic constraints).

Since the financial burden of residue treatment covers a significant amount of the annual budget of the citrus processing industry, its competitiveness may be considerably enhanced by the economically sound management systems of citrus residues (Zema, 2017). Furthermore, also the environmental constraints have to be properly considered regarding land and water conservation. Thus, the optimal solution has to combine the most efficient and environmentally sustainable technology for treatment/valorisation and the specific economic constraints, linked to the local market conditions. Over the years, researchers worldwide have been focusing on developing different processing methods for complete exploitation of CPW (De Gregorio et al., 2002; Lo Curto et al., 1992; Safari and Karimi, 2018; Sharma et al., 2017; Tripodo et al., 2004); however, more awareness and research are needed in order to change traditional attitudes, which consider citrus processing residues as a waste to be disposed of in landfills rather than a valuable resource for reusing in the bioeconomy (by a direct use or after further processing in biorefineries) thanks to its numerous applications in various fields. If the great potential in CPW valorisation by green economy schemes is realized, the negative impacts of citrus processing industries on the environment may be lessened.

After an analysis of the quantitative and qualitative characteristics of CPW, this paper proposes an overview of the possible uses and management systems of citrus residues; their pros and cons are discussed, considering the factors influencing the treatment and utilisation of citrus residues. Starting from this, an analysis of the most recent valorisation alternatives proposed in the scientific literature is carried out, in order to provide company managers and other stakeholders an insight into the most suitable solution for the economic and environmental sustainability of the citrus residue management chain.

2. Citrus processing systems

2.1. Citrus processing products

The main product of the citrus processing industry is juice, used in many beverages (e.g. soft drinks) or as ingredient in many foods. Other products include marmalades, jellies, potpourris, candied peel, jams, flavouring agents for beverages and health drinks, oils and essences, used as food-grade products (Fig. 2) (Kimball, 1999; Sharma et al., 2017; 2018). As will be discussed later (see Section 4.2.2), other food-grade products are extracted from citrus processing residues (mainly fibres and pectins) (Fig. 3).

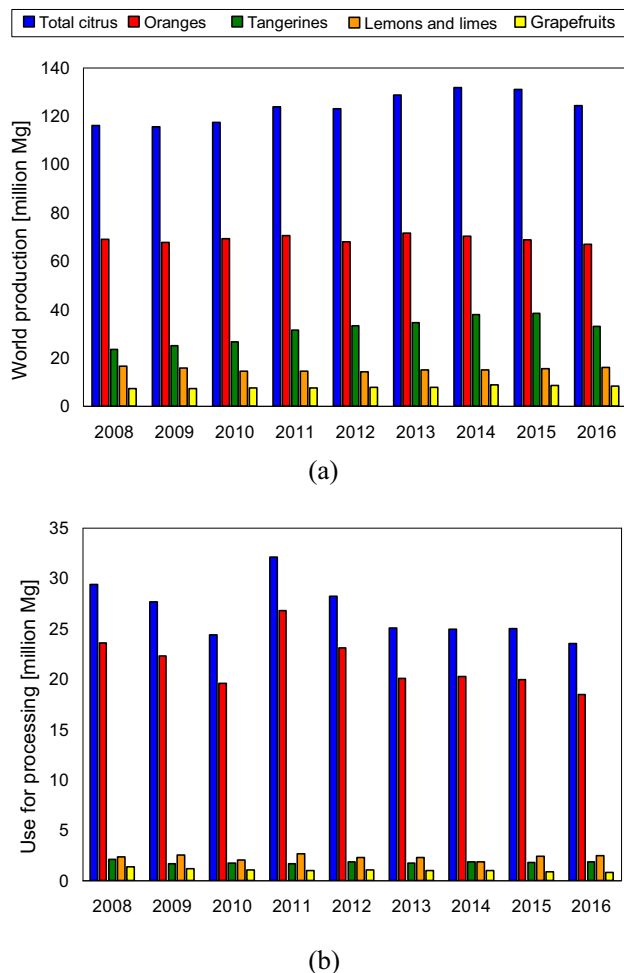


Fig. 1. (a and b) Produced and processed citrus fruits in the World. Source: FAOSTAT, 2017

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