



Review

Pomegranate peel and peel extracts: Chemistry and food features

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ABSTRACT

The present review focuses on the nutritional, functional and anti-infective properties of pomegranate (*Punica granatum* L.) peel (PoP) and peel extract (PoPx) and on their applications as food additives, functional food ingredients or biologically active components in nutraceutical preparations. Due to their well-known ethnomedical relevance and chemical features, the biomolecules available in PoP and PoPx have been proposed, for instance, as substitutes of synthetic food additives, as nutraceuticals and chemopreventive agents. However, because of their astringency and anti-nutritional properties, PoP and PoPx are not yet considered as ingredients of choice in food systems. Indeed, considering the prospects related to both their health promoting activity and chemical features, the nutritional and nutraceutical potential of PoP and PoPx seems to be still underestimated. The present review meticulously covers the wide range of actual and possible applications (food preservatives, stabilizers, supplements, prebiotics and quality enhancers) of PoP and PoPx components in various food products. Given the overall properties of PoP and PoPx, further investigations in toxicological and sensory aspects of PoP and PoPx should be encouraged to fully exploit the health promoting and technical/economic potential of these waste materials as food supplements.

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1. Introduction

Pomegranate (*Punica granatum* L.) is better known in some countries as the fruit of *Eden* (Al-Quran) for its pleasant taste and excellent health benefiting properties. Over the last decade, pomegranate fruit and fruit extracts have been shown to possess preventive and attenuating activities against numerous chronic and health/life threatening maladies such as cancer (Lansky & Newman, 2007; Orgil et al., 2014), type 2 diabetes (Banihani, Swedan, & Alguraan, 2013), atherosclerosis and cardiovascular diseases (Al-Jarallah et al., 2013; Aviram et al., 2008; Hamoud et al., 2014; Rosenblat, Volkova, Coleman, & Aviram, 2006; Sestili et al., 2007). Interestingly, the above nutraceutical properties are not limited to the edible part of pomegranate fruit: in fact the non-edible fractions of fruit and tree (i.e. peel, seeds, flowers, bark, buds and leaves), although considered as waste, contain even higher amounts of specific nutritionally valuable and biologically active components as compared to the edible fruit (Orgil et al., 2014; Rosenblat et al., 2006; Sestili et al., 2007). Indeed, PoP and PoPx, hold significant free radical scavenging, anti-microbial, antiatherogenic and antimutagenic properties and are reported to produce ameliorating effects against many critical maladies (Aviram et al., 2008; Malviya, Jha, & Hettiarachchy, 2013; Sestili et al., 2007; Zahin, Aqil, & Ahmad, 2010). Unfortunately, functional foods containing PoP or PoPx are not, in general, well accepted by consumers because of their relatively reduced sensory features (Akpınar-Bayizit, Ozcan, & Yilmaz-Ersan, 2012; Ismail, Akhtar, Riaz, & Ismail, 2014; Sharma, Prakash, Gupta, Prakash, & Sharma, 2014; Syed, Chamcheu, Adhami, & Mukhtar, 2013).

Nonetheless, the above health promoting features prompt the food entrepreneurs to focus on PoP and PoPx-containing food preparations including food supplements, nutraceuticals and phenolics enriched diets (Ismail, Sestili, & Akhtar, 2012; Kanatt, Chander, & Sharma, 2010; Naveena, Sen, Vaithyanathan, Babji, & Kondaiah, 2008b; Qu, Breksa, Pan, Ma, & Mchugh, 2012). In addition to their nutraceutical relevance, PoP and PoPx exhibit important technical functions (antioxidant, antimicrobial, colourant and flavouring) and may also act as excellent natural additives for food preservation and quality enhancement. As a consequence, on account of these whole properties the use of peel's fractionated compounds in food and nutraceutical industry is on the rise (Ismail et al., 2012; Kanatt et al., 2010; Naveena et al., 2008b; Qu et al., 2012). In particular, since the peel fraction of pomegranate is a valuable reservoir of diversified polyphenols such as sugar-free mono and oligomeric ellagitannins, it has been frequently utilized as natural antioxidant in various dietary supplements. Currently, to minimise the problem of its bad taste, commercial formulations of PoPx dietary supplements are available as capsules, tablets, and soft gels.

