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Catechin and Caffeine Content of Green Tea Dietary Supplements and Correlation with Antioxidant Capacity

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The health benefits associated with tea consumption have resulted in the wide inclusion of green tea extracts in botanical dietary supplements, which are widely consumed as adjuvants for complementary and alternative medicines. Tea contains polyphenols such as catechins or flavan-3-ols including epicatechin, epigallocatechin, epicatechin gallate, and epigallocatechin gallate (EGCG), as well as the alkaloid, caffeine. Polyphenols are antioxidants, and EGCG, due to its high levels, is widely accepted as the major antioxidant in green tea. Therefore, commercial green tea dietary supplements (GTDS) may be chemically standardized to EGCG levels and/or biologically standardized to antioxidant capacity. However, label claims on GTDS may not correlate with actual phytochemical content or antioxidant capacity nor provide information about the presence and levels of caffeine. In the current study, 19 commonly available GTDS were evaluated for catechin and caffeine content (using high-performance liquid chromatography) and for antioxidative activity [using trolox equivalent antioxidant capacity (TEAC) and oxygen radical antioxidant capacity (ORAC) assays]. Product labels varied in the information provided and were inconsistent with actual phytochemical contents. Only seven of the GTDS studied made label claims of caffeine content, 11 made claims of EGCG content, and five specified total polyphenol content. Caffeine, EGCG, and total polyphenol contents in the GTDS varied from 28 to 183, 12−143, and 14−36% tablet or capsule weight, respectively. TEAC and ORAC values for GTDS ranged from 187 to 15340 and from 166 to 13690 μmol Trolox/g for tablet or capsule, respectively. The antioxidant activities for GTDS determined by TEAC and ORAC were well-correlated with each other and with the total polyphenol content. Reliable labeling information and standardized manufacturing practices, based on both chemical standardization and biological assays, are recommended for the quality control of botanical dietary supplements.

KEYWORDS: Green tea; polyphenols; catechins; flavan-3-ols; caffeine; TEAC; ORAC

INTRODUCTION

It is estimated that over 60% of Americans use some form of complementary and alternative medicine therapy, among which the use of dietary supplements (botanicals or herbals, vitamins, and minerals) is extremely popular (*1*−*4*). The widespread use of botanicals is due to their general regard as being safe arising out of their long history of traditional use resulting in many being included on the generally regarded as safe list of the U.S. Food and Drug Administration (*1*−*4*).

Tea (*Camellia sinensis* L.), the second most-consumed beverage in the world (to water), has been used for centuries by ancient cultures for its medicinal properties and is popularly consumed in unfermented (green tea), semifermented (oolong teas), and fermented (black and pu-erh or red) forms (*5*). Approximately 76−78% of the tea produced and consumed worldwide is as black tea, 20−22% is as green tea, and <2% is as oolong tea (*6*−*9*). The consumption of green tea is especially popular in Asian cultures, and its association with human health benefits has resulted in the inclusion of green tea extracts (GTEs) as common botanical ingredients in dietary supplements, nutraceuticals, and functional foods. The chemical composition of tea includes proteins, chlorophyll, minerals and trace elements, volatile compounds, amino and organic acids, lignins, alkaloids (caffeine, theophylline, and theobromine), and polyphenols (catechins or flavan-3-ols, theaflavins, thearubigins, and proanthocyanidins) (*8*, *9*). Among tea phytochemicals, the polyphenols, and in particular catechins, have received immense attention (*9*). The major green tea catechins are epicatechin (EC), epigallocatechin (EGC), epicatechin gallate (ECG), and epigallocatechin gallate (EGCG) (**Figure 1**). EGCG makes up about 40% of the total catechin content and is widely accepted as the major antioxidant ingredient in green tea and GTEs (*5*, *6*, *8*). The antioxidant activity is based on the radical scavenging and

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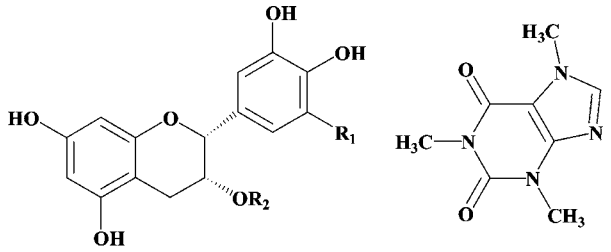

