A Frequent Drinking of Green Tea Lowers the Levels of Endogenous Oxidative Stress in Small Intestines, Erythrocytes and Kidneys in Rats

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Summary  Endogenous antioxidative potential was examined in rats given green tea as daily drinking water for 4 weeks. Rats ingested 196 µmol/kg body weight/day of catechins (sum total of 8 kinds of catechins), and plasma levels were around 0.24 µM. The green tea also contained 2.1 mM ascorbic acid, but the plasma level was similar to that in control rats drinking water, about 30 µM. The tea-drinking rats had significantly lower levels of lipid peroxidation in the small intestines and kidneys, 30% and 40% lower, respectively, than the controls, and their erythrocytes showed significant resistance to aqueous peroxyl radicals generated from azo initiator. Then, the effects of 8 catechins were examined on the antioxidative potency of ascorbic acid in \textit{in vitro}. Catechins suppressed the oxidation of deoxyguanosine after the immediate exhaustion of ascorbic acid. Thus, frequent daily drinking of green tea improved the antioxidative potential of ascorbic acid.

Key Words: green tea, catechins, antioxidative potency, small intestines, kidney

Introduction

Most of the teas consumed worldwide are prepared from the same plant species, \textit{Camellia sinensis} L. Green tea occupies approximately 80% of the world market, and is the most popular tea in Japan and China. The daily consumption of green tea has been reported to reduce the risk of many degenerative diseases [1–6]. Green tea contains around 40 mmol catechins in 100 g dried leaves, the highest level in any plant species [7]. The catechins are (+)-catechin (C), (−)-gallocatechin (GC), (−)-catechin gallate (Cg), (−)-gallocatechin gallate (GCg), (−)-epicatechin (EC), (−)-epigallocatechin (EGC), (−)-epicatechin gallate (ECg), and epigallocatechin gallate (EGCg). EGCg is considered one of the strongest antioxidants in dietary factors [8, 9], and believed to contribute to the prevention of diseases by suppressing oxidative stress in target organs and tissues [10–15].

In the living body, there is a system of defense against oxidative stress involving enzymes such as superoxide dismutase and glutathione peroxidases and endogenous antioxidants like uric acid, glutathione, tocopherols, and ascorbic acid [16], which cooperate to quench both water- and lipid-soluble reactive oxygen species (ROS) under normal conditions [17]. However, diet can introduce xenobiotics and generate ROS \textit{via} detoxifying processes with neutrophilic phagocytosis and cytochrome P450.
enzymes [18, 19]. To cope with such situations, the living body must maintain a high endogenous antioxidative potential and/or low levels of oxidative stress.

The green tea drinking had been thus known well to reduce the risks of various diseases by the strong antioxidative potency. However, less understanding is provided in the actions of green tea drinking under healthy conditions. We were interested in the improvement of antioxidative potential in healthy animals not under oxidative stress. The present study was aimed at assessing whether daily drinking of green tea enabled this. Rats were given a bottled green tea instead of water and levels of polyphenolic antioxidants and conditions of oxidative stress in plasma and several organs were examined. Then, the effects of catechins on the actions of an endogenous antioxidant, ascorbic acid, were evaluated by conducting in vitro kinetic experiments.

Materials and Methods

Chemicals

The green tea used here was a commercial beverage in bottled form, and the antioxidative ingredients were determined (Table 1). For the determination, eight standard catechins were purchased from Kurita Kogyo (Tokyo, Japan). Other flavonoids were from Extrasynthèse (Genay, France). Ascorbic acid, butylated hydroxytoluene (BHT), 2,2'-azobis(2-amidinopropane)dihydrochloride (AAPH), 2'-deoxyguanosine (2'-dG), and thiobarbituric acid (TBA) were obtained from Wako Pure Chemicals Industries, Ltd. (Osaka, Japan). β-Glucuronidase/sulfatase (crude solution from Helix pomatia) was from Sigma-Aldrich (Irvine, UK). Water was distilled twice, and all other reagents were of the highest grade available.

