Leaves of *Camellia sinensis*: Ordinary Brewing Plant or Super Antioxidant Source?

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ABSTRACT

Tea (*Camellia sinensis*) is well known not only for its taste and aroma, but also for its health benefits, considered to be a medicine. The manuscript presents tea species profile and chemical composition, its occurrence and possible usage directions. A great number of tea origin substances have been reported to possess antioxidant properties as trapping agents and free radical quenchers, presenting a wide range of health benefits for human health and wellness. Tea polyphenols are the main constituents responsible for a tea’s properties and specific taste and are also the major group of constituents that can be used as direct supplements and as very potential food antioxidants in different systems. The main tea polyphenols are flavonols or catechins, in particular epicatechin, epicatechin-3-gallate, epigallocatechin and epigallocatechin-3-gallate. The world literature presents many studies showing the antioxidant activity contributions of polyphenols; however within this review detailed information on the specificity of tea polyphenols will be presented. Tea polyphenols are reported to be strong antioxidants in living organisms and lipid systems, including fish and vegetable oils, and animal fats. This paper reviews what is known of green tea species, its leaf processing and changes that occur in tea components and highlights the potential of green tea, its health benefits and bioavailability. Current possible mechanisms of polyphenol antioxidant activity are also described. The world’s food industry needs new sources of natural substances presenting antioxidant activity that are acceptable to consumers, and which increase the shelf life and quality of food.

Keywords: tea, *Camellia sinensis*, polyphenols, catechins, antioxidant activity, bioavailability

Abbreviations: C, (+)-catechin; EC, (-)-epicatechin; ECG, (-)-epicatechin gallate; EGC, (-)-epigallocatechin; EGCG, (-)-epigallocatechin gallate; GA, gallic acid; GC, (+)-gallocatechin

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INTRODUCTION

Constituents of plant origin such as polyphenols are the subject matter of much research because of their possible beneficial properties in the human body. A diet rich in polyphenols may be helpful in scavenging free radicals, taking part in major degenerative diseases. Although the average polyphenol daily intake is approximately one gram, it is still growing as human habits change over the years, as the result of a “healthy lifestyle” (Scalfert and Williamson 2000; Gramza and Korczak 2005).

Tea leaves as an everyday beverage could be a source of polyphenols, especially catechins, a decisive group for their antioxidative activity. The main green tea polyphenols are catechins: (+)-catechin C, (-)-epicatechin EC, (+)-gallocatechin GC, (-)-epigallocatechin EGC, (-)-epicatechin gallate ECG, (-)-epigallocatechin gallate EGCG (Balentine et al. 1997).

The biosynthetic pathway of catechins in tea plant is shown in Fig 1. Catechin is synthesized through malonic acid and shikimic acid metabolic pathways, starting from glucose pool. EGC is produced by hydroxylation of EC, whereas ECG and EGCG are produced by esterification of catechins with gallic acid, derived from an intermediary product of the shikimic acid metabolic pathway (Chu and Juneja 1997; Hara 2001).

There are many mechanisms of antioxidant activity of tea plant phenols, like oxygen scavenging, chelating metal ions, absorbing UV radiation, decomposing peroxides and non-radical products or partial regenerating of primarily
Tea is grown in many regions of the world, mainly in China, India, Japan and on Ceylon Island (Weisburger 1997; Fernandez et al. 2002). According to ancient Chinese mythology, the tea plant was discovered thousands years ago in South-East Asia. Aboriginal tea leaf infusions had been considered for medicine, and became a most popular beverage all over the world many centuries later. The tea leaf market is very differentiated and diverse. Basic tea division consists of green, oolong and black (Kakuzo 1987; Harbowy and Balentine 1997; Chen et al. 2006a). Presently cultivated tea belongs to Camellia sinensis, classified into two varieties: assamica and sinensis (Chu 1997).

The meaning of the word tea is applied widely. Apart from green, oolong and black tea C. sinensis flavourful leaf infusions, several herbal, fruit and aromatized beverages not related to Camellia spp. infusions are also called tea.

