Coordination Chemistry Reviews xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Coordination Chemistry Reviews

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

Review

Effect of polyphenols-membrane interactions on the performance of membrane-based processes. A review

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ARTICLE INFO

Article history:
Received 23 March 2017
Received in revised form 12 June 2017
Accepted 18 June 2017
Available online xxxx

Keywords:
Polyphenols-membrane interactions
Membrane performance
Polymeric membranes
Ceramic membranes
Computational analysis

ABSTRACT

Polyphenols have received a great attention in the last years due to growing evidence of their health-promoting activities and antioxidant characteristics.

In this review, the effect of polyphenols-membrane interactions, phenolic-phenolic interactions or interactions with feed components on the performance of polymeric and ceramic membranes employed for separating, purifying and concentrating phenolic compounds from their original sources is critically analysed. These interactions, as well as solution effects on the membrane, solute/membrane properties and operating conditions play a key role on the removal efficiency and/or permeation of phenolic compounds through membranes.

An overview on the available computational studies concerning polyphenols-membrane interactions is also presented and discussed with the aim of clarifying the target interactions at molecular scale very difficult to obtain experimentally.

Contents

1. Introduction

Polyphenols are a group of chemical substances naturally present in fruit and vegetables characterized by the presence of more than one phenol group per molecule [1].

They have attracted a great interest since the 1990s due to growing evidence of their health-promoting activities and antioxidant characteristics as demonstrated by epidemiological and intervention studies [2]. Indeed it has been demonstrated that the long term consumptions of diets rich in plant polyphenols offer protection against coronary heart disease [3,4], development of cancers [5,6], diabetes [7,8], aging [9], osteoporosis [10] and neurodegenerative diseases [11,12]. As antioxidants these compounds act mainly by preventing the formation of free radicals implied in the process of auto-oxidation [13].

Polyphenols are chemically characterized as compounds with phenolic structural units and may be classified into different groups according to the number of their phenol rings and of the structural elements that bind these rings to one another [14,15].

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http://dx.doi.org/10.1016/j.ccr.2017.06.013

Please cite this article in press as: A. Cassano et al., Effect of polyphenols-membrane interactions on the performance of membrane-based processes. A review, Coord. Chem. Rev. (2017), http://dx.doi.org/10.1016/j.ccr.2017.06.013

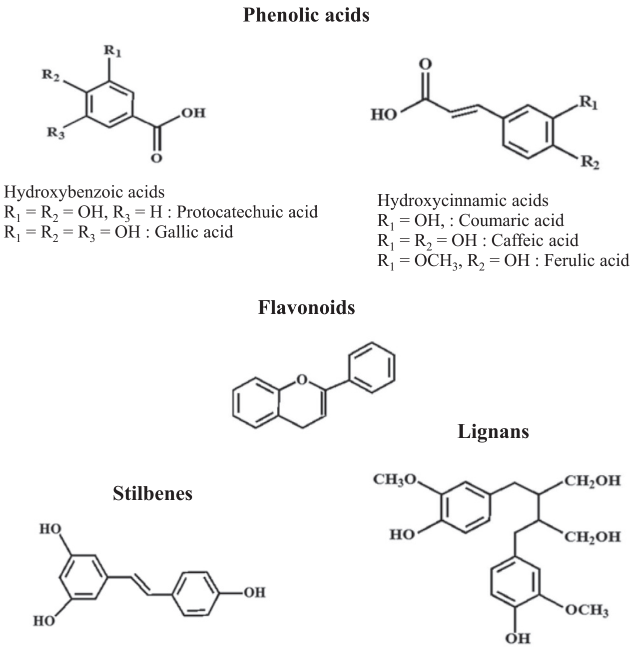

Fig. 1. Chemical structures of polyphenols.

They are typically divided into 4 classes: phenolic acids, flavonoids, stilbenes and lignans (Fig. 1).

Phenolic acids are non-flavonoid polyphenolic compounds which can be distinguished as benzoic acid and cinnamic acid derivatives based on C1–C6 and C3–C6 backbones, respectively.

Flavonoids are low molecular weight compounds consisting of 2 aromatic rings (A and B) that are bound together by 3 carbon atoms that form an oxygenated heterocyclic (ring C). According to the type of heterocyclic involved they may be divided into different subclasses: flavonols, flavones, isoflavones, flavanones, anthocyanidins and flavanols (catechins and proanthocyanidins) (Fig. 2).

Low quantities of stilbenes are present in the human diet and the main representative is resveratrol detected in more than 70 plant species, including grapes, berries and peanuts.