Animals and diets

The treatment of animals conformed to the “Guidelines for the care and use of experimental animals, Rokkodai Campus, Kobe University”. Male Wistar rats (3-week-old, 37 ± 2.5 g, Japan SLC, Shizuoka, Japan) were divided at random into two groups of 5 each. They were housed in a controlled room (temperature, 25 ± 1°C; humidity, 45–50%; light-dark cycle, 12 h each), with free access to either green tea or tap water (control group) for 4 weeks. A laboratory chow from Japan SLC was used for the daily diet in the both groups, which did not contain a detectable amount of ascorbic acid. The rats were anesthetized with 5% pentobarbital, and blood was collected by cardiac puncture in heparinized tubes. The plasma and erythrocytes were separated by centrifuging at 800 g for 10 min. Also, the liver, kidneys, thymus, spleen, and small intestines were removed and weighed. All samples were analyzed immediately.

| Table 1. Antioxidative polyphenol levels in plasma of green tea-drinking rats |
|-----------------------------------|---------------------|---------------------|
| Polyphenols                        | Bottled green tea1 | Plasma2 of tea-drinking rats Forms: |
|                                   | µM                  | nM                  |
| C                                 | 146 ± 21            | u.d.                | 83.1 ± 23.9 |
| GC                                | 410 ± 26            | u.d.                | u.d.        |
| Cg                                | 31 ± 9.0            | u.d.                | u.d.        |
| GCg                               | 201 ± 30            | u.d.                | u.d.        |
| EC                                | 62 ± 7.0            | u.d.                | 93.4 ± 29.4 |
| EGC                               | 223 ± 13            | u.d.                | u.d.        |
| ECg                               | 34 ± 3.0            | u.d.                | 25.9 ± 2.1  |
| EGCg                              | 166 ± 14            | 33.7 ± 22           | 5.0 ± 5.0   |
| Kaempferol glycosides3            | 24 ± 2.0            | u.d.                | u.d.        |
| Quercetin glycosides4             | 30 ± 3.0            | u.d.                | u.d.        |
| Myricetin-3-O-rutinoside          | 16 ± 2.0            | u.d.                | u.d.        |
| Isovitexin                        | 13 ± 1.0            | u.d.                | u.d.        |

1 A commercial bottled green tea was used in this study. The other detectable phenolics are 40 µM of gallic acid and 610 µM of caffeine.
2 Plasma was obtained from rats consuming bottled green tea (154 ± 47 mL/kg body weight/day) or water (144 ± 41 mL/kg body weight/day) for 4 weeks. Values are the mean ± S.D. (n = 5), and “u.d.” means under detection limits in the present analysis.
3 The sum total of kaempferol glycosides mainly its -3-O-glucoside and -3-O-rutinoside.
4 The sum total of quercetin glycosides mainly its -3-O-rhamnose.
Determination of polyphenols in plasma and erythrocytes

Polyphenols in the plasma and erythrocytes were determined with the method of Chen et al. [20] modified slightly. Briefly, the plasma was acidified at pH 5.0 with 1.0% acetic acid and divided equally into two parts. One was incubated with 8.0 µL of enzyme solution possessing 1 x 10^6 units/L of β-glucuronidase and 7.5 x 10^6 units/L of sulfatase activity at 37°C for 30 min, to hydrolyze conjugated forms of catechins to free aglycones. The other was incubated under the same conditions but in the absence of enzymes. Erythrocytes were washed with 10 volumes of 150 mM NaCl three times, and induced to undergo hemolysis by adding 5 volumes of distilled water. Then, the erythrocytes were treated with the enzymes similarly as plasma after dividing the solution into two parts. The solutions of plasma and erythrocytes were extracted with 2 volumes of ethyl acetate twice, adding 0.5 nmol flavone as an internal standard. Once dried under nitrogen gas, the residues were dissolved in 100 µL of dimethylsulfoxide and filtrated through a 0.2 µm membrane filter Millex-LG (Millipore Co., Billerica, MA). A part of it (20 µL) was subjected to high-performance liquid chromatography (HPLC) with a Capcell pak C18 UG120 column (250 x 4.6 mm I.D., S-5, 5 µm, Shiseido Co., LTD., Tokyo, Japan) equipped with a guard column (10 x 4.0 mm I.D.). The columns were thermostatically maintained at 35°C. The mobile phase was acetonitrile/100 mM sodium phosphate buffer (pH 2.5) containing 0.1 mM ethylenediaminetetraacetate disodium salt (14:86, v/v) for catechins, and methanol/100 mM sodium phosphate buffer (pH 3.3) containing 0.1 mM ethylenediaminetetraacetate disodium salt (55:45, v/v) for other flavonoids at a flow rate of 1.0 mL/min. Eight kinds of catechins were detected with an electrochemical detector (ECD) (IRICA Σ2875, Kyoto, Japan) at +700 mV, and the others at +600 mV. The detection limits for antioxidative polyphenols in plasma were 5.0 nM with this method.

