HOSTED BY
ELSEVIER

Contents lists available at ScienceDirect

Asian Pacific Journal of Tropical Biomedicine

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

Review article http://dx.doi.org/10.1016/j.apjtb.2016.06.010

Phenolic compounds of green tea: Health benefits and technological application in food

José Manuel Lorenzo[1*], Paulo Eduardo Sichetti Munekata[2]

[1]*Meat Technological Center of Galicia, Galicia Street No. 4, Parque Tecnológico de Galicia, San Cibrao das Viñas, 32900 Ourense, Spain*

[2]*Department of Food Engineering, Faculty of Animal Science and Food Engineering, University of São Paulo, 225 Duque de Caxias Norte Ave, Jardim Elite, Postal Code 13.635-900, Pirassununga, São Paulo, Brazil*

ARTICLE INFO

Article history:
Received 12 Jan 2016
Received in revised form 29 Jan 2016
Accepted 1 Apr 2016
Available online 11 Jun 2016

Keywords:
Phenolic profile
Healthy
Neurodegenerative diseases
Extraction of polyphenols
Antioxidant mechanism
Food stability

ABSTRACT

Green tea has been an important beverage for humans since ancient times, widely consumed and considered to have health benefits by traditional medicine in Asian countries. Green tea phenolic compounds are predominately composed of catechin derivatives, although other compounds such as flavonols and phenolic acids are also present in lower proportion. The bioactivity exerted by these compounds has been associated with reduced risk of severe illnesses such as cancer, cardiovascular and neurodegenerative diseases. Particularly, epigallocatechin gallate has been implicated in alteration mechanisms with protective effect in these diseases as indicated by several studies about the effect of green tea consumption and mechanistic explanation through *in vitro* and *in vivo* experiments. The biological activity of green tea phenolic compounds also promotes a protective effect by antioxidant mechanisms in biological and food systems, preventing the oxidative damage by acting over either precursors or reactive species. Extraction of phenolic compounds influences the antioxidant activity and promotes adequate separation from green tea leaves to enhance the yield and/or antioxidant activity. Application of green tea phenolic compounds is of great interest because the antioxidant status of the products is enhanced and provides the product with additional antioxidant activity or reduces the undesirable changes of oxidative reactions while processing or storing food. In this scenario, meat and meat products are greatly influenced by oxidative deterioration and microbial spoilage, leading to reduced shelf life. Green tea extracts rich in phenolic compounds have been applied to increase shelf life with comparable effect to synthetic compounds, commonly used by food industry. Green tea has great importance in general health in technological application, however more studies are necessary to elucidate the impact in pathways related to other diseases and food applications.

1. Introduction

Green tea (produced from *Camellia sinensis*) is a popular leaf usually consumed as infusion with pleasant taste with believed positive effect in general health even at high doses of 8–16 cups a day [1]. Leaves of green tea are rich in bioactive compounds, particularly phenolic compounds with antioxidant activity. The elevated proportion of catechins is related to biological functionality, although recent studies have identified several other phenolic compounds at lower concentration, in particular flavonols and phenolic acids [2,3].

Scientific studies have indicated the effects of green tea consumption in general health and reduction of risk in severe diseases. This is a trend with promising and positive results to assist the control of body weight [4], protection against ultraviolet radiation [5], physical functional performance [6,7], oral health [8], bone health [9] and other physiological effects. Special attention has been given to specific diseases including those with severe effects such as neurodegenerative and cardiovascular diseases. The beneficial effects of green tea

*Corresponding author: José Manuel Lorenzo, PhD in Food Science and Technology at European level, Meat Technological Center of Galicia, Galicia Street No. 4, Parque Tecnológico de Galicia, San Cibrao das Viñas, 32900 Ourense, Spain.
Tel: +34 988548277
E-mail: jmlorenzo@ceteca.net

Peer review under responsibility of Hainan Medical University. The journal implements double-blind peer review practiced by specially invited international editorial board members.

consumption are associated with polyphenolic compounds that have aroused the interest in food industry and among researchers [10].

The use of phenolic compounds from natural sources in food is an interesting opportunity for the application of biological activities of these compounds, particularly the antioxidant potential, and allows the production of food without synthetic antioxidants for consumers, because the current concern about the impact of food on health has been influencing the consumer choice of food on the basis of its formulation [11]. Synthetic antioxidants are additives commonly used in food industry; however, because of controversial results in literature about the biological effect in some diseases, healthy organizations such as European Food Safety Authority recommended acceptable daily intakes for butylated hydroxyanisole and butylated hydroxytoluene (BHT) of 1.0 and 0.25 mg/kg body weight/day [12,13].