Chen et al. (2006b) provide a detailed description of molecular methodologies to try and discern between the world’s tea species and show how molecular biology and functional genomics could elucidate the genetic composition of tea, including the floral aroma formation-related genes.

The average world tea consumption is about 120 ml/day/person (Mukhtar and Ahmad 1999), but the tea consumption preferences are different in various regions of the world. Tea consumption is very specific in countries where tea is grown, the Japanese and Northern China inhabitants prefer the healthiest – green tea; oolong tea is mainly consumed in Taiwan and Southern China, most Europeans and Americans prefer black tea. According to the average world production of tea which is nearly three million tons, over 70% of the annual output is black tea while green tea accounts for about 20% (Tea Council 2001).

The tea plant is an evergreen shrub or tree from the Theaceae family, species Camellia. There are two basic botanical varieties: Chinese tea shrub (Camellia sinensis) as well as the Indian tea tree (Camellia assamica) (Sanderson 1972; Anonymous 2000). Leaves of tea are shiny and dark green, growing opposite and round. Its flowers are large, coloured white, pink or red and fruits are small and brown (Chu and Juneja 1997).

Tea harvesting lasts throughout the year, but tea brewing’s quality is influenced by time. The most aromatic and delicate teas are from the spring collecting, top grade expensive teas however, are gained from young leaflets of top twigs and undeveloped leaves, showing uncommon suitable taste and aroma features (Bokuchava and Skobeliva 1980; Chu and Juneja 1997). There are many processed tea leaf classifications, one is based on different fermentation degree: non-fermented (green), semi-fermented (oolong) as well as totally fermented (black). The main tea production process consists of four basic stages. After manual or automated collection the tea shrub or tea leaves undergo partial withering, afterwards the leaves undergo roasting to inactivate oxidative enzymes, rolling up, drying and sorting. As a result gentle and stringent green tea is produced. The process of black tea production is more complicated. The leaves also undergo withering while the first fermentation processes occur, than rolling up and further fermentation. The next step of fermented leaves is roasting, blocking enzyme (polyphenol oxidase and glycosidase) activity, until the appearance of the dark-brown or black colour and suitable aroma (Chu and Juneja 1997; Lin et al. 1998). Partially fermented oolong tea undergoes a considerably shorter fermentation time than black tea. There are also other well known teas like white (non-fermented), yellow (very lightly fermented) and red (Pu-erh tea), which, after the fermentation process undergo a long-term storage (Fig. 2; Balentine et al. 1997).

Concerning chemical composition, tea leaves mainly consist of proteins and carbohydrates, including cellulose fibers, almost insoluble in water (Table 1; Chu and Juneja 1997).

Other components are amides, nucleic protein acids and amino acids, like theanine and glutamic acid as well as arginine and aspartic acid (Chu and Juneja 1997; Juneja et al. 1999). Specific sensory features of tea are given by low molecular mass compounds leached from tea leaves with hot water. Tea leaves contain vitamins like A, B₁, B₂, K, niacin and ascorbic acid, although the fermentation process causes their decomposition resulting in their lower quantities (Graham 1992).

Tea leaves consist of mineral elements like Zn, Fe, Mg, Cu, Na, K as well as Ni, P and Ca (Table 2; Tsushima and Takeo 1977; Chu and Juneja 1997; Fernandez-Caceres et al. 2001; Ferrara et al. 2001).

Researches showed however that the metal content in...
Table 1 General chemical components of tea leaves (based on Chu and Juneja 1997).

<table>
<thead>
<tr>
<th>Kind of tea (100 g)</th>
<th>Protein (g)</th>
<th>Lipid (g)</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>24.0</td>
<td>4.6</td>
<td>35.2</td>
</tr>
<tr>
<td>Oolong</td>
<td>19.4</td>
<td>2.8</td>
<td>39.8</td>
</tr>
<tr>
<td>Black</td>
<td>20.6</td>
<td>2.5</td>
<td>32.1</td>
</tr>
</tbody>
</table>

Table 2 General inorganic elements of tea leaves (based on Tsushida and Takeo 1977; Chu and Juneja 1997; Fernandez-Caceres et al. 2001; Ferrara et al. 2001).