	R_1	R_2
EC	H	H
EGC	OH	H
ECG	H	gallate
EGCG	OH	gallate

Tea Catechins (Flavan-3-ols)

Caffeine

Figure 1. Structures of green tea catechins and caffeine.

metal ion-chelating potential (*10*). In addition, tea polyphenols exhibit a large range of biological activities such as inhibition of proliferation and angiogenesis, induction of cell cycle arrest and apoptosis, and alteration of cell signaling (*11*). Recently, tea polyphenols have also been shown to induce weight loss and therefore have been included in weight loss supplements (*12*).

Commercially available green tea dietary supplements (GTDS) include formulations that are based predominantly on GTEs as well as those that contain GTEs in addition to other botanical extracts. Currently, there are few reports on comparative analyses of the quality of tea products as well as correlation of label claims with actual phytochemical contents (*9*, *13*, *14*). In addition, label claims of GTDS may or may not inform consumers about the presence and levels of caffeine in their products. The presence and levels of caffeine in GTDS are very important in lieu of the well-documented stimulatory, psychoactive, neurological, and weight loss effects attributed to caffeine consumption and the preference for decaffeinated products by many consumers (*15*, *16*). In this study, we evaluated 19 commonly available commercial GTDS (labeled as supplements A−S) for their tea catechin and caffeine contents using high-performance liquid chromatography−ultraviolet (HPLC-UV) methodology. Supplements A−I contained GTEs in addition to other botanical extracts, while supplements J−S contained GTEs as their only botanical extracts. We also report on the antioxidative potential of the GTDS using two widely validated antioxidant assay protocols: trolox equivalent antioxidant capacity (TEAC) and oxygen radical antioxidant capacity (ORAC) assays (*17*−*20*) and the correlation between these two assays. Our study provides useful information regarding quality control and label claims of dietary supplements. In addition, in light of existing issues regarding standardized antioxidant methodologies (*21*), our study provides useful information regarding correlation between two widely used antioxidant assay protocols.

MATERIALS AND METHODS

Materials. All solvents were HPLC grade and purchased from Fisher Scientific Co. (Tustin, CA). Caffeine and catechin standards were purchased from Sigma Aldrich Co. (St. Louis, MO).

Nineteen GTDS were obtained based on accessibility to the average consumer (purchased from retail stores, chain pharmacies, Internet, or mail order) as follows: Shape-Up (With Dr. Phil McGraw; CSA Nutraceuticals, LLC, Irving, TX); EAS (ThermodynamX Body Shape; EAS Inc., Golden, CO); Equate (Diet Smart; Wal-Mart Stores, Inc., Bentonville, AR); Herbalife (Total Control and Green Tea Supplement; Los Angeles, CA); Metabolift (Ephedra Free Formula; Twin Laboratories Inc., American Fork, UT); Muscletech (Hydroxycut: MuscleTech R&D Inc.; Mississauga, ON, Canada); Rite Aid (Trim Support; Rite Aid Corp., Harrisburg, PA); Trim Spa (Formula ×32; TRIMSPA, Whippany, NJ); GNC Herbal Plus (Standardized Green Tea; General Nutrition Corp., Pittsburgh, PA); GNC Natural Brand (Green Tea Extract; General Nutrition Corp.); Mega-T (Green Tea Dietary Supplement; CCA Industries Inc., E. Rutherford, NJ); Natrol (Green Tea; Natrol Inc., Chatsworth, CA); Nature's Way (Green Tea Standardized; Nature's Way Products Inc., Springville, UT); New Chapter (Green & White Tea; New Chapter Inc., Brattleboro, VT); Nutrilite (Cholesterol Health; Access Business Group International LLC, Ada, MI); Pharmanex (Tegreen; Pharmanex LLC, Mfd. For Pharmanex LLC, Provo, UT); Schiff (Green Tea Diet; Schiff Products, Salt Lake City, UT); and Weight Smart (One-a-Day; Bayer Corp., Morristown, NJ). All GTDS were analyzed prior to their expiration dates as stated on their packages.