Ascorbic acid levels in plasma

Plasma (100 µL) was mixed with 900 µL of 10% metaphosphoric acid and centrifuged at 800 g for 10 min. The supernatant was analyzed in ascorbic acid in a HPLC system equipped with ECD (+600 mV) according to the method of Tsao and Salimi [27], using a Capcell pak C18 UG120 column and 100 mM NaHPO₄, 0.1 mM EDTA-2Na and 5 mM tetra-n-butylammonium phosphate (pH 2.5) for the mobile phase.

Measurement of lipid peroxidation level

Endogenous levels of Lipid peroxidation were estimated as thiobarbituric acid reactive substances (TBARS) basically according to the method of Ohkawa et al. [22] with some modifications. Briefly, the small intestines, liver, thymus, spleen, and kidneys were washed with ice-cold 0.15 M KCl and homogenized in 4 volumes of the KCl. The protein amount in homogenate was analyzed with the method of Lowry et al. [23]. The homogenate (0.2 mL) was added to 0.5 mL of water, 1.5 mL of a 0.8% TBA solution, 50 µL of 0.8% BHT in acetic acid, 0.2 mL of 8.1% sodium dodecyl sulfate, and 1.5 mL of 20% aqueous acetic acid in this order, and then adjusted to pH 3.5 with 10 N NaOH and made up with water to a total volume of 4 mL. The mixture was stood at 4°C for 60 min, and then heated at 100°C for 60 min. After cooling with an additional 1.0 mL of water, the mixture was extracted with 5.0 mL of n-butanol:pyridine (15:1, v/v), and centrifuged at 800 g for 10 min. The organic phase was determined in TBARS fluorometrically with excitation at 535 nm and emission at 553 nm.

Resistance of erythrocytes against oxidative hemolysis

Erythrocytes were induced to undergo an oxidative hemolysis according to a modified version of the method of Miki et al. [24]. In brief, well-washed erythrocytes were suspended in 125 volumes of phosphate-buffered saline pH 7.4 (PBS) and 4 mL was mixed with 1 mL of 200 mM AAPH in PBS. After incubation at 37°C for 60 min with gentle shaking, the erythrocytes were centrifuged at 800 g for 10 min, and then the absorbance of the supernatant was measured at 540 nm.

In vitro kinetic study to determine antioxidative potency of catechins combined with ascorbic acid

Additional effects of 8 kinds of catechins on the antioxidative potency of ascorbic acid were evaluated using 2'-dG as the target for oxidation as mentioned previously [25]. A mixture of ascorbic acid (50 µM) and 8 catechins (5.0 µM of each) was incubated with 0.5 mM 2'-dG and 25 mM AAPH at 37°C. The formation of an oxidation product, 8-hydroperoxy-2'-dG (8-OHdG), was determined with the incubation time on a reverse-phased HPLC system with UV at 254 nm, and simultaneously, consumption of ascorbic acid and catechins was measured by HPLC as mentioned above.

Data analysis

Data were analyzed with a one-way ANOVA followed by Fisher’s PLSD post-hoc test with Stat View software (Abacus Concepts, Berkeley, CA). Probability values less than 0.05 were considered statistically significant.

Results

Plasma levels of catechins and ascorbic acid

Table 1 shows polyphenol contents of the commercial bottled green tea used here. The green tea contained a considerable amount of catechins, with 100 mL assumed to be equal to around 3 g of tea leaves based on the data from
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our previous analysis [7]. The major catechins in tea leaves were EGC (179 µmol/g) and EGCG (149 µmol/g), while those in the bottled tea were GC (410 µM), EGC (220 µM), GCg (200 µM), and EGCG (170 µM). The bottled green tea also contained a large amount of ascorbic acid (2.1 ± 0.13 mM) and small amounts of other polyphenols such as flavonoids. The rats consumed 154 ± 47 mL/kg body weight/day of the bottled green tea for 4 weeks. The intake of catechins was estimated to be 196 ± 19 µmol/kg body weight/day, and ascorbic acid was 324 ± 19.4 µmol/kg body weight/day. The body weight of the tea-drinking rats was 180 ± 17 g at the end of experiments and was similar to that of the water-drinking control rats (183 ± 8 g). The consumption of fluid and food was also similar between the two groups.