<table>
<thead>
<tr>
<th>Minerals (mg)</th>
<th>Kind of tea (100 g)</th>
</tr>
</thead>
</table>
| Zn           | Green 63 Fe 20 Mg 120-300 Cu 2.7 Na 3 K 2.200 Ni 1.3 P 280 Ca 440 | Oolong 44 32.4 27.8 1.04 7 1.800 1.9 230 | Black 73 17.4 34.4 4.05 3 2.000 1.3 320

Plant products are very good sources of polyphenols (Ho et al. 1997; Hollman and Arts 2000), often called flavonoids or vitamin P, because of their wide spectrum of biological influence in living organisms (Dreosti 1996; Czeckot 2000). Fresh leaves of green tea consist of flavonoids and phenolic acids, making up to 30% of its dry weight but only 10% of the dry weight of black tea (Wang et al. 2000a). The most important tea leaf polyphenol group is the flavonoids (Hollman 2001), among them the most important is epigallocatechin gallate (EGCG), which occurs only in tea leaves (Graham 1992; Chu and Juneja 1997). There are three basic polyphenol groups in tea leaves: catechin, theaflavins and thearubigens (Hagerman and Carlson 1998; Yanishlieva-Maslarowa and Heinonen 2001). Green tea contains large quantities of simple flavonoids, which transform to complexed forms of theaflavins and thearubigens during fermentation process (Graham 1992; Balentine et al. 1997). Flavanols occur in young tissues both in a monomeric form, the catechins, and polymers, as proantocyanidins (Spencer et al. 1988). Other compounds like tannins are responsible for the specific astringent infusion’s aroma and taste (Chung et al. 1998; Hagerman et al. 1998; Kallithraka et al. 2000; Riedl and Hagerman 2001). Tea leaves’ catechin content is correlated with infusion quality, and the highest catechin content was found in teas from young tea leaves (Thanaraj and Seshardi 1990).

**TEA POLYPHENOLS**

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**FACTORS INFLUENCING TEA LEAVES’ POLYPHENOL CONTENT DURING PROCESSING**

During the fermentation of tea leaves the activity of polyphenol oxidase causes the oxidation of catechins to quinones, further undergoing polymerization to biflavans and more complexed structures of the flavonoids, hyperquinones and higher molecular mass compounds (Stagg 1974; Bailey and Nursten 1993; Halder et al. 1998; Lin et al. 1998; Tanaka et al. 2002). Another consequence of fermentation is a gradual lowering of the flavanol content; however the alkaloid content does not change significantly (Schulz et al. 1999; Sava et al. 2001). Tea leaves with an occurrence of suitable qualitative features are dried to inhibit further oxidation reactions, which is the indispensable factor for product stability during storage (Dougan et al. 1979; Temple et al. 2001).

There are many studies on the quantity of catechin extracted during the brewing of tea leaves. It was found that a rise in catechins content was proportional to temperature and period of brewing time increase, and the highest quantity of catechins was extracted at 77-80°C (Chen et al. 1996a; Khokhar and Magnusdottir 2002). Results showed that a high water temperature and tea leaf infusion (120°C, 30 min) causes epimerization of C, EGCG, ECG, EGC and EC, undergoing conversion to suitable epimers: (-)-gallocteichin gallate (GGG), (-)-catechin gallate (CG), (-)-gallocatechin (GC) as well as (-)-catechin (Wang et al. 2000; Chen et al. 2001). The results of Chen et al. (1998, 2001) suggest that an increase in the pH causes an increase in catechin degradation, while acid pH resulted in its large stability (Zhu et al. 1997; Friedman and Jurgens 2000). The way of preparing tea leaf infusions for consumption depends on the regional traditions or country. There are many possible ways in which people drink tea; in Ireland, England and Canada tea is often consumed with milk. There is no correlation between milk proteins and a decrease in green tea polyphenol activity (Hara 1997; van het Hoff et al. 1998; Hollman et al. 2001). Other authors have examined the possibility of biological activity of tea modification by the addition of milk (300 mL freshly brewed black tea with milk) (Lorenz et al. 2007). The induction of vasorelaxation in rat aortic rings and increased endothelial nitric oxide synthase were obtained in individuals who consumed pure black tea. All those effects were inhibited by the addition of milk to the tea infusion. The authors suggested that probably milk proteins, the casseins formed complexes with tea catechins, resulting in no positive effect on vascular function.

