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Review

Interactions between starch and phenolic compound

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The non-covalent interactions between starch and phenolic compounds may impact on the physicochemical and nutritional properties of food. Starch and phenolic compound interact to form either inclusion complex in the form of amylose single helices facilitated by hydrophobic effect, or complex with much weaker binding most through hydrogen bonds. The outcome of the interactions and their impact on the food properties appear to be dependent on the type and structure of both phenolic compound and starch as well as the method of preparing the complex. This review summarises the current knowledge of the influence of the interactions on the physicochemical properties and digestion of starch system, the bioavailability of phenolic compound, and the non-covalent nature of starch-phenolic compound interactions. Plant extracts rich in phenolic compounds as well as purified phenolic compounds are included. Research opportunities to better understand and utilize these interactions for food applications are suggested.

Introduction

The consumption of plant foods rich in phenolic compounds has been linked with reduced risk of diverse non-communicable chronic diseases such as cardiovascular and neurodegenerative diseases, certain cancers, type II diabetes, and osteoporosis. These have been attributed to their diverse bioactivities such as anti-oxidation, anti-inflammation, modulation of signal transduction, anti-microbial activity, and anti-proliferation (Velderrain-Rodriguez *et al.*, 2014). Apart from the nutritional benefits, phenolic compounds contribute to the organoleptic properties of foods, especially by their astringency, bitter taste, colour, and by their participation in haze formation (Le Bourvellec & Renard, 2012). Phenolic compounds occur in a variety of dietary and medicinal plants, and mainly include phenolic acids, flavonoids, coumarins, lignans, stilbenes, quinones, and tannins (Cai, Sun, Xing, Luo, & Corke, 2006). Some of the compounds mentioned such as certain stilbenes may not strictly be phenolic compounds. Nevertheless, they are included in this review due to their similar structures. Molecular structures of representative phenolic compounds discussed in this review are illustrated in Fig. 1.

Starch, as a major food macronutrient, consists of two major types of α-glucans on the molecular level: the linear amylose and the branched amylopectin. On the granular level, α-glucan chains are naturally assembled in the form of semi-crystalline granules. There is great variation in the composition, molecular and granular structure, and physicochemical properties of starches from diverse botanical sources (Pérez & Bertoft, 2010). The physicochemical and nutritional properties of starch and the interactions with other food components to a large extent determine the overall quality of starchy food products (Zhu, 2010). There has been surging interest in the interactions between starch and phenolic compounds during the last few years. One scenario is the applications of phenolic compounds and plant extracts as functional ingredients for formulation of novel functional foods and beverages (Bordenave, Hamaker, & Ferruzzi, 2014). Also, food/beverage processing often involves tissue disruption and cellular decompartmentalization, resulting in the release of intracellular and extracellular compounds originally confined (e.g., processing of pigmented cereals). The released endogenous polyphenols come into contact and interact with other components such as starch, non-starch polysaccharides, and protein, contributing to the quality of the food products (Le Bourvellec & Renard, 2012). The amount of knowledge on physical and chemical aspects of starch and phenolic compound is individually tremendous. However, a better understanding of the physicochemical interactions between starch and phenolic compound as a basis for maintaining and improving the quality of starch based foods is still to be better explored. It may be interesting to point out that the non-covalent interactions between non-starch polysaccharides (e.g., arabinoxylans in cereals) and phenolic compounds are also little understood.

This review aims to summarise the current understanding of the effect of the non-covalent interactions on the physical and nutritional properties of starch as well as the bioavailability of the phenolic compounds, and the molecular basis of the interactions between starch and phenolic compound. Research opportunities to better understand the starch-phenolics interactions are suggested.