At the end of experiments, antioxidative polyphenol levels in the plasma were examined (Table 1). The tea-drinking rats showed existence of 4 kinds of catechins and 0.24 µM as the sum total in plasma. Among them, C, EC and ECg were glucuronide/sulfate conjugates while EGCG was mainly in an original free form. The concentrations of ascorbic acid was 26.2 ± 2.1 µM and was similar to the level in control rats (27.9 ± 0.8 µM). Concentrations of the other catechins and polyphenols were below the detection limit (below 5 nM in plasma).

Effects of drinking green tea on endogenous levels of lipid peroxidation

TBARS levels in the small intestines, spleen, thymus, kidneys, and liver were compared between green tea-drinking and water-drinking rats (Fig. 1). The drinking of green tea instead of water significantly reduced the TBARS levels in the small intestines and kidneys by approximately 30% and 40%, respectively. Three kinds of catechins, C, EGC, and EGCG, were detected in the small intestines of green-tea drinking rats as amount of 490, 510, and 80 pmol/g tissue, respectively (Table 2).

The erythrocytes were subjected to an evaluation of susceptibility to oxidative stress (Fig. 2). When exposed to the AAPH radical and examined for signs of the hemolysis, the erythrocytes of the tea-drinking rats showed significant resistance to oxidative stress compared to those of control rats. The erythrocytes of tea-drinking rats contained 0.13 µM of a total of 3 kinds of catechins (Table 3). Interestingly, forms of the catechins were different from those in plasma. In the erythrocytes, 34% of C, 63% of ECg and 61% of EGCG were aglycone forms, whereas most of the C and ECg were conjugated forms in plasma. The aglycone form is known to be more antioxidative than the hydroxyl group masked-conjugate form [26, 27]. The resistance against oxidative stress of the erythrocytes of tea-drinking rats was considered to be attributable to these catechins.

The results, thus, indicated that when consumed daily, green tea lowered endogenous lipid peroxidation level in the small intestines and kidneys, and increased the resistance of erythrocytes to oxidative stress.

Effects of catechins on oxidative stress in vitro

In the animal study, antioxidative catechins and ascorbic acid were detected in rat plasma. Then, antioxidative effects of combinations of the 8 catechins and ascorbic acid were evaluated in vitro, using 2′-dG as the target of oxidation and AAPH as generator of aqueous peroxyl radicals [25]. Levels of catechins in human plasma have been reported to be around 5.0 µM [28, 29], and those of ascorbic acid, about

Table 2. Catechin levels in small intestines and liver of green tea-drinking rats

<table>
<thead>
<tr>
<th></th>
<th>Small intestines</th>
<th>Liver</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>490 ± 270</td>
<td>u.d.</td>
</tr>
<tr>
<td>EGC</td>
<td>510 ± 360</td>
<td>380 ± 100</td>
</tr>
<tr>
<td>EGCG</td>
<td>80 ± 50</td>
<td>70 ± 20</td>
</tr>
</tbody>
</table>

1 Polyphenol contents in both organs were analyzed after enzymatic hydrolysis. Figures are the mean ± S.D. and “u.d.” means under the detection limit. Other polyphenols were under detection limits. The small intestines and liver of water-drinking rats did not have any catechins or other polyphenols.
Fig. 2. A comparison of resistance of erythrocytes to oxidative hemolysis between tea-drinking and water-drinking rats. Erythrocytes were suspended at a concentration of 0.8% in PBS (pH 7.4) and incubated with 40 mM AAPH at 37°C for 60 min. After centrifugation, the supernatant was measured for absorbance at 540 nm. Columns and bars represent the mean ± SD (n = 5), and asterisks indicate a significant difference from water-drinking rats (*P < 0.05).

50 μM [30, 31]. Fig. 3 shows that 2'-dG was easily oxidized to 8-OHdG on incubation with AAPH. However, the addition of the mixture containing 5.0 μM each of the 8 catechins and 50 μM of ascorbic acid suppressed completely the oxidation. Among the antioxidants, ascorbic acid was consumed first, then EGCg, GCg, EGC, GC, ECg, Cg, EC, and finally C in that order. The order was the same as we have previously found for the magnitude of their antioxidative effect [25]. After all of the catechins and ascorbic acid were depleted, the formation of 8-OHdG proceeded immediately.