Apart from the established inclusion of PoP in several ayurvedic therapies and the recent tendency to an increased utilisation, the food use of PoP and PoPx is still poor and underestimated (Ismail et al., 2012, 2014). The aim of the present review is to highlight the importance of PoP, PoPx and their biological fractions as food bulking agents and/or valuable substitutes of common synthetic food additives, providing baseline information on their potential applications with regard to the general issues of food safety, preservation, enrichment and quality enhancement.

2. Pomegranate peel phytochemistry

PoP – which accounts for about 50% of fruit weight is characterised by the presence of high molecular weight phenolics, ellagitannins, proanthocyanidins, complex polysaccharides, flavonoids and appreciable quantities of microelements that, on the whole, exhibit strong anti-mutagenic, antioxidant, antimicrobial and apoptotic

properties (Dikmen, Ozturk, & Ozturk, 2011; Li et al., 2006; Prakash, Mathur, Vishwakarma, Vuppu, & Mishra, 2013; Ricci, Giamperi, Bucchini, & Fraternali, 2006; Tezcan, Gultekin-Özguven, Diken, Ozelik, & Erim, 2009). The fruit contains a rich variety of flavonoids, constituting nearly 0.2–1.0% of the fruit weight; approximately 30% of all fruit anthocyanidins are concentrated in the peel portion. The reciprocal concentration of these compounds depends on the cultivar type and on the various developmental phases of the fruit, and is responsible for the variations in pomegranate peel colour (Fischer, Carle, & Kammerer, 2011; Kumari, Dora, Kumar, & Kumar, 2012; Zhao, Yuan, & Fang, 2013).

Data from literature indicate that 124 different phytochemicals can be found in pomegranate fruit; amongst these phytochemicals, high molecular weight polyphenols (e.g. ellagitannins and the pomegranate-peculiar punicalagin) are likely to mediate the protective effects against a wide range of oxidative and inflammatory disorders, including cancer (Heber, 2011). Nearly 48 phenolic compounds (anthocyanins, gallotannins, hydroxycinnamic acids, hydroxybenzoic acids and hydrolysable tannins i.e. ellagitannins, and gallagyl esters) have been identified in PoP and other anatomical parts of the fruit. The whole fruit is rich in large polyphenolic compounds such as punicalagin isomers, ellagic acid derivatives and anthocyanins (delphinidin, cyanidin and pelargonidin 3-glucosides and 3,5-diglucosides) but, interestingly, PoP contains the most promising pool of phenolics (predominantly those from hydrolysable tannins) as compared to their concentration in any other anatomical part of the fruit.

Mounting evidence suggests that hydrolysable polyphenols in PoP, specifically ellagitannins, are the most active antioxidants amongst the tannins contained therein. These compounds (ellagic acid, punicalagin, punicalin and gallagic acid) have been shown to hold heightened antioxidant and pleiotropic biological activities and notably, to act synergistically together (Seeram & Heber, 2011). Nevertheless *in vivo* studies suggest that the antioxidant properties of dietary absorbed polyphenols are tied to their metabolised compounds, e.g. urolithins (Johanningsmeier & Harris, 2010).

High molecular weight ellagitannins are water soluble plant phenolics that yield different biologically relevant by-products upon hydrolysis. Under normal physiological conditions, orally ingested ellagitannins undergo microbial hydrolysis by gut microflora to relatively smaller compound, i.e. ellagic acid and, upon further bacterial metabolism, urolithins. Ellagitannins' hydrolysis, either through acid, base or microbial activity yields ellagic acid. Punicalagin is unique to pomegranate and is part of a family of ellagitannins which include the minor tannins called punicalin and gallagic acid, which are characterised by good water solubility.

Hydrolysable tannins are reported to be the first plant polyphenols subjected to analytical research around 200 years ago (Arapitsas, 2012); nonetheless data are still scant to interpret the nutraceutical and food features of a substantial number of PoP polyphenols. Amongst a wide array of PoP isolated fractions of phytochemicals (Fig. 1A and B) only a few have been thoroughly investigated to date for their efficacy against certain disorders and their potential to be technologically exploited as food additives. Since the major and most studied phenolics of PoP are punicalagin and its metabolites, it would be advisable to study more in depth other PoP compounds to establish their potential role as nutraceutical and food additives.

3. Structure activity relationship of PoP phenolics

Ellagitannins are commonly referred to as metabolites of gallotannins. As briefly discussed above, this unique group of phenolics is easily hydrolysable. Hydrolysis releases hexahydroxydiphenic

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