Food Chemistry 225 (2017) 10–22

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Review

Bioactives from fruit processing wastes: Green approaches to valuable chemicals

Jhumur Banerjee[a], Ramkrishna Singh[a], R. Vijayaraghavan[b], Douglas MacFarlane[b], Antonio F. Patti[b], Amit Arora[a,*]

[a] CTARA, IITB-Monash Research Academy, IIT Bombay, Mumbai, Maharashtra 400076, India
[b] School of Chemistry, Faculty of Science, Monash University, Clayton Campus, VIC 3800, Australia

ARTICLE INFO

Article history:
Received 2 August 2016
Received in revised form 6 December 2016
Accepted 27 December 2016
Available online 28 December 2016

Keywords:
Fruit processing waste
Bioactives
Biorefinery
Nutraceuticals

ABSTRACT

Fruit processing industries contribute more than 0.5 billion tonnes of waste worldwide. The global availability of this feedstock and its untapped potential has encouraged researchers to perform detailed studies on value-addition potential of fruit processing waste (FPW). Compared to general food or other biomass derived waste, FPW are found to be selective and concentrated in nature. The peels, pomace and seed fractions of FPW could potentially be a good feedstock for recovery of bioactive compounds such as pectin, lipids, flavonoids, dietary fibres etc. A novel bio-refinery approach would aim to produce a wider range of valuable chemicals from FPW. The wastes from majority of the extraction processes may further be used as renewable sources for production of biofuels. The literature on value addition to fruit derived waste is diverse. This paper presents a review of fruit waste derived bioactives. The financial challenges encountered in existing methods are also discussed.

Contents

* Corresponding author at: Indian Institute of Technology, Powai, Maharashtra, India.
E-mail address: aarora@iitb.ac.in (A. Arora).

http://dx.doi.org/10.1016/j.foodchem.2016.12.093
0308-8146/

1. Introduction

The vast imbalance between food production and consumption may be estimated from the fact that on average 30–40% of food is wasted in many parts of the world (Laufenberg, Kunz, & Nystroem, 2003; Parfitt, Barthel, & Macnaughton, 2010; Wadhwa & Bakshi, 2013). Out of many factors contributing to the global environmental burden in recent years, the effect of fruit waste has been identified as a major concern. For instance, the fraction of discarded materials in the majority of fruit processing industries is typically very high (Laufenberg et al., 2003; Parfitt et al., 2010) depending on the location and method of harvest (e.g. mango 30–50%, banana 20%, pomegranate 40–50% and citrus 30–50%). This fruit waste, being rich in moisture and microbial loads, lead directly to environmental pollution. Processing industries, especially in developing countries, face the constraints of finance, space and in some cases stringent government regulations with respect to waste disposal. The majority of these industries are micro and small-scale which mainly fall under informal sector and, thus, processing waste is considered to be of negligible value compared to the processed fruit. The current classification of FPW (fruit processing waste) as "general waste" makes it an ignored feedstock globally. Compared to developed countries such as Europe, where the fruit and vegetable processing waste was found to be fifth highest contributor (8% of total food waste) to overall food waste (Fava, Totaro, Diels, Reis, Duarte, Carioca, H, M., Ferreira, & B. S., 2015), majority of the fruit and vegetable processing sector data for developing countries was found to be fragmented and insufficient (Wadhwa & Bakshi, 2013). Primary data from developing countries indicate that large scale industries process FPW into biogas or compost it to obtain biofertilizer. Waste from organized and unorganized processing industries, with the exception of very few major composting and biogas generation facilities, is for the most part disposed of through municipal waste disposal systems. Many recent reports have focussed on food waste recovery (Pfaltzgraff, De bruyn, Cooper, Budarin, & Clark, 2013) and general approaches to lignocellulosic biomass value addition from this waste (Credou & Berthelot, 2014; Van Dyk & Pletschke, 2012). The segregation and study of FPW as a particular type of food waste helps in the development of additional biorefinery processes and ultimately improve the economics of food waste based bio-refinery concept. With respect to waste reduction and recovery, a biorefinery operation would have a substantial incentive to develop products and processes for by-product and waste utilization. This paper will review current status of FPW utilization and valorisation and discuss its potential as a bio-refinery feedstock of the future.