**TEA LEAF CATECHINS**

Flavan derivatives in a group of flavonoids, the catechins are distinguished by a high degree of heterocyclic ring oxidation and good water solubility (Sanderson et al. 1976). Green tea catechins appear in leaves in the form of gallic acid esters, mainly as C, EC, GC, ECG, EG, and ECG (Graham 1992; Ninomiya et al. 1997; Dreosti 2000; Gramza et al. 2006). One of the most active antioxidant compounds
is EGCG, consisting of eight active free groups (OH). It was found that black tea consists of a smaller amount of catechins, but a larger quantity of gallic acid than in green tea (Khokhar and Magnusdottir 2002). The catechin content in a cup of green tea leaves is high and might be dispersed as 90-400 mg of polyphenolic antioxidants, of which 200 mg is EGCG (Graham 1992; Mukhtar and Ahmad 1991). Tea consumers must be aware not only of the quality of tea leaves, but also of the infusion preparation instructions to obtain the best brew possible.

THE MECHANISM OF ANTIOXIDANT ACTIVITY OF TEA POLYPHENOLS

Polyphenols are strong antioxidants which were found to act as antiradical compounds, blocking free radicals (Rice-Evans et al. 1997; Tosti et al. 2000; Gramza and Korczak 2004); reducing compounds delivering hydrogen of hydroxyl groups (Yanishlieva-Maslarowa 2001); metal chelators, creating complex compounds with metals (Miller et al. 1996; Gramza et al. 2005); inhibiting oxidative activity of the oxidase group of enzymes and the active oxygen atom (Opie et al. 1993; Salah et al. 1995).

The oxidation reactions are complex in character, and polyphenol activity is a result of the kind and number of substituents. The first step is hydrogen separation from the hydroxyl group and the creation of fenoxyl radicals, which further undergo oxidation to compounds classified as being the most reactive of all natural products, the semiquinones, and then to the ortho- and paraquinones, or participate in reactions with radicals such as dimerisation, radical substitution, and reactions with different radicals (Gramza and Korczak 2005). Brown, high-molecular compound polyme- rization of the quinones is a major pathway of their transformation in food. As a result of nucleophilic substitution amines join quinones, and its products undergo transformation to brown melanin (Tanaka et al. 2002).

Effective radical scavenging activity of polyphenols is a result of the presence of the o-dihydroxy structure in the B ring, resulting in higher stability of the radical form which participates in electron delocalization; the 2,3 double bond conjugated with the group 4-oxo in the C ring participates in electron delocalization from the B ring and the highest radical-scavenging ability of the 3,5-hydroxy group with the 4-oxo group in the A and C rings (Salah et al. 1995; Burda and Oleszk 2001).

BIOAVAILABILITY AND ABSORPTION OF TEA LEAVES’ COMPONENTS

Pharmacological proprieties of green tea leaf infusion has been well-known for centuries, and confirmed by recent studies (Sato and Miyata 2000; McKay and Blumberg 2002; Wu and Wei 2002). Absorption and metabolism of polyphenols depends highly on its chemical structure, and it was not considered important because of the presence of the β-glycoside form (Price and Spitzer 1994; Hollman 2001). Food polyphenols are absorbed from the digestive tract, penetrating the blood and binding with albumins, which probably mask their antioxidant activity. In the stomach flavonoids undergo hydrolysis to simpler constituents, become absorbed and work as antioxidants (Arts et al. 2001, 2002). An important determinant of flavonoid bioavailability is the sugar particle, glucose whose presence allows for the increase in absorption of the flavonoids occurring in the form of glycosides. Absorption of catechins occurring in food in the form of aglycones has not been explained yet (Hollman and Arts 2000). Metabolization of flavonols and flavanols occurs mainly in the liver and large intestine (Takahashi and Nioymiya 1997; Rechner et al. 2002), where it is subject- ed to glucuronidation and sulfatation of phenolic groups and methylation of catecholic groups (Manach et al. 1999). Another way of not absorbing polyphenols is the secretion of bile into the small intestine and disintegration by colonic bacteria (Griffith and Smith 1972). Many studies showed that a definite quantity of polyphenolic compounds after consumption remain in the body, suggesting that frequent green tea infusion consumption permits maintenance of high EGCG levels (Nakagawa et al. 1997; Saganuma et al. 1998; Yang et al. 1998).