Quantification of Catechins and Caffeine Content in GTDS. *Standards.* Caffeine and catechins: EC, EGC, ECG, and EGCG, all 1 mg, were individually dissolved in 1 mL of methanol:water (1:1, v/v) and sonicated for 20 min (stock solutions). Catechin standard stock solutions were further diluted to afford 40, 20, 10, 5, and 2.5 μg/mL concentrations. The caffeine standard stock solution was further diluted to a final concentration of 20, 10, 5, 2.5, and 1.25 μg/mL concentrations. Standard calibration curves were constructed for each reference standard. Catechin and caffeine concentrations were determined from the peak area by using the equation for linear regression obtained from the calibration curve.

Samples. Once the label information was recorded, tablets or capsules were sampled from each bottle/packet in duplicate, weighed, analyzed by HPLC, and reported as an average value ± standard deviation (SD). Tablets were crushed, or contents of capsules were collected, and 100 mg sample aliquots were quantitatively dissolved in methanol:water (1:1, v/v) in 100 mL volumetric flasks and sonicated for 20 min.

HPLC Conditions. The HPLC system consisted of a 600 pump, 717 autosampler, 996 photodiode array detector, and Millenium^{32} Chromatography Software (all Waters, United States). The mobile phase, solvent A (acetonitrile) and solvent B (0.2% aqueous phosphoric acid), was used under binary linear gradient conditions as follows: 0−5 min, 10% A in B; 5−20 min, 10−20% A in B; 20−25 min, 20% A in B; with a flow rate of 1.0 mL/min. All samples (50 μL injection volume) were filtered (0.22 μm) and analyzed on a Waters (Symmetry C18, 100 mm × 4.6 mm, 3.5 μm) column. The wavelength was monitored at 278 nm for detection and quantification of tea catechin and caffeine reference standards (**Figure 2**).

TEAC. The assay was performed as reported (*18*). Briefly, 2′,2′-azinobis(3-thylbenzothiazline-6-sulfonic acid)diammonium salt (ABTS) radical cations were prepared by adding solid manganese dioxide (80 mg) to a 5 mM aqueous stock solution of $ABTS^{\bullet+}$ (20 mL using a 75 mM Na/K buffer of pH 7). Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), a water soluble analogue of vitamin E, was used as an antioxidant standard. A standard calibration curve was constructed for Trolox at 0, 50, 100, 150, 200, 250, 300, and 350 μM concentrations. Samples were extracted in methanol:water (1:1, v/v) (10 mg/mL concentrations) by vortexing for 30 min, sonicating for 5 min, and centrifuging for 10 min at 2000*g*. Samples were diluted appropriately according to antioxidant activity in Na/K buffer, pH 7. Diluted samples were mixed with 200 μL of $ABTS^{\bullet+}$ radical cation solution in 96 well plates, and the absorbance was read (at 750 nm) after 5 min in a ThermoMax microplate reader (Molecular Devices, Sunnyvale, CA). Samples were assayed in six replicates. TEAC values were calculated from the Trolox standard curve and expressed as Trolox equivalents (in μM). This assay was performed with a coefficient of variance (CV) of 8.1 for interassay and 0.9 for intraassay repeats.

ORAC. The ORAC assay was performed as described previously (*19*) except that sodium acetate buffer (75 mM, pH 5.5) was used to stabilize the catechins. In the final mixture of 0.2 mL, fluorescein (5.7 μmol/L) was used as a target of free radical attack and 2,2′-azobis-amidinopropane dihydrochloride (24 mM) was used as a peroxyl radical generator at 37 °C. Trolox (5 μM) was used as a standard control. The decrease in fluorescence of fluorescein was determined by collecting

