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# Encapsulation of phenolic compounds present in plants using protein matrices

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ABSTRACT

Many plants which are rich in phenolic compounds possess several health benefits, such as preventing urinary tract infections, stomach ulcers, and dental diseases. These phenolic compounds are generally stable and bioactive when present in plants. However, they are prone to degradation after extraction, which is a challenge when processing foods. Encapsulation is a process where the compounds of interest are enveloped by one or a mixture of polymers referred as matrix materials. It protects phenolic compounds from a relatively rapid degradation and helps to control the release of these compounds. Proteins are natural food grade polymers which are used as encapsulating matrices and do have a wide range of applications, especially in the food industry. In this review, the major phenolic compounds that are present in plants are outlined. The encapsulation methods and recent researches performed to encapsulate phenolic compounds present in plants using protein matrices are critically discussed.


**Contents**



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## 1. Introduction

Plants contain many bioactive phenolic compounds, such as anthocyanins, flavonols, flavan-3-ols, proanthocyanidins, phenolic acid derivatives, and curcumin. These phenolic compounds have antioxidant and antimicrobial properties and therefore, fruits like cranberries have many health benefits as they can help preventing some diseases such as urinary tract infections (Blumberg et al., 2013), stomach ulcers and cancers (Pappas & Schaich, 2009), and dental diseases (Weiss, 1999). However, these phenolic compounds are chemically unstable in most environments, such as at neutral pH and when exposed to oxygen (Betz et al., 2012). To improve the bioavailability of phenolic compounds in the human body, encapsulation seems to be an ideal method. There are many encapsulation techniques available to encapsulate these compounds, such as emulsion, spray drying, extrusion, electrospinning, and coacervation.

Among the wall materials, proteins are ideal because they are generally regarded as safe (GRAS) and contain a high nutritional value (Chen, Remondetto, & Subirade, 2006). Most proteins can be easily digested by the human gastrointestinal tract (Joye & McClements, 2014). Furthermore, proteins are insoluble in acidic conditions as the isoelectric point (pI) of most proteins ranges between pH 3 and pH 5. Proteins matrices are usually dissolved at alkaline pH to encapsulate the compounds of interest and the solution is thereafter acidified to form particles (Nesterenko, Alric, Silvestre, & Durrieu, 2013). Both animal and plant proteins have been used as encapsulating matrices. The most common animal proteins used include gelatin, caseins and whey proteins (mainly β-lactoglobulin). Plant-derived protein matrices include zein, soy protein, etc. (Joye & McClements, 2014; Nesterenko et al., 2013).

In recent years, the encapsulation of phenolic compounds has been researched increasingly. Excellent reviews discussing the encapsulation of phenolic compounds are found in the literature (Cavalcanti, Santos, & Meireles, 2011; Fang & Bhandari, 2010; Munin & Edwards-Lévy, 2011). However, to the best of the authors' knowledge, there is no review article discussing the encapsulation of phenolic compounds using proteins. Therefore, the objectives of this review are to summarize the phenolic compounds found in plants and to critically discuss the encapsulation of these compounds using proteins as starting materials for the synthesis of encapsulating matrices.

## 2. Phenolic compounds in plants

The main categories of bioactive compounds found in plants like cranberries are anthocyanins, flavonols, flavan-3-ols (catechin monomers), proanthocyanidins, and phenolic acid derivatives (Cote, Caillet, Doyon, Sylvain, & Lacroix, 2010a). Moreover, flavanones and nonflavonoid polyphenols are present in lower amount (Pappas & Schaich, 2009). Curcumin is also present in plant *Curcuma longa*, which is another polyphenol commonly used in the food industry. The chemical structures of the major phenolic compounds present in plants are shown in Fig. 1.

### 2.1. Anthocyanins

The chemical structure of anthocyanins is shown in Fig. 1(a). The R1 and R2 groups of anthocyanins can be a methoxy group, a hydroxyl group or a hydrogen atom. Anthocyanins are water-soluble bioactive compounds which are widely present in flowers, fruits, and vegetables (Flores, Singh, & Kong, 2014b). The high amount of anthocyanins contributes to the color of the plants (Blumberg et al., 2013). Their color depends on the pH: at pH below 3, anthocyanins exist as red-colored flavylium cations, which are the stable form; at pH ranging from 6 to 8, they convert to quinoidal base (blue color), which is an unstable state and therefore, the bioavailability of anthocyanins is decreased (Oidtmann et al., 2012). In plants, the pH of the cells is acidic therefore, anthocyanins are stable. However after extraction, anthocyanins are prone to degradation, as they tend to be unstable at high pH and in the presence of oxygen (Betz et al., 2012; Flores et al., 2014b). Heat treatment, UV light exposure, presence of specific enzymes or some metallic ions also can degrade anthocyanins (Betz et al., 2012; Frank, Kohler, & Schuchmann, 2011). After digestion, anthocyanins are absorbed by the stomach and the intestine (Zhang et al., 2014). However, the environmental conditions in the gastrointestinal tract trigger the degradation of anthocyanins, which is why the bioavailability of anthocyanins is very low (Betz & Kulozik, 2011b).

Berry fruits, such as bilberries, blackberries, blueberries, and cranberries are rich in anthocyanins (Szajdek & Borowska, 2008). However, the concentration of anthocyanins in berry fruits varies at different stages. For example, the average content of anthocyanins in cranberries is 95 mg/100 g at harvest (Cote, Caillet, Doyon, Sylvain, & Lacroix, 2010b). The concentration can increase in response to climatic factors, such as light and temperature (Cote et al., 2010b). The most common anthocyanin molecules are cyanidin, delphinidin, and peonidin, which bind to one or more sugar molecules. The glycosylation almost always occurs at the C3 position of the anthocyanidin molecule (Cote et al., 2010b).

### 2.2. Flavonols

Flavonols are mainly concentrated in the skin of fruits (Cote et al., 2010b). They are present as yellow undertones which only contribute slightly to the color of berries (Pappas & Schaich, 2009). The chemical structure of flavonols is shown in Fig. 1(b). Like anthocyanins, flavonols are also bound to sugars at the C3 position (Cote et al., 2010b). The content of flavonols in cranberries is higher than in blueberries and blackberries (Pappas & Schaich, 2009). On a weight basis, the average flavonol content in cranberries is 20–30 mg/100 g (Neto, 2007), while in bilberries,