Table 3 shows the starting times of 8-OHdG formation when 8 catechins and ascorbic acid were individually added to the incubation mixture of 2'-dG and AAPH. Each of them delayed the formation of 8-OHdG by a little time, and the combined addition of 8 catechins (5.0 μM each) and ascorbic acid (50 μM) delayed the 8-OHdG formation by 200 min, which was similar to a sum total of delaying times by the individuals. These results showed that catechins have an additive effect on the endogenous water-soluble antioxidant ascorbic acid, not a synergic effect.

![Antioxidative action of ascorbic acid with 8 catechins against the oxidation of 2'-dG to 8-OHdG by aqueous peroxyl radicals.](image)

Fig. 3. Antioxidative action of ascorbic acid with 8 catechins against the oxidation of 2'-dG to 8-OHdG by aqueous peroxyl radicals. Ascorbic acid (50 μM) and 8 kinds of catechins (each of 5.0 μM) were added to 0.5 mM 2'-dG and incubated with 25 mM AAPH at 37°C. At the times indicated, 8-OHdG formation (×, without this combined system; ◆, with combined system) and the consumption of ascorbic acid (◇), EGCg (●), GCg (▲), EGC (○), GC (△), ECg (■), Cg (▼), EC (□) and C (▽) were determined by HPLC as mentioned in Materials and Methods.

<table>
<thead>
<tr>
<th>In erythrocytes Forms:</th>
<th>Aglycone</th>
<th>Conjugates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>µM</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>13.8 ± 6.0</td>
<td>27.1 ± 14.7</td>
</tr>
<tr>
<td>EC</td>
<td>u.d.</td>
<td>u.d.</td>
</tr>
<tr>
<td>ECG</td>
<td>43.1 ± 24.2</td>
<td>25.2 ± 20.7</td>
</tr>
<tr>
<td>EGCg</td>
<td>13.2 ± 7.1</td>
<td>8.4 ± 1.3</td>
</tr>
</tbody>
</table>

1 Figures are the mean ± SD and “u.d.” means under the detection limit. Other polyphenols were under detection limits. The erythrocytes of water-drinking rats did not have any catechins or other polyphenols.
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Table 4. Delay of 8-OOHdG formation by antioxidants

<table>
<thead>
<tr>
<th>Antioxidant</th>
<th>Starting time of 8-OOHdG formation (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without antioxidants</td>
<td>0</td>
</tr>
<tr>
<td>Ascorbic acid (50 μM)</td>
<td>60</td>
</tr>
<tr>
<td>Catechins (5.0 μM)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>15</td>
</tr>
<tr>
<td>GC</td>
<td>15</td>
</tr>
<tr>
<td>Cg</td>
<td>17.5</td>
</tr>
<tr>
<td>GCg</td>
<td>20</td>
</tr>
<tr>
<td>EC</td>
<td>15</td>
</tr>
<tr>
<td>EGC</td>
<td>15</td>
</tr>
<tr>
<td>ECg</td>
<td>17.5</td>
</tr>
<tr>
<td>EGCg</td>
<td>22.5</td>
</tr>
<tr>
<td>Ascorbic acid (50 μM) and 8 catechins (5.0 μM each)</td>
<td>200</td>
</tr>
</tbody>
</table>

Discussion

The present study was designed to assess whether the drinking of green tea instead of water improved the endogenous antioxidative status in healthy animals. The rats received a bottled green tea for 4 weeks. In the plasma, 4 kinds of catechins, C, EC, Ec, and EGC, were detected and the sum total amount was 0.24 μM (Table 1). These catechin levels were similar to the results in human trials afterward the consumption of foods containing high levels of catechins [32–34]. On the other hand, ascorbic acid levels remained unchanged. In the rats, endogenous lipid peroxidation levels were significantly lower in the small intestines and kidneys than control values (Fig. 1), and 3 kinds of catechins were detected in the small intestines (Table 2). The erythrocytes also incorporated 3 catechins (Table 3) and showed significant resistance to oxidative stress compared to the erythrocytes of control rats (Fig. 2). Thus, green tea as the daily drinking water was clearly helpful in improving antioxidative status even in healthy animals under ordinary conditions, and the increase in antioxidative potential was attributed to the catechins.