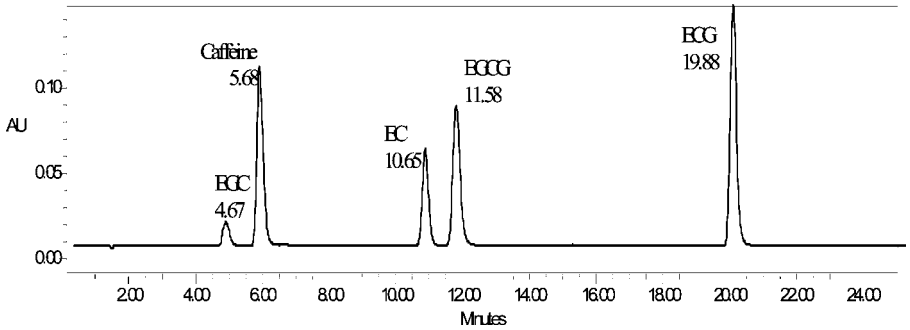

Figure 2. HPLC chromatograms of caffeine and catechin reference standards. A binary linear gradient solvent system consisting of solvent A (acetonitrile) and solvent B (0.2% aqueous phosphoric acid) and a detection wavelength of 278 nm were used.

Table 1. Catechin and Caffeine Content (Expressed as % Tablet Weight) and Antioxidant Capacities (TEAC and ORAC) of 19 Commercially Available GTDS[a]

									label claims (%)		
GTDS	caffeine	EGCG	EGC	ECG	EC	total polyphenols	TEAC[b]	ORAC[b]	caffeine	EGCG	total polyphenols
A	5.8 ± 1.3	14.8 ± 0.7	3.1 ± 0.6	5.3 ± 0.2	2.5 ± 0.4	25.7 ± 1.8	7135.0 ± 53.1	5629.6 ± 209.8		2.9	
B	13.5 ± 1.2	6.8 ± 0.6	2.4 ± 0.2	2.9 ± 0.1	2.1 ± 0.4	14.3 ± 1.3	3676.3 ± 64.3	5072.4 ± 201.7	31.6	22.2	42.7
C	3.5 ± 1.5	1.6 ± 0.1	0.1 ± 0.1	4.7 ± 0.1	0.2 ± 0.1	6.7 ± 0.2	196.0 ± 3.5	166.0 ± 43.2		1.7	
D	9.3 ± 3.4	7.9 ± 0.8	3.0 ± 0.5	1.7 ± 0.1	1.1 ± 0.4	13.7 ± 1.1	3776.1 ± 48.3	3566.4 ± 387.6		50.0	
E	15.5 ± 1.5	0.1 ± 0.1	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	0.5 ± 0.2	777.6 ± 77.3	2133.7 ± 270.0	22.0	-	
F	7.7± 2.9	2.7 ± 0.4	0.8 ± 0.1	1.0 ± 0.1	0.3 ± 0.1	4.8 ± 0.6	1606.5 ± 48.9	1803.9 ± 168.1		22.2	34.6
G	0.4 ± 0.2	2.4 ± 0.3	0.2 ± 0.1	0.7 ± 0.1	0.1 ± 0.1	3.2 ± 0.4	187.8 ± 11.9	481.6 ± 1.2		1.7	
H	4.5 ± 1.8	2.5 ± 0.3	0.1 ± 0.1	0.8 ± 0.1	0.1 ± 0.1	3.5 ± 0.5	554.7 ± 6.0	650.7 ± 1.7	16.0		
I	1.5 ± 1.6	2.7 ± 0.8	0.4 ± 0.1	1.0 ± 0.2	0.6 ± 0.2	4.7 ± 1.2	775.6 ± 8.7	1206.1 ± 117.6		1.9	
J	3.8 ± 1.4	11.5 ± 0.7	4.3 ± 0.2	4.7 ± 0.3	2.6 ± 0.2	23.1 ± 1.5	5907.3 ± 110.0	5147.3 ± 295.9			
K	2.3 ± 0.2	3.8 ± 0.1	2.0 ± 0.4	1.1 ± 0.1	0.8 ± 0.1	7.7 ± 0.5	1862.4 ± 39.4	2187.7 ± 718.1			
L	1.1 ± 1.1	44.4 ± 0.7	3.6 ± 0.1	11.0 ± 0.2	4.3 ± 0.6	63.3 ± 1.5	15340.7 ± 109.1	13210.2 ± 698.8			
M	8.8 ± 0.3	7.7 ± 0.1	3.4 ± 0.2	2.3 ± 0.1	1.7 ± 0.1	15.1 ± 0.4	4301.1 ± 69.4	5405.6 ± 542.2	4.9	8.9	
N	11.1 ± 0.9	14.1 ± 0.1	6.8 ± 1.5	5.4 ± 0.3	3.0 ± 0.1	29.3 ± 2.5	7448.2 ± 97.6	6989.6 ± 598.8	6.1		21.6
O	1.8 ± 1.3	27.1 ± 2.2	3.4 ± 0.9	7.5 ± 0.4	1.9 ± 0.3	39.8 ± 3.9	10252.4 ± 40.0	8424.8 ± 444.9		55.0	75.0
P	9.2 ± 1.4	10.2 ± 1.4	9.0 ± 0.3	2.4 ± 0.4	2.4 ± 0.2	24.0 ± 2.3	6782.9 ± 98.6	6512.0 ± 208.9	9.0		
Q	4.9 ± 2.0	25.7 ± 1.1	0.5 ± 1.2	18.6 ± 0.7	5.1 ± 0.7	49.9 ± 3.7	12620.6 ± 28.9	13690.7 ± 1301.3		29.2	
R	17.4 ± 5.4	21.3 ± 6.9	7.3 ± 1.0	9.9 ± 2.8	5.6 ± 2.6	44.1 ± 13.3	9085.9 ± 39.1	8837.7 ± 116.2	11.4	20.5	
S	1.5 ± 0.1	8.6± 2.1	1.6± 0.7	5.7± 0.2	1.7 ± 0.2	17.6 ± 2.1	6017.1 ± 12.5	6759 ± 453.2			40.0