There are studies showing the negative influence of tea drinking on mineral administration in the human body. It was stated that tea consumption resulted in the slowing down of iron absorption (Disler et al. 1975) and increase of anaemia (Merhav et al. 1985). Another result is the lowering of the total nutritious value of food, because condensed tannins inhibit trypsin and block proteins (Los and Podsetek 2004). Unlike condensed tannins, low polymerized phenols practically do not inhibit trypsin activity (Quesada et al. 1996), and tannins also show a high resistance to digestive tract pH and the presence of bile acids and protease (Hagerman et al. 1998).

There are studies showing the partial absorption of polyphenols in human body tissues, suggesting probable health advantages of drinking tea brews (Dreosti 1996). There is no data showing the direction of tea polyphenol consumption, or limitations in its daily intake. The positive side is that no data has been observed on the toxic effect of tea polyphenol overdose (Takahashi and Nioymiya 1997). Nevertheless, it is probably to clear up any misunderstandings it was stated that tea polyphenol activity and the effect in the human body depends on factors such as lifestyle and can possibly be masked by specific factors of the examined population (Yang 1999). There is much research, but polyphenol activity, bioavailability and metabolism has not yet been explained.

PROPERTIES OF TEA POLYPHENOLS IN BIOLOGICAL SYSTEMS

Recently research is focusing on the protective potential of substances naturally occurring in food with respect to their possible influence in the human body. Scientists examined the correlations between diets rich in fresh plant products and the mortality rate by different diseases (Yamane et al. 1996; Parr and Bolwell 2000; Sato and Miyata 2000). Strong and diverse biological proprieties of polyphenols, especially the flavonoids turned special attention to tea leaves and its brews.

Tea therapeutic value is well known (Ramarathan et al. 1995; Yang and Landau 2000; McKay and Blumberg 2002). It was found that according to the activity of tea polyphenols in scavenging superoxide radicals, tea could be a helpful tool in preventing oxidative stress-related diseases, responsible for cellular membrane disintegration and other degenerative diseases (Halliwell et al. 1995; Unno et al. 2000).

An indispensable component of life, oxygen, undergoes a transformation to reactive oxygen species (superoxide anion radical (O2•−), hydroxyl radical (OH•) and hydroperoxide (H2O2) (Frankel 1998; Squadrarti and Peyer 1998). The human organism possesses a very effective defensive system against oxidative stress induced by reactive oxygen species, which unfortunately diminish with ageing, and leading to disturbances in red-ox balance (Oswa et al. 1995; Sato and Miyata 2000; Wu and Wei 2002). Many reports confirmed very strong antioxidative properties of flavonols isolated from green, black and red tea leaves (Xie et al. 1993; Vastag 1998). It was stated that flavonoids’ antioxidative activity is probably based on the protection by endogenous antioxidants (vitamin E, ascorbic acid, and glutathione). Absorption of catechins occurring in food in the form of aglycones has not been explained yet (Hollman and Arts 2000). Metabolization of flavonols and flavanols occurs mainly in the liver and large intestine (Takahashi and Ninomiya 1997; Rechner et al. 2002), where it is subjected to glucuronidation and sulfatation of phenolic groups and methylation of catecholic groups (Manach et al. 1999).
ble diet manipulation may be a strong tool in cancer prevention (Weisburger 1996; Jankun et al. 1997). Many studies stated that green tea anticancerogenic properties are related to the presence of flavonoids, especially the catechins, EGCG (Kinlen et al. 1988; Oguni et al. 1988; Ahmad et al. 1997; Katiyar and Mukhtar 1997; Mukhtar and Ahmad 1999; Swiercz et al. 1999; Smith and Dou 2001). Knowledge about the anticancerogenic properties of tea polyphenols could be essential in a strategy against tumours (Fujiki et al. 1998), unfortunately no clear anticancerogenic mechanism has been found yet.