2. Current use and disposal Patterns for FPW

Millions of dollars are spent globally to dispose of FPW (Okino-Delgado & Fleuri, 2015). For instance, in Europe, the disposal of 1 tonne of solid waste or 1 m^3 of effluent costs $28–60 which includes a landfill tax of $10 (Gendebien et al., 2001). In developing countries such as India, the average transportation cost was found to be $11–15 per tonne per trip (FICCI, 2010) which may indicate > $300 million for total landfilling cost. Land filling term in Indian context is implicitly filling of dumping grounds with solid waste. Due to high moisture content of fruit waste, incineration may not be efficient and viable option compared to general solid waste. Though landfilling is a standard disposal method, it is the least economical way to deal with this global issue. Landfilling is also associated with risks of greenhouse gas emissions (Roggeveen, 2010). For example, global food processing waste related greenhouse gas emission was found to be the third highest contributor after total emissions for China and USA (Eckard & Victoria, 2008; FAO, 2013). FPW accounted for 16% of this total food waste with a contribution of 6% (>20 million tonnes of carbon dioxide equivalent) of global greenhouse gas emissions (FAO, 2013), (mainly methane and nitrous oxide due to decomposition inside landfills). Asia, Europe and North America were found to be the highest contributors (FAO, 2013; NGWA, 2016).

The valorisation of FPW as a soil improvement additive is a common approach which is followed extensively in many countries. Composting and the use of charcoal has a long history in agriculture (Sener et al., 2015) and has been used to promote agronomic productivity for centuries. This tradition can be modernized by way of pyrolysis equipment especially engineered to heat the biomass at designated temperatures in the absence of oxygen. The resulting product is termed as biochar. Biochar can potentially provide a number of benefits to the soil including carbon sequestration, improve quality of acidic soil by increasing the pH of the soil, habitat for microorganisms and exchange sites for plant nutrient support. Contrary to composting, it provides a significant reduction of greenhouse gas emissions (Sener et al., 2015), thus, biochar materials are receiving significant attention from scientists, engineers and farmers. To date several exploratory studies have assessed the response of bacteria, fungi, and enzymes to biochar (Lehmann, Rillig, Thies, Masiello, Hockaday, & Crowley, 2011) incorporation into soil. Various critical examinations of the effects of biochar on crop yields and soil properties have indicated that different outcomes are obtained, both beneficial and negative, depending on a number of variables. These include, the type of biomass used to produce the biochar, conditions used to make the biochar, soil type, addition of other components (e.g. minerals and other plant nutrients) climate and the interaction between microbiota and the active substances (e.g. polyphenols) and the effect of sorption of minerals due to the differential porosity. Significant further research, especially in the understanding of plant nutrients from FPW, is needed to understand the effects of these different variables on the efficacy of biochar (Lehmann et al., 2011; Mlambo & Mapiye, 2015). Looking at the availability of biomass other than FPW, it seems that FPW may not provide greater advantages when compared with other agricultural residues, in soil improvement alone. However, the key issues to be addressed are nutrient recovery from the feedstock into soil.

3. Composition and application of FPW based bioactives

Various compositional studies of the FPW suggests presence of a wide range of bioactive compounds in different residual fractions. These bioactive compounds are essentially primary and secondary metabolites of plants. Phenolics, alkaloids, glycosides (the active metabolite bound to a sugar moiety), volatile oils, mucilage, gums and oleoresins are some of the examples of secondary metabolites (Biesalski, Dragsted, Elmadfa, Grossklaus, Muller, Schrenk, Walter, & Weber, 2009). Bioactive-rich extracts may be used in a diverse range of novel applications due to the proven health effects on long term consumption. Apart from being a rich source of bioactive carbohydrates such as pectin, FPW may be an important source for recovery of cellulose from peels (Pfaltzgraff, De bruyn, M., Cooper, E. C., Budarin, V., & Clark, & J. H., 2013), hemicellulose from pomace (Chantaro, Devahastin, & Chiewchan, 2008; Scheller & Ulvskov, 2010; Singh, Banerjee, & Arora, 2015), lignin (Van Dyk & Pletschke, 2012) from peels and seed coats (Van Dyk & Pletschke, 2012; Scheller & Ulvskov, 2010). Cellulose can be converted into sugars and further to biofuels and biochemicals. Mesoporous cellulose can also be obtained as a by-product of pectin extraction. It was found to be effective in variety of applications such as catalysis, chemical sensors and molecular separation as a