[a] Supplements A–I contain GTEs as well as other botanical extracts. Supplements J–S contain GTEs as their only botanical extract. Catechin and caffeine contents represent the mean ± SD ($n = 2$). TEAC and ORAC values are expressed as the mean ± SD ($n = 6$). [b] μmol Trolox/g.

readings at excitation 535 nm and emission 595 nm every 2 min for 70 min in a Perkin-Elmer HTS Bio Assay Reader (Norwalk, CT). The ORAC value was evaluated as the area under the curve (AUC) and calculated by taking into account the Trolox reading using the following equation: $(AUC_{sample} - AUC_{buffer})/(AUC_{Trolox} - AUC_{buffer}) \times$ dilution factor of sample $\times$ initial Trolox concentration (μM) (*22*). Samples were extracted in a methanol:water mixture (1:1, v/v), diluted in sodium acetate buffer, and measured in six replicates. This assay was performed with a CV of 8.5 for interassay and 6.9 for intraassay repeats.

Statistical Analysis. For each catechin and caffeine analysis, each GTDS bottle or packet was sampled twice. HPLC analyses of each sample were done in triplicate and are reported as mean values ± SD. TEAC and ORAC values were determined in six replicates, and the mean values ± SD are reported. The Pearson correlation coefficient for the antioxidant activity determined by TEAC and ORAC and total polyphenol content was analyzed using PRISM statistical analysis software package version 4 (GraphPad Software, San Diego, CA).

RESULTS

Table 1 shows the catechin and caffeine content and antioxidative potential of 19 commercial GTDS commonly available to consumers. Supplements A−I contained GTEs in addition to other botanical extracts, and supplements J−S contained GTEs as their only botanical extract. The catechin and caffeine contents of the GTDS are expressed as a percentage present based on the weight of a tablet or contents of a capsule. Weights of the GTDS in **Table 1** have not been reported to obscure manufacturer's identities.

Label Information. Product labels were found to vary in the information provided. Only seven of the 19 GTDS studied made label claims about the quantities of caffeine present. Actual caffeine levels varied from 43 to 182% of the label claims. One GTDS had label claims, which corresponded to the actual amount (supplement P: label claim, 9%; actual content, 9.2%); three of the GTDS contained more caffeine than their label claims (supplement M: label claim, 4.9%; actual content, 8.8%; supplement N: label claim, 6.1%; actual content, 11.1%; and supplement R: label claim, 11.4%; actual content, 17.4%), and three GTDS contained less caffeine than their label claims (supplement B: label claim, 31.6%; actual content, 13.5%; supplement E: label claim, 22%; actual content, 15.5%; and supplement H: label claim, 16%; actual content, 14.5%).

Eleven of the GTDS provided information about EGCG levels, which ranged from 12 to 143% of label claims. The label claims of EGCG content in three of the GTDS corresponded to the actual amount (supplement C: label claim, 1.7%; actual content, 1.6%; supplement I: label claim, 1.9%; actual content, 2.7%; and supplement R: label claim, 20.5%; actual content, 21.3%). Two of the GTDS contained more than the claimed amount (supplement A: label claim, 2.9%; actual content,

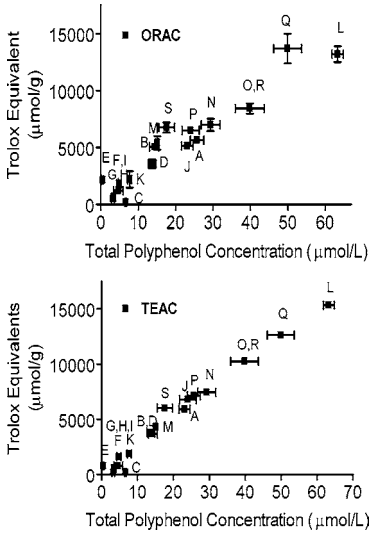

Figure 3. Correlation of antioxidant activity determined using TEAC or ORAC to total tea polyphenol concentration. Values are means ± SD; $n = 2$ for tea polyphenol content, and $n = 6$ for TEAC and ORAC.

14.8%; and supplement B: label claim, 1.7%; actual content, 2.4%). Six of the GTDS contained less than the claimed amount (supplement B: label claim, 22.2%; actual content, 6.8%; supplement D: label claim, 50.0%; actual content, 7.9%; supplement F: label claim, 22.2%; actual content, 2.7%; supplement M: label claim, 8.9%; actual content, 7.7%; supplement O: label claim, 55.0%; actual content, 27.1%; and supplement Q: label claim, 29.2%; actual content, 25.7%).

Five of the 19 GTDS studied made claims about the amount of total tea polyphenols, which ranged from 14 to 36% of their label claims. Of these, none contained the claimed amount. Four of the GTDS contained less than their label claims (supplement B: label claim, 42.7%; actual content, 14.3%; supplement F: label claim, 34.6%; actual content, 4.8%; supplement O: label claim, 75.0%; actual content, 39.8%; and supplement S: label claim, 40.0%; actual content, 17.6%). One of the GTDS contained more tea polyphenols than the claimed amount (supplement N: label claim, 21.6%; actual content, 29.3%).

TEAC and ORAC Values. The antioxidant activity using TEAC and ORAC ranged from 187 to 15340 and from 166 to 13690 μmol Trolox equiv/g tablet or capsule, respectively, as shown in **Table 1**. Among the GTDS, supplements G (187.8 ± 11.9 μmol Trolox/g) and L (15340 ± 109.1 μmol Trolox/g) showed the lowest and highest TEAC values, respectively. Supplements C (166 ± 43.2 μmol Trolox/g) and L (13210.2 ± 698.8 μmol Trolox/g) showed the lowest and highest ORAC values, respectively. The antioxidant activities determined by TEAC and ORAC were correlated significantly ($r = 0.98$, $p < 0.0001$) (**Figure 3**). In addition, both antioxidant activity measurements were correlated significantly to the total polyphenol content ($r = 0.95$, $p < 0.0001$) (**Figure 3**). There were no differences in antioxidant/polyphenol correlation among the supplements containing other botanical extracts in addition to GTEs (i.e., supplements A−I) as compared to those containing only GTEs (i.e., supplements J−S).

DISCUSSION

We surveyed 19 GTDS for their catechin and caffeine contents and for TEAC and ORAC antioxidant activities (**Table 1**). Because of the complexity of food matrices for, e.g., oils, beverages, capsules, and hard tablets, the estimation of their phytochemical contents and their antioxidative potentials is especially difficult. Hence, to accurately evaluate phytochemical contents and antioxidative potentials in different matrices, methodologies and models must account for the chemical, physical, and environmental conditions specific to a particular product.

In our study, 19 GTDS were analyzed by reverse phase HPLC with UV detection for the quantification of the major green tea catechins (EC, ECG, EGC, and EGCG) and caffeine. For evaluation of the antioxidative potentials of the varying GTDS, we used the TEAC and ORAC assays. The characteristics of various methods to determine antioxidant activity have been reviewed in detail by Prior et al. (*17*). Although the ORAC assay represents a hydrogen atom transfer reaction mechanism and the TEAC assay represents a single electron transfer-based method, both assays are based on Trolox (a water soluble derivative of vitamin E) equivalents (*17*, *18*, *20*). The ORAC assay measures antioxidant inhibition of peroxyl radical-induced oxidation and therefore reflects the classical radical chain-breaking antioxidant activity by hydrogen atom transfer (*17*, *19*, *20*). The reaction of the fluorescence probe with the peroxyl radical is followed by loss of fluorescence over 1 h. The antioxidant activity is calculated as the AUC and evaluated as compared to the antioxidant activity of Trolox. The TEAC assay, on the other hand, is based on the scavenging ability of antioxidants of the radical cation $ABTS^{\bullet+}$. The antioxidant activity is measured as the ability to reduce $ABTS^{\bullet+}$, which leads to a decrease in color, proportional to the antioxidant activity. This process is determined at a set end point. This end point varies depending on the source of antioxidants. For example, our laboratory recently demonstrated that the reaction was completed at 5 min using a tea polyphenol solution as compared to 60 min using plasma (*22*). The choice, compatibility, and suitability of antioxidant assays should take the characteristics of the sample to be analyzed into consideration. Because in the present study we analyzed GTDS extracts, the end point was set to 5 min for the TEAC assay. Therefore, the end point was set at the completion of the antioxidant activity and results should be comparable to data acquired using the ORAC assay. On the basis of the chemical reactions used by the ORAC assay, it is well-suited to measure the antioxidant activity of a wide variety of compounds including protein/albumin, uric acid, α-tocopherol, and ascorbic acid (*23*). The TEAC assay, on the other hand, is not as suitable for the determination of the antioxidant activity of protein (*23*). Because we were testing extracts of GTDS, the use of ORAC in comparison with the TEAC assay was appropriate. This has been confirmed by the data presented here. The antioxidant activities for GTDS determined by TEAC and ORAC were well-correlated with each other and with the total tea polyphenol contents (**Figure 3**). Similar results have been demonstrated by Proteggente et al. where foods with polyphenols and vitamin C, as main antioxidant contributors, showed similar and well-correlated results using the ORAC and TEAC assays (*24*). We observed similar values for the TEAC and ORAC antioxidative capacities among the GTDS although we observed significant differences for supplement E (777 μmol Trolox/g for TEAC and 2133 μmol Trolox/g for ORAC). It should be noted that although we observed correlation between total polyphenol contents and antioxidant values, dietary supplements might contain a wide range of botanical and nonbotanical ingredients that could contribute to their overall antioxidant potential.

For the phytochemical assays, we found that with the exception of supplement E, which contained small quantities of catechins, EGCG was the major tea polyphenol present in

all supplements. It is also noteworthy that although caffeine was present in all of the GTDS, only seven of these indicated caffeine levels on their labels. Caffeine, a natural constituent of tea, can reach high levels in tea products and is known for its thermogenic, cardiovascular, and other health effects in humans (*7*, *8*, *10*, *15*, *16*). Therefore, it is important that consumers are informed of the presence and levels of caffeine in food products.

In conclusion, our study highlights some of the problems that exist with quality control in the dietary supplement market and herbal medicine industry specifically pertaining to labeling claims. It is recommended that reliable labeling information and standardized manufacturing practices, using a combination of both phytochemical and biological assays, be used for the quality control of botanical dietary supplements. Our study also shows that there is high correlation between two widely used antioxidant methodologies, TEAC and ORAC assays, and that their values increase with increasing polyphenol contents.

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