Another important activity of tea polyphenols is their germicidal properties, helping to lower the pathogen (Escherichia coli) population, but without influencing the lactic acid bacteria Lactobacillus and Bifidobacterium existing large intestine (Sakanaka et al. 1989; Okubo and Jun-jea 1997). It was found that both green and black tea leaf components possibly damage bacterium’s cellular membrane, and has been used in the treatment of diarrhea, cholera and typhus infections (Toda et al. 1990; Sheety et al. 1994). It was proved that only EC and EGC gallates from tea leaves inhibit RNA reverse transcriptase, playing an essential part in HIV virus replication (Nakane and Ono 1989; Gupta et al. 2002). Thearflavins, black tea polyphenols, protected rats’ healthy liver cells against reactive oxygen stress, and prevented DNA damage (Feng et al. 2002). Other observations suggested that the consumption of more than three tea leaf infusion cups daily as a possible protective factor against breast tumours in its early stage (Inoue et al. 2001). Another investigation showed that the consumption of more than 10 cups of green tea infusion daily results in a decrease in blood cholesterol level (Imai and Nakachi 1998). Tea flavonoids help to protect the low density lipoprotein (LDL) fraction against oxidation, by antiplatelet properties and by activation of prostaglandin synthesis (Acker et al. 1998; Hodgson et al. 1999; Sung et al. 2000).

Research also showed that individuals consuming tea extract three times daily burned 266 kcal/day more than the control group (i.e. without the addition of catechins), which allowed authors to presume a helpful component in over-weight and obesity control (Dullo et al. 2000). Research on the property of thermogenic tea showed the synergistic action of caffeine and catechins (Dulio et al. 1999). Kao and co-workers found that green tea catechins influence the endocrine system. ECGG considerably lowered food intake, body mass, estradiol, testosterone and leptine levels in studied rats. It was found that EGCG may interact specifically with a component of a leptin-independent appetite control pathway (Dullo et al. 2000). Tea flavonoids showed inhibitory effect on the release of somatostatin, such as leucotrienes and prostaglandins, by modifying the activity of enzymes taking part in inflammation of the human body (Middleton et al. 1998).

Among the tea constituents caffeine, or theine is a very important alkaloid that does not accumulate in the body (Graham 1997). Caffeine is a trimethyl derivative of purine 2,6-diol, first discovered in coffee by Runge in 1820. A similar isolated from tea named theine, when combined, could stimulate fat reduction, and attenuate obesity induced by a high fat diet in mice. Scientists suggest that both green and oolong tea components may promote body weight and fat loss by stimulating thermogenesis (Dulio et al. 1999, 2000; Komatsu et al. 2003; Berube-Parent et al. 2005). The first thermogenic effect of green tea was attributed to its caffeine content (Asstrup et al. 1990). However Dulio et al. (2000) reported that green tea extract stimulates brown adipose tissue thermogenesis to a much greater extent than that which can be attributed to its caffeine content per se in rats. In another study the same group of authors found that green tea extract ingestion increased 24 h energy expenditure by 4% (328 kJ) in 10 healthy men, reflecting green tea’s stimulatory effect on thermogenesis (Dulio et al. 1999). The catechins in green and oolong teas may stimulate thermogenesis and fat oxidation through an inhibition of catechol-O-methyl-transferase, an enzyme that degrades noradrenaline (Borchardt and Hu-
The potential protective properties of tea polyphenols on fried meat were investigated by Weisburger et al. (2002). Meat slices were coated on both sides with a layer of green and black tea polyphenols. The ground beef patties were treated with aqueous solutions of polyphenols (green and black tea), afterwards cooked on the grill. The experiment showed that the formation of mutagenic compounds on both sides of meat was inhibited in a dose-related fashion (Weisburger et al., 2002). Koketsu and Satoh (1997) investigated the antioxidant activity of green tea polyphenols in edible oils and fried noodles. Green tea polyphenols consisted of 27.1% EGCG, 19.3% GC, 16.7% GCG, 16.1% EGC, 8.1% ECG, 7.5% EC and 5.2% C. Antioxidant activity was dose dependent. Highest activity of green tea extract was evaluated in addition of 60 ppm to lard and soybean oil. The addition of green tea polyphenols (60 ppm) into fried oil improved fried noodles’ oxidative stability. Tang et al. (2001) investigated the antioxidative effect of dietary tea catechins supplementation at various levels (50, 100, 200 and 300 mg kg⁻¹) fed on chicken breast and thigh meat susceptibility to lipid oxidation during frozen storage (-20°C) for 9 months. It was found that supplementation with tea catechins showed antioxidative effects for both meats and demonstrated to be an effective alternative to vitamin E as a natural dietary antioxidant.

