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Review Article

Designing Functional Foods with Bioactive Polyphenols: Highlighting Lessons Learned from Original Plant Matrices

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Abstract

Dietary polyphenols have received immense research attention for their biological functionality including quenching reactive oxygen species and mitigating inflammatory processes within the body. As a result, polyphenols are being incorporated into many developed functional food products. Given the relative instability of these compounds, this manuscript highlights the importance of evaluating polyphenol interactions within their native plant matrices and understanding the physicochemical impact of the original matrix on polyphenol stability. Such lessons should guide the development and design of functional food matrices for protecting the active form of polyphenols throughout the harsh environments of food processing and digestion.

Numerous food products are marketed with enhanced quantities of bioactive food compounds (BFC) and these products are collectively referred to as functional foods. Although the term *functional foods* has no legally defined meaning in the United States, the scientific community and its representative organizations acknowledge the potential benefit of including these foods into the diet. As such, several organizations have drafted working definitions for functional foods which have provided consumers with more information about the intended meaning of this term. For example, according to the recently released Position Paper on Functional Foods by the Academy of Nutrition and Dietetics, functional foods are defined as whole foods along with fortified, enriched, or enhanced foods that have a potentially beneficial effect on health when consumed as part of a varied diet on a regular basis at effective levels [1]. The emphasis of this working definition on foods rather than supplemental intake of BFC acknowledge the impact of the vehicle of delivery – FOOD. Although supplement intake may be recommended under certain circumstances or in specific disease states, food-focused intake of nutrients and non-nutrients is the recommended approach by the Dietary Guidelines for Americans 2010 for acquisition of compounds known to influence health [2].

Given the potential health benefits of bioactive food compounds and the emphasis of the nutrition community on food first behaviors, functional foods formulated with bioactive compounds are being developed with matrices to improve compound stability, bioactivity, and bioavailability. In order to optimize delivery of BFC, many lessons can be learned from the original food matrix housing the BFC. Collectively, the food matrix represents a structurally diverse network of nutrients and non-nutrients interacting physically and chemically in a given food. Within each matrix, the physicochemical properties have been shown to influence the release, mass transfer, accessibility, digestibility, and stability of many food compounds including phenolic compounds which are abundant in plant foods [3]. Furthermore, the physicochemical properties of the matrix impact nutrient-nutrient as well as nutrient-non-nutrient interactions. Although each food matrix allows for a multiplicity of interactions, some are synergistic or additive while others may be antagonistic or neutralizing in effect. As such, if the dynamics of the original matrix and its impact on bioactive compounds within are fully understood, the lessons learned can be utilized to guide the development and design of functional food matrices for protecting the active form of BFC throughout the harsh environments of food processing and digestion. Additionally, these structurally-designed matrices may assist in delivering the active compound to the intended site of action within the body. The following examples provide a brief overview of lessons learned from plant matrices housing polyphenols with emphasis on protein-polyphenol interactions and their impact on polyphenol stability and bioavailability.

Phenolic compounds, which are highly researched for their antioxidant and anti-inflammatory activities, have a basic structure containing at least one aromatic ring with several hydroxyl groups. In general, these compounds are relatively unstable in comparison to other secondary plant metabolites such that they are easily degraded during food processing and digestion [4-6]. However, in some foods, polyphenols exist as conjugates with proteins resulting in soluble and insoluble protein-polyphenol complexes which have a stabilizing effect on polyphenols [7,8]. As a result of this effect, protein-rich ingredients are being investigated for the potential to bind phenolic compounds and increase polyphenol stability in developed functional foods. For example, complexation of blueberry anthocyanins to protein matrices of defatted soybean flour has resulted in a stable ingredient capable of delivering more anthocyanins to the intestinal tract compared to an equal amount of blueberry juice when evaluated using the TNO gastrointestinal model [9]. Additionally, soy protein powder complexed with water-soluble polyphenols from blueberry and green tea extract has been shown to be an effective stabilizing ingredient and carrier for polyphenols as evidenced by the gut-derived phenolic metabolomic profile in runners supplemented with the polyphenol-enriched protein powder [10]. By stabilizing polyphenols through protein complexation, enhanced delivery matrices have the potential to boost the health benefits to be derived from intake of these BFC.

In addition to issues related to stability, polyphenols vary in their degree of bioavailability depending on compound structure and/or conjugation with sugar moieties. For example, research has shown that most polyphenols are present in plant matrices in the form of esters, glycosides, or polymers that cannot be absorbed unless they are hydrolyzed to their aglycone, non-sugar hydrolysis product, by intestinal enzymes or enzymes from gut microflora [4]. As a result of the influence of the matrix composition on compound structure and subsequent bioavailability from plant foods, functional food matrices are being developed for delivering the active form to the intestinal tract for mobilization to various tissues. Given the stabilizing effect of proteins on phenolic compounds, encapsulation of these compounds on gelatin beads is being investigated for delivery of the stable aglycone form to the appropriate segment of the gastrointestinal tract for release and uptake [11]. In addition to targeted release, various encapsulation coatings are being formulated to assist in moderating the rate of BFC release. As such, a slower release rate in the gastrointestinal system may facilitate maximum absorption and utilization of the bioactive compound of interest. While encapsulation is not the only way to incorporate polyphenols in developed food products, it represents a unique approach for delivering the active form of these BFC by utilizing a stabilizing ingredient and process technique that hinders the early degradation of phenolic compounds within the intestinal tract [12].

The importance of evaluating BFC in their natural matrices extends beyond polyphenols to other bioactive plant compounds. Thus, additional research is warranted in order to improve the stability and bioavailability of these compounds in developed functional foods. As a result of advances in food chemistry, structurally-designed matrices have the potential to positively impact human health when they are developed in light of lessons learned from the physicochemical dynamics of the original matrix housing these compounds.

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