Lignans are produced by oxidative dimerisation of two phenylpropane units; the free form, in comparison with glycoside derivatives, is mostly present in nature. These compounds have shown potential applications in cancer chemotherapy and various other pharmacological effects [16].

The antioxidant activity of phenolic compounds is strictly correlated to their structure: generally, they act mainly by preventing the formation of free radicals implied in auto-oxidation processes, donating hydrogen atoms or electrons or chelating metal cations [17].

Polyphenols are widely distributed in the plant kingdom including fruits, vegetables, cereals and herbs. More than 8000 phenolic structures are currently known, and among them over 4000 flavonoids have been identified. The content of phenolic compounds of the major vegetable sources is illustrated in Table 1. Variations of

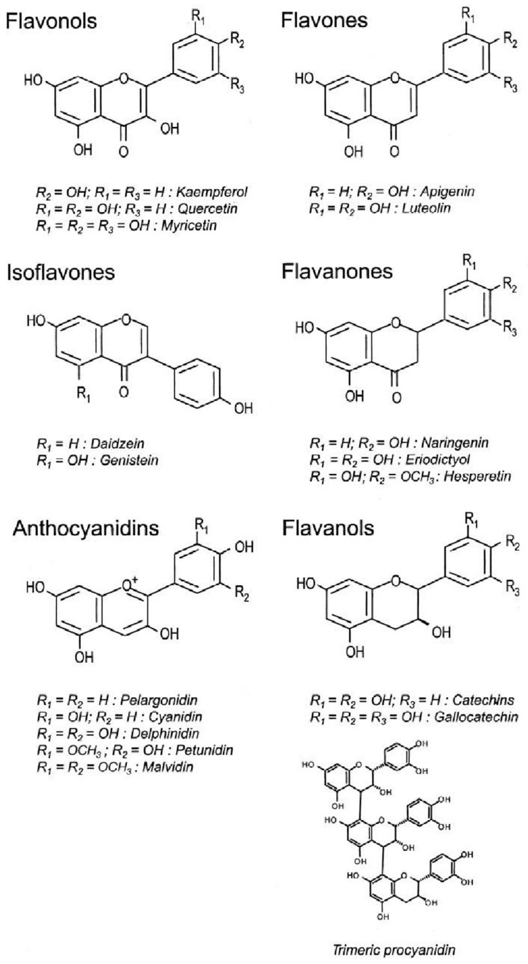

Fig. 2. Chemical structures of flavonoids.

Table 1
Phenolic content of fruit and vegetables.

Vegetal source	Total phenolics content	Reference
Apple	296.3 ± 6.4[a]	[136]
Banana	11.8 ± 0.4[a]	[137]
Black plum	143.5 ± 40.6[b]	[138]
Blackberry	26.7–452.7[a]	[139]
Blueberry	270–930[a]	[140]
Broccoli	101.6 ± 40.6[a]	[141]
Brussel sprout	68.8 ± 1.3[b]	[142]
Cabbage	92.5 ± 2.4[b]	[142]
Carrot	55.0 ± 0.9[b]	[142]
Cherry	105.4 ± 27.0[b]	[138]
Cranberry	527.2 ± 21.5[a]	[136]
Cucumber	48.0 ± 0.9[a]	[142]
Grapefruit	135 ± 10.1[c]	[143]
Guava (white)	247.3 ± 4.5[a]	[137]
Lemon	164 ± 10.3[c]	[143]
Lichi	28.8 ± 1.7[a]	[137]
Mango	56.0 ± 2.1[a]	[137]
Mint	399.8 ± 3.2[b]	[142]
Orange	154 ± 10.2[c]	[143]
Peach	84.6 ± 0.7[a]	[136]
Papaya	57.6 ± 4.1[a]	[137]
Persimmon	1.45[c]	[144]
Pineapple	94.3 ± 1.5[a]	[136]
Plums	174–375[a]	[145]
Raisins	399.4 ± 57.6[b]	[138]
Rambutan	1.64 ± 0.04[c]	[144]
Raspberry	13.7–177.6[a]	[146]
Redgrape	220.6 ± 61.2[c]	[138]
Spinach	91.0 ± 8.5[a]	[141]
Starfruit	209.9 ± 10.4[a]	[137]
Strawberry	160.0 ± 1.2[a]	[136]
Tomato	68.0 ± 1.6[d]	[142]
Yellow onion	76.3 ± 1.9[a]	[141]

[a] Gallic acid equivalent/100 g fresh weight.
[b] Catechin acid equivalent/100 g fresh weight.
[c] Chlorogenic acid equivalent/100 g fresh weight.
[d] Ferulic acid equivalent/100 g fresh weight.

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