Green tea can be included in the formulation of some products to increase the general antioxidant activity for nutritional or technological purposes. Prevention of lipid oxidation in food can be achieved by several mechanisms in a similar manner as observed in biological structures (*e.g.* free radical scavenging and metal-chelating activity). Lipid oxidation can modify physical–chemical and sensory characteristics such as color, flavor and taste. Among the diversity of food requiring the application of antioxidants, meat and muscle products are particularly affected by lipid oxidation, demanding the addition of antioxidants to extend shelf life [14,15].

This review focuses on the phenolic composition, the antioxidant mechanism by which green tea polyphenols exert antioxidant activity, the biological activity of green tea with potential health benefits, and finally the influence of technology to enhance the extraction of phenolic compounds and the application in food industry.

2. Phenolic composition of green tea

The great interest in green tea composition has been associated with the antioxidant activity and consequently with elevated phenolic content. More recently, a wide diversity of compounds have been identified and several methods were developed to identify and quantify these compounds. Some characteristics of phenolic compounds have been considered for identification of each class of phenolic compounds in several matrices. The thermal sensibility demands techniques such as liquid chromatography instead of gas chromatography, because degradation of important phenolic compounds in green tea can reach 70% at temperatures lower than that usually applied in gas chromatography [16]. The double bonds in the aromatic ring of phenolic allow spectrophotometric measures in UV–visible range. The evaluation of maximum absorption indicates, at least the subclass (*e.g.* flavanol, flavonol and flavones) or supports the identification with a standard. The unique fragmentation pattern of each phenolic compound permits the identification in mass analyzers or a provisional identification for compounds without an available standard, even for complex and high molecular weight compounds [17]. Considering the above characteristics, the liquid chromatography separation followed by spectrophotometry and/or analysis by mass spectrometry can provide valuable information for the investigation of phenolic profile in green tea extracts. Other analyses were also conducted to provide solid information on the phenolic profile of green tea using nuclear magnetic resonance (NMR) [18].

Flavonoids are a group of phenolic compounds with several sub-classes: anthocyanidins, flavanones, flavanols, flavones, flavonols and isoflavones. These sub-classes have a common basic structure made of 15 carbons with a three carbon bridge connecting two aromatic rings in the configuration C6–C3–C6. Along with flavonoids, phenolic acids are another important group divided in hydroxybenzoic acids and hydroxycinnamic acids. Gallic acid is a relative simple structure also known as 3,4,5-trihydroxybenzoic acid. This compound is the basis of hydroxybenzoic acids and other derivatives with reported antioxidant activity such as ellagic acid. The counterpart, the hydroxycinnamic acid derivatives have the *p*-coumaric acid as basic structure that is formed by an aromatic ring with one hydroxy substitution and one propenoic acid [19].

Studies evaluating the phenolic composition of green tea have provided valuable information about the structure and also about the antioxidant activity (Table 1). The phenolic content is widely diverse, although catechins are the major constituents and other flavonoids and phenolic acids have been identified and quantified.

Table 1
Studies about the identification of phenolic compounds in green tea.

Technique	Number of compounds identified (subclass)	Confirmation with standards
HPLC-DAD-ESI-MS	8 (flavanol)	Yes
LC-MS^n and HPLC-MS-SPE-NMR	9 (flavanol) 22 (flavonol) 6 (phenolic acid)	No
LC-DAD-ESI-MS	6 (flavanol) 5 (phenolic acid)	Yes
UPLC-DAD-ESI-MS	17 (flavanol) 27 (flavonol) 12 (phenolic acid) 4 (other phenolics)	Yes
HPLC-DAD-ESI-MS	5 (flavanol) 8 (flavonol) 4 (phenolic acid)	Yes
UHPLC-MS/MS	8 (flavanol)	Yes
LC-ESI-MS^n	5 (flavanol) 9 (flavonol) 2 (phenolic acid)	Yes
HPLC-DAD LC-DAD-MS	7 (flavanol) 4 (flavonol) 5 (flavanol) 2 (phenolic acid) 1 (other phenolics)	Yes No
HPLC-DAD	7 (flavanol) 1 (phenolic acid)	Yes

2.1. Flavanols

The importance of flavanol content in tea phenolic composition leads to quantification of total and individual flavanols that include gallocatechin, catechin gallate, gallocatechin gallate, epicatechin, epigallocatechin, epicatechin gallate and epigallocatechin gallate [20,21]. This flavonoid subclass is the most abundant in phenolic composition of green tea, accounting for more than 70% of total phenolic content, as reported in several studies [18,22,23]. The online antioxidant activity of individual phenolic compounds of green tea measured by