Research of the activity of tea polyphenols in food products should always consider the influence of other compounds like protein, whose interactions could possibly influence its final antioxidative effect (Arts et al., 2002).

The enrichment of food products with tea leaf polyphenols would effectively influence their oxidative stability and their additional penetration into the human organism could possibly decrease morbidity caused by degenerative diseases.

CONCLUDING REMARKS

Tea could be an important source of dietary polyphenols possessing strong antioxidant capacity, preventing many diseases and food oxidation. The large family of plant polyphenols, which constitutes a group of different chemically structured compounds, possesses variable biological properties. Research showed tea polyphenols beneficial properties in in vitro and in vivo systems. Although there is much promising evidence, there still is a need for further investigations to understand benefits and contributions of tea polyphenols to human life.

The enrichment of food products with tea leaf polyphenols could profitably influence its oxidative stability and additional incorporation into the human body could improve lifestyles.

ACKNOWLEDGEMENTS

We wish to thank Prof. Jozef Korczak for the tutorial contribution, and the Ministry of Education and Science of Poland for their financial support.

REFERENCES


Arts MJTJ, Haenen GRMM, Voss HP, Bast A (2001) Masking of antioxidant capacity by the interaction of flavonoids with protein. Food and Chemical Toxicology 39, 43-47.


Hara Y (1997) Influence of tea catechins on the digestive tract. Journal of Cel-
Antioxidants of Camellia sinensis leaves. Gramza-Michalowska and Bajenska-Jarzewska

tracts in stabilization of triacylglycerols, II Euro Fed Lipid Congress: Fats
and Lipids in a Changing World, Edinburgh, Scotland, 5-8 September
NUHE-52, p 235

Sanderson GW, Ranadive AS, Eisenberg LS, Farrel FJ, Simons R, Manley
CH, Coggan P (1976) Contribution of polyphenolic compounds to the taste
of tea. ACS Symposium Series 26, 14-46

Sanderson GW (1972) The chemistry of tea and tea manufacturing In: Rune-
cckes VC (Ed) Structural and Functional Aspects of Phytochemistry, Acade-
mic Press, NY, pp 247-316

tional Pharmaceuticals 16, 315-317

Sava VM, Yang SM, Hong MY, Yang PC, Huang GS (2001) Isolation and
characterization of melanin pigments derived from tea and tea polyphenols.
Food Chemistry 73, 177-184

Scalbert A, Williamson G (2000) Dietary intake and bioavailability of poly-
phenols. Journal of Nutrition 130, 2073S-2085S

plication of near-infrared reflectance spectroscopy to the simultaneous pre-
diction of alcaloids and phenolic substances in green tea leaves. Journal of
Agricultural and Food Chemistry 47, 5064-5067

Sealy JR (1958) A Revision of the Genus Camellia, The Royal Horticultural
Society, London, England

(Camellia sinensis) and coffe (Coffea arabica) with special reference to
Salmomella typhimurium. Journal of Communicable Diseases 24, 147-150

Shimotoyodome A, Haramizu S, Inaba M, Murase T, Tokimitsu I (2001) Ex-
ercise and green tea extract stimulate fat oxidation and prevent obesity in
mice. Medicine and Science in Sports and Exercise 37, 1884-1892