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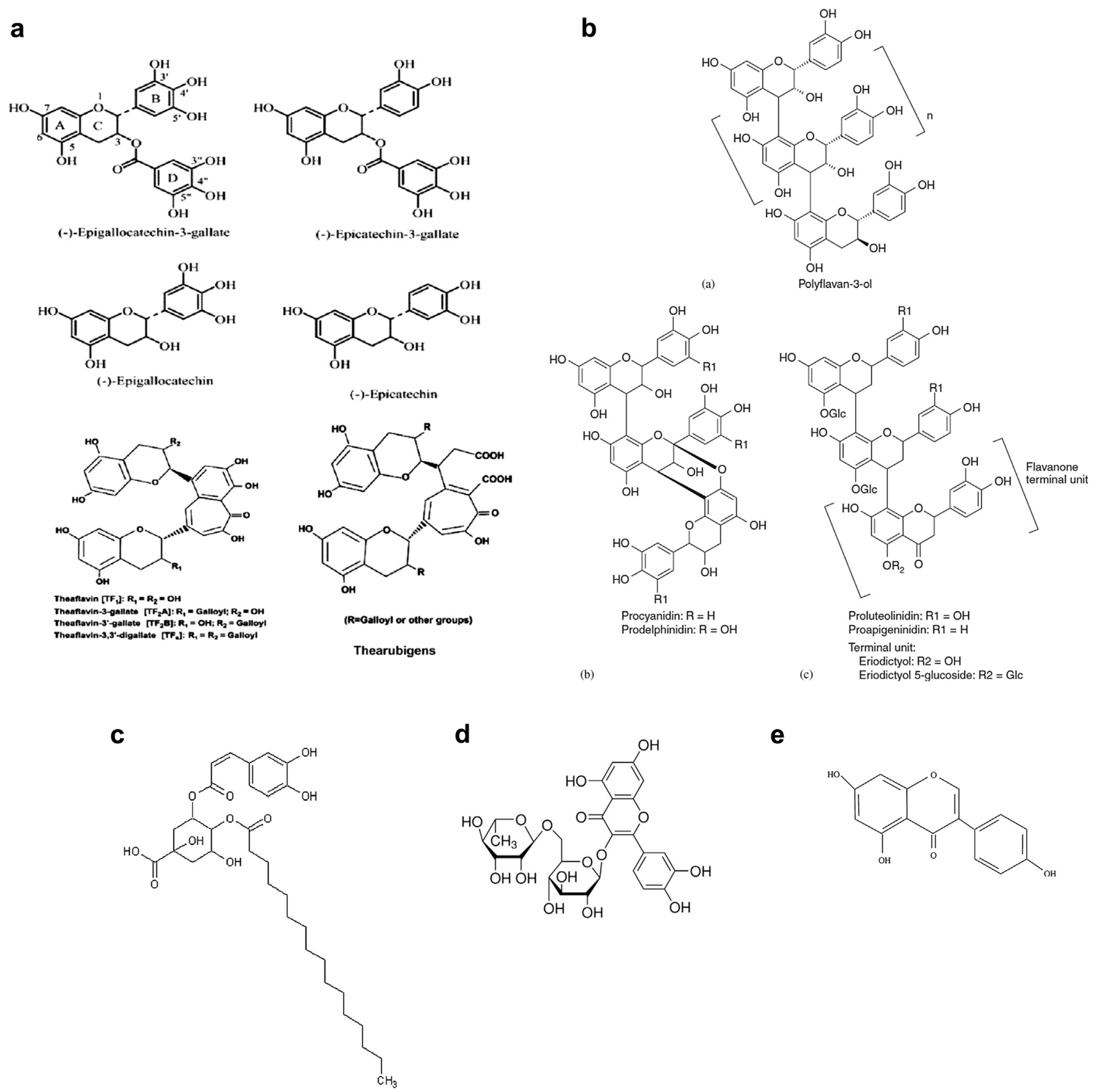

Fig. 1. Chemical structures of representative phenolic compounds discussed in the review (With permission from publishers). a. Structures of major tea polyphenols (Khan & Mukhtar, 2007). b. Representative phenolic compound structures of proanthocyanidins reported in sorghum (Dykes & Rooney, 2006). c. Structure of 4-*O*-palmitoyl chlorogenic acid (Lorentz *et al.*, 2012). d. Structure of rutin (adapted from sigmaaldrich.com). e. Structure of genistein (Cohen *et al.*, 2008).

Effect of phenolic compounds on the physical properties of starch

When starch is heated in the presence of water, the granules start to absorb water and swell, some components leach out and solubilise. With the increasing temperature and water absorption, the granules rupture with the disordering of chain organization. The general term gelatinization applies to this process. When the gelatinized starch is cooling, the disordered chains undergo re-association through hydrophobic interactions and hydrogen bonding. This process is termed retrogradation (Zhu, 2010). The gelatinisation and retrogradation are fundamental and central for diverse food applications of starch. Plant extracts rich in phenolic compounds or purified phenolic compounds (e.g., phenolic acids, flavonoids, coumarins, stillbenes, and tannins) have been added into starch system, altering diverse functional properties of starch such as rheological properties, gelatinization, retrogradation, and gelling (Table 1). While plant extract addition provides