The present results demonstrated that green tea drinking improved the antioxidative status of blood, small intestines and kidney, but not of liver. The bioavailability of catechins is known to be very low [20, 34, 35]. The absorption rate is less than 1% of the ingested amount, and small amounts of incorporated catechins are circulated mostly in conjugated forms and excreted through urine within a few hours of ingestion. The conjugates express very little antioxidative activity because the conjugations occur mostly on antioxidative hydroxyl groups [26, 27]. In the present study, the rats consumed 154 ± 47 mL/kg body weight of green tea daily, which contains 8 kinds of catechins in a sum total of 1.27 mM (Table 1). The catechins in rat plasma were of 4 kinds and the total amount was 0.24 μM. This means that catechins have very low absorption rates even under conditions of permanent drinking. Also, the plasma catechins were mostly in conjugated forms that were easily excreted through urine. On the other hand, EGC has been reported to occur abundantly as a free aglycone form in the plasma [30], and aglycone EGC is believed to be the strongest antioxidant [8, 9]. In the present study, a considerable amount of aglycone EGC was detected in plasma. The green tea contained another antioxidative flavone and flavonol glycosides (Table 1), but they were below the detection limits (5.0 nM) in plasma. Bottled green tea used in this study did not elevate the endogenous ascorbic acid level though it contained high amount of ascorbic acid (2.1 mM). It seems likely that rats maintain the endogenous level homeostatically because rats can produce ascorbic acid [36]. Thus, it is concluded that the bioavailable antioxidants in green tea are catechins, particularly EGC.

Another interesting point suggested in this study is the distribution of green tea catechins of rats. Total catechin contents were 2.4 times higher in the small intestines than in the liver (Table 2). Chen et al. also reported that quite amount of catechins was distributed in the kidney comparing with the liver after administration of green tea to rats [37]. In general, catechin levels in the liver might be lower than those in the small intestines and kidney. This study showed that green tea-drinking improved the antioxidative status of the small intestines and kidney, but not of liver (Fig. 1). Green tea catechins were also reported to inhibit small intestinal carcinogenesis but not hepatocarcinogenesis [38]. Such interesting differences probably result from the different distributions of catechins among the organs.

In the erythrocytes, C, EC, and EGC were detected, and interestingly, 30–60% of them were aglycone forms (Table 3), although they were mostly conjugate forms in plasma (Table 1). The conjugates have been believed to be difficult to re-incorporate into body cells [39, 40]. This phenomenon suggests two possibilities: erythrocytes possess β-glucuronidase activity or erythrocytes directly receive the aglycones from intestinal cells. However, further examination might be required.

Another important issue is to know the additional effects of catechins on ordinary antioxidative potential. Therefore, the antioxidative actions of catechins were examined using an in vitro model (Fig. 3). In this experiment, human-like conditions were employed for the antioxidative levels [28–31], 50 μM of ascobic acid and 5.0 μM each of 8 catechins. The ascorbic acid was easily consumed, and catechins greatly prolonged the start of oxidation of 2′-dG by scavenging aqueous peroxy radicals generated from AAPH. This means that ascobic acid plays a most important role in
scavenging water-soluble radicals. After the exhaustion of ascorbic acid, catechins were consumed in the order EGCg>GCg>EGC>GCG>ECg>C, which coincided with the order of antioxidative potency as found previously [25]. This indicates that the catechins facilitate the actions of ascorbic acid in this order and the most helpful catechin is EGCg. This is an in vitro model, but probably allows the following speculation. Oxidative genetic damage caused by ROS can induce degenerative diseases such as cancers, atherosclerosis and diabetes mellitus [41–43]. The damage occurs mainly on 2'-dG in DNA since this base is free at the 8 position and its redox potential is low [44]. Water-soluble antioxidants such as ascorbic acid and catechins, thus, can prevent degenerative diseases by protecting against genetic damage. Ascorbic acid is known to be recycled enzymatically and/or nonenzymatically in plasma, however, the recycling from dehydoroascorbic acid would take time. In the absence of antioxidative ascorbic acid, we believe that green tea extracts, especially EGCg, play an antioxidative role in scavenging water-soluble ROS, and the actions of catechins occur in the small intestines, erythrocytes and kidneys, with which the absorbed catechins come into contact. Thus, the daily drinking of green tea can build up antioxidative potential and resistance to oxidative stress, and is associated with the prevention of degenerative diseases.

References

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