Smith DM, Dou QP (2001) Green tea induces polyphenols epigallocatechin
inhibits DNA replication and consequently induces leukaemia cell apoptosis.
International Journal of Molecular Medicine 7, 645-652

Spencer CM, Cai Y, Martin R, Gaffney SH, Goulding PN, Magnolato D,
Journal of Agricultural and Food Chemistry 48, 3973-3978

Tsuchida T, Taeko T (1977) Zinc, copper, lead and cadmium contents in green
tea. Journal of the Science of Food and Agriculture 28, 255-258


and their epimers on superoxide anion radicals generated by a hyperoxic and
taxantine oxidase system. Journal of the Science of Food and Agriculture 80,
601-606

van Het Hof KH, Xivitzis GAA, Weststrate JTA, Tijburg LBM (1998) Bio-
availability of catechins from tea: the effect of milk. European Journal of Cli-
nical Nutrition 52, 356-359

Vazquez CM, Klammer S, Hollis D (1999) Tea polyphenols, their functions,
utilization and analysis. Trends in Food Science and Technology 11, 152-160

flavonoids and sensory qualities of green tea beverage. Journal of Agricul-
tural and Food Chemistry 48, 393-396

Food Chemistry 50, 393-396

Wanasundara UN, Shahidi F (1996) Stabilization of seal blubber and men-
haned oils with green tea. Journal of the American Oil Chemists Society 73,
WHO, Geneva, www

Wang Z, Provan GJ, Hellwell K (2000a) Tea flavonoids, their functions, utili-
ization and analysis. Trends in Food Science and Technology 11, 152-160

Wei SH, Hattab FN, Melberg JR (1989) Concentration of fluoride and selec-
ted other elements in teas. Nutrition 5, 237-240

(Eds) Handbook of Antioxidants, Marcel Dekker, NY, pp 469-486

19, 114 (1-2), 315-317

polyphenols inhibit the formation of mutagens during the cooking of meat.
Mutation Research 516, 19-21

Westereelp-Plantenga MS, Lejanne PM, Kovacs EM (2005) Body weight loss
and weight maintenance in relation to habitual caffeine intake and green
tea supplementation. Obesity Research 13, 1195-1204

Woodward M, Tunstall-Pedoe H (1999) Coffee and tea consumption in the
Scottish Heart Health Study follow-up: conflicting relations with coronary
risk factors, coronary heart disease and all-cause mortality. Journal of Epide-
miology and Community Health 53, 481-487

World Health Organization (2000) Obesity: preventing and managing the

adenyl cyclase activity and lipolysis in rat adipocytes. Phytomedicine 8, 292-
297

Oral Health 18, 442-443

tionship among habitual tea consumption, percent body fat, and body fat
distribution. Obesity Research 11, 1088-1095

Xie B, Shi H, Chen Q, Ho C-T (1993) Antioxidant properties of fractions and
polyphenol constituents from green, oolong and black teas. Proceedings of
the National Science Council, Republic of China. Part B, Life Sciences 17,
77-84

Yamane T, Nakatani H, Kikuoka N, Matsumoto H, Iwata Y, Kitao Y, Oka
Takahashi T (1996) Inhibitory effects toxicity of green tea polyphenols in
cancer prevention. Journal of Nutrition 130, 5472-5478

Yang CS, Landau JM (2000) Effects of tea consumption on nutrition and
health. Journal of Nutrition 130, 2409-2412

and urine levels of tea catechins after ingestion of different amounts of green
tea by human volunteers. Cancer Epidemiology Biomarkers and Prevention
7, 351-354


Yanishlieva-Maslarova NV, Heinonen IM (2001) Sources of natural antioxi-
dants: vegetables, fruits, herbs, spices and teas. In: Pokorny J, Yanishlieva
N, Gordon M (Eds) Antioxidants in Food – Practical Applications, CRC Press,
Woodhead Publishing, Cambridge, pp 210-249

lieva N, Gordon M (Eds) Antioxidants in Food – Practical Applications, CRC

catechins. Journal of Agricultural and Food Chemistry